RELATIONSHIP BETWEEN DRIVING BEHAVIOR AND TRAFFIC ACCIDENTS - ACCIDENT DATA RECORDER AND DRIVING MONITOR RECORDER

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ABSTRACT

A field trial has been carried out using a set of automatic recording system, Driving Monitoring Recorder (DMR) and Accident Data Recorder (ADR) installed on 20 vehicles in a fleet of cars in Tokyo area, in order to assess the implications in driving behavior and accidents. The 38 subjects, who drive the 20 vehicles were monitored during driving by the DMR for one year. Simultaneously, the data in pre- and post accident were recorded by ADR whenever accidents occurred. In addition, the drivers were examined by a driving aptitude test.

The data by DMR are analyzed focusing on fluency of occurrence of emergency brake operation and/or rapid start performance as representing driving behavior as a trial.

The 23 accident cases including cross accident, rear-end accident, turning accident, are collected by ADR for one year. The accident data are analyzed focusing on environmental condition in pre- accident stage and driving behavior.

Relationships between driving behavior and accident are proposed as results of data analysis. In particular, the accident mechanisms of specific accidents, in which the subject ranked careless driver involved can be explained in terms of driving behavior, which is determined by his cognition and/or judgment when he is facing specific environmental situations. A set of the automatic recording systems offer very clear benefits to study traffic accident mechanism in particular on the manner of driving immediately before accident, and they will provide hitherto unavailable information in the field of road safety.

1. INTRODUCTION

For the prevention of traffic accidents, it is important to clarify the relationship between the traffic situation immediately before the occurrence of a traffic accident and the characteristics of individual driver. This mutual relationship, however, is so complicated that accident investigations conducted based on conventional investigation techniques and many inspections and studies made to identify the characteristics of drivers have scarcely succeeded in clarifying it.

Driver education requires that information on these key factors leading to a traffic accident be informed to drivers in a concrete and specific manner. In this driver education, however, information on how traffic accidents occur through this complicated mutual relationship between the traffic situation and drivers' characteristics is provided only briefly and insufficiently; more practical driver education techniques need be developed. The previous report described the effectiveness of the technique of collecting data on the behavior of drivers just before the traffic accidents by using automatic recording systems.(1),(2),(3)

In the paper, the accident data recorder and driving monitoring recorder are installed on commercial vehicles and collected, and analyzed data. Specifically, the accident data recorder was used to collect physical data at the occurrence of traffic accidents, i.e., the change in speeds, impact acceleration, the state

of braking and lighting, etc., just before the traffic accidents and the driving monitoring recorder was used to collect data on the everyday behavior of drivers, i.e., road speed, the frequency of rapid starting and sudden braking, etc.

In this report, one traffic accident that a certain driver encountered is taken up and the situation in which this traffic accident occurred is analyzed in full detail, focusing on the relationship between the traffic situation and the behavior of this driver. The results of this analysis indicate that they can be used as practical data for driver education. The outline of this analysis is described in the following chapters.

2. AUTMTIC RECORDING SYSTEM

2.1 Accident Data Recorder

The accident data recorder (ADR: UDS2156) is the in-car recorder developed by MANNESMANN KIEINZEL which records and stores in memory on speed, longitudinal and lateral acceleration, yaw angle, brake activation (on/off), left and right direction indicators (on/off) , plus six or so on/off channels.(3),(4),(5) While a vehicle is being driven, data, sampled at 500Hz, is stored in temporary memory where it is continuously analyzed by the accident detection algorithm. When the algorithm recognizes the characteristic features of an accident, the previous 30s and after 15s of data is transferred in coded form to a permanent memory. After data is stored, this recorder stands by, waiting for the next collision. It can record data on the first and second collisions.

2.2 Drive Monitoring Recorder

The driving monitoring recorder (DMR: YAZAC-5064)(6) is the in-car safety driving recorder developed by YAZAKI METER Co., Ltd. It was developed as a recorder capable of monitoring the conditions of everyday traveling of vehicles. All other travel conditions such as running speeds, travel distance etc., are recorded as digital data. The data may be informed an important clue to identify and appreciate the behavior of drivers from view of safety driver.

