ATTITUDINAL FACTORS OF NIGHT TRAIN OPERATORS AND THEIR CORRELATION WITH ACCIDENT/INCIDENT STATISTICS

Kenji ITOH[1], Henning Boje ANDERSEN[2], Hiromasa TANAKA[3], Masaki SEKI[3]

(1): *Tokyo Institute of Technology, Tokyo, Japan*
E-mail: ken@ie.me.titech.ac. jp
(2): *Risø National Laboratory, Roskilde, Denmark*
E-mail: henning.b.andersen@risoe.dk
(3): *Central Japan Railway Company, Tokyo, Japan*

ABSTRACT

The paper reports the results of a questionnaire-based survey of night train operators' attitudes toward management, organizational issues and other aspects that impact on safety. Responses have been collectied from operators of *track maintenance trains* for a Japanese *high-speed railway* (*Shinkansen*). The questionnaire - the TMAQ - is based on Helmreich's FMAQ and its derivative, the SMAQ (Flight [Ship, Train] Management Attitudes Questionnaire) and seeks to elicit from subjects their views and attitudes concerning a range of safety related factors including morale, motivation, leadership and human relations in their organization.

In the first part of the study two analyses were made. In the first analysis, seven attitudinal factors were extracted, accounting for 60% of the cumulative variance, by applying the principal component analysis to data from two track maintenance companies. The second analysis, focusing on the correlation between the attitudinal factors and railway safety, we analysed relations between the factor scores derived by the principal component analysis and the branch-based accident/incident rate for one of the two companies. A close correlation was found between factor scores of the operator's morale and motivation and the accident/incident rates for all five branches located in separate cities: Branches which employ operators who have relatively higher morale and motivation exhibit a lower accident/incident rate. In addition, we found an evidence that the levels of morale and motivation seem to be correlated with other attitudinal factors such as satisfaction with management, and with manuals and checklists.

In the second part of study, a revised and briefer version of the TMAQ was made containing a smaller number of questions. This was distributed to operators in all the track maintenance companies working for the high-speed railway in order to extend the above-mentioned single-company based results to more robust and generalisable findings. From this second study involving approximately 500 respondents from the four companies as well as their accident/incident statistics, we obtained a result closely matching to what we found in the five-branch investigation of a single company.

Based on the results of the questionnaire survey, we discuss potential risk factors for train accidents and some implications for the improvement of railway safety.

KEYWORDS

Attitudinal factors, Morale, Motivation, Railway safety, and TMAQ

INTRODUCTION

Attitudes and cognitive processes play a crucial role for safety in high-tech man-machine domains such as aviation, ship handling and the operation of railways. This is evident from the fact that human error is the predominant cause of accidents both in aviation (Miller & Swain, 1987) and at sea (Harralds et al., 1998; and Margetts, 1976). Similarly, it has been pointed out that the majority of contributing causes of major accidents may be attributed to the organizations that shape the safety climate within which the employees operate (Hee et al, 1999; see also Reason, 1997). However, it is not uncommon that organizational problems that might be root causes of accidents remain unidentified (Pate-Cornell & Murphy, 1996). Therefore, it has been suggested that the quality and safety with which operators accomplish their

tasks are affected not only by their professional technical competence and skills but also by their attitudes to and perceptions of their jobs, their organization and management (e.g., Andersen et al., 1999; and Helmreich & Merrit, 1998). In particular, operators' attitudes are important indices of safety levels since they are demonstrably correlated with safety/risk. In addition, we can measure attitudes before accidents take place, and therefore the method of measuring safety attitudes seems to be of great useful especially in domains/companies where incidents and accidents rarely occur. Since train operations share many of the characteristics of aviation and shipping, it is useful to adapt some of the research methods and survey techniques that have been developed for application in the latter domains to investigating human factors aspects of railway safety.

Recently, an investigation of train operators' morale and motivation was reported based on data from a five-branch track maintenance company which is a subsidiary of a Japanese high-speed railway (Shinkansen) company (Itoh & Andersen, 1999). This study reported that there was a correlation between train operators' responses to questions on morale and motivation and the rate of accidents/incidents of their individual branches of the company, and it was suggested that there are operator's morale and motivation are likely to impact on railway safety.

In the present study, perceptions and attitudes of operators of *track maintenance trains* were once again collected and responses were analysed in order to identify factors that correlate with, and possibly, influence safety. The choice of focus was motivated by the following reasons: The operations of track maintenance trains are performed under conditions that are more changeable and stressful than those of regular passenger trains. For example, track maintenance trains are operated by a two-man team consisting of a supervisor and a driver both working in the locomotive cockpit during night only when high-speed passenger trains are not running. Thus, the task of the crew involves a close monitoring of the tracks and the surrounding environment with a very low frequency of actual manipulations of controls. This often leads operators to a state of underload and reduced vigilance. Moreover, no traffic signals are provided at all during the period when track maintenance trains are running, and it thus requires the crew to make go/stop decisions based only on their own perception and judgment. Finally, the accident/incident rate of the track maintenance train is higher than that of passenger trains even though it is actually very low in terms of the absolute number of accidents (e.g., there has been no loss of lives and very few injuries in the operations of this specific type of trains on the Japanese high speed rails ever since the start of operations in 1964).

