Analysis of Driver's Consciousness for Hazards at Automatic Full-Barrier Crossings

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Abstract

Inquiries about driver's consciousness for hazards at automatic full-barrier crossings have been analyzed by means of the quantification theory (III). For the analysis, drivers were classified in some groups according to driving experiences, ages, and sexes. From the present result, we obtained some useful suggestions for improvement of the design of railroad crossing systems in various geometrical situations and traffic conditions.

1. Introduction

In 1982, we obtained the correlation of car accidents with the condition and geometry of automatic full-barrier crossings from the analysis of the quantification theory (II and III).[1] Japanese National Railway (JNR) has promoted the completion of protective devices, the improvement of crossing-road structures, the grade separation of crossings with heavy traffic of trains and cars, and the abolition of crossings with no barrier and no alarm. Especially, for the completion of protective devices, JNR has aimed that all the crossings for cars have automatic full-barriers. In 1984, crossings of JNR (29, 411 places) were improved by 63% like this, so that car accidents decreased by 40% during the last ten years. However, recently, the accident ratio seems to be saturated to around 0.02/crossing-year without further decreasing. Therefore, it is necessary for the further decrease of accidents to grasp the driver's consciousness for hazards at the crossing in addition to the completion of protective devices. For this purpose, inquiries about driver's consciousness for hazards at the crossing have been analyzed in the present study by means of the quantification theory (III).[2,3]

2. Inquiry Method and Analysis

The inquiry form as shown in Table 1 was referring to the Ikeda's form.[4] The present inquiry has 24 items which has 5 categories (A, B, C, D, and E). The inquiries were made at the Fukui Driver Education Center in May, 1983 for 1493 drivers who were classified

Table 1 Inquiry form for automatic full-barrier crossing

Sex : Male Female, Age : , Occupation :
Scool carrier : University High school Secondary school
Mean driving days/month :
Driving carrier (years) :
Suspension of license : Yes No

Question : When you pass an automatic full-barrier crossing by car, how do you feel the hazard for the following situations (items). Please mark one of the below categories by a circle (○) for all items. When you have no experience for some items, please mark it according to your judgement.
The categories means as follows :
A : very dangerous, B : fairly dangerous, C : somewhat dangerous, D: little dangerous, and E : not dangerous at all.

Items	Categories
1. When you cannot know the existence of a crossing in advance just to it,	A B C D E
2. When you cannot know the heavy traffic at a crossing in advance,	A B C D E
3. When it is hard to see a crossing even close to there,	A B C D E
4. When the stop line at a crossing is not remakable.	A B C D E
5. When it is hard to see the red light of an alarm,	A B C D E
6. When it is hard to hear the sound of an alarm,	A B C D E
7. When the coming direction of a train is not clear,	A B C D E
8. When it is not clear if a train is coming from the contrary way,	A B C D E
9. When it is not clear how far a train is coming,	A B C D E
10. When the warning time of an alarm is long due to stoppage or slow speed of a train,	A B C D E
11. When it is feared that a car is intercepted on a crossing due to rapid shutting of barriers at the outside,	A B C D E
12. When it is feared that a car is intercepted on a crossing due to shutting of a full barrier at the outside,	A B C D E
13. When barriers do not rise soon after train passed,	A B C D E
14. When the visibility of a train at a crossing is poor,	A B C D E
15. When the road illumination at a crossing is poor,	A B C D E
16. When a walk is not separated on a crossing from a roadway,	A B C D E
17. When a road is paved poorly on a crossing,	A B C D E
18. When a crossing width is narrower than a road at the outside,	A B C D E
19. When a crossing is too long,	A B C D E
20. When a road is sloped before or behind a crossing,	A B C D E
21. When a road crosses obliquely with a railroad,	A B C D E
22. When a road crosses with a road near a railroad crossing,	A B C D E
23. When an emergency alarm is not noticeable,	A B C D E
24. When it is hard to understand how to operate an emergency alarm,	A B C D E

for the analysis of the quantification theory (III) to (a) good drivers of no license suspension during the last five years (423), (b) bad drivers of heavy accident or habitual violation (132), (c) young drivers of 18-24 years old (93), (d) drivers of 25-34 years old (247), (e) drivers of 35-44 years old (184), (f) drivers of 45-59 years old (165), and (g) female drivers (249).

3. Analytical Results and Discussion

3. 1 Structure Analysis of Driver's Consciousness[5)]

The analysis of the quantification theory (III) give the category score as x_1 and x_2 for each category. Such scores are plotted in Figs. 1-7. ; for example, the score point given as 2A in Fig. 1 represents the score of category 2A (that is, category A of item 2 in Table 1) for the above good-driver group.

The value of x_1 represents the relative degree of hazard consciousness. The larger positive value corresponds to the more harzardous consciousness and the larger negative value does to the less one. The value of x_2 is the secondary measure of the relative degree hazard consciousness for comparison between categories having the similar value of x_1 : the larger is the more hazardous.

(a) Good-driver group

The pattern of category scores for this group is nearly of a V-type as shown in Fig. 1.

