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ORIGINAL ARTICLE

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Track maintenance train operators' attitudes to job, organisation and management, and their correlation with accident/incident rate

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Abstract The present paper reports the results of a questionnaire-based survey of night train operators' attitudes toward management, operating procedures, and other organisational issues that potentially impact on safety. Responses were collected from all of the operators of track maintenance trains servicing the Japanese high-speed railway (Shinkansen). Two versions of the questionnaire, the TMAQ (Train Management Attitudes Questionnaire), were developed based on Helmreich's FMAQ (Flight MAQ) and its derivative, the SMAQ (Ship MAQ). The TMAQ and its progenitor seek to elicit respondents' views of, and attitudes to, a range of safety related factors including morale, motivation, leadership and human relations in their organisation.To identify dimensions of safety culture as elicited through the TMAQ, a principal component analysis was applied to the questionnaire responses of the original TMAQ. The analysis yielded seven attitude factors, including morale and motivation. Of the seven factors, a close correlation was identified between the factor scores representing operators' morale and motivation and the actual accident/incident rates for each of the five branches belonging to a single-track maintenance company. A branch that employed train operators having relatively higher morale and motivation exhibited a lower accident/incident rate. Furthermore, the very same correlation was also found for company based responses collected from all track maintenance companies working for the high-speed railway.

In addition to the branch and company based comparisons for track maintenance train operators, we also compared attitude factors between different groups of operators (drivers and supervisors), and between two different periods surveyed in a two year interval. Finally, we examined differences in terms of attitude factors between track maintenance operators and seafarers surveyed by applying slightly different variants of the same generic form of questionnaire (Helmreich's SMAQ). Based on these survey results, we discuss potential risk factors for accidents of track maintenance trains and some implications for improving railway safety.

Keywords Attitude factors · Morale · Motivation · Railway safety · FMAQ · TMAQ

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1 Introduction

Human factors play a crucial role for safety in high-tech human-machine domains such as aviation, ship handling and operations in railways. This is evident from the fact that human error is the predominant cause of accidents in aviation (Amalberti 1998; Miller and Swain 1987), at sea (Bryant 1991; Harralds et al. 1998; Margetts 1976) and in other high-tech industries (Hollnagel 1998). Similarly, in recent decades organisational factors have been recognised to be of great importance for safety in human-machine system operations (Griffiths 1985; Powell et al. 1971; Reason 1993). It is well-known that organisational problems are frequently latent causal factors that contribute to the occurrence of human error made by frontline personnel (Reason 1997), and it has been pointed out that the preconditions of disasters are typically rooted in the social and organisational arrangements of the overall socio-technical systems associated with large-scale hazards (Pidgeon 1991). Indeed, the majority of contributing causes to major accidents may be attributed to the organisations themselves, that shape the *safety culture* or *safety climate* within which the employees operate (Hee et al. 1999; Reason 1997). For instance, it was reported that 40% of incidents in the Dutch steel industry were caused by organisational failures (van Vuuren 2000).

Regarding the construct of safety culture, there are many proposed definitions (such as ACSNI 1993; Flin et al. 2000; Pidgeon and O'Learry 1994; Zohar 1980), which have unfortunately led to difficult interpretations and explanations of such a concept. However, one of the more succinct definitions was presented in a report by the UK Advisory Committee on the Safety of Nuclear Installations (ACSNI 1993) stating that safety culture "is the product of individual and group values, attitudes, perceptions, competencies and patterns of behaviour that determine the commitment to and the style and proficiency of an organisation's health and safety management". Following this definition, safety culture is coupled not only to management's commitment to safety, its communication style, and the overt rules for reporting errors, but also to employees' motivation, morale, perception of errors and attitudes towards management and factors that impact on safety, for instance fatigue, risk taking, and violations of procedures (Andersen 2002). In addition, an organisation's culture reflects its policies regarding error management and sanctions against operators who commit errors or violations, the openness of communications between management and operators, and the level of trust between individuals and senior management (Helmreich 2000).

Several approaches have been applied to investigating the safety culture of particular organisations, ranging from safety audits, structured interviews with management and employees, and behavioural observations, to questionnaire surveys. The approach that has been pursued in the study reported here focuses on attitudes of individual employees grouped by job roles and functions – for example supervisors and drivers. A number of studies have been carried out during the last two decades that have similarly sought to measure perceptions and attitudes of individuals belonging to various employee groups (Cox and Cheyne 2000; Williamson et al. 1997; Zohar 1980).

So far, a relatively small number of studies have examined the relations between operators' attitudes and accident risk or ratio; and nearly all of them have examined self-reported accident and incident rates rather than actual or objective ones.