3. METHOD

3.1 Data Collection

The accident data recorder and driving monitoring recorder were mounted on 20 commercial vehicles. The accident data recorder tracks the vehicles on which it is mounted. On the other hand, the driving monitoring recorder tracks the drivers of these vehicles on which it is mounted. A 20 regular drivers were selected for 6 months, and after 6 months another group of 20 regular drivers were selected as subjects. The actual number of subjects selected this way, however, was 36 for reasons related to the combination of vehicles and drivers.

Each subject carries his own identification card; he inserts his card into the driving monitoring recorder each time he gets on a vehicle and pulls the card out when he goes off duty. Each card had a capacity of 65 KB and was withdrawn every two weeks to be integrated into a collection of actual records.

Data on all accidents that these 20 vehicles encountered during the twelve-month period were collected. The accident data recorder (ADR) can record data on two traffic accidents that occur successively. To verify whether these two successive traffic accidents are recorded as two successive events in the accident data recorder, it is necessary to check the operating conditions of this recorder. In the experiment, a line of communication was established beforehand so that data on accidents that occurred could be collected immediately. After all data were collected, the accident data recorder was automatically set back in service, getting itself ready to handle the next traffic accident.

3.2 Driving Behavior

Figure 1 shows an example of data collected by DMR (This data is from an accident later described in Figure 2). The change in speeds and all other travel conditions

are recorded. It is possible to analyze and/or calculate how many times of the speed limit is exceeded, the number of times of rapid starts and sudden braking according to a definition rate.

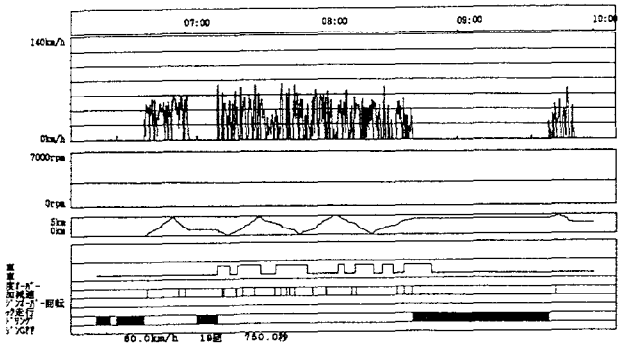

Fig.1 An Example of DMR Data

Based on DMR data collected, the number of times of sudden braking (exceeded by 3.75m/s2), rapid acceleration and starting (exceeded by 3.00m/s2), and the frequency of them per 100 km were analyzed. As an attempt to assess the driving characteristics of each subject objectively, the safety diagnostic indicators (radar chart) shown in the following were studied.

Specifically, the frequency of sudden braking, rapid starts and hard acceleration, speed distribution, the ratio of travel distance under loaded condition to that under unloaded condition (the loaded condition means traveling with a passenger and the unloaded condition means traveling without a passenger), economic efficiency, etc., were selected as elements for the assessment of driving characteristics. Values of these elements were recorded for all subjects and they also were calculated to obtain average values.

With these averaged values defined as 100, recorded values were plotted to make a radar chart; in other words, data on each individual subject was processed in a way that it could be represented on the basis of specified benchmarks and be plotted as indicators to make a chart as shown in Figure 2. This radar chart allows the identification at first sight of how each subject's driving characteristics differ from the overall average.

Unsafe driving behavior requiring special attention, a much greater frequency of sudden braking, for example, or overall driving characteristics of each subject can be identified by simply viewing the shape of this chart. Detail data analysis is now under consideration.

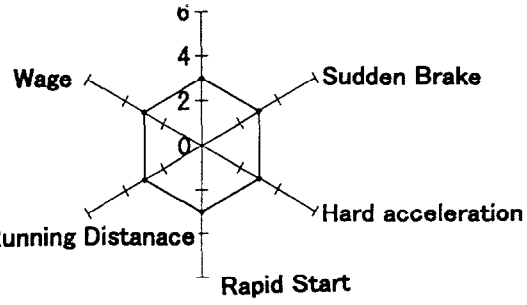

Fig. 2 A Radar Chart represented Driving Characteristics.

3.3 Accident Data

A 20 Data obtained by ADR, specifically, data on 13 different cases were analyzed in full detail. Further, in order to identify a mechanism of the traffic accidents based on the results of accident data analysis, we went to the actual site where a traffic accident occurred to verify the road conditions and to make various site surveys. We used data obtained this way to relate it to the driving behavior (speed, the state of acceleration and deceleration, braking, operation of direction indicators, etc.) just before the occurrence of the traffic accident.

