Weighting Method Which Reflects Risk Cognition of Railway Users

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We executed the social investigation in order to grasp risk cognition of users with regard to railway accidents and transportation disturbances. Based on the result of investigation, we constructed a "Risk cognition model of railway users" which consists of two factors. The first factor shows proximity of risk cognition, and another factor shows level of fear of risk cognition. Based on this model, we have developed a weighting method which reflects risk cognition of railway users.

Keywords: risk cognition, railway accident, factor analysis

1. Introduction

For effective risk management, it is necessary to grasp the situations inside and outside the organization. Therefore, we executed investigations and researches to grasp actual status of users' cognition regarding the risks of railways in Japan.

We investigated the contents of the cases that users consider hazardous [1], [2]. Furthermore, we investigated the number of accidents and fatalities which were caused due to the contents of those hazards, magnitude of their influence, and the degree of considering them hazardous. As a result of investigation, we confirmed a gap (cognitive bias) between the actual one and the estimated one with respect to the incident number of accidents and transportation disturbances as well as number of fatalities [3]. This phenomenon is the same as that of the general events causing death.

Moreover, we constructed a social cognitive model in railways, consisting of the two factors [4]. The first factor shows evaluation about the "occurrence rate of incidence" as well as "encounter rate of oneself" regarding the accidents generated due to the contents of hazards, and another factor shows evaluation about "magnitude of the influence (injury)" and "the risk (dangerousness)" when accidents occurred due to the contents of hazards. We proposed to calculate the total risk score by adding the points evaluated by these two factors. However, cognition about the organization for implementing countermeasures and their contents are not included in this model of factors.

In this research, we confirmed that even if cognition regarding the countermeasures was added to the model, the factor structure which is the same as that of the survey at the previous time was observed. Furthermore, we constructed a "risk cognition model of railway users" and a calculation method of weighting, from a series of research results.

2. Confirmation of the two-factor model for risk cognition by railway users

2.1 Survey data

We executed an internet survey by targeting 8 regions

(Hokkaido, Tokyo, Niigata, Nagano, Aichi, Osaka, Hiroshima, and Fukuoka prefectures) from August to October, 2012 [5]. Subjects (target persons) of the survey are the men of the ages between 20 to 59 who have a railway commuter passes and who had experienced service disruption and/or operational delay of over 30 minutes in the preceding during this one year. Number of analysis data amounted to 2,068 persons who use railways twice or more a week.

2.2 Survey items

Subjects were asked about their perception of the selected hazardous situations in Table 1, firstly with the question, "likelihood of encountering the situation oneself," with possible answers ranging from "very unlikely" to "very likely." Then, they were asked about the "magnitude of impact" (Table 2) and "perceived risk" (4-point scale) when they actually encountered one of the described hazardous situations. These questions are based on representative questions to evaluate the factors in the previous survey [4]. In the survey of this time, evaluation of "risk" consists of two items, which are "for oneself" and "for society."

Furthermore, they answered two questions about "To what extent is it possible for them to allow the time necessary for preventing accidents that occur due to contents of hazards ? (see Table 3)" and "Importance of respective countermeasures (the seven-point scale of 'not important at all' ~ 'very important')." In the former question, they answered for two situations (the cases where damage becomes half and the damage becomes zero, by the effect of countermeasures).

They further answered questions about reliability on the organization that executes countermeasures, with regard to three items. It relates to whether judgment of the organization "can be entrusted or not" (5-point scale), "can be considered as capable or not" (5-point scale), and "is considered as righteous" (5-point scale). With respected to the items that indicate attribute of individuals, they also answered questions about the railway companies which they utilize most often, and about reliability on those companies (7-point scale).