The present paper seeks to reinforce and amplify the results of the former study (Itoh & Andersen, 1999) in two ways, viz. by first, applying more powerful means of data analysis which allow us to identify attitudinal factors; and second, by computing the correlation between the qualitative measures of perceptions and attitudes and the objective safety indices derived from accident and incident records. Thus, to satisfy the first objective we extracted a set of *attitudinal factors* by applying the principal component analysis to the questionnaire responses collected from operators of two track maintenance companies. For the other objective, an additional sampling of responses was made, based on a reduced version of the questionnaire, collecting responses from operators of all four track maintenance companies for the Shinkansen high-speed railway. We then examined the correlation between operators' attitudes in terms of derived attitudinal factors and the accident/incident rates for all these companies.

Based on the questionnaire investigation performed in this study, we discuss potential risk factors for accidents of track maintenance trains. Some implications from the questionnaire results are also presented for enhancement of railway safety.

QUESTIONNAIRE AND RESPONDENTS

Original TMAQ

Two versions of TMAQ (Train Management Attitudes Questionnaire) were employed in this study. The original TMAQ was adapted from the questionnaire applied to the maritime domain (Andersen et al., 1999). This allows us to compare the results with other domains, i.e., maritime and aviation. The original version of maritime questionnaire, the SMAQ was adapted by the Danish Maritime Institute and Risø National Laboratory in collaboration with the University of Texas at Austin (Aerospace Crew Research Project), where the original aviation oriented questionnaire, the FMAQ, has been developed by Helmreich and his associates

(Helmreich, 1984; and Helmreich et al., 1993).

We transformed terms and statements from the SMAQ to fit the working situation of night train operators, keeping the same meaning and intention for each question. The original TMAQ has approximately 100 questions in total divided into five sections: (1) general questions, (2) questions on cooperation, (3) organisational issues, (4) train management, and (5) automation. Respondents were asked to rate each question on a five-point scale between 1 and 5 (from 'very low satisfaction' to 'very high satisfaction' and from 'strongly disagree' to 'strongly agree'). It took a respondent around 20-30 minutes to answer all the items in the questionnaire.

The questionnaire was distributed to all drivers and supervisors working in two of the special track-maintenance companies, referred to as Companies P and Q in the following (subsidiaries of the Shinkansen high-speed railway company). The survey was made in the autumn of 1997 (for Company P) and 1998 (for Company Q). Company P has five branches dispersed between Tokyo and Osaka, each of which manages a number of track maintenance bases. The company operates several types of special-purpose track maintenance trains for the entire line. In contrast, the other company, Q, is responsible for a limited area, and most of its trains are for general purpose track maintenance. A total of 291 response samples were collected from the two companies in total, the response rate being almost 100% due to strong organisational support of the survey. Mean ages of drivers and supervisors were 33.7 and 48.8 years, respectively. Mean years of working experience in present position were 4.4 and 5.8 years for the two categories.

Shortened questionnaire

To collect a greater number of responses from all four track maintenance companies, another version of TMAQ having a smaller number of questions was generated so that respondents might provide their responses more easily and within a much shorter time. As will be described later in the next section, the shortened questionnaire was resulted from taking away items the original TMAQ based on results of the principal component analysis as well as those of the Kruskal-Wallis test for question-based analysis of operators' attitudes. The revised TMAQ has 30 questions.

The shortened questionnaire was distributed to all train operators working in all four track maintenance companies. Each of these is a subsidiary of the Shinkansen high-speed railway company, including Companies P and Q which also participated in the former investigation using the original TMAQ. The other two companies, R and S, have track maintenance tasks similar to those of Company Q, which operates general-purpose track maintenance trains in a limited area divided locally between Tokyo and Osaka. We obtained 493 valid responses from employees of all the four companies, and the response rate was once again nearly 100%.

NIGHT TRAIN OPERATOR'S ATTITUDES

Attitudinal factors

The principal component analysis was applied to response data, based on the original TMAQ collected from two track maintenance company. The purpose of this analysis was to establish a common framework for analysing operators' attitudes concerning a range of safety related factors. General questions and questions on organisational issues of the questionnaire were used for this analysis, and 222 valid samples were obtained in total. As an outcome of the analysis, seven *attitudinal factors* were extracted accounting for 60% of the cumulative variance. For the first principal component, which explains 25.8% of variance, almost all the questions were positively high loaded. Factor loadings of the following questionnaire items were particularly high: "I am proud to work for this company", "This company practices the highest maintenance standards", "I know the proper channel for safety procedure to be routed" – for details see these and other items in Table 1.