Examining behaviours and attitudes, Clarke (1996) found a relationship between employee perception of management commitment to safety and employee willingness to report incidents: employees who rate managers' safety commitment as relatively low are less likely to submit reports. Addressing accident and incident rates, Sheehy and Chapman (1987), however, reported a study in which evidence was uncovered of a correlation between employee attitudes and accident risk based on objective data on accidents and incidents. A similar study has applied the framework of Person-Environment (P-E) Fit Theory to suggest a relationship between *self-reported* occupational injuries and employees' attitudes towards their work environment and their supervisors (Sherry 1991). Likewise, Diaz and Cabrera (1997), using questionnaire responses of three comparable companies, reported that rank orders of employees' attitudes towards safety coincided with those of employees' *perceived* safety level. Also, in the last decade, Donald and Canter (1994) and their research group conducted several projects to assess possible correlations between safety culture and operational safety in process plant industries. In these projects, Donald and Canter conducted questionnaire surveys on safety attitudes and self-reported accident rates at ten chemical sites in the UK. They found that statistical correlations between most of the "safety attitude" questions contained in their questionnaire and the self-reported accident rates which had been derived from respondents' indication of whether they had had an accident in the previous six months. In a case study based on a survey of a power generation company, Donald and Young (1996) reported effects of an intervention aiming at improving safety performance, such as the setting up of safety teams and the introduction of written action plans on operators' safety attitudes, absenteeism and self-reported accident rates. Hurst et al. (1996) conducted a similar investigation in which attitude scale scores derived from their "Safety Attitude Survey Questionnaire" were compared with respondents' self-reported accident rates for six sites for the purpose of testing a hypothesis that positive attitudes to safety reflect good safety performance. However, the authors were unable to demonstrate that respondents' scores on attitude scales had any statistically significant correlation with the self-reported accident rate (Hurst et al. 1996).

Based on studies such as the above and on findings of major differences in terms of pilots belonging to different airlines (Helmreich et al. 1999), it has been suggested that the quality and safety, by which the operators accomplish their tasks, is affected not only by their professional and technical competence and skills level, but also by their attitudes to and perceptions of their job roles, their organisation, and management (Andersen et al. 1999; Helmreich and Merritt 1998). In addition, one may argue that it is to be expected on intuitive and qualitative grounds that a close relation will exist between operators' safety attitudes and accident risks.

Following on from this interpretation, it may be possible to demonstrate a robust relation between operator attitudes and accident risk for any given unit or organisation. Such a result could be used, firstly, to diagnose an organisation's safety culture and, secondly, to predict the relative risk of individual units within an organisation. For this purpose, we need to establish a framework for analysing operator's attitudes towards job, management and organisational issues in relation to safety culture, and to examine also the correlation of such attitude factors with operational safety/risk measures taken from objective, actual accident data samples.

In achieving such an objective, the operators' attitudes would become important indices of their organisation's safety level. In particular, it is possible to measure operators' attitudes before accident events, and therefore make predictions on the level of the organi-

sational safety and risk, especially for work domains and companies where accident events rarely occur.

The present paper focuses on the driving operation of track maintenance trains and seeks to identify operators' attitudes to factors that are believed to impact on safety, and to ascertain the extent to which attitude measures correlate with objective safety indices relating to actual performance outcomes. To do so, we extracted a set of attitude factors by applying the principal component analysis to questionnaire responses collected from track maintenance train operators. To obtain robust results concerning the impact of safety culture on railway safety, *two* different data sources from track maintenance organisations were applied to analyse the correlation between operators' responses (attitude factors) and actual accident/incident rates.

The first data source was a set of response samples from a five-branch track maintenance company which is a subsidiary of the Japanese high-speed railway (Shinkansen). The other source included company-based data that were collected from all four-track maintenance companies working for the high-speed railway. In addition, data of the train operators' responses were compared to those obtained through similar surveys of seafarers, who work in a different transportation domain requiring human-machine system operations, to highlight characteristics of the train operator's attitudes. The maritime data had been gathered using an almost identical questionnaire from a sample of Japanese seafarers. Based on the results of the surveys, potential risk factors for track maintenance train accidents were discussed and a number of conceptual implications of the overall results have been reported and discussed in terms of potential enhancements on the railway systems.

2 Questionnaire and respondents

2.1 Train operations

Our choice of focusing on track maintenance trains of the high-speed railway in Japan was motivated in part by the fact that the operations of track maintenance trains are performed under more changing and stressful conditions than those of normal passenger trains. For example, track maintenance trains, which are operated at night after the last and before the first bullet train, have no traffic signals available. As may be expected, therefore, their accident rate is higher than that of passenger trains – although it is actually very low in terms of the absolute number of accidents (there has been no loss of lives in the operations of either type of train since the start of operations in 1964.).