4. RESULTS

4.1 Evaluation Driver Behavior

Data on the driving behavior of drivers collected with the driving monitoring recorder over a period of about one year were evaluated, focusing attention on the number of times of sudden braking and rapid starts and distance traveled. Table 1 shows the results.

Figure 3 shows the radar chart represented driver behavior on driver A. He is characterized as careless driver because driving behavior with high frequency of rapid braking, start and acceleration.

Table 1 An Example of Result of Driving Behavior by DMR.

subject	frequency of them per 100 km			
	acceleration	starting	braking	starts
A	20.57	40.36	3.09	302
B	2.12	1.32	1.59	424
C	2.23	14.35	1.59	128
D	13.99	13.03	15.26	522
E	16.33	13.36	3.86	369

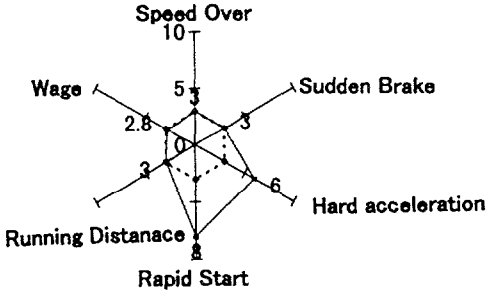

Fig. 3 The Radar Chart represented Characteristic of Driver "A"

4.2 An Example of Traffic Accident Data

Figure 4 shows an example of data on traffic accidents collected by ADR. The data is raw data acquired by the recorder showing the change in speeds and state of braking during the period of 45 seconds just before and after the occurrence of traffic accidents. As is evident from this figure, the operation of data storage starts in response to the front-to-back (and side-to-side) impact acceleration which occurred just short of the 30-second point (called a trigger point) along the abscissa axis.

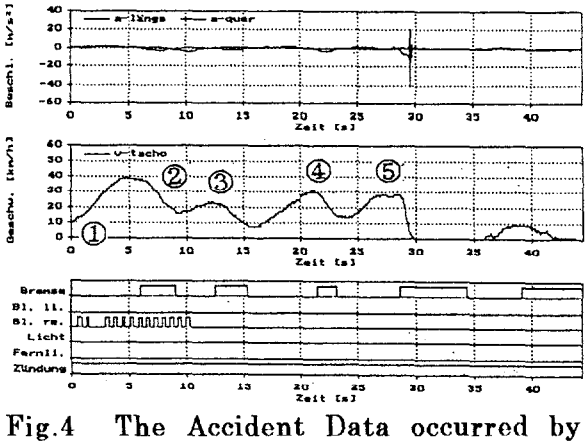

Fig.4 The Accident Data occurred by Driver "A".

As shown in Figure 4, the change in speeds can be verified as follows:

(1) The vehicle that caused the traffic accident increased the speed for about four seconds, starting at about 10 km/h, and reached 40 km/h. During all this time, the right direction indicator remained on. As it reached 40 km/h, it slightly decreased the speed for about 2 seconds and continued running by maintaining this decreased speed, and

(2) it decreased the speed to about 17 km/h by braking, and then

(3) it increased the speed to about 23 km/h and immediately slowed down by braking. After repeating this cycle of decreasing and increasing the speed twice, it reached the site of the traffic accident.

This driving situation can be interpreted as follows:

The driver increased the speed from 10 km/h to 40 km/h while keeping the right direction indicator on, that is, turning the vehicle right. As he reached 40 km per hour, he decreased the speed (about 1.8 m/s^2) by braking. Then he repeated a cycle of increasing the speed and decreasing speed by braking to reach the target speed of about 30 km/h. This indicates that he was driving carefully.

Under what traffic situation did he drive his vehicle this way? Why did the traffic accident occur though he drove carefully? We analyzed data in more detail to understand the situation just before the occurrence of the traffic accident as follows:

After the step (3) mentioned earlier,

(4) after the vehicle reached approximately 30 km/h, it immediately decreased the speed,

(5) it again reached about 30 km/h and maintained this speed for approximately 3 seconds.