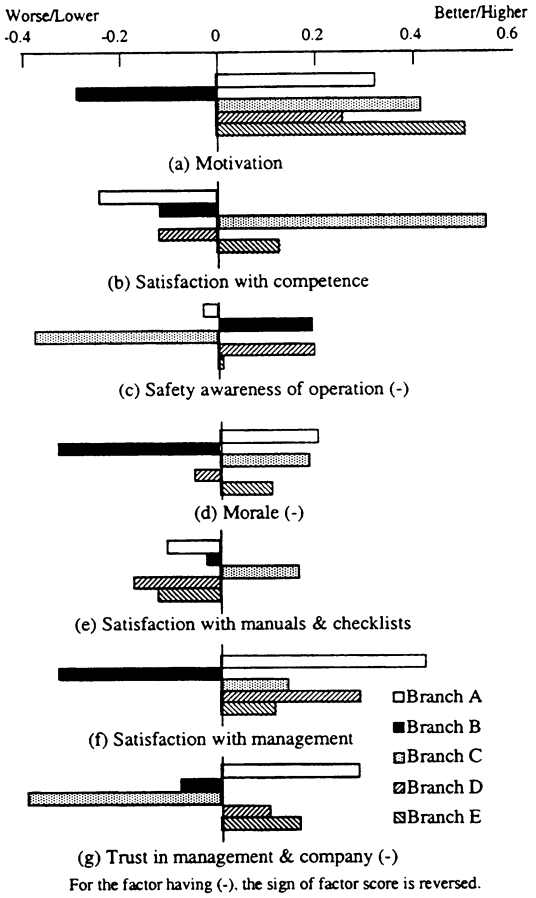
Table 1 Attitudinal factors derived by principal component analysis

Factors/Highly related questions	% variance(Cum. var.) Loading
I: Motivation	**25.8% (25.8%)**
Proud to work for company	0.807
Company's highest standards of maintenance	0.719
Proper channels for safety procedures	0.711
Receipt of a proper hand-over for a new train	0.677
Crewmembers' ability to cope with fatigue	0.668
I like my job	0.646
Task assignments cross-checked and verified	0.634
Good morale in the company	0.583
Training of crew cooperation in an emergency	0.575
Colleagues trained for emergency procedures	0.549
Satisfaction with mgt's regular feedback	0.495
II: Satisfaction with competence	**8.5% (34.30%)**
Satisfaction with ability in handling emergencies	0.555
Satisfaction with basic operation instructor's skills	0.554
Satisfaction with recurrent instructor's skills	0.533
Company's deal with problematic members	-0.506
Satisfaction with normal operation's ability	0.416
III: Safety awareness of operation (-)	**6.4% (40.7%)**
Required more open discussion for solving a problem	-0.497
Common to abandon performance in non-danger	0.431
Crewmembers' ability to cope with fatigue	0.351
More attention to sleep before performing a task	-0.336
IV: Morale (-)	**5.3% (46.0%)**
Common to abandon performance in non-danger	0.706
Operator's reluctance to have full responsibility	0.629
Required more attention to sleep before task	0.526
V: Satisfaction with manuals & checklists	**5.1% (51.1%)**
Operator's reluctance to have full responsibility	0.513
Satisfaction with operation manuals	0.454
Report of accidents & emergencies according to rules	0.439
Satisfaction with safety manuals	0.422
VI: Satisfaction with management	**4.5% (55.6%)**
Crewmembers' ability to cope with fatigue	-0.479
Satisfaction with safety manuals	0.441
Operator's reluctance to have full responsibility	-0.379
Proper channels for safety procedures	-0.347
Proud to work for company	0.318
Satisfaction with operation manuals	0.291
VII: Trust in management & company (-)	**4.0% (59.6%)**
Proud to work for company	-0.421
Good morale in the company	-0.407
Required more open discussion for solving a problem	0.36
Required more attention to sleep before task	0.332

(-): positive attitude is represented as a negative factor score
Italicised items were selected as representative questions for each factor.

Correspondingly, we interpreted this factor as motivation. As for the second principal component, highly loaded items were items about respondent's satisfaction with own competence, e.g., "your ability in handling emergency situations", "your own instructor's skills in basic operations", "your own recurrent [post-qualification] training instructor's skills", and "your ability in handling normal operations". Accordingly, the factor comprising these items was called "satisfaction with own competence". All the seven principal components derived by the analysis were interpreted in this way, based on their factor loadings, as can be seen in Table 1. In the table, for factors having a (-) sign, negative factor scores are indicated as positive attitudes according to their meaning.

Averaged factor scores are shown for each attitudinal factor based on the branches of Company P in Figure 1.



For the factor having (-), the sign of factor score is reversed.

Figure 1 Branch-based principal component score for each attitudinal factor

The data of Company Q was excluded from this figure since there were not enough samples from this company to produce a meaningful branch-based plotting. In the figure, any factor item in which a negative factor score means positive attitude has its sign reversed so that a positive value indicates positive attitude literally for each factor. As can be seen in this figure, operators in Branch B had relatively negative attitudes for most factors compared to the other branches. In particular, their motivation, morale and satisfaction with management were much lower than those in the other branches. In contrast, Branches A and E, which are quite similar in their attitudinal factors, exhibit a pattern opposite of that of the Branch B operators. Thus, Branch A and E operators have higher motivation, morale, satisfaction with management, trust in management and satisfaction with company. Branch C showed a pattern rather similar to these

two positive-attitudinal branches, operators scoring high on motivation and morale. In addition, the Company C operators are highly satisfied with their competence as well as with manuals and checklists unlike the operators in the other branches. This branch alone operates special types of trains, taking care of the entire area between Tokyo and Osaka, while the other branches operate the same type of general-purpose track maintenance trains in their limited local areas. This difference in tasks may be the reason why Branch C expressed some differences, albeit small, from Branches A and E.

