Evaluation of Driver Characteristics on Expressways

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ABSTRACT

This paper describes evaluation and classification methods for driver characteristics on expressways. The investigations have been carried out in four stages. First a questionnaire of 149 drivers was conducted to confirm the initial classification method of drivers' characteristics. The drivers included males and females from 18 to 61 years old. Four types of drivers were classified by the questionnaires. Those were aggressive (A type), keep speed (B type), following (C type) and safety (D type). Second, a driving test was used to confirm those driver types with four drivers selected from each type, for a total of 16 drivers. Third, 11 drivers were selected as a sample of the motoring population to carry out an investigation on Keiyo expressway in Japan using a test vehicle. The test vehicle was installed with accelerator, brakes, engine speed and vehicle speed sensors. Galvanic skin response (GSR) and drivers' view point devices were also installed to collect the psychological data of driver. The surrounding of the vehicle was monitored by a video camera on a helicopter which was chasing the vehicle. The fourth stage was evaluating these data using a hyperbolic function. The findings are based upon the results of investigations that driver characteristics could be estimated by the desired speed and the desired spacing using parameters of the hyperbolic function. The parameter $1/\mu$ can be expressed the desired speed of the driver. The parameter μ and λ were changed by not only the driver but also the surroundings around the vehicle. The changing trends of those parameters are parallel lines on the plane of μ - λ relations. Those lines were arranged in a certain order of driver type. It is concluded that driver type can be estimated by questionnaire and can be applied to traffic flow simulation.

INTRODUCTION

It is thought that driver characteristics reflect the inherent character of individual drivers. When many vehicles run simultaneously, however, the characteristics are influenced by many factors. For instances, if only one vehicle were running on the expressway, the driver would drive with freedom under the condition of regulations and road structures and so on. If the number of vehicle increase on the same road, the situation becomes more complex. The influences mutually occur with each vehicle. In the situation of traffic congestion, driver characteristics were hidden by limit of freedom. Therefore, traffic flow is affected by individual driver characteristics. Driver characteristics are changed by the driving situations or surroundings. The aim of this study is evaluation of the method to estimate driver characteristics. Driver characteristics are an important index to apply in traffic flow simulation.

INVESTIGATION METHOD

Initial Classification Using Questionnaire

The questionnaire about driving behavior was carried out with a total of 149 driver license holders (95 male and 54 female). The range of driver age was 18 to 61 years old. The questionnaire consists of 20 questions personal driving skill or characteristics mainly. The questionnaire included some questions to investigate the psychological state of the driver in the driving situation. Those questions examined whether a driver did an active or a passive action in particular driving situations. For instance, one situation was related to frustration in following the vehicle ahead. If that vehicle were running slower than one's speed, the driver may get irritated. From the results of the questionnaire, four driver types were identified

A driver of A type has an aggressive driving character. The driving characteristics of this type drives high speed, quick change lane, following the vehicle with short range of spacing, take over and so on. Sometime A type driver gets overconfident. The results were total 12.1%, Male : 12.6%, Female : 11.1%. B type is a driver who drives a vehicle with keeping one's desired speed. However, sometime a driver of this type will change the character to an aggressive driving to get a situation of one's desired speed. The results were total : 11.4%, Male : 11.6%, Female : 11.1%. C type is a driver who is following the vehicle ahead. A driver of this type does not drive aggressively to keep one's speed. This type is unsure of one's driving technique. The results were total : 12.8%, Male : 14.7%, Female : 9.3%. D type is a driver who drives safely. The results were total : 63.7%, Male : 61.1%, Female : 68.5%