Table 1 Hazardous situations used in surveys

Classification	Hazardous situation (abbreviated description)
Relating to natural disasters	1. Wind & rain, typhoon
	2. Snow
	3. Dense fog
	4. Earthquake
	5. Fallen leaves, fallen tree and falling rocks
	6. Intrusion of animals onto railway track
Relating to facilities	7. Trouble of structures
	8. Trouble of signal equipment
	9. Trouble of electric equipment
	10. Failure of crossing gate etc.
Relating to train themselves	11. Train collision and derailment
	12. Train fire
	13. Breakdown or dysfunctioning vehicles
	14. Sudden braking of train
	15. Operational error by driver
	16. Error by conductor
	17. Error by station staff
	18. Error by maintenance staff
	19. Error by operational manager
Relating to inside the station & platforms	20. Trouble between passengers and station staff on the platform
	21. Trouble cause by suspicious individuals
	22. Rushing up or down the stairs etc.
	23. Gust of wind from passing trains
	24. Narrowness of platform
	25. No platform screen doors or gates
	26. Falling from platform
Relating to track & wayside	27. Intrusion by railway staff onto track
	28. Intrusion by passengers onto track
	29. Crossing gate (car crossing at the last-minute)
	30. Crossing gate (car or lost wheel on track)
	31. Crossing gate (pedestrians crossing at last-minute)
	32. Crossing gate (pedestrian on the track or lost wheel)
	33. Rail enthusiast in dangerous position to take photographs
	34. Stones or other obstacle left on the track
	35. wayside fire
Others	36. Passenger suicide
	37. Act of terror

Table 2 Degree of injury when one has encountered an accident

Choices	Answer
1	State of not being injured in any case
2	State of slight scratching and bruising
3	State of requiring treatment, but not requiring trip to hospital
4	State of requiring trip to hospital
5	State of requiring hospitalization
6	State of being bedridden
7	State of fatal injury

Table 3 Acceptable delay to allow for implementation of countermeasures

Choices	Answer
1	15 minutes or less
2	1 hour or less
3	Several hours or less
4	1 day
5	Several days
6	1 month
7	2 to 3 months
8	6 months
9	1 year
10	Several years

2.3 Confirmation of factor structure

Regarding each item among the 10 question items, we calculated the average value of contents about hazards (see Table 1) and performed factor analysis. However, the data about “act of terror” was excluded from the following analysis. The reason is that, the answer to this item showed extremely biased value for the two indices of reliability (capability and trust) on the organizations.

The eigenvalues of the two factors were not less than 1. These two factors explained 72.1% of the total variance of data. The factor loading after Promax Oblique Rotation is shown in Fig. 1. This structure is a simple factor structure

of the two factors which are the same as those of the previous survey, and contents of each factor also corresponded to those of the previous survey.

However, correlation between the factors was $r = 0.410$, showing some degree of correlation between them, unlike in the previous survey. This is because the evaluation target of the three indices of reliability of the organization were directed to the same railway company.

- a** : Evaluation of impact at encounter
- b** : Evaluation of risk for society
- c** : Evaluation of risk for oneself
- d** : Evaluation of importance of countermeasures
- e** : Evaluation of capability of railway company
- f** : Evaluation of fairness of railway company
- g** : Evaluation of trust in railway company
- h** : Evaluation of acceptable delay to allow for implementation of countermeasures for cases where damage can be avoided (zero damage)
- i** : Evaluation of acceptable delay to allow for implementation of countermeasures for cases where damage is halved
- j** : Evaluation of likelihood of encountering such a situation

Fig. 1 Factor structure of the risk recognition of the railway user

2.4 Attribute of the respondents

Regarding “evaluation of likelihood of encountering such a situation” which is a representative index of the Factor 1 and “the evaluation of risk for oneself” which is a representative index of the Factor 2, ANOVA was per-

formed, where attributes of the respondents (gender, generation, resident area, evaluation of reliability on the organizations of the railway companies which they utilize most often) were put as independent variables, respectively. The result is shown in Table 4.