Graph plotting of all the branches in terms of motivation and morale is shown in Figure 2. It is seen from this figure that the two attitudinal factors are well correlated. The more motivated the operator is, the higher morale he has.

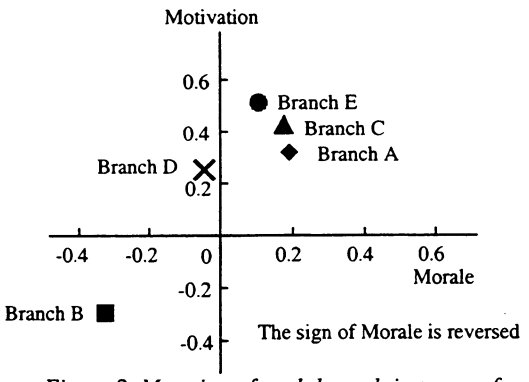


Figure 2 Mapping of each branch in terms of operator's morale and motivation

To easily identify the absolute level of each factor, percental agreement (or satisfaction) and disagreement (or dissatisfaction) are calculated. The percental [dis]agreement or [dis]satisfaction is defined as the rate of the total number of 5 and 4 responses [or 1 and 2 responses] over the total number of responses for the specific items of each factor. The representative items of each attitudinal factor are indicated in italic in Table 1. As before, items that represent negative attitudes have their signs reversed, so items having negative factor loadings are marked with a (-) sign and the rating of agreement (satisfaction) 5 and 4 responses and vice versa. Table 2 shows the percental agreement and disagreement for each attitudinal factor based on the branches. This table also includes the indices calculated by responses using the shortened TMAQ (established two years later) and it thus shows the minor changes over time of attitudinal levels to be discussed later.

Table 2 Comparisons of attitudinal factors for each branch at diffrenent two time points(1997 & 1999)

Attitudinal factors	Branch A	B	C	D	E
I. Motivation	61.5%	49.8%	64.5%	57.1%	66.7%
	50.9%	50.6%	56.8%	49.3%	62.7%
II. Satisfaction with competence	28.0%	20.8%	57.3%	24.8%	38.3%
	50.0%	38.3%	44.1%	30.7%	58.5%
III. Safety awareness of operation	82.1%	77.8%	83.1%	80.5%	72.2%
	77.9%	80.5%	70.4%	75.8%	66.3%
IV. Morale	52.7%	39.5%	52.1%	52.9%	48.3%
	53.1%	41.3%	58.7%	51.0%	51.9%
V. Satisfaction with manuals & checklists	53.1%	47.3%	63.2%	47.7%	51.3%
	58.1%	69.6%	62.3%	50.0%	54.3%
VI. Satisfaction with management	47.8%	36.7%	54.2%	47.1%	45.9%
	53.5%	47.1%	55.1%	50.0%	47.5%
VII. Trust in management & company	28.5%	22.8%	25.8%	31.0%	35.3%
	35.6%	28.9%	40.0%	40.8%	41.1%

Upper row: % combined response of 'agree strongly' and 'agree slightly' in 1997
Lower row: % combined response of 'agree strongly' and 'agree slightly' in 1999

As an overall trend, the percental agreements of Branch C are the highest for nearly all the attitudinal factors. In contrast, those of Branch B are the lowest for most factors. As for some of these factors such as motivation, morale and satisfaction with management, the percental agreements of this branch are far lower than those of the other branches. In particular, the percental agreements of 'top' branch, C, are higher by 16.9 points for motivation and by 13.2 points for morale than the most 'negative' one (Branch B), and the maximum difference between these two branches is 36.5 points for satisfaction with their own competence. The rest of the branches, A, D and E, are located intermediately between the two extreme branches in terms of the level of the attitudinal factors.

The above result, which was based on several representative items for each attitudinal factor, well matches the one derived by factor scores that included all the items and their weights. This indicates that the items or questions selected as representatives for each factor, as shown in Table 1, are appropriate.

In addition, the above-mentioned variation in the absolute levels of responses between the branches is interesting and revealing since the branches are, in the formal sense, entirely alike: They do not differ at all in terms of employment, management system nor in operating procedures, training system, and manuals and checklists. Therefore, it is reasonable to consider that each branch may have developed its own local ways and informal culture and that such an informal system with its tacit canons of conduct may vary independently of the formal system. It might reveal important clues to establishing means of shaping the informal elements of safety culture if it were possible to identify the causal factors behind such safety cultural differences.