Driving operations in the track maintenance train are performed by a team consisting of a driver and a supervisor in the train cockpit under the direction and control of station-based traffic controllers. In the track maintenance organisation, the position of the supervisor is higher than the driver's. This hierarchy is reflected in the task distribution in the cockpit of the track maintenance train – like the distribution of tasks between a bridge officer and his helmsman on a ship bridge: The supervisor will himself not normally carry out any manual task but will be exclusively occupied with supervising the driver according to a prescribed plan and the directives received from the remote traffic controller. The driver, on the other hand, will control the train within the well-defined safety bounds, usually by just manipulating acceleration and break levers according to the time schedule and the supervisor's commands. Most of the time, the driver and the supervisor will be monitoring the rails and tracks and their surroundings, for instance switches, other trains and possibly loose objects too close to the track. This type of monitoring is quite tedious – there are few objects, loose objects or incorrectly set switches, so drivers and supervisors are likely to be "under-loaded" and so influenced by their monotonous task. As is well known, this may be just as dangerous as situations involving heavy workloads; therefore, it requires a high level of motivation and morale to maintain safe operation in order to cope with such a monotonous, self-controlled task.

2.2 Original TMAQ

Since train operations, not only of passenger trains but also of track maintenance trains, 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. Therefore, we developed questionnaires to elicit the attitudes of track maintenance train operators towards their job, management, safety and so forth by adapting a questionnaire applied to the aviation and maritime domains.

Two versions of the questionnaire, named TMAQ (Train Management Attitudes Questionnaire) were employed in this study. The original TMAQ was adapted from the SMAQ (Ship Management Attitudes Questionnaire) applied to the maritime domain (Andersen et al. 1999), which in turn had been adapted by Risø National Laboratory, the Danish Maritime Institute, and the University of Texas at Austin (Aerospace Crew Research Project) based on the well-known FMAQ (Flight Management Attitudes Questionnaire) developed and refined by Robert Helmreich and his associates for the aviation domain (Helmreich 1984; Helmreich et al. 1993).

We transformed terms and statements from the SMAQ to fit the working situation of track maintenance train operators in Japan, keeping the same meaning and intention for each question. The original TMAQ had 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. Descriptions of general questions

and questions on organisational issues and train management, which are at the heart of the analysis in this study, are provided in Appendix A. Respondents were asked to rate each question on a five-point Likert scale between 1 and 5 (from "very low satisfaction" to "very high satisfaction", or from "strongly disagree" to "strongly agree"). The TMAQ questionnaire – like its predecessors, the SMAQ and the FMAQ – also includes four open-ended questions on management's role and commitment to safety, efficiency and operators' satisfaction and perception of their company and work conditions, and so on. Time to completion of the questionnaire was about 20–30 minutes.

The questionnaire was distributed to all drivers and supervisors working in two of the track maintenance companies, referred to as Companies P and Q, which are subsidiaries of the high-speed railway company. The survey was made in autumn of 1997 (Company P) and 1998 (Company Q). Respondents were promised strict anonymity and so were not required to give their names or other identifying information. Company P has five branches dispersed between Tokyo and Osaka, each of which manages several track maintenance bases. This company operates several types of special-purpose track maintenance trains for the entire line of the high-speed railway. In contrast, Company Q is responsible for a limited area of the line, and most of its trains are general-purpose track maintenance trains. A total of 291 response samples were collected from the two companies, the response rate being almost 100% (no doubt as a result of strong organisational support of the survey). All respondents were male, as indeed were all drivers and supervisors of the track maintenance companies. Mean ages of drivers and supervisors were 34 and 49 years, respectively. Mean years of working experience in their current position were 4.4 and 5.8 years for the two job categories.

2.3 Shortened questionnaire

To collect a greater number of responses from all four track maintenance companies, a shortened version of TMAQ was developed so that respondents could provide their responses more easily and within a much shorter time. As will be described in more detail later, the shortened questionnaire was formulated by removing items from the original TMAQ based on results of the principal component analysis (see Sect. 3.1), as well as on those of the Kruskal-Wallis test (see Sect. 4.3). Items with higher loading on factors and those that served to distinguish between high and low risk organisations were included into the shortened questionnaire. The shortened TMAQ comprised 30 Likert-scale question items as well as the same open-ended questions (six in total) as the ones in the original TMAQ.

The shortened questionnaire was distributed in the autumn of 1999 to all train operators working for the four track maintenance companies under the Shinkansen corporation, including Companies P and Q that also participated in the first TMAQ study described above. The two other companies, R and S, have track maintenance tasks quite similar to those of Company Q, operating 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, the response rate once again being nearly 100%.

3 Night train operators' attitudes

3.1 Attitude factors

Principal component analysis was applied to response data of the original TMAQ collected from two track maintenance companies. The purpose of this analysis was to identify the underlying factor structure of the questionnaire and so to investigate operators' attitudes concerning a range of safety related factors. General questions, and questions on organisational issues and train management in the questionnaire were used for this analysis. The analysis yielded seven attitude factors accounting for 60% of the cumulative variance. Eigenvalues for all these seven factors were higher than 1.0.