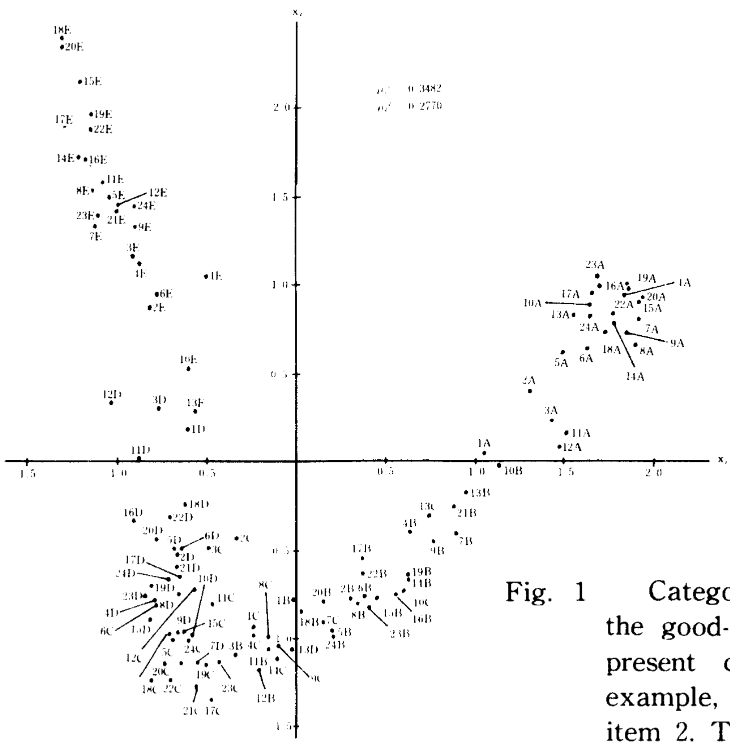

Fig. 1 Category response pattern for the good-driver group. Signs represent category numbers ; for example, 2B means category B of item 2. The meaning of categories are explained in Table 1.

The score of category A for all items lie in the zone of $+x_1$ and $+x_2$, suggesting the heavy hazard consciousness. The score of category B for all items gives the value of x_1 less than caoegory A and furthermore the negative value of x_2, suggesting the hazard consciousness lighter than category A. The score of categories C, D, and E lie in the zone of $-x_1$ suggesting the hazard consciousness further lighter than category B. It should be noticed that almost the scores of respective categories for all items swarm in a certain zone. This means that good drivers can distinguish the degree of the hazard consciousness of items clearly.

(b) Bad-driver group

The pattern for this group in fig. 2 indicates that the score of category A for all items lie together in a certain zone, but the scores of other categories are confused broadly in contrast to Fig. 1. This means that bad drivers cannot distinguish the degree of the hazard consciousness of items clearly except category A. The separation of category groups is the worst as compared with the following groups as well as the good-driver group.

(c) Young-driver (18-24 year-old) group

The pattern for this group in fig. 3 indicates that the value of x_1 for all items are not so different between categories A, B, C, and D except E so that the difference between categories can be distinguished only by the value of x_2 ; that is, the value of x_2 is roughly in the order of A, B, and (C+D). This means that young drivers cannot so clearly distinguish the hazard consciousness between categories A, B, C, and a part of D as the difference is shown by x_1.

(d) 25-34 year-old driver group

The pattern for this group in Fig. 4 is almost the same with that for the good-driver group, although they scores of the same category lie not so densely between items as in Fig. 1. This means that drivers of this age bracket have the appropriate hazard consciousness as the good driver group because they are sound physically and mentally in the prime of life.

(e) 35-44 year-old driver group

The pattern for this group in Fig. 5 indicates that the category scores of x_1 are not so different between categories A and B like for young drivers in Fig. 3. This means that drivers of this age bracket take the hazard consciousness rather easy from experience.

(f) 45-59 year-old driver group

The pattern for this group in Fig. 6 is almost the same with that in Fig. 4 although the scores of categories A and B lie not so densely between items as in Fig. 1. This means that drivers of this age bracket take the hazard consciousness severer than 35-44 year-old

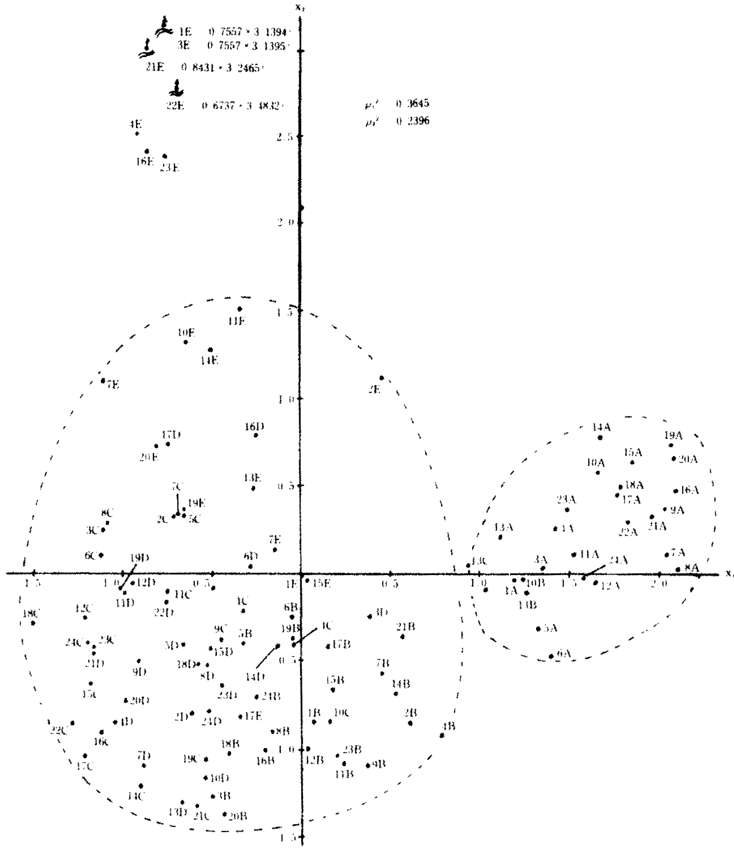

Fig. 2 Category response pattern for the bad-driver group.