Regarding “evaluation of likelihood of encountering

Table 4 The main effect by the attributes of the respondent

Item contents See Table 1	Evaluation of likelihood of encountering situation				Evaluation of risk for oneself			
	Resident area	Gender	Generation	Reliability on the organizations	Resident area	Gender	Generation	Reliability on the organizations
Related to natural disasters	1.	25.50	9.12	13.06	-	1.80	-	4.69
	2.	36.63	5.99	-	2.92	-	3.88	2.85
	3.	8.60	-	-	4.71	-	16.08	4.09
	4.	16.93	28.58	3.05	2.47	3.86	-	-
	5.	11.92	-	-	7.28	-	4.55	-
	6.	7.71	-	-	8.25	-	-	5.54
Related to facilities	7.	3.10	21.71	-	7.36	-	-	-
	8.	7.54	12.60	3.12	7.95	-	6.08	-
	9.	5.27	9.33	5.39	6.81	-	12.35	-
	10.	6.41	7.39	-	11.60	-	-	2.64
Related to trains themselves	11.	-	22.78	-	12.26	-	4.25	-
	12.	-	19.91	-	11.03	-	12.43	-
	13.	8.76	8.11	4.56	5.65	-	26.81	-
	14.	5.92	11.15	-	6.93	-	19.15	-
	15.	4.71	-	-	14.45	-	7.83	-
	16.	4.12	4.76	-	14.84	-	14.07	-
	17.	4.01	4.54	-	15.35	-	12.00	-
	18.	4.57	-	2.63	14.51	-	9.80	-
	19.	3.72	-	2.71	15.89	-	11.51	-
Related to inside the station & platforms	20.	34.47	4.56	6.20	3.86	-	3.95	-
	21.	25.86	4.50	6.68	5.09	-	11.88	-
	22.	9.61	14.64	2.87	6.67	-	12.01	-
	23.	4.97	13.34	-	10.48	-	17.99	-
	24.	11.61	-	2.41	9.48	1.98	12.29	-
	25.	16.62	-	3.96	4.87	-	12.82	-
	26.	30.93	3.95	2.07	2.61	-	13.96	-
Related to track & wayside	27.	5.79	10.20	4.18	10.91	-	-	4.63
	28.	26.34	8.27	5.05	4.04	-	9.45	3.57
	29.	8.39	-	5.19	6.62	-	-	-
	30.	7.06	-	5.37	7.32	-	5.50	-
	31.	7.73	-	3.14	7.81	-	8.32	-
	32.	6.99	-	3.66	7.30	-	9.45	-
	33.	5.29	-	2.74	9.97	-	4.18	3.46
	34.	5.15	7.67	-	9.44	-	11.46	-
	35.	10.95	-	3.32	7.71	-	20.99	-
Others	36.	22.77	6.32	7.23	2.35	-	4.01	3.63
	37.							

※ Quantity of official approval F-number only shown when the main effect is meaningful ($p < 0.05$). Boxes left blank indicate that the main effect was not meaningful.

Fig. 2 Risk cognition model of railway users

such a situation,” the main effect by resident areas of the respondents and evaluation of reliability on the organizations of the railway companies which they utilize was able to be confirmed for almost all the items. Furthermore, the main effect by gender and generation was confirmed for some items.

On the other hand, regarding “the evaluation of risk for oneself,” the main effect by gender and evaluation of reliability on the organizations of the railway companies which they utilize was confirmed in many items. However, the main effect by resident areas and generation was confirmed for very few items.

2.5 Risk cognition model of railway users

The structure model of relationship among the items which show risk cognition of railway users is shown in Fig. 2.

The upper part of Fig.2 shows the subjective evaluation by railway users of the likelihood that they themselves may encounter an accidents and/or transport disruption, against the number of actual accidents (in addition to the number of incidents, the number of casualties and affected time period). In this aspect, a difference in resident areas and utilized railway lines of the respondents to the survey is reflected. This aspect has been named “risk cognition of proximity.”

The lower part of Fig.2 shows the aspect of risk cognition relating to the evaluation of the influence and risk at the time of encounter by the users. This evaluation is not significantly affected by the resident areas of the users and actual generation status of accidents. This aspect has been named “risk cognition of awfulness.”