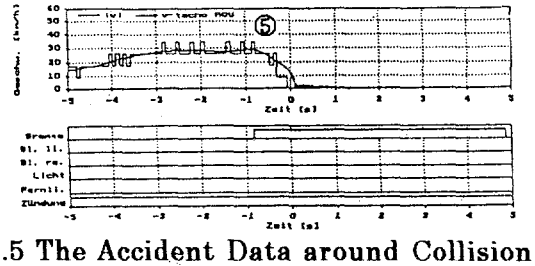

Fig.5 The Accident Data around Collision occurred in Figure.4.

In Figure 5, data are expanded with the trigger point (0) as the center of expansion. That is, the brake was applied immediately after the vehicle maintained the speed of about 30 km/h for about 2 seconds. At the point about 0.8 second after the brake was applied, the collision occurred.

When this collision occurred, the vehicle's speed was about 12 km/h. Right after this collision, the wheels were locked and a reading on the speedometer was 0. It is also noted that the driver continued to step on the brakes for 5 seconds after this collision.

It is estimated that the brake was applied a little too late but why? Is it simply the matter of a little slow reaction on the part of the driver? Is it related to this particular traffic situation?

In Figures 6 and 7, the traffic situation of the accident site is shown. The accident site is in the typical downtown area of Tokyo where a narrow one-way road crosses another narrow road. In Figure 6, the route that the vehicle followed right before the occurrence of the accident is shown. This one-way road is used as a detour that allows drivers to enter from the main street (A), go through eight small crossings and get on the main street (B) which leads to the heart of Tokyo about 230 m away from where this one- way road meets the main street (B). In Figure 7, photos of a intersection with traffic lights and the crossing where the accident occurred are shown. The crossing where the accident occurred is the third crossing.

This crossing is the only crossing where the one-way road leading to the main street (B) crosses a two-way road. Considering that this one-way road crosses other one-way roads at all other crossings, this particular crossing is estimated worth special attention.

With reference to data on this traffic accident shown in Figures 4 and 5, the behavior of the vehicle that caused the traffic accident can be analyzed according to Figure 6 as follows:

(1) the vehicle in question running at the speed of about 10 km/h increased the speed just short of the intersection with traffic signal lights of the main street (A). With the right direction indicator turned on, it approached the crossing that had traffic lights. At this time, it increased the speed to 40 km/h.

(2) just short of the crossing that had traffic lights, it decreased the speed to about 17 km/h by braking and turned right at the crossing and entered the one-way road (speed limit: 20 km/h).

(3) over a distance of about 50 m short of the first crossing, it slightly increased the speed. As it was approaching the crossing, it decreased the speed to about 9 km/h by braking.

(4) over a distance of about 30 m short of the second crossing, it increased the speed to 30 km/h. Just short of the crossing, it decreased the speed to about 15 km/h by braking.

(5) Over a distance of about 30 m short of the third crossing (where the accident occurred), it increased the speed according to the same pattern of driving behavior and approached the crossing. It seemed to decrease the speed as it did when approaching the crossing mentioned under (4) above but it actually did not decrease the speed; it kept on traveling at the speed of about 30 km/h for about 2 seconds.

There is similarity in the behavior described based on each specific distance traveled to each crossing. As Figure 5 indicates, however, after it reached the speed of approximately 30 km/h, the brake was applied 1.5 to 2 seconds later when approaching the third crossing (where the accident occurred) than when approaching the first and second crossing. Figure 8 shows the relationship between distances from the point of collision as a base point and speeds at each distance. That is, it is found from Figure 8 that the speed was increased at the point 10 m short of the point of collision.

The speed and time in Figure 5 indicate that the vehicle was approaching the crossing where the accident occurred while starting to increase the speed at the point approximately 5 seconds before the collision. After it reached

the speed of about 28 km/h, it decreased the speed for an instant. Because the driver did not step on the brakes at this moment, it is estimated that he released the accelerator pedal and consequently the speed decreased for an instant. Then the driver depressed the accelerator pedal and the speed increased, which indicates that he intended to pass through the crossing without decreasing the speed.