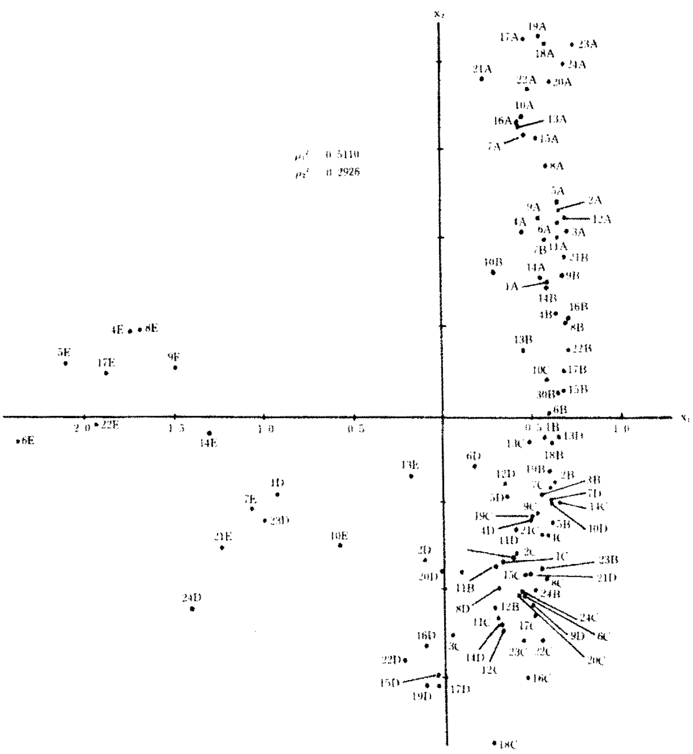

Fig. 3 Category response pattern for the young-driver group.

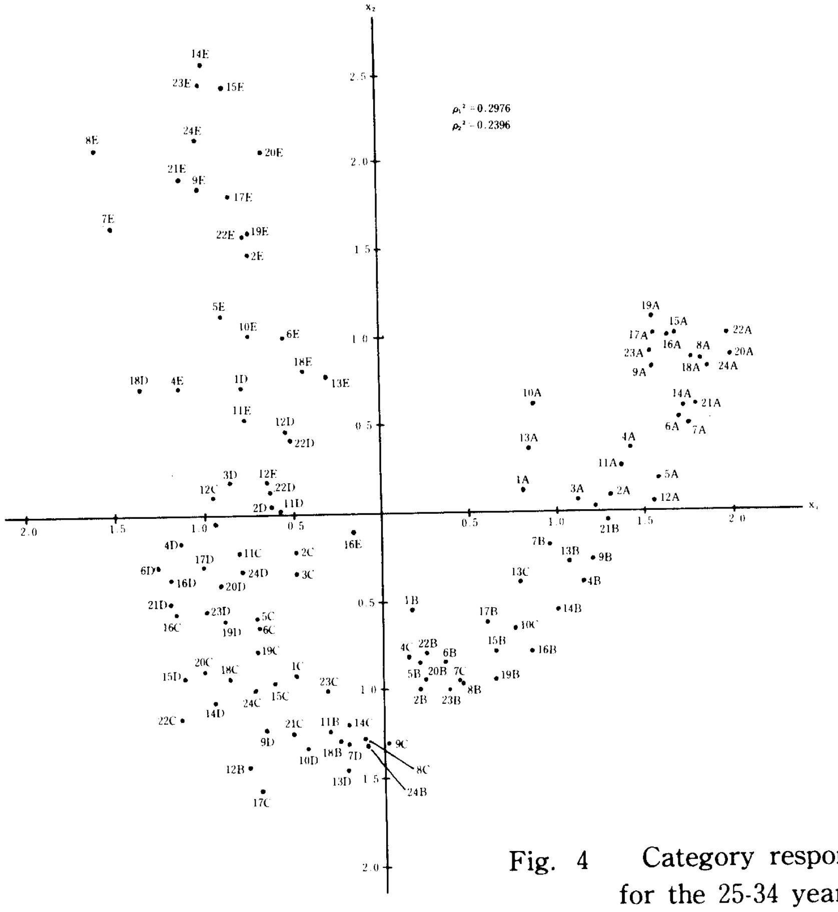

Fig. 4　Category response pattern for the 25-34 year-old driver group.