As for the first principal component, which explained 25.8% of variance, almost all the questions were highly positively loaded. Factor loadings of the following question items were particularly high: "I am proud to work for this company", "This company practices the highest maintenance standards", and "I know the proper channel for safety procedure to be routed" (see Table 1). We gave this factor the title "motivation". The second principal component was composed of items expressing respondents' satisfaction with their own competence and skills such as: "Your ability in handling emergency situations", "Your own instructors skills in basic operations", "Your own post-qualification training instructors skills", and "Your ability in handling normal operations". Accordingly, the factor comprising these items was called "satisfaction with own competence". All seven principal components derived from the analysis were interpreted in this way based on highly loaded items on each factor, as can be seen in Table 1. These attitude factors are motivation, satisfaction with own competence, safety awareness of operations, morale, satisfaction with manuals and checklists, satisfaction with management system, and trust in management. In the table, factors that have a minus sign ("–") attached have been reverse-scored due to their wording and valence.

Notably, the above-mentioned factors seem to closely relate to those identified across previous research on safety culture or safety attitudes (Diaz and Cabrera 1997; Hurst et al. 1996), suggesting a certain degree of concurrent validity to the present factor structure identified. For example, Diaz and Cabrera (1997) extracted

Table 1 Attitude factors derived by principal component analysis

Factors/Highly loaded items	% Variance (cum. var.)/loading	Cronbach's alpha
I: Motivation	25.8% (25.8%)	0.643
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 management's regular feedback	0.495	
II: Satisfaction with own competence	8.5% (34.3%)	0.901
Satisfaction with ability in handling emergencies	0.555	
Satisfaction with basic operation instructor's skills	0.554	
Satisfaction with post-qualification instructor's skills	0.533	
Company deals with problematic members	−0.506	
Satisfaction with normal operation's ability	0.416	
III: Safety awareness of operation (−)	6.4% (40.7%)	0.323
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	
Required more attention to sleep before task	−0.336	
IV: Morale (−)	5.3% (46.0%)	0.312
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 and checklists	5.1% (51.1%)	0.737
Operator's reluctance to have full responsibility	0.513	
Satisfaction with operation manuals	0.454	
Report of accidents and emergencies according to rules	0.439	
Satisfaction with safety manuals	0.422	
VI: Satisfaction with management system	4.5% (55.6%)	0.553
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	4.0% (59.6%)	0.573
Proud to work for company	−0.421	
Good morale in the company	−0.407	
Required more open discussion for solving a problem	0.360	
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

six factors by applying the principal component analysis to samples of their safety climate questionnaire gathered from subjects working in airport ground handling companies: company policies towards safety, emphasis on productivity versus safety, group attitudes towards safety, specific strategies of accident prevention, safety level perceived in the airport, and safety level perceived on the job. These factors seem closely related to the factor of "safety awareness of operations" extracted in the present study. A different set of factor titles identified by Diaz and Cabrera seems to be due to the specific focus of their questionnaire on safety attitudes and individual perceptions of safety.

Zohar (1980) extracted two dimensions of safety culture: perceived relevance of safety to job behaviour, and perceived management attitude towards safety. Factors I through IV extracted in the present study are related to the former dimension, while the other three factors in Table 1 fall into the latter dimension.

3.2 Relative comparisons of attitude factors

Branch-based averaged factor scores for Company P are depicted in Fig. 1. The data of Company Q were excluded from the analysis since there were not enough samples collected from this company to produce a reliable branch-based plotting. In this figure, factor items in which negative values indicate a positive attitude have their signs reversed so that positive values indicate positive attitudes literally for each factor: these are reverse-score items. As can be seen in this figure, operators in Branch B had relatively negative attitudes for most factors compared to those in the other branches. In particular, their motivation, morale and satisfaction