Both aspects of risk cognition relate to the evaluation of countermeasures for accidents. The upper part of the model relates to the evaluation of acceptability for the burden of countermeasures, and the lower part of the model relates to the importance evaluation of countermeasures. Such evaluation of countermeasures for accidents relates to the evaluation of reliability on the organizations of the railway companies.

3. Calculation method for weighting

3.1 Proximity score

We investigated the relationship between the results of “evaluation of likelihood of encountering the situation oneself” and the actual number of incidents.

To achieve this, the number of accidents and transportation disturbances that correspond to the contents of hazards (see Table 1), the 2010 data [6] were counted up by each area classification.

The target of analysis was the case people who reside in the same area of more than 100 people and use the same railway company. The case became seven area classifications. One of the seven area classifications was the case where metro companies of plural areas were combined into one.

If plural content items of the hazards which were used at the survey correspond to one case example of the accident and/or transportation disturbance, the number of incident(s) was counted into respective values of the corresponding items. In the event of zero case, 1 was added to the number of incident (s) of all items for the sake of convenience, then natural logarithmic transformation was carried out, and standardization by Z-transformation (average: 50, standard deviation: 10) was performed.

As a result, the correlation coefficient between the results of “the evaluation likelihood of encountering such a situation oneself” and the value for the actual number of incidence after Z-transformation was $r=0.637$. Since some degree of correlation became apparent, the prediction outcome for “likelihood of encounter” from the actual number of incidents is assumed to be the “proximity score” (Formula (1)).

Regarding the seven area classifications, prediction of “likelihood of encounter” was attempted using the actual number of accidents and transportation disruptions. As a result, the explanation rate for “evaluation of the likelihood of encounter” by the regression equation (1) was $R^2 = 0.46$. Since evaluation by each person has often a large error, the explanation rate $R^2 = 0.46$ obtained in the survey is

Table 5 Example of calculation result for weighting, the score for “level of fear”(F_{ij}) and Adjusted score (A_{ij})