EFFECTS OF ATTITUDINAL FACTORS

Accident/Incident statistics

In this section, we discuss the relationship between, on the one hand, train operators' responses as they are aggregated in terms of the factors regarding morale and motivation and, on the other, the rate of train accidents/incidents. A branch-based statistics of the track maintenance company surveyed, i.e., Company P, for the last five years (1994-1998) is shown in Table 3. In the Shinkansen company, accidents and incidents of track maintenance trains are classified into three types in terms of lost money and delay of the 'first' morning bullet train: big, small and no-loss accidents/incidents. A 'big accident' is defined as one in which more than 500,000 Japanese yen is lost or more than a ten-minute delay is caused to the first bullet train. A 'small incident' involves a delay and a loss that are shorter and smaller. A 'no-loss incident' is a very minor event that causes no loss and no delay to the bullet train, and all of the ones that have occurred in the past are indeed faults or dysfunctions of the vehicle or its sub-part. Therefore, the no-loss incident was excluded from analysis of the accident/incident statistics. Each class of accident/incident rate is indicated in the number of accidents/incidents per 100 km of territory a year averaged for the last five years. To produce a one-dimensional rate, we asked 24 managers in the track maintenance section of the Shinkansen company to indicate the relative severity of 'big' and 'small' accidents/incidents, putting to them the following question: "How many 'small' incidents are equivalent to one 'big' accident?" As a result of their rating, the severity of a big accident was perceived on average to be 5.54 times that of a small incident, and its median as 5. Accordingly, a weighted total accident/incident rate is defined, using a weight of 0.2 for a small incident as follows:

1 big accident = 5 small incidents,

so the weighted rate is accordingly,

Big accident rate + small incident rate * 0.2

Table 3 also includes this one-dimensional accident/incident rate for each branch. It is seen from this table that there were very few accidents and incidents produced by this track maintenance company. Only Branch B produced a few big accidents during the five-year period, but its rate was not high, i.e., about 0.4 accident per 100 km of territory a year on average. The other branches made no accident, and not even a small incident took place within Branches C and E in the five-year period.

Table 3 Branch-based averaged accident/incident rates for the last five years (1994-1998)

	Branch A	B	C	D	E	Total
Big accident(1)	0	0.397	0	0	0	0.109
Small incident(2)	0.571	0.397	0	0.333	0	0.326
Weighted total(3)	0.114	0.477	0.	0.067	0	0.174

(No. of accidents/incidents per 100km of territory a year)

(1): 500+ Kyen or 10+ min. delay of bullet train
(2): 500- Kyen and 10- min. delay of bullet train
(3): Total accidents/incidents converted in terms of big accident

Correlation with Accidents/Incidents

As mentioned above, only Branch B, whose levels of motivation and morale were far lower than the other four branches, produced big accidents. In contrast, the two top branches on motivation, i.e., Branches E and C, made not even any small incident, and the operators in these branches also had relatively high morale. To represent the effects of these two factors on railway safety quantitatively, each branch is mapped on the geometric plane of motivation/morale and the weighted total accident/incident rate, as shown in Figure 3. As can be seen from this figure, both motivation and morale are negatively correlated with the accident/incident rate. In particular, perfect matching can be obtained between motivation level and the weighted total accident/incident rate for all the five branches investigated in this section.

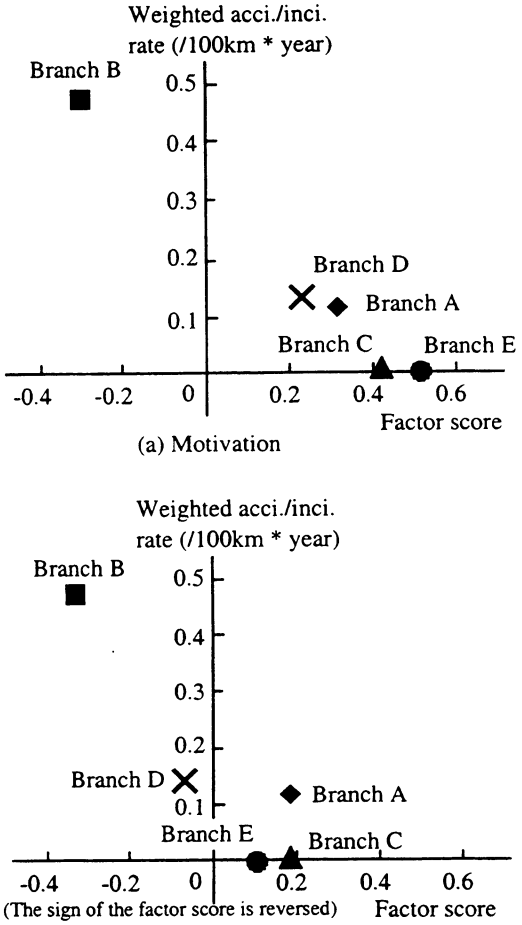


Figure 3 Relations between attitudinal factor and accident/incident rate

Question-based analysis

Based on the above-mentioned questionnaire results, we can divide the branches into two extreme types in terms of operators' motivation and morale, and thus in their accident/incident risk: low-risk branches (Branches A, C and E) versus a high-risk branch (Branch B). As mentioned previously, Branch C has somewhat different duties and working style compared with the others as they maintain the whole area and operate different types of special track maintenance trains. Thus, excluding Branch C from the low-risk group, we seek to identify "diagnostic" questions which can differentiate between the low-risk branches (A and E) and a high-risk branch (B) based on the Kruskal-Wallis test.