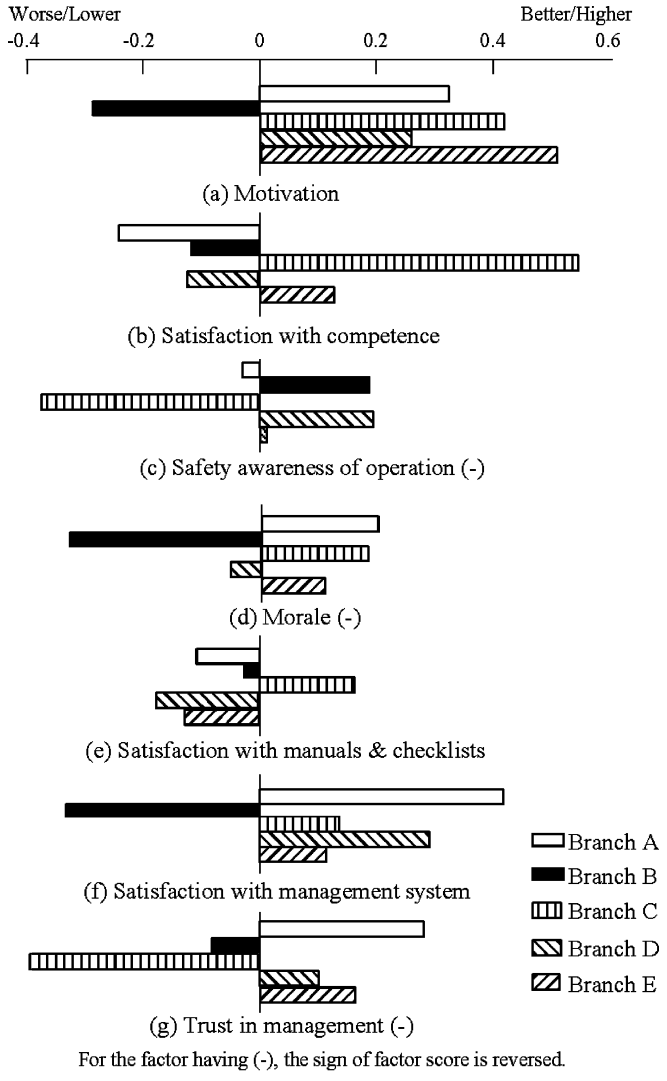

Fig. 1 Branch based factor scores for each attitude factor

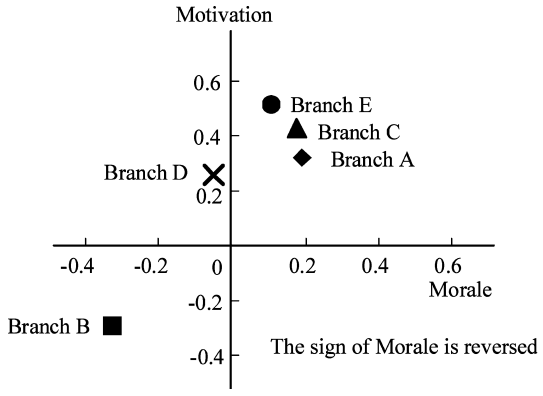

Fig. 2 Mapping of five branches surveyed in terms of operators' morale and motivation

with the management system were much lower compared to the operators of the other branches.

In contrast, Branches A and E, which were similar in their attitude factors, exhibited a pattern opposite to that of that of Branch B. Therefore, Branch A and E operators had relatively higher motivation, morale, satisfaction with management system and trust in management. Branch C showed a pattern rather similar to these two "positive attitude" branches, its operators scoring as high on motivation and morale as Branches A and E. In addition, Branch C operators were highly satisfied with their own competence, as well as with manuals and checklists, unlike the operators in the other branches. It should be added that this branch alone operated a special type of track maintenance trains responsible for the entire area between Tokyo and Osaka, while the other branches operated several types of the same specific purpose track maintenance trains in their limited local areas. This difference in tasks may possibly be a reason why Branch C operators expressed some differences, albeit small, compared to Branches A and E.

Graph plots of all the branches in terms of motivation and morale are shown in Figure 2. It is seen from this figure that these two attitude factors are well correlated (although a statistical test was not performed due to the small number of samples – five branches): the more motivated the operator, the higher their morale. Descriptions of differences in terms of factor scores between operation groups are not meaningful since there are only two classes. Therefore, these differences will be mentioned together with those between the branches in the next subsection in terms of absolute levels of responses.

3.3 Absolute level comparisons

To easily identify the absolute level of each factor, percentage agreement and disagreement quotients have been calculated. The percentage of agreement is defined as the rate of the total number of "5" responses (strongly agree) and "4" (slightly agree) over the total number of responses for the specific items of each factor; and similarly, but *mutatis mutandis*, for *dis*agreement. Basically, the three most highly loaded items have been selected as being representative. Subsequently, a few changes in selecting representative items have been made to keep the semantic meaning of the suggested factor title reasonably coherent *and* to avoid overlapping items for multiple factors. Representative items for each factor have been quoted in italics in Table 1. This table also includes information on Cronbach's alpha for a set of the italicised, representative items of each factor.

Table 2 shows percentage agreement and disagreement for each attitude factor based both on the branches and operation groups. As with the factor scores mentioned previously, items that represented negative attitudes had their signs reversed in Table 1. Therefore, items having negative factor loadings also have their ratings of agreement reversed from 5 and 4 to 1 and 2

Table 2 Comparisons of percentage agreement and disagreement[a] for each attitude factor from operators' responses in a single company