		A _{ij}							F _{ij}	Example of calculation result for weighting							
		①	②	③	④	⑤	⑥	metro		①	②	③	④	⑤	⑥	metro	SD
Related to natural disasters	1.	16.99	16.93	14.96	17.25	24.18	4.05	16.74	55.19	125.80	134.93	137.01	133.77	146.60	122.23	121.92	9.0
	2.	4.09	22.80	6.41	-3.73	5.40	25.05	-6.40	45.45	101.03	126.82	111.43	97.90	105.26	134.73	95.12	15.1
	3.	-14.98	5.19	-2.82	-8.96	3.81	-2.35	-13.64	38.90	68.28	91.25	79.21	79.08	90.58	82.80	70.04	9.0
	4.	9.42	9.82	6.85	6.05	-0.29	1.15	4.55	72.77	135.81	134.86	131.89	125.66	124.84	126.04	133.39	4.7
	5.	-4.42	-3.94	-13.44	-7.28	-17.69	-8.65	-11.54	50.51	90.45	104.79	93.60	102.56	96.15	98.20	83.75	7.2
	6.	-9.60	-3.42	-23.31	-10.34	-12.72	-7.96	-10.83	35.94	75.01	87.99	80.05	86.89	77.63	91.62	69.89	7.8
Related to facilities	7.	-9.74	-1.58	4.84	4.35	4.89	-0.45	-0.97	57.50	109.73	111.58	113.56	114.81	111.73	111.59	109.98	1.8
	8.	6.57	1.79	3.96	8.00	1.13	-0.49	2.36	51.65	117.42	113.03	116.80	118.67	115.18	116.48	115.64	1.8
	9.	13.37	8.67	8.91	11.10	7.92	12.93	11.96	48.70	110.74	110.79	110.79	111.08	108.98	111.47	110.65	0.8
	10.	1.95	11.98	11.17	14.41	8.99	9.79	2.64	49.47	100.09	109.13	109.06	117.59	108.97	107.56	96.89	6.8
Related to train themselves	11.	-4.92	-4.41	1.17	-0.04	0.28	5.32	-3.96	76.26	115.70	119.99	120.56	119.80	119.42	124.64	117.08	2.8
	12.	-7.90	0.01	-7.36	-5.39	-6.23	0.22	-3.67	73.07	109.53	113.66	108.84	109.06	109.72	116.35	114.18	3.0
	13.	-4.13	-6.64	-10.94	-3.50	-9.61	-6.47	-4.80	60.64	121.32	117.05	114.20	120.06	115.49	121.96	123.36	3.5
	14.	6.38	3.14	0.70	5.11	4.00	6.21	8.05	58.84	109.58	104.70	102.67	105.33	105.72	108.11	111.67	3.1
	15.	-4.26	-5.89	-2.08	-3.36	1.21	4.06	8.82	61.36	105.77	105.70	102.41	104.01	105.45	111.67	114.96	4.5
	16.	-5.01	-5.49	-6.23	-10.71	-4.63	-3.33	0.80	49.98	93.64	94.12	90.11	91.09	93.22	98.77	100.77	3.9
	17.	-5.75	-2.87	-6.14	-5.30	0.12	1.65	5.24	48.80	91.72	91.82	89.02	89.51	91.80	96.70	98.82	3.6
	18.	-5.63	-5.54	-3.00	-4.95	-4.94	-0.20	-3.50	51.82	94.86	94.84	91.95	92.88	94.75	99.92	101.77	3.6
	19.	-14.13	-8.76	-8.76	-11.65	-10.27	-5.53	-11.29	53.69	96.36	97.01	93.35	94.58	96.54	100.28	102.45	3.2
Related to inside the station & platforms	20.	16.69	0.10	4.89	6.86	5.16	0.91	18.22	40.09	101.14	82.91	91.34	91.92	88.13	84.06	103.09	7.8
	21.	15.57	2.85	5.06	9.75	4.07	0.02	15.98	42.50	102.43	85.93	90.69	93.63	89.45	85.58	103.26	7.3
	22.	-0.32	-0.30	-0.50	-1.73	-1.97	-3.98	6.99	39.46	83.50	79.74	82.09	79.11	80.37	78.54	91.23	4.4
	23.	-7.65	-2.23	-2.45	-4.38	-3.90	-3.98	-3.67	38.68	75.39	77.03	79.36	75.68	77.66	77.76	79.79	1.7
	24.	1.04	-1.52	-1.89	-3.94	-2.43	-6.04	0.89	43.56	88.96	82.62	84.80	81.00	84.01	80.58	89.23	3.5
	25.	7.87	2.03	2.56	0.39	2.83	-0.40	8.61	46.91	99.14	89.52	92.60	88.68	92.62	89.57	100.30	4.7
	26.	-1.26	-5.78	7.64	-0.72	1.80	0.97	-0.79	50.46	113.37	97.64	106.52	103.09	103.76	99.73	117.19	7.1
Related to track & wayside	27.	-4.30	-1.63	-3.74	-4.42	-2.82	-5.84	-5.09	34.61	74.67	75.70	74.00	71.57	74.67	71.83	79.51	2.7
	28.	-0.58	-7.17	-4.47	-4.62	-9.25	-8.15	-1.60	40.00	100.55	88.30	95.79	94.26	90.05	83.97	96.62	5.6
	29.	6.38	3.08	5.54	13.06	3.35	7.52	-2.20	49.18	99.92	100.82	104.69	108.25	104.03	99.76	91.76	5.2
	30.	3.65	-1.88	4.01	-0.77	-2.29	-1.94	-2.83	49.85	97.86	101.39	105.08	105.48	104.01	98.99	91.80	4.9
	31.	3.65	-2.25	4.59	0.71	3.88	3.80	-8.60	45.70	93.71	94.91	98.71	98.72	100.09	92.56	87.09	4.5
	32.	4.39	0.11	2.11	2.61	10.19	-1.16	-3.67	45.70	94.45	95.11	97.78	97.89	98.77	92.84	86.81	4.1
	33.	-0.57	2.74	2.56	0.65	0.51	-0.95	-4.52	38.34	82.13	81.66	84.03	80.37	81.73	80.45	78.60	1.7
	34.	-3.60	-7.13	-1.72	-6.34	-3.08	-9.26	-6.43	55.88	103.77	103.47	108.15	104.76	105.16	104.40	99.44	2.6
	35.	1.45	-6.59	-2.18	-1.02	-2.54	-7.93	0.40	49.77	99.89	96.14	96.01	101.29	96.57	92.92	94.95	2.9
Others	36.	-11.33	-6.88	2.53	2.17	0.33	0.78	-8.13	48.79	116.30	103.07	111.90	109.98	110.92	105.36	117.06	5.2
	37.																