As the analysis results, questions shown in Table 4 turned out to distinguish between the low-risk branches and the high-risk branch. For example, the response to one of the motivation-related questions, "I am proud to work for this company" showed a highly significant difference ($p<0.01$) – 4.02 vs. 3.35, respectively, in averaged response points of the two groups.

Table 4 Questions capable of identifying higher/lower morale and motivation

Questions	Significance level (p)
Satisfaction with recurrent training	0.009
Satisfaction with recurrent instructor's skills	0.044
Satisfaction with operation manuals	0.044
Satisfaction with safety manuals	0.005
Company's highest standards of maintenance	0.013
Proud to work for company	0.001
Receipt of a proper hand-over for a new train	0.040
I like my job	0.048
Colleagues' secondary task carried out	0.024
Operator's reluctance to have full responsibility	0.001
Alcohol problem in the company	0.002
Effective performance even in fatigued	0.017
Organization's rule should not be broken	0.010
Acceptance of advice for good performance	0.010
Good decision making ability even in emergency	0.001
Briefing and critique of procedure is important	0.028
I am likely to make an error in emergency	0.006
Performace not affected by inexperienced member	0.017
Able to forget personal problems while on duty	0.016

There are also significant differences between the high- and low-risk branches for several questions that were not loaded heavily for any factors derived by the principal component analysis such as "Even when fatigued, I perform effectively during critical times of operation" ($p<0.017$; 4.30 vs. 3.95).

Based on these results of the Kruskal-Wallis test as well as the ones of the principal component analysis mentioned previously, we generated a revised version of questionnaire so that the respondent's morale, motivation and other attitudinal factors can be effectively diagnosed with a smaller number of questions. Applying this shortened questionnaire to all the four track maintenance companies, this survey was extended to all the track maintenance train operators working for the high-speed railway.

EXTENDED INVESTIGATION TO ALL TRACK MAINTENANCE COMPANIES

Responses from all the companies

For responses from each company, percental agreement (or satisfaction) and disagreement (or dissatisfaction) were calculated for each attitudinal factor in the same manner as the ones of the branch-based analysis made of the original TMAQ. Company-based results are shown in Table 5. An almost identical pattern can be identified for the company-based analysis to the branch-based study. That is, there are differences in several attitudinal factors such as motivation,

morale, and satisfaction with management between the four companies. Furthermore, companies whose operators are highly motivated, i.e., Companies P, R and S, also exhibit higher morale and satisfaction with management, and vice versa. The percental agreement of the company having the most 'negative' attitudes, i.e., Company Q, is lower by about 14.4 points in motivation, and also by 15.2 points in morale, compared to the "top" company - similar to the results of our branch-based analysis above using response data from just a single company. Regarding the other attitudinal factors, we can also identify differences between the four companies, but these differences are smaller than those for the above three factors. This tendency is almost identical to that of the branch-based study. These results indicate that a company-based culture affects train operators' attitudes almost as heavily as local culture.

Table 5 Company-based comparisons of percent (dis)agreement for each attitudinal factor

Attitudinal factors	Company P	Q	R	S	Total
I. Motivation	52.8%	38.4%	52.0%	49.5%	50.1%
	16.8%	20.5%	12.2%	23.7%	16.2%
II. Satisfaction with competence	42.4%	39.4%	41.6%	25.0%	39.9%
	18.9%	13.8%	16.1%	29.5%	18.2%
III. Safety awareness of operation	75.2%	74.1%	79.2%	80.1%	77.0%
	10.4%	9.0%	8.3%	12.1%	9.6%
IV. Morale	50.4%	45.0%	52.8%	60.2%	51.5%
	26.6%	25.0%	25.9%	31.2%	26.5%
V. Satisfaction with manuals & checklists	58.1%	56.4%	58.7%	62.2%	58.5%
	16.2%	10.6%	12.7%	17.0%	14.1%
VI. Satisfaction with management	50.4%	37.5%	46.1%	50.0%	46.9%
	24.5%	26.9%	23.8%	30.4%	25.2%
VII. Trust in management & company	36.9%	22.1%	34.3%	38.3%	33.9%
	47.1%	54.4%	45.7%	51.1%	48.0%

Upper row: % combined response of 'agree strongly' and 'agree slightly'
Lower row: % combined response of 'disagree strongly' and 'disagree slightly'

In addition, we found the percental agreement for items within the two factors, satisfaction with management and trust in management and company to be as relatively low for all the companies, compared to the other factors. The ranking of companies in terms of these factors is identical to those in motivation and in morale. This indicates that operators' satisfaction with and trust in their management and organisation is tightly coupled with their motivation and morale and, in turn, with railway safety. Therefore, it may also be of importance for managers to develop good relations with operators and in general to implement measures that enhance satisfaction with management.