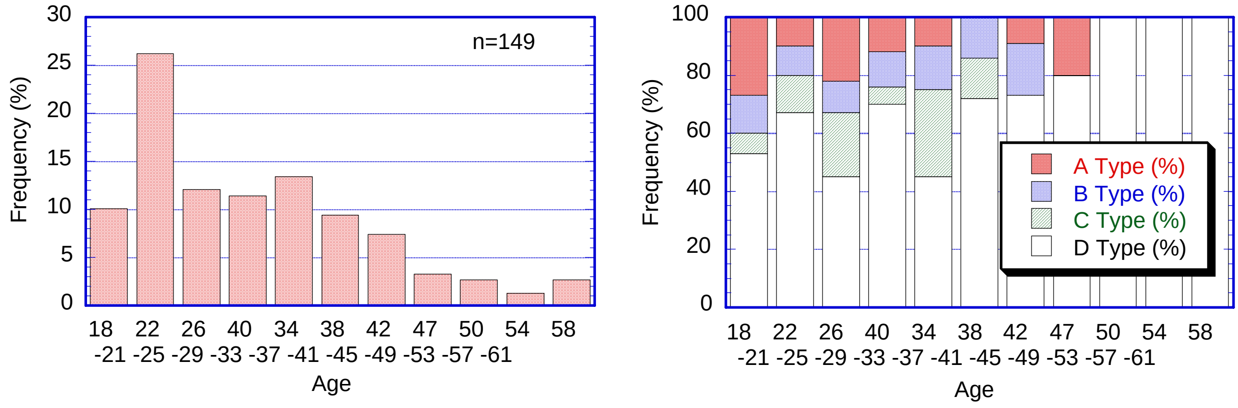


Figure 1. The range of driver age and driver type

The 4 representative people from each type were selected to confirm these classification results and let them drive a car in the third step. As a result of driving test, the driver of each type showed the driving characteristics to satisfy classification result generally.

The Test Vehicle

The test vehicle was used Nissan 2 liter automatic transmission 4 door sedan. The vehicle was installed with following sensors and data were collected with microcomputer.

Accelerator Opening Measurement Device

The displacement conversion device LVDT was installed on the accelerator to measure the degree of accelerator opening. The degree of accelerator opening ranged from 0 % in the off condition to the 100 % in the full open condition.

Brake Pressure Measurement Device

A pressure gauge was installed on the brake pedal to measure the power of the brake pedal. The output signal indicates the status of the brakes within 0-100% range.

Traveling Speed Measurement Device

Pulse signal output data from a transmission was converted to voltage data through the F/V (Frequency to Voltage) converter. The traveling speed was measured after having removed noise using a low pass filter.

Engine speed

Engine speed was measured by pulse signal and through the F/V converter to record the data in microcomputer.

Acceleration Measurement

Acceleration in the longitudinal and lateral directions were measured with acceleration sensors installed at the centered of the vehicle.

Steering

The angle of steering was measured by pulse sensor installed on the steering column.

Spacing Measurement Device

A laser spacing measurement device was equipped on the roof of the test vehicle to measure spacing to the vehicle ahead. The digital measurement data were collected using the microcomputer through the parallel interface and its measurement accuracy is 1 meter.

GSR (Galvanic Skin Response)

GSR utilizes sweat produced on the palm of the hand and sole of the foot by a change of human psychology state. Electrical resistance is measured, and psychology trend is estimated from that change. The change of the electrical resistance was recorded through an amplifier by the microcomputer.