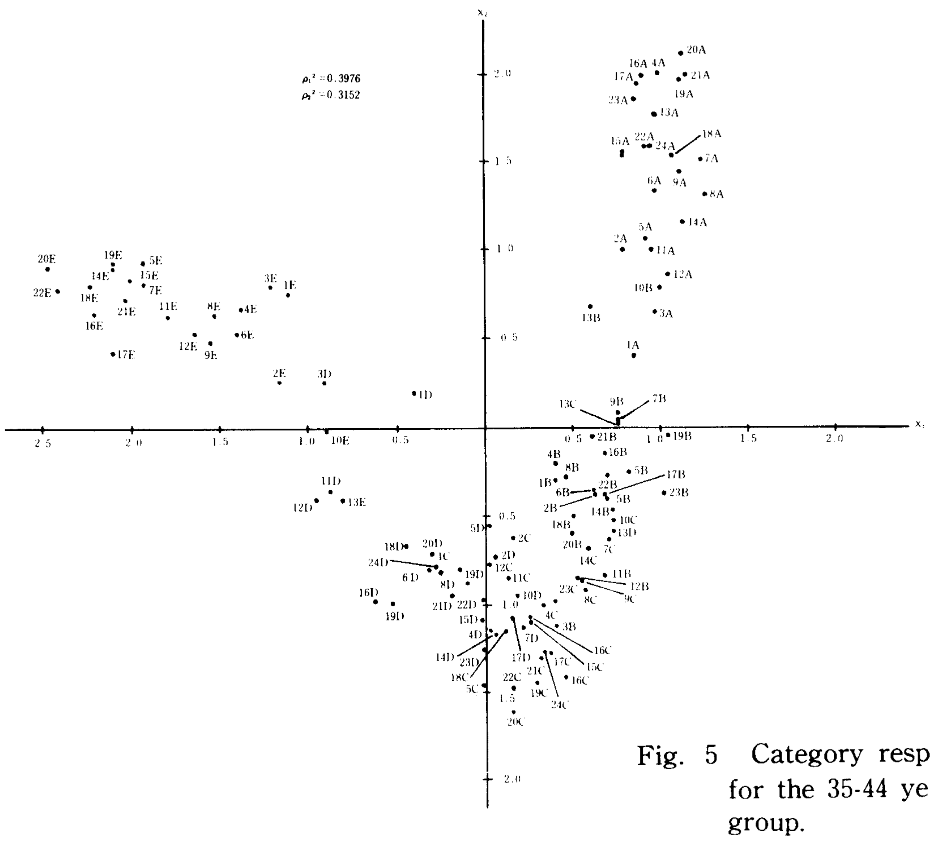

Fig. 5　Category response pattern for the 35-44 year-old driver group.

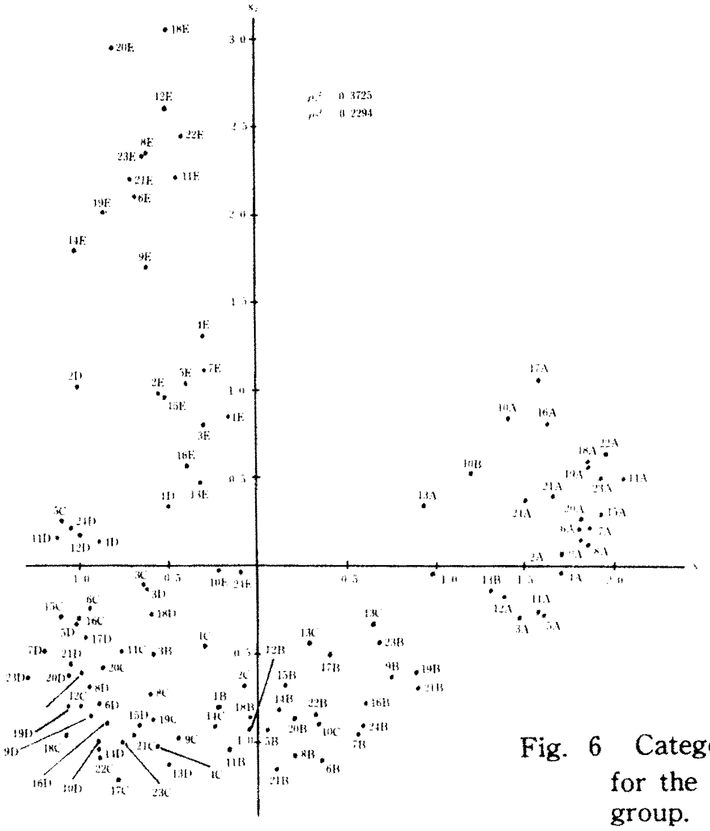

Fig. 6 Category response pattern for the 45-59 year-old driver group.