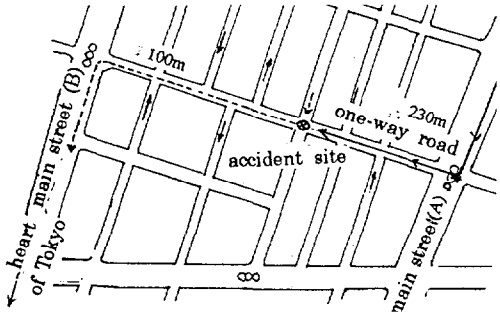

Fig.6 The Plan of Accident Site.

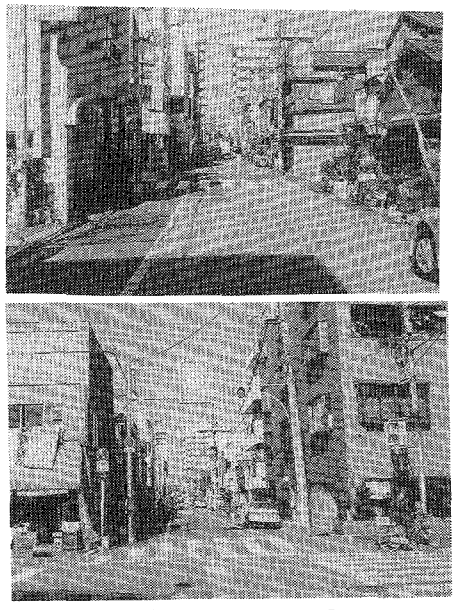

Fig.7 The Scene of Accident Site.

Judging from the fact that the vehicle collided with the back of the other vehicle entering the crossing, the driver of the vehicle in question could not see the other vehicle approaching the same crossing because the wall of a house in the corner interrupted the view. That is, it is presumed that the driver of the vehicle that caused the accident tried to pass through the crossing while increasing the speed without checking the entry of the other vehicle to the crossing.

What matters here is the driver's judgment. Why did he enter the crossing though he recognized the other vehicle entering the same crossing?

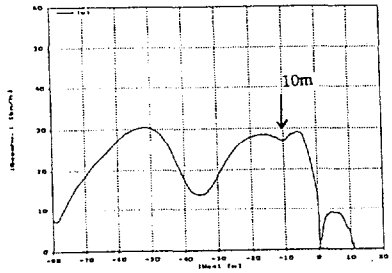

Fig.8 The Speed vs. Distance around Collision occurred.

The first point that need be considered is that this vehicle was traveling on a one-way road which was given the right of way. On the other hand, the other vehicle was traveling on a road with the stop-and-go sign which does not have the right of way.

This awareness of the right of way is thought to be a possible cause of the accident; more specifically, the driver recognized the other vehicle with awareness of the right of way given to the road he was traveling on and reconfirmed in his mind that his vehicle had the right of way over the other vehicle.

This inference may not be well convincing because it cannot account for the behavior of decreasing the speed when approaching the first and second crossings.

The next inference is that the driver intended first to let the other vehicle pass through before his vehicle and then to pass through himself by going directly behind the back of the other vehicle. To do this, he adjusted the speed at the point 10 m short of the crossing. He made a mistake, however, in adjusting the speed and collided with the back of the other vehicle.

In this case, it is presumed that the driver would try to pass behind the other vehicle and to turn the steering wheel to the right. In reality, however, the vehicle behaved just before the collision as shown in Figures 11 and 12, that is, the driver turned the steering wheel to the direction where the other vehicle was proceeding, i.e., he turned it to the left.

Considering these two inferences, the former inference seems to better explain the base of the judgment made by the driver; the driver decreased the speed about 12 m short of the crossing as he did when approaching the second crossing but he judged at the point about 10 m short of the crossing that no vehicle would enter the crossing.

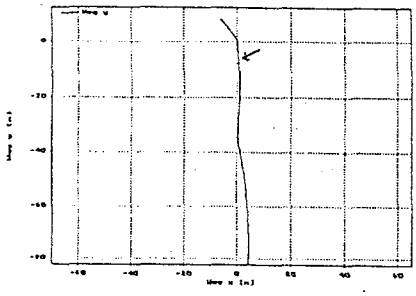

Fig.11 Trajectory of Vehicle Behavior.