Driver's View Point

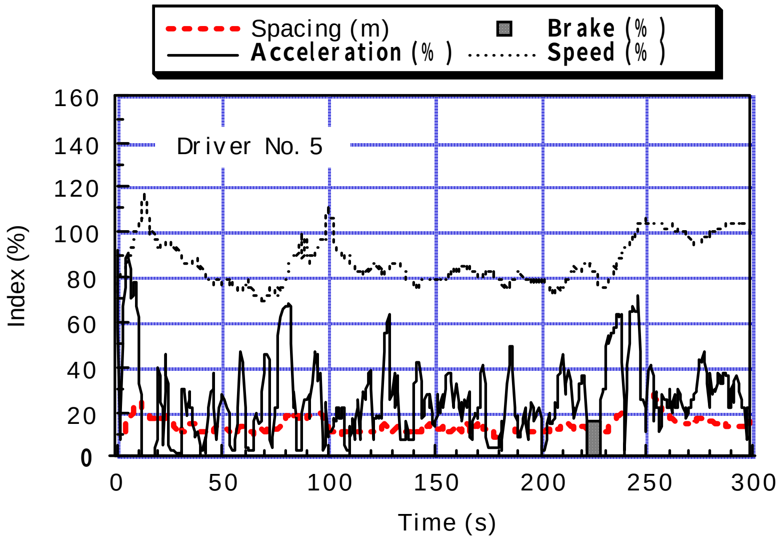
Movement of eyeball is measured by a change of the reflection angle by hitting an eyeball with beam of light. Driver's view point data are superimposed on an image of drivers' vision, and it is recorded by video recorder.

Investigation of Driving Behavior Using Test Vehicle

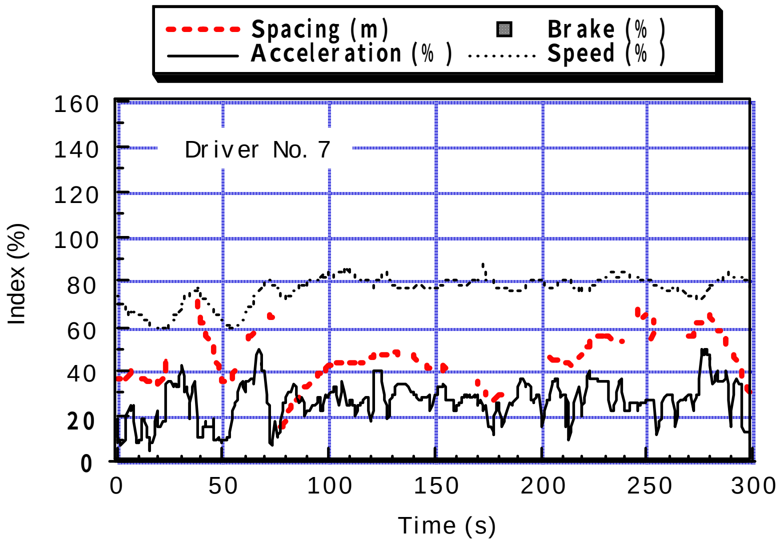
The investigations of driving behavior were carried out using the test vehicle with 11 selected drivers including types A, B, C and D. The investigation route was approximately 8 km in length between Makuhari Parking Area and Funabashi Toll plaza on Keiyo expressway, Chiba prefecture in Japan. The investigation was conducted by 11 drivers with a total of 72 times. The drivers were given instructions to drive normally. Data collection was started with the digital data recorder, computer and video camera synchronized at departure. The synchronized signal was used for the data collectors at the departure and the arrival time. Among the driving investigations, the test vehicle was chased by helicopter, and the traveling environment of the vehicle was recorded with a video camera.

RESULTS OF THE INVESTIGATION

Because of congestion, the several data in this investigation were removed from the object for this analysis. Four drivers were selected by driving investigations and result of the questionnaire for explanation of the findings in this paper. They are the most aggressive driver No.5 (A type), the safest type driver No.2 (D type) and the median type driver's No. 1 (B type) and No.7 (C type).



(a) Results of driving test (Driver No.5)



(b) Results of driving test (Driver No.7)

Figure 2. Results of driving test using test vehile

Trajectories of Driving Behavior

Ceder (1) discussed the car-following phenomena using Gordon's observed data (2,3). Those microscopic clockwise-looping trajectories were drawn in the plane on spacing - relative speed. It was applied to explain the macroscopic traffic phenomena. The data that were observed by this study were similar to Gordon's observation results. These trajectories are looping around the point of desired spacing and zero relative speed. In this study, a spiral function was introduced to express the numerical modeling for traffic flow simulation. It was assumed that the acceleration of the vehicle is identified using the spiral curve. The spiral function is deformed by six parameters; four of these parameters used for deform the curve that are used constant selected value in this time, and another two parameters were identified using desired spacing and traveling speed of individual driver. It was applied to the proposed car-following theory (4,5,6). This model can express the one's personal space for driving safely. Lane change behavior to avoid a dangerous state also can be expressed by this model.