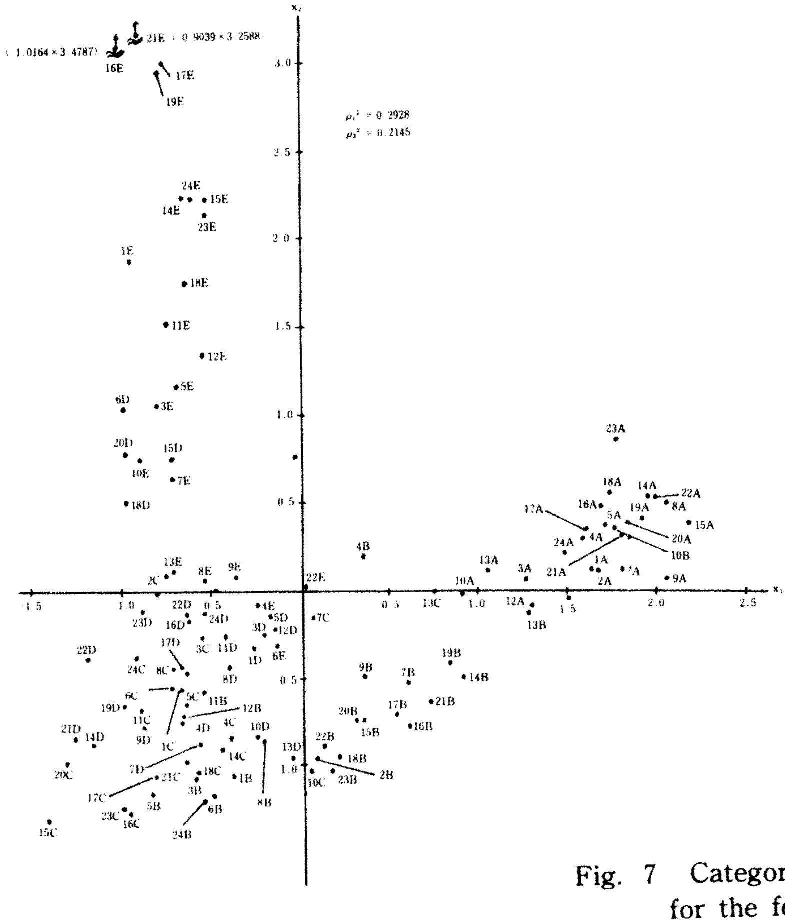

Fig. 7 Category response pattern for the female-driver group.

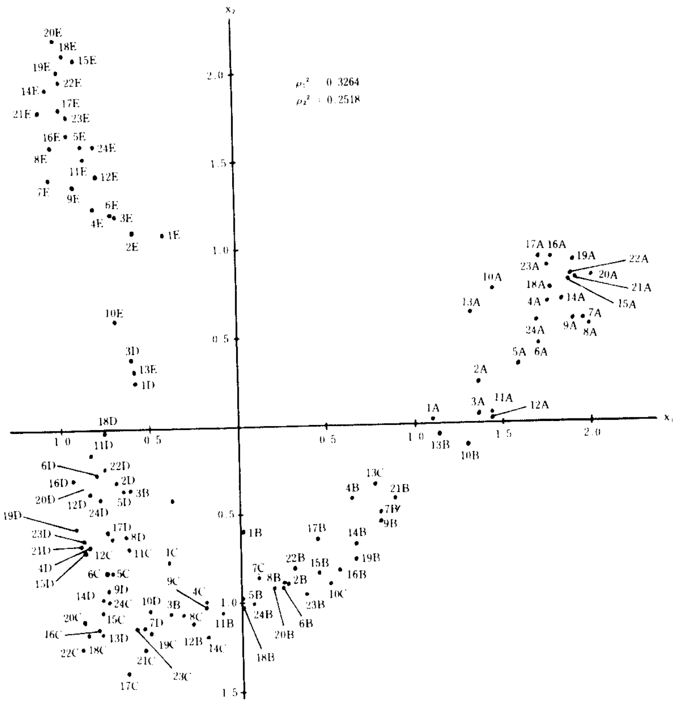

Fig. 8　Category response pattern for all drivers.

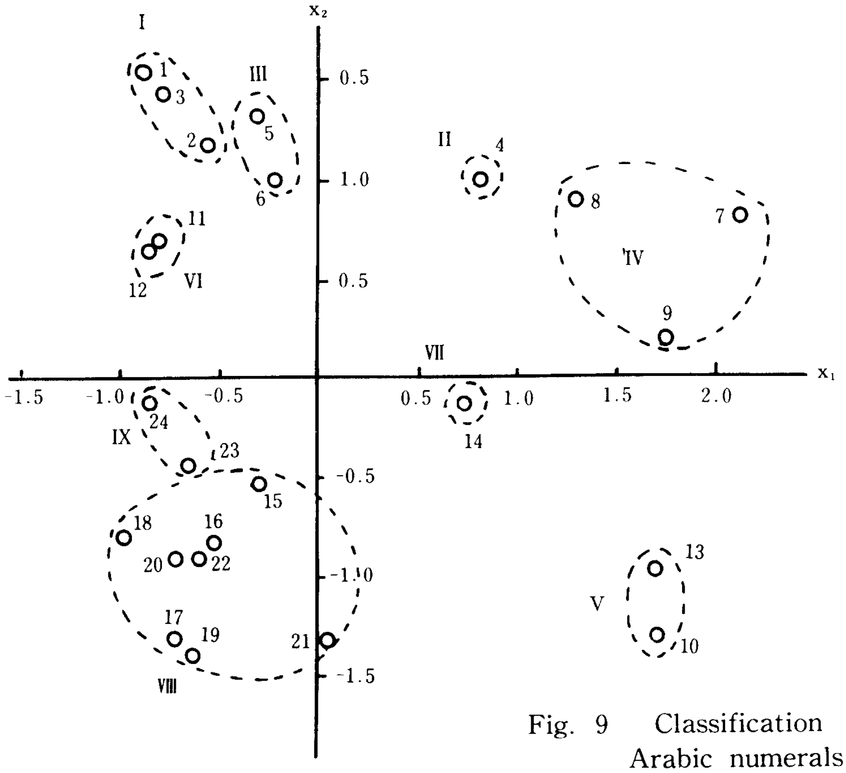

Fig. 9　Classification of items. Arabic numerals represent item number in Table 1. Roman numerals represnt item-group number explaind in 3.3.

drivers.

(g) Female-driver group

The pattern for this group in Fig. 7 is almost the same with that in Fig. 6.