Contribution to railway safety

Table 6 shows the accident/incident rate of each track maintenance company in the same indices as the branch-based statistics of a single company shown in Table 3. The rates also vary between the companies. The annual rate of the 'big' accident of Company Q is approximately twice of that of the second highest company, R. The correlation of motivation and morale with the weighted accident/incident rate is clearly depicted in Figure 4.

Regarding the effects of these attitudinal factors, a pattern of the results of this company-based analysis is identical with the one found in the five-branch study of a single company P: companies which employ operators who have higher morale and motivation exhibit lower accident/incident rates.

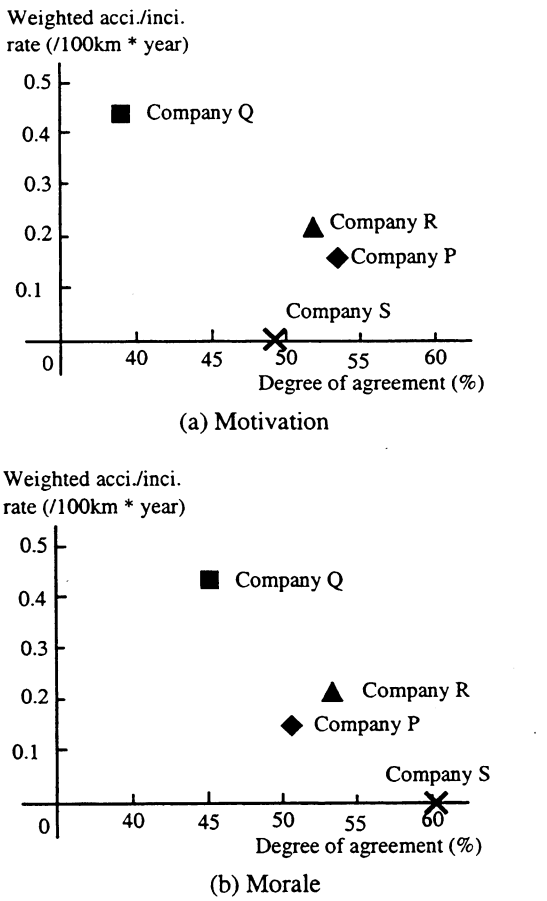


Figure 4 Effects of motivation/morale on accident/ incident rate for each company

Table 6 Averaged accident/incident rates of all the track-maintenance companies for the last five years (1994-1998)

	Company P	Q	R	S
Big accident	0.109	0.423	0.215	0
Small incident	0.326	0	0	0
Weighted total	0.174	0.423	0.215	0

(No. of accidents/incidents per 100km of territory a year)

Comparison over time

As mentioned in the section, "Questionnaire and Respondents", we collected responses twice from Company P, separated by a two-year interval. Here, we discuss a change over two years in terms of the levels of the attitudinal factors for each branch of this company. The levels of each factor at the two different sampling points, i.e., in 1997 and 1999, are shown in Table 2, and they show that the overall tendency obtained from the responses in 1997 is maintained two years later. The ranking of branches within each factor has not been changed very much over the two years although percental agreements for some factors, e.g., satisfaction with competence, are largely increased. Such improvement may have been achieved as an outcome of continuous company-wide activities aimed at improving the railway safety over the two years in question. Since no unexpectable changes happened between the two surveys, we believe that the subjective data collected in the present survey are reliable enough to derive sound conclusions about the operators' attitudes and their relations to the risk of train accidents.

The operators working for Branch B still have the lowest morale and motivation of the five branches. However, their levels within these critical attitudinal factors - as well as within the other factors - have improved over the two-year period, very likely promoted by the above-mentioned safety enhancement activities promoted by the company and the branch. The improvement of the operators' attitudes is supported by the fact that this branch did not produce any big or any small accident/incident during the entire year (1999) when the second questionnaire survey was made (nor did the other branches, in fact).

CONCLUSION

This paper reported the integrated results from a questionnaire-based survey and analysis of the accident/incident statistics in track maintenance train operations. The aim of this investigation was to uncover night train operators' perceptions and attitudes concerning their job, own competence, management, safety awareness, etc. and to assess their connection with railway safety. In addition to the data partially obtained in the former study (Itoh & Andersen, 1999) for the same purpose, we collected operators' responses from all the track maintenance companies working for the Japanese high-speed railway.

We, first, extracted a set of attitudinal factors by the principal component analysis: motivation, morale, satisfaction with own competence, with management and with manuals and checklists, trust in management and company, and safety awareness of operations. Then, the correlation analyses were performed between the levels of the attitudinal factors and the accident/incident rates, using both branch- and company-based responses. The two samples of data yielded identical results and it was shown that the operators' motivation and morale are key factors for railway safety and, therefore, are potential risk factors that may be identified *before* accidents happen. It was also seen that these two attitudinal factors are highly related to respondents' satisfaction with management, and their trust in management and company. These organization-related factors include issues concerning training, manuals and checklists, and work schedule and procedures as well as management style and organisational rules. Therefore, these results suggest that it is of great importance to change or adapt training schemes, working procedure and management style, considering both the formal and informal ways in which safety culture is shaped, and to improve manuals and checklists, in order to enhance morale and motivation and, in turn, railway safety.