Hence, desired spacing and traveling speed are important parameters for spiral function, however, it is very difficult to estimate each of the driver's parameters. In this study, the relation between traveling speed and desired spacing was confirmed as shown below. The desired speed could be estimated by the relation in the plane on spacing - time headway also as shown below.

Estimate of The Desired Speed

The data of free flow condition (non-congestion condition, more than 60 km/h traveling speed) are selected and plotted in the plane on spacing - time headway. Those data were distributed along the straight line. According to the results of regression analysis of those data, the correlation coefficients showed mainly more than 0.9 as shows in Figure 3. The equation of this straight line shows as equation (1).

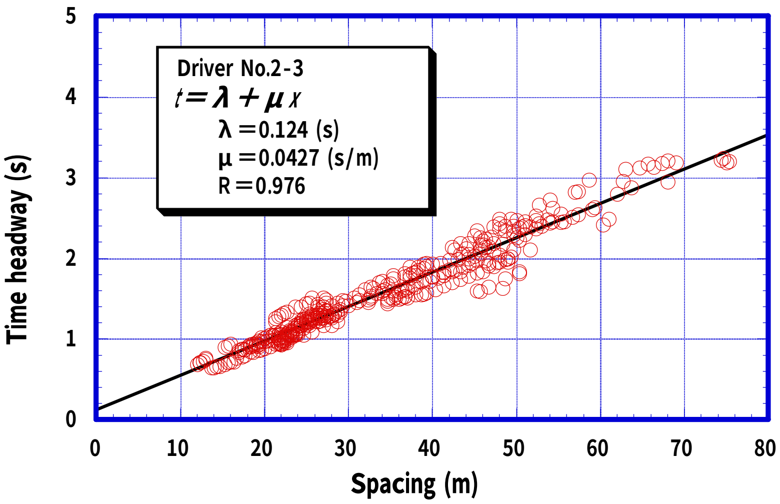


Figure 3. Relation between Time headway and Spacing (Driver No.2-3)

$$t = \lambda + \mu x \qquad (1)$$

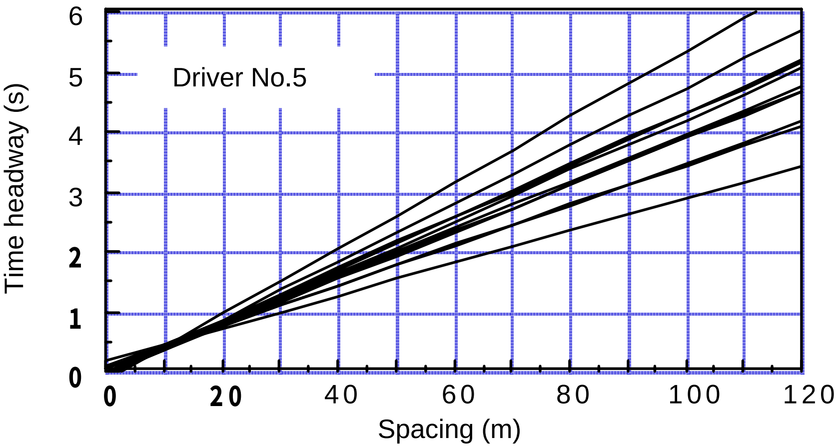
Here, λ = intercept (s), μ = slope (s/m), t = time headway (s), x = spacing (m), v = speed (m/s)
Equation (2) was transformed from equation (1) to a hyperbolic function as showed in below.