3. 2 Correlation of Hazard Consciousness between Driver Groups

The pattern, obtained from inquiries of all drivers, is shown in Fig. 8. As comparing this pattern with those for respective groups (Figs. 1-7), it is noticeable that the patterns for 18-24 year-old drivers (Fig. 3) and 35-44 year-old drivers (Fig. 5) as well as bad drivers (Fig. 2) are different from this pattern in Fig. 8. That is, the hazard consciousness of these drivers is loose. As a matter of course, the confused pattern in Fig. 2 indicates that bad drivers, who caused heavy accidents or repeated the violation of traffic rules, cannot distinguish the degree of the hazard consciousness clearly for various situations at all.

3. 3 Hazard Consciousness Measured by Item Groups

Since drivers answered A or B for almost the items, the quantification theory (III) was apllied only to such samples; that is, other samples were omitted for the present analysis. The result is shown in Fig. 9, in which the figure represents the item number in Table 1. From this result, the items can be grouped as shown by dotted circles which are numbered by Roman. These item groups can be characterized as follows:

I Visibility of a crossing from a vehicle (items 1-3),

II Visibility of the stop line of a crossing (item 4),

III Visibility of warning lights and hearing of warning sound (items 5&6),

IV Rationality of notification of the coming direction of a train at a crossing (items 7-9),

V Rationality of the shutting time of crossing barriers (items 10&13),

VI Rationality of a crossing-barrier operating method (items 11&12),

VII Visibility of a train from a crossing (item 14),

VIII Rationality of crossing structures (items 15-22), and

IX Operationality of emergency alarms (items 23&24).

Mean category scores of these item groups for respective driver groups are plotted as a radar chart in Fig. 10. For this plotting, at first, we must determine the mean category score of all items; for example, when numbers of female drivers answering A, B, ⋯, E for item i are n_{iA}, n_{iB} ⋯, n_{iE} respectively, the mean value of item i for the female group is obtained from

$$\bar{x}_{1i} = \frac{x_{iA}n_{iA}+x_{iB}n_{iB}+\cdots+x_{iE}n_{iE}}{n_{iA}+n_{iB}+\cdots+n_{iE}}$$

where x_{iA} represents the value of x_1 for $_{iA}$ in Fig. 8. Then, the mean value of item group I for the female group is obtained like

$$\bar{x}_{I} = \frac{\bar{x}_{11}+\bar{x}_{12}+\bar{x}_{13}}{3}$$

because item group I consists of three items (items 1, 2, and 3 as shown in Fig. 9.)

It is the most noticeable in Fig. 10 that the mean value of item group VI is the largest for all the driver groups except the bad-driver group. This means that almost the drivers have the strong hazard consciousness for interception of a car by automatic full-barriers. In fact, accidents due to such an interception account for 20% of all accidents in 1983 and increase gradually for the last years. The counterplan for the interception by the barriers is necessary without delay.

The mean value of item group IX is large for the female and bad-driver groups. This means that the operation of an emergency alarm is not familiar for them. The greater part of accidents due to cars stalling on a track in front of a coming train and due to falling-off road of a wheel on a track may be prevented by making the proper operation of an emergency alarm well-known.

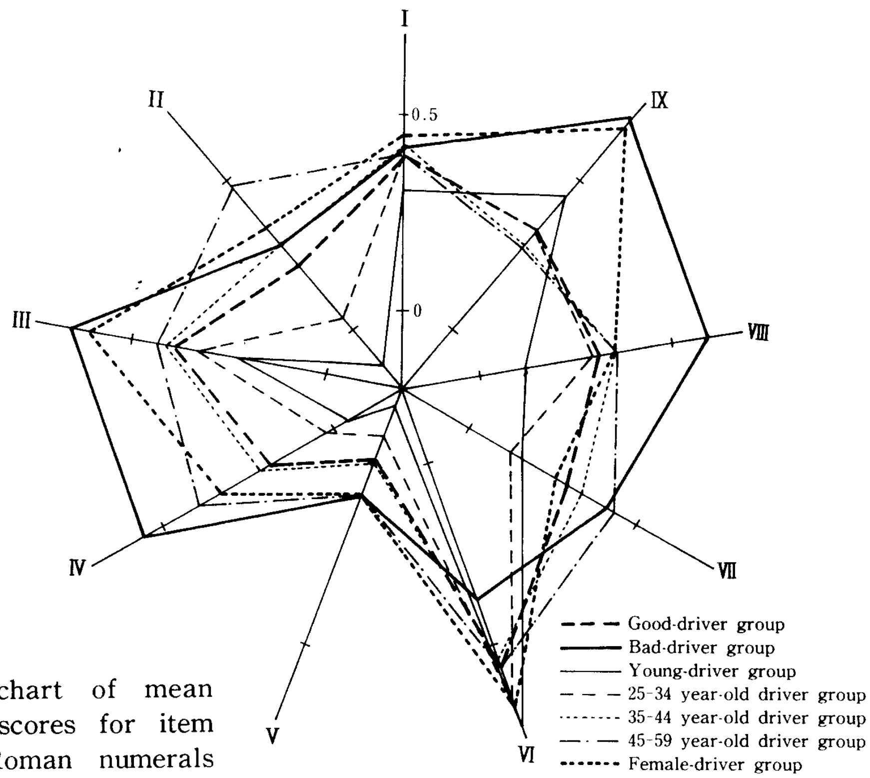

Fig. 10 Radar chart of mean category scores for item groups. Roman numerals represnt item-group number defined in Fig. 9.

The mean values of item groups I and III are rather large for some driver groups because, recently, it is frequently difficult for drivers to recognize the existence of a crossing by means of audible or light warning due to advertisement boards, illiminations, and traffic lights near a crossing and also the sound of car radio. Therefore, the advance indication for the existence of a crossing by using the warning plate and writing the warning on the road surface is more important than the improvement of the warning light and alarm.