Attitudinal factors	Branch					Operation group		
	A	B	C	D	E	Drv.	Spv.	Total
I Motivation	60%, 16%	51%, 22%	59%, 15%	56%, 19%	66%, 6%	46%, 24%	66%, 13%	57%, 17%
II Satisfaction with own competence	26%, 37%	19%, 38%	50%, 15%	20%, 34%	34%, 14%	11%, 44%	38%, 18%	26%, 31%
III Safety awareness of operation	71%, 12%	69%, 9%	68%, 17%	72%, 11%	63%, 14%	68%, 9%	71%, 14%	69%, 12%
IV Morale	37%, 41%	28%, 51%	37%, 50%	37%, 42%	36%, 37%	29%, 47%	40%, 43%	34%, 45%
V Satisfaction with manuals and checklists	61%, 9%	44%, 14%	75%, 8%	51%, 12%	62%, 9%	43%, 14%	64%, 8%	55%, 11%
VI Satisfaction with management system	39%, 26%	31%, 37%	47%, 34%	42%, 26%	33%, 27%	35%, 28%	40%, 33%	37%, 30%
VII Trust in management	53%, 14%	40%, 23%	43%, 17%	56%, 18%	64%, 10%	39%, 25%	56%, 16%	50%, 18%

[a]The result for each branch or operation group is presented in the format:
% agreement: combined response of "agree strongly" and "agree slightly" in %
% disagreement: combined response of "disagree stongly" and "disagree slightly" in %

Table 3 Training programmes prepared for track maintenance train operations

Types	Description	Frequency	Hours used
1. Basic training	(1) Off-JT at in-company school for new employees (operations in emergency)	1	7 h
2. OJT	(1) OJT on the track in order to get license	31days	16 h
	(2) OJT for introduction of new train	1	4 h
	(3) OJT at regular train maintenance	1	4 h
3. Safety education	(1) Education at in-company school (safety and occupational health, driving operations)	2	6∼8 h
	(2) Meeting to discuss how to avoid accidents (learning from accident and incident data)	1∼2	2 h
	(3) Everyday talk at starting time of operation		a few minutes
4. Training of operations for emergency	(1) Education at in-company school (operations for emergency)	1	7 h
	(2) Education to explain new trains and equipment at their introduction	1	varied
	(3) Education at each branch (mainly for recovery operations from derailing, twice/y.)	2	8 h
5. Training for acquiring skills to detect dangerous situations	(1) Education at in-company school (new comers, and employees every four years)	1	3 h
	(2) Meeting to discuss how to avoid accidents	1∼2	20 min
	(3) Everyday talk at starting time of operation		20 min

responses. Ratings of disagreement were likewise reversed from 1 and 2 to 5 and 4 responses, respectively. As an overall trend, Branches A, C, and E were found to form a "positive" attitude branch group for nearly all the attitude factors. Regarding motivation, Branch E was the highest, followed by Branches A and C both of which were also at a high level. There were only small differences in morale between three of the four branches, but Branch B stood out: here operator attitudes were the lowest for most factors. For some of these factors – such as motivation, morale and satisfaction with the management system – the percentage agreement of this branch is far lower than those of the other branches. In particular, the percentage agreements of this most "negative" branch were lower by 15 points for motivation and by 13 points for morale compared to the top branch. The maximum difference between branches (viz. between B and C) in terms of satisfaction with their own competence was 31 points.

The above-mentioned result, based on representative items for each attitude factor, coincides with the one derived by factor scores that included all the items and their weights. This indicates that the items selected as representatives for each factor, as shown in Table 1, are appropriate. In addition, the variance in the absolute response levels between the branches is interesting since the branches are, in terms of structure, entirely alike. They differ neither in terms of employment and management systems, nor in operating procedures, training system (see Table 3), manuals or checklists. Therefore, if different safety climates may exist within a single company, as already documented by previous research (Schneider and Reichers 1983), it is reasonable to consider that each of the track maintenance branches may have developed its own local ways and informal culture. Moreover, it seems that such an informal system with its tacit practices and conduct may vary independently of the structural or formal system. In this connection, 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.

Similarly to previous research studies into British Rail (Clarke, 1999), the results in Table 2 also indicate the absolute differences between the two operation groups in most of the attitude factors. As an overall trend, the supervisor group exhibited more "positive" attitudes than the driver group. In particular, there were differences of approximately 20 points in motivation between these two groups, 10 points in morale and 25 points in satisfaction with own competence. However, even for the driver group, the absolute levels of motivation, safety awareness of operations and satisfaction with manuals and checklists were not really "low" – percentage agreements were higher than percentage disagreements for these factors and more than twice for some of these factors.

In contrast, the operators' levels of satisfaction with management systems were not high for both groups. Moreover, the drivers are more critical of their management than the supervisors, considering the responses to trust in management. Such low levels of satisfaction with the management system may have been caused primarily by employee complaints over payment and working conditions. Interestingly, this tendency was also observed in the study conducted into British Rail (Clarke 1999).