$$x = \frac{\lambda v}{1 - \mu v} \qquad (x>=0, \quad 0=<v<1/\mu) \qquad (2)$$

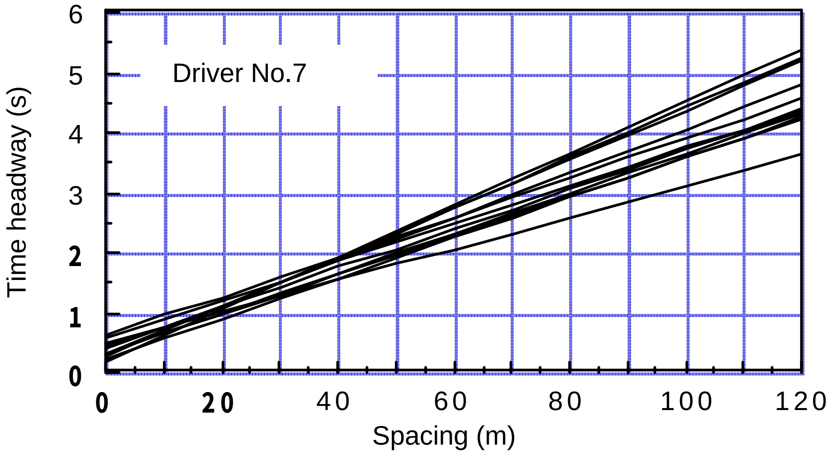
The slope μ and intercept λ of the straight line equation were changed by the drivers. It can be found out by analyzing data of many drivers to be the same as the above method. The parameter λ of equation (2) is the initial slope of hyperbolic curve and the parameter $1/\mu$ is the asymptote of a hyperbola in the plane on traveling speed and spacing (7). The desired speed can be estimate using the parameter $1/\mu$. For instance, in case of driver No.2, his desired speed can be estimated $1/\mu$ = 23.4m/s (84km/h) as shows in Figure 3. According to the driver No.2 in the test sequence 3 investigation data, his fastest speed was recorded with 110.2km/h. However, his driving speed was mostly 75-85km/h, and average driving speed was 82.7km/h. It seems that the estimated drivers' desired speed is larger than average driving speed except A type driver (Driver No.5).

The analyzed parameters of each driver are distributed as below. The results of the driver No.1 (B type) are λ: -0.0257 to 0.492, μ: 0.0283 to 0.0448. The driver No 2's (D type) results are λ: -0.0396 to 0.559, μ: 0.0268 to 0.0500. The driver No.5's (A type) results are λ: -0.135 to 0.199, μ: 0.0270 to 0.0548. The driver No.7's (C type) results are λ: 0.194 to 0.628, μ: 0.0261 to 0.0434.

In this study, driving investigations were carried out on the same route (same geometry condition) but different traffic environments. These two parameter λ and μ were changed by not only driver but also driving environments. It was seemed that driver characteristics on expressways were affected by one's environments of driving. It became clear that the tendencies of parameters change were related to driving environments. It means that the parameters λ and μ can be utilized as the parameters to express the driver characteristics as discussions as below.



(a) Results of regression analysis of the driver No.5 (A type)



(b) Results of regression analysis of the driver No.7 (D type)