It is interesting that the mean value of item group V is the smallest for all the driver groups and that the mean value of item group VIII is rather small for the driver groups except the bad-driver group.

So far, we discussed the hazard consciousness only in terms of x_1. When the mean value of x_2 for item groups is estimated similarly with x_1, the pattern of mean item-group scores for the driver groups is obtained separately for the item groups as shown in Fig. 11 to confirm the correlation of hazard consciousness between the driver groups as discussed already in 3. 2. Since the value of the good-driver group may be the standard, the deviation from this value may be used as a measure of the deviation from the standard hazard consciousness for other driver groups. Generally speaking, as expected from 3. 2, the values for the bad, young, and female groups are largely deviated from that for the good-driver group.

4. Conclusion

When the pattern of hazard consciousness at a automatic full-barrier crossing, obtained by means of the quantification theory (III), is compared between the driver groups, as a whole, the consciousness structure seems to be almost the same essentially between the groups except the bad-driver group of heavy accident or habitural violation. However, some characters are noticed for some groups as pointed out in 3. 2. These characters are discussed in detail in 3. 1.

Next, the hazard consciousness was analyzed from the standpoint of crossing items (3. 3). The result indicates that drivers have the strong hazard consciousness for "I Visibility of a crossing from a vehicle", "III visibillity of warning lights and hearing of warning sound", "VI rationality of a crossing-barrier operating method", and "IX operationality of emergency alarms". Counterplans for these items are proposed in 3. 3.

As shown in the present study, the application of the quantification theory (III) to the analysis of crossing accidents is very useful for making the counterplan of suppressing accidents.

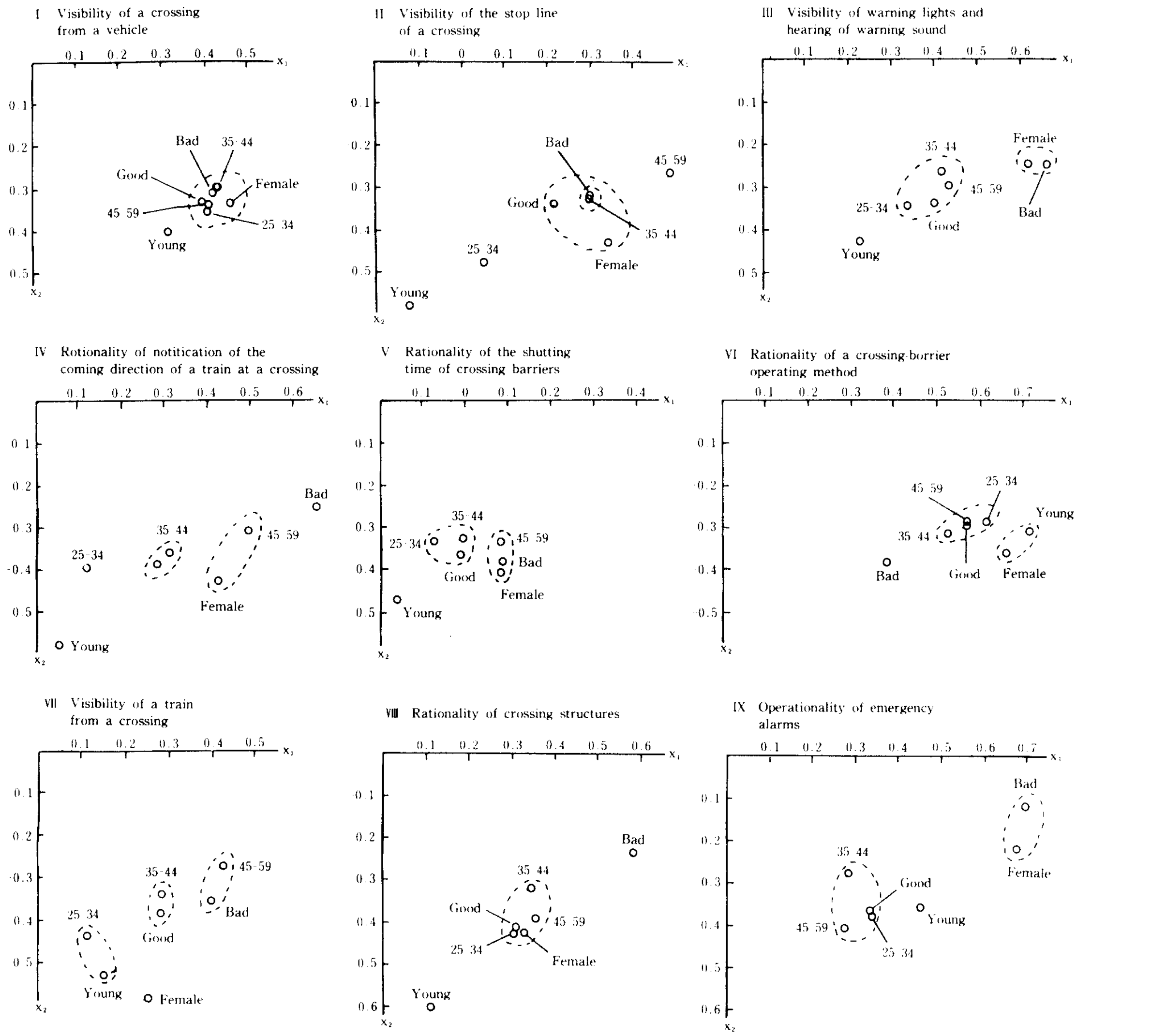

Fig.11 Mean category-reponse pattern of driver groups for various item groups.