※ 1) Values where $10 \leq |A_{ij}|$, are highlighted in boxes with dashed contours. Values where $A_{ij} > 0$, are in red and indicated that the evaluated likelihood of encountering such a situation oneself was higher than the predicted value obtained from the actual number of incidents, per area.

※ 2) Values where $F_{ij} > 50$ are in red font and in red gothic font for values of $F_{ij} > 60$. In either case, these results show that the evaluation of the risk is relatively high.

※ 3) When the weighted value > 100 the numbers are in boxes with hashed contours, whereas for weighted values of > 120 figures are highlighted in red gothic font. In either case, these results suggest that the weighted risk cognition by railway users is relatively high.

not a low value. However, it is not sufficient for prediction.

Therefore, in order to correct the predictive value, the difference between the predictive value obtained with (1) and the average evaluation value obtained from the survey (adjusted score) was calculated for each of the seven area classifications (Formula (2)).

$$P'_{ij} = 0.007 \times Zij^2 + 31.84 \quad (1)$$

$$P_{ij} = (0.007 \times Zij^2 + 31.84) + A_{ij} \quad (2)$$

$P_{ij}(P'_{ij})$: Predicted value of the “likelihood of encounter” of an accident with regard to the “hazard description”_j at “area classification”_i (score of “proximity”)
 Z_{ij} : Z score standardized after natural logarithmic transformation in the case where 1 is added to the actual number of accidents in the “hazard description”_j at “area classification”_i.
 A_{ij} : Adjusted score for the respective “hazard description”_j at “area classification”_i (see Table 5)

3.2 Scoring level of fear

We extracted the principal components of three indices, namely the “evaluation of event at encounter,” “evaluation of risk for oneself,” and “evaluation of risk for society,” and them standardized them so that the average value was 50, and the standard deviation was 10. The “level of fear” score was then expressed as (F_{ij}).

A mutual correlation coefficient of 0.939 to 0.986 was obtained for the “level of fear” score, respectively for the 7-area classifications. Since the correlation coefficient is very high, we calculated one principal component score from these scores (see Table 5). The contribution ratio of this principal component is 93.6%.

3.3 Example of calculation result for weighting

The sum value of the scores for proximity and level of fear of recognized risk corresponds to the weighting of railway user risk cognition (see Table 5).

For questions relating to natural disasters other than earthquakes, the standard deviation (SD) of weighting for the seven area classifications was large, compared to questions relating to in “stations and platforms” and “track and wayside.” Furthermore, difference by the area classification was big. Namely, these values are reflecting the cognition of users by each area.

The SD for facilities related questions was fairly small, whereas it was higher for failure of crossing gates. For question about the inside of stations and platforms, the SD was relatively large on the question about trouble between

passengers and station staff and of suspicious individuals on station platforms, along with the danger of falling from platforms. As for the items in which difference by area classifications is big, the reason of difference is due to the causes out of control by railway companies.

4. Conclusion

In this research, we have constructed the “social cognitive model in railways” comprising the two sides of risk cognition which are “proximity” and “level of fear” Also, we have examined the calculation method for weighting the risk cognition of railway users, on the basis of this model.

In order to resolve the cognitive bias, longitudinal surveys and studies are required for the issues of what kind of factors exist and how much is their influence. This research will continue in order to clarify the mechanisms causing and influencing cognitive bias, and to find more effective ways to communicate about risk, and other related matters.

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