In particular, the formal training scheme is alike in all the companies investigated in this study since it follows the Shinkansen railway company's standard. The present scheme is biased towards introductory training when people start to work. Thus, some kinds of post-qualification training may be required to keep and improve employee's skills and competence at a satisfactory level. At the same time, it was found that respondents in these companies had little awareness of the effects of fatigue and stress. This may be a common characteristic for Japanese workers since we detected a similar,

and even stronger tendency for Japanese seafarers (Itoh & Andersen, 1999)

In the process of collecting responses from all the track maintenance companies, we generated the shortened questionnaire based on the results of the principal component analysis and the Kruskal-Wallis test. This questionnaire was aimed at eliciting more easily and effectively operators' critical responses to items about railway safety. This type of easy-to-use questionnaire can be applied periodically to diagnose changes in the morale, motivation and other attitudinal factors of employee groups. In particular, it may be used to measure the effects of safety enhancement programmes and initiatives - to the extent that other working factors – such as tasks, environment, and staff – are not changed.

Finally, given the statistically significant correlation between operators' responses to specific questions regarding motivation, morale and so forth and their risks of having accidents or incidents, the questionnaire-based method employed in this study may be a useful supplement to accident/ incident data in order to identify high and low risk work units. This is of importance if whenever there is a possibility that accident/incident reporting is incomplete; and, equally, while accident/incident reporting is a retrospective index of safety levels, the survey data may be used prospectively.

ACKNOWLEDGEMENTS

We are heavily indebted to Robert L. Helmreich, the University of Texas at Austin who provided not only the original Flight Management Attitudes Questionnaire but who also inspired the adaptation of this survey instrument to the railway domain. We would like to acknowledge Kunihiro Kondo, Takehiro Hoshino, Masahiro Kawagoe and Ken-ichiro Hisanaga, Central Japan Railway Company, as well as Toshitatsu Ishii and Jushiro Takahashi, Nihon Kikai Hosen, Co. Ltd., Akikazu Umoto and Norimasa Nogawa, Futaba Tetsudo Kogyo, Co. Ltd., for their cooperation in this project. We also thank Satoru Mashino, Tokyo Institute of Technology, and Thomas Bove, Risø National Laboratory, for their assistance with the data analysis of the questionnaire.

REFERENCES

Andersen, H.B., Garay, G. and Itoh, K. (1999). Survey Data on Mariners: Attitudes to Safety Issues. Technical Report I-1388, Systems Analysis Department, Risø National Laboratory, DK-4000 Roskilde, Denmark.

Harrald, J.R., Mazzuchi, T.A., Spahn, J., Van Dorp, R., Merrick, J., Shrestha, S. and Grabowski, M. (1988). Using System Simulation to Model the Impact of Human Error in a Maritime Risk Assessment, *Safety Science*, 30: 235-247.

Hee, D.D., Pickrell, B.D., Bea, R.G., Roberts, K.H. and Williamson, R.B. (1999). Safety Management Assessment System (SMAS): A Process for Identification and Evaluating Human and Organization Factors in Marine System Operations with Field Test Results. *Reliability Engineering and System Safety*, 65: 125-140.

Helmreich, R.L. (1984). Cockpit Management Attitudes, *Human Factors*, 26: 63-72.

Helmreich, R.L. and Merrit, A.C. (1998). *Culture at Work in Aviation and Medicine: National, Organizational and Professional Influences*. Ashgate, Aldershot, UK.

Helmreich, R.L., Merritt, A.C., Sherman, P.J., Gregorich, S.E., and Wiener, E.L. (1993). The Flight Management Attitudes Questionnaire (FMAQ). Technical Report 93-4, University of Texas, Aerospace Crew Research Project, Austin, Texas.

Itoh, K. and Andersen, H.B. (1999). Motivation and Morale of Night Train Drivers Correlated with Accident Rates. *Proceedings of the International Conference on Computer-Aided Ergonomics and Safety*. Barcelona, Spain, May 1999 (CD ROM).

Margetts, B.D. (1976). Human Error in Merchant Marine Safety, The National Research Council, Washington DC.

Miller, D.P. and Swain, A.D. (1987). Human Error and Human Reliability. In G. Salvendy (Ed.), *Handbook of Human Factors*, John Wiley & Sons, New York. pp.219-250.

Pate-Cornell, M.E. and Murphy, D.M. (1996). Human and Management Factors in Probabilistic Risk Analysis: The SAM Approach and Observations from Recent Applications. *Reliability Engineering and System Safety*, 53: 115-126.

Reason, J. (1997). *Managing the Risk of Organizational Accidents*. Ashgate, Aldershot, UK.

Sherman, P.J., Helmreich, R.L. and Merritt, A.C. (1997). National Culture and Flightdeck Automation: Results of a Multi-Nation Survey, *International Journal of Aviation Psychology*, 7(4): 311-329.