4 Effects of attitude factors

4.1 Accident/incident statistics

In this section, we examine a relationship between, on the one hand, responses aggregated in terms of factors relating to morale and motivation and, on the other, the accident/incident rate of track maintenance trains. Branch-based statistics of the track maintenance company surveyed (Company P), for the last five years (1994–1998) are shown in Table 4. On the high speed railway (Shinkansen) company accidents and incidents of track maintenance trains are classified into three categories 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 (approximately 4,000 US dollars or Euros correspondingly) is lost, or more than a ten minute delay is caused to the first bullet train. A "small incident" involves a delay that is shorter and/or a loss that is smaller. A "no-loss incident" is a very minor event that causes no loss and no delay to the bullet train; examples include faults or dysfunctions of the vehicle or its components. Therefore, the no-loss incident was excluded from the analysis of accident/incident statistics. The accident/incident rate of each category 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 measure of safety, 24 managers and staff in the track maintenance section of the high-speed railway company were asked to indicate the relative severity of "big" and "small" accidents/incidents and were given the following question: "How many small incidents are equivalent to one big accident?" The mean rating received from the 24 respondents indicated that the severity of a big accident was perceived to be 5.5 times of a small incident, and 5.0 when computed as the median rating of the respondents. Accordingly, using a weight of 1/5 for a small incident, the weighted total accident/incident rate is defined as follows:

$$\text{weighted total accident/incident rate} = \text{big accident rate} + (\text{small incident rate} \times 0.2)$$

Table 4 also includes the one-dimensional weighted total accident/incident rate for each branch. It is seen from this table that very few accidents and incidents took place in this track maintenance company. Only Branch B had a few big accidents during the five-year period; yet its rate was not high – approximately 0.4 accidents per 100 km of territory per year on average. The other branches had no big accident, and moreover, Branches C and E succeeded in avoiding altogether even small incidents in the five year period.

Table 4 Branch (A, B, C, D, E) based averaged accident/incident rates for the last five years (1994–1998)

	A	B	C	D	E	Total
Big accident [a]	0	0.397	0	0	0	0.109
Small incident [b]	0.571	0.397	0	0.333	0	0.326
Weighted total [c]	0.114	0.477	0	0.067	0	0.174

(Number of accidents/incidents per 100 km of territory a year)
[a]500+ Kyen or 10+minutes delay of bullet train
[b]500- Kyen and 10–minutes delay of bullet train
[c]Weighted total accidents/incidents converted in terms of big accident

4.2 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, Branches E and C, had neither a big accident nor even a small incident, and the operators in these branches also had relatively higher morale. To visualise the effects of these two attitude factors on railway safety quantitatively, each branch is mapped on the geometric plane of motivation/morale and the weighted total accident/incident rate shown in Figure 3. As can be seen from this figure, both motivation and morale were negatively correlated with the

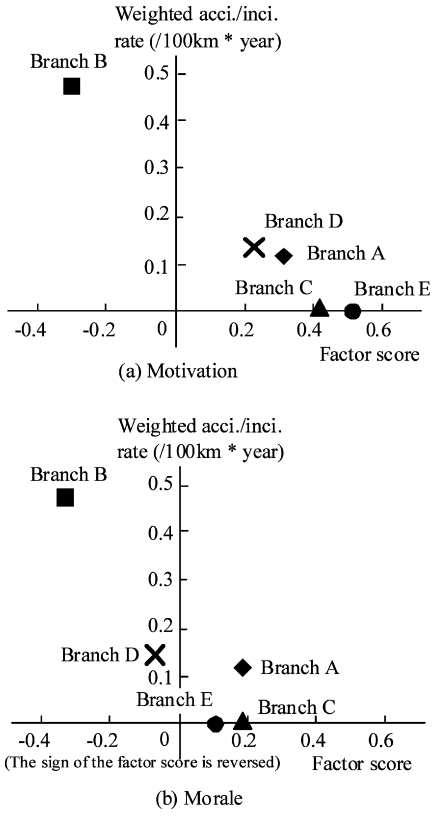

Fig. 3 Correlations of motivation and morale with accident/incident rate using branch based data

accident/incident rate. In particular, consistent matching was obtained between motivation level and the weighted total accident/incident rate for all of the five branches investigated in this section.

4.3 Questions diagnosing risk level

Considering the integrated results of questionnaire responses and accident/incident statistics, we can divide the branches into two extreme classes in terms of train operators' motivation and morale and therefore accident risk: low-risk branches (Branches A, C and E) versus a high-risk branch (Branch B). As mentioned in Sect. 3, Branch C has somewhat different duties and working style from the others. This branch works in the entire area of the line and operates different types of special track maintenance trains. Therefore, excluding Branch C from the low-risk group, we seek to identify "diagnostic" questions that can differentiate between the low-risk branches (A and E) and the high-risk branch (B) based on the Kruskal-Wallis test (being the standard test applied to rank-based data involving several independent groups).

Given the analysis results, questions shown in Table 5 turned out to distinguish statistically (on the basis of $p < 0.05$) the low-risk branches from 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 average response scores of the two risk groups. Several items among such diagnostic questions were the ones that were not loaded heavily on any factors derived by the principal component analysis, such as "Even when fatigued, I perform effectively during critical times of operation" ($p < 0.05$; 4.30 vs. 3.95).