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APPENDIX

Application of the quantification theory Type III

As shown in Table A, one sample responds in categories in each item, Q is the total number of types with mark ∨, and L_1, L_2, ⋯, and L_R mean the categories. The idea of Type III is that samples with similar response pattern of categories must be arranged to gather closely in such a table so that we may understand the similarity of the sample and the correlations among the categories, and also classify the samples and the categories into some similar groups. Statistically this corresponds to determination of values of y_i (a value given for the sample i) and x_j (a value for the category L_j) so as to maximize the correlation coefficient ρ between y_i and x_j. If the closeness (or similarity) among samples or categories is treated on the one-dimensional basis, it may be represented using only one axis. Otherwise, that is, if the one-dimensional analysis is not effective, we may represent it with two-dimensional plane.

Let us denote $\delta_i(j) = 1$ for the sample i having a response in the j'th category (with the mark ∨) and $\delta_i(j) = O$ for on response in the j'th category.

Then we may write

Table A Response pattern for the Type III

Category	L_1	L_2	L_3 ⋯⋯⋯	L_j	⋯⋯⋯⋯⋯⋯⋯ L_R
Samples					
1	∨		∨		
2		∨		∨	
3			∨	∨	∨
4	∨		∨		
⋮					
j		∨			∨
⋮					
Q	∨			∨	∨

$$\ell_i = \sum_{i=1}^{R} \delta_i(j), \text{ and } n = \sum_{i=1}^{Q} S_i,$$

where ℓ_i is the number of categories having responses in the sample i, S_i the number of the samples in the type i, N the size of the sample, and Q the total number of the types with the mark ∨. If we define $\sigma_x{}^2$, $\sigma_y{}^2$, and C_{xy}

as $$\sigma_x{}^2 = \sum_{i=1}^{Q}\sum_{j=1}^{R} \delta_i(j)S_i x_j{}^2/(\bar{\ell}_n) - \left\{\sum_{i=1}^{Q}\sum_{j=1}^{R} \delta_i(j)S_i x_j/(\bar{\ell}_n)\right\}^2,$$

$$\sigma_y{}^2 = \sum_{i=1}^{Q} S_i\ell_i y_i{}^2/(\bar{\ell}_n) - \left\{\sum_{i=1}^{Q} S_i\ell_i y_i/(\bar{\ell}_n)\right\}^2,$$

and $$C_{xy} = \sum_{i=1}^{Q}\sum_{j=1}^{R} \delta_i(j)S_i x_j y_i/(\bar{\ell}_n) - \left\{\sum_{i=1}^{Q}\sum_{j=1}^{R} \delta_i(j)S_i x_j/(\bar{\ell}_n)\right\} \times \left\{\sum_{i=1}^{Q} S_i\ell_i y_i/(\bar{\ell}_n)\right\},$$

where

$$\bar{\ell}_n = \sum_{i=1}^{Q} S_i\ell_i$$

The correlation coefficent ${}^1\rho$ (the superscript 1 means one-dimensional) can be expressed as

$${}^1\rho = \frac{C_{xy}}{\sigma_x\sigma_y}, \qquad \text{(A. 1)}$$

Maximizing ${}^1\rho$, we obtain

$$\sum_{j=1}^{R} h_{jk}x_j = {}^1\rho^2 \sum_{j=1}^{R} f_{jk}x_j \quad (k = 1, 2, \cdots\cdots\cdots R), \qquad \text{(A. 2)}$$

where

$$h_{jk} = \sum_{j=1}^{Q} \frac{\delta_i(j)\delta_i(k)}{\ell_i} S_i - \frac{1}{\bar{\ell}_n} \sum_{i=1}^{Q} \delta_i(j)S_i \cdot \sum_{i=1}^{Q} \delta_i(k)S_i$$

$$f_{jk} = \frac{1}{\bar{\ell}_n} \sum_{i=1}^{Q} \delta_i(j)S_i \cdot \sum_{i=1}^{Q} \delta_i(k)S_i \,; (\text{for } j \neq k),$$

and $$f_{jk} = \sum_{i=1}^{Q} S_i\delta_i(k) - \frac{1}{\bar{\ell}_n} \sum_{i=1}^{Q} \delta_i(j)S_i \cdot \sum_{i=1}^{Q} \delta_i(k)S_i \,; (\text{for } j = k).$$

In solving Eq (A. 2), we utiltize matrix representation

$$\boldsymbol{HX} = \rho^2\boldsymbol{FX} \qquad \text{(A. 3)}$$

where $\boldsymbol{H} = [h_{jk}]$, $\boldsymbol{F} = [f_{jk}]$, and $\boldsymbol{X} = [x_j]$

In solving Eq (A. 3), the latent equation is utilized as in the case of Type II theory, and the maximum element of latent vector gives ${}^1\rho^2$. Such a treatment can be extend to multi-dimensional analysis as in the Type II theory. The two-dimensional analysis can be done by putting a value v_i (i=1, 2, ⋯, Q) to the sample i and a value u_j (j=1, 2, ⋯, R) to the category j and maximizing the correlation coefficient $\rho = {}^1\rho \cdot {}^2\rho$, where ${}^2\rho$ is the correlation coefficient between v_i and u_j.