Figure 4. Comparison between the driver No.5 and the driver No.7

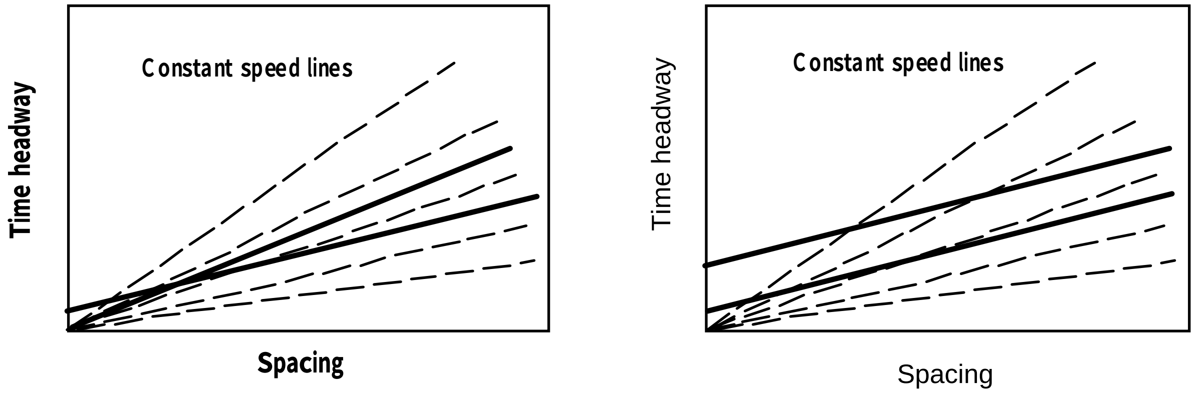
DISCUSSION ABOUT THE PARAMETERS λ AND μ

Relation Between Desired Spacing and Traveling Speed

In the plane on spacing - time headway shows in Figure 4, the straight line through the origin shows the constant traveling speed. For instance, if the slope of the line has large value, it will express a constant low speed, and if the slope has small value, it will express a constant high speed. Draw the straight line that was calculated by regression analysis with the data of the drivers' driving investigations. It will be drawing across these constant traveling speed lines. If the one's driving behavior is traveling from short to long spacing along the regression line and across the constant speed lines, it will express the driving speed increasing together. It means that the driver is controlling the vehicle spacing with the condition of one's traveling speed. Let us imagine the different type of drivers' regression line that means the driver with different parameters λ and μ. It can be found out that this driver is driving the vehicle with different pattern of spacing and traversing speed. These relationships are expressing that the driver was choosing his desired spacing at the moment of the traveling speed.

Changing Pattern of The Regression Line

According to those analyzed parameters, it can be found out that there are two kinds of changing patterns. The first one is observed with the driver No.7 except three time's investigation data as shows in Figure 4 (b). This is the case of the parameter λ changes bigger than μ. If only parameter λ changes, the line will shows parallel lines. From the geometric consideration in the plane on spacing - time headway, the driver who has this changing pattern drives the vehicle with the clear relation between spacing and traveling speed but these relations are variable. It will change to another situation with the traffic environments. Thus, the driver controls the vehicle under the condition of traveling speed and its environment.



(a) In the case of Driver No.5

(b) In the case of Driver No. 7

Figure 5. Changing pattern of λ and μ

The second one is observed with the driver No.1, 2 and 5. These are the case of the parameter μ changes bigger than λ. The regression lines can be seen as rotating on the axis of the origin axis point which is on the own line as shows in Figure 4 (a). The origin axis point of the driver No.5 can be found out very clearly at approximately 13m at spacing and 0.5s at time headway. The No.1 and 2's axis point can be found out each of the ranges approximately 29m, 1.2s and 27m, 1.3s. From the same geometrical consideration, it can be understood that the driver who has own origin axis point as No.5 has the boundary of desired speed for changing one's driving characters. In case of No.5, the boundary of desired speed is approximately 94km/h. If the driver has the desired speed below the boundary desired speed, it means in case of λ is below zero, the relation between spacing and traveling speed is indefinite. This kind of results can be found out aggressive type. The driver who has own origin axis point drives lower traveling speed mostly than the boundary of desired speed. In this case, the parameter λ takes should be positive value.