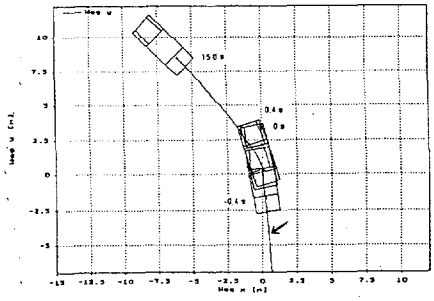

Fig.12 Vehicle Behavior around Collision Point.

In addition to this judgment, he was aware of the right of way given to the road his vehicle was traveling on and also he had experience of driving to the main street (B) (about 130 m ahead) in the same traffic situation. More specifically, he judged that no vehicles would enter his way because three of the remaining four crossings were all T-junctions. It is thought that on this judgment he adjusted the speed to cope with the state of traffic signals on the main street and tried to pass through the crossing where the accident occurred as quickly as possible

5. DISCUSSION

5.1 Accident and Situation

Although data just before the accidents can be collected with the accident data recorder, it is difficult to explain the traffic accident occurrence mechanism unless investigations are pursued to the level where the psychological aspect of drivers' behavior is elucidated. We can safely say that we must further develop the studies in the behavior of drivers through continued effort to collect and analyze data. One thing can be clearly pointed out here: drivers' awareness of the traffic situation is closely associated with the occurrence of traffic accidents. In this particular case, the driver knew that all crossings ahead of the crossing where the accident occurred were T-junctions and that he could drive this distance of about 100 m in a stable smooth manner. Furthermore, it is presumed that still other situation-specific elements affected the driver's behavior, namely, he could see the status of traffic signals at the entry to the main road from a distance and, therefore, he could possibly adjust his speed to have his vehicle slide into the main road smoothly. All in all, the present study suggests that data collected with the accident data recorder can be used effectively to conduct practical studies in the correlation between the traffic accidents and the traffic situation from various angles.

5.2 Relationship between Data of ADR and DMR

According to data collected by the driving monitoring recorder, this driver who caused the traffic accident is identified as being the driver "A" (shown in Table 1) who practice hard acceleration and rapid starts with much greater frequency than other drivers.

Even greater volumes of data are required to study the relationship between the driving behavior under a normal driving situation and traffic accidents and, at the same time, various studies need be conducted to identify how such volumes of data can be analyzed.

The relation with the conventional driver aptitude test in particular is now listed as one of subjects that require studies. The results of the present study indicate that a high frequency of sudden braking and other types of driving behavior generally considered the

factors of ineligibility as a driver can be one of the indexes to identify the characteristics of drivers.

5.3 DMR Data for Safety Education

Data collected with the driving monitoring recorder shows detailed information on individuals' everyday driving and can possibly be used to point out dangerous ways of driving objectively and improve them.

Four subjects were interviewed and results of analysis made on their individual driving data were shown to them. They were advised to improve their driving behavior with respect of two to three driving deficiencies, a greater number of times of sudden braking, for example. Explanations were given as to how the driving monitoring recorder is monitoring their driving behavior at all times and that drivers are required to be well aware of their deficiencies and to have the positive attitude to improve themselves.

The number of driving deficiencies pointed out to each driver is limited to only two or three which may be the limits he can manage to improve at one time. Also such driving deficiencies to be pointed out are limited to the type of behavior that is obviously considered an unsafe driving pattern, such as sudden braking. Also each driver's attention was called to how different his driving data is from data of other subjects, so that each driver as a subject can have a good understanding of the characteristics of his driving behavior.

If it is possible to acquire data attesting to the possibility to improve the driving behavior of professional drivers by giving such simple instructions, the type of education based on data collected by the driving monitoring recorder will be considered worth notice and a new demonstrative approach to the safety education.

6. CONCLUSION

The present study demonstrates that data before and after the occurrence of a traffic accident can be recorded with the accident data recorder and driving monitoring recorder and that a traffic accident can be reproduced in full detail, including the driving behavior just before the occurrence of a traffic accident. If it becomes possible to relate the results of this close investigation into the cause of a traffic accident to the characteristics of drivers' everyday driving behavior, this new approach to the driver education can be an important breakthrough in the prevention of traffic accidents. It is expected that this approach to the driver education based on the effective use of information collected by these automatic recording systems can be a powerful means of practical driver education and can offer convincing clarification on how and why traffic accidents occur through complicated combinations of drivers' characteristics and situation-specific factors.

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