Relation Between Parameter λ and μ in Different Traffic Environments

Figure 6 shows the results of the driver No.1, 2, 5 and 7's parameters λ and μ in the different environments condition. Each of the driver types' parameters are plotted along a straight line, and these lines are parallel each other. The results of the regression analysis are shown in the figure. The correlation coefficients are up to 0.7. It can be expressed from these results that each of the driver characteristics was changed uniquely. The traffic environment or surroundings around the vehicle is one of the factors that affect to one's driving character. The parameter λ and μ have unique relation. It shows the trends of driving characteristics. The driver who has the trend to more safety takes large value of intercept. Conversely, the aggressive type driver takes low value of intercept. It can be seemed that the driver classification method using the questionnaire was effective. However, there are not enough data to confirm the relation between traffic environment or surrounding around the vehicle. The recorded video image taken from the helicopter did not have enough information to compare with each other using the local traffic density. The measured data of GSR and drivers' view point are also not enough data to conform the changing of driver characteristics. It needs more detailed data to confirm these relations.

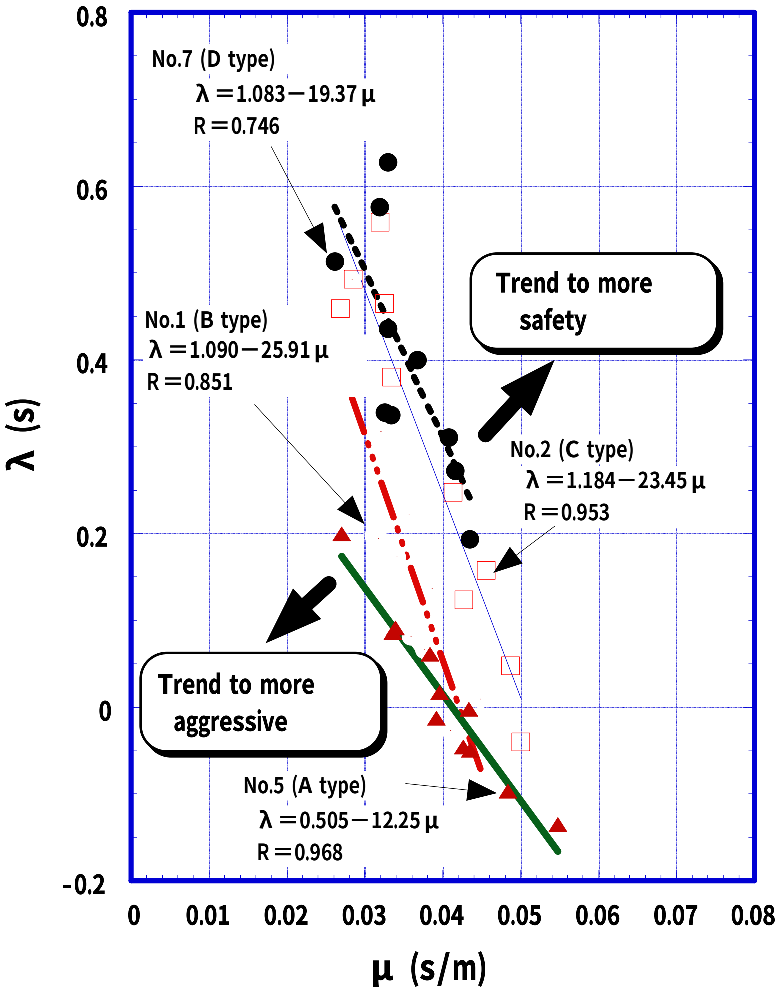


Figure 6. Relation between parameter λ and μ

CONCLUSION

A classification method of driver characteristics has been evaluated in this study. It is conclude that the results of the questionnaire can be used for roughly classifying driver characteristics. Driver characteristics can be expressed by the parameters λ and μ that were calculated by regression analysis in the plane on spacing - time headway. The changing of these parameters were shown the unique relations. It expressed how the driver controlled the vehicle in the different traffic environments. It means that the driver characteristics will be changed by the traffic environment or surroundings around the vehicle. These relations could not be reconfirmed in this study. However, there is the possibility of application to microscopic traffic simulation such as the proposed spiral model.

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