Table 5 Question items capable of identifying high/low risk organisations

Questions	Significance level (p)
Satisfaction with post-qualification training	0.009
Satisfaction with post-qualification 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 when fatigued	0.017
Organisation'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
Performance not affected by inexperienced member	0.017
Able to forget personal problems while on duty	0.016

Based on these results, as well as those of the principal component analysis, we generated a revised version of the questionnaire with a smaller number of questions, as mentioned in Sect. 2.3. This questionnaire aimed to reliably and effectively diagnose the safety culture of each operation unit, including morale, motivation and other attitude factors. Applying this shortened questionnaire to the four track maintenance companies, the survey was extended to all of the track maintenance train operators working for the high-speed railway.

5 Extended investigation of all train operators

5.1 Responses from all of the companies

Company-based percentage agreements and disagreements for each attitude factor are shown in Table 6. These indices were calculated by applying the same procedure of the branch-based analysis to the responses of the shortened TMAQ collected from all of the track maintenance train operators working in the four subsidiary companies. Three items of the representative item set appearing in the original TMAQ (refer to Table 1) were removed in the shortened TMAQ used in the company-based survey. These items are "satisfaction with post-qualification instructor's skills" (Factor II),

Table 6 Company (P, Q, R, S) based comparisons of percentage agreement and disagreement[a] for each attitude factor

Attitudinal factors	P	Q	R	S	Total
I Motivation	61%, 16%	41%, 24%	60%, 13%	57%, 27%	57%, 17%
II Satisfaction with own competence	42%, 19%	39%, 14%	42%, 16%	25%, 30%	40%, 18%
III Safety awareness of operation	78%, 8%	78%, 7%	80%, 8%	82%, 13%	79%, 8%
IV Moral	39%, 41%	34%, 39%	38%, 43%	44%, 46%	38%, 42%
V Satisfaction with manuals & checklists	66%, 8%	63%, 6%	61%, 5%	59%, 14%	63%, 7%
VI Satisfaction with management system	41%, 29%	35%, 29%	37%, 30%	43%, 37%	39%, 30%
VII Trust in management	63%, 18%	35%, 32%	61%, 11%	62%, 27%	58%, 18%

[a]The result for each is presented in the format:
% agreement: combined response of "agree strongly" and "agree slightly" in %
% disagreement: combined response of "disagree strongly" and "disagree slightly" in %

"crewmember's ability to cope with fatigue" (Factor III) and "satisfaction with safety manuals" (Factor V). Therefore, it is noted that a set of representative items were slightly changed for each of these attitude factors.

From the calculation result of percentage agreement and disagreement, an almost identical pattern can be identified for the company-based analysis compared with the branch-based study mentioned in Sect. 3.3. That is, differences were identified between the four companies in terms of several attitude factors such as motivation, morale, and satisfaction with management system. Furthermore, companies whose operators were highly motivated (Companies P, R and S) exhibited higher morale, satisfaction with the management system and trust in management, and vice versa. The percentage agreements of the company having the most "negative" attitudes, (Company Q) were lower by approximately 20 points in motivation and 10 points in morale compared to the "top" company – similar to the results of the branch-based analysis using response data from a single company. There were also large variations in operators' satisfaction with their own competence and trust in management. Absolute ranges of both factors from the top to the bottom companies were 17 and 28 points, respectively. Regarding the other attitude factors, differences were also identified between the four companies, but here the absolute differences were smaller: less than 10 points in range. Thus, this tendency is almost identical to that of the branch-based study. These results indicate that a company-based culture as well as local branch culture may affect train operators' attitudes towards their work, company and management.

As in the branch-based survey within a single company, it was also found that the percentage agreement for satisfaction with the management system was not high, and almost as low as morale for all companies. The ranking of companies in terms of this factor was similar to those in motivation and in morale. This may indicate that operators' satisfaction with their management system and organisation may possibly be coupled with their motivation and morale. Therefore, it would seem to be of importance for managers to gain or maintain the trust of their employees and in general to implement measures that foster confidence in management's commitment to safety and satisfaction with the management system.

Table 7 Averaged accident/incident rates for all of the track maintenance companies (P, Q, R, S) for the last five years (1994–1998)

	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

(Number of accidents/incidents per 100 km of territory a year)

5.2 Contribution to railway safety

Table 7 shows the accident/incident rate of each track maintenance company in the same indices as the branch-based statistics within a single company. The accident/incident rates also varied between the companies. The averaged rate of the "big" accident of Company Q was approximately twice of that of the second highest scoring company, Company R. The correlation of motivation and morale with the weighted total accident/incident rate is depicted in Figure 4. As clearly indicated in this figure, the effect of these attitude factors on railway safety in this company-based analysis is remarkably similar to the one found in the five-branch study within a single company, Company P: companies which employ operators who have higher morale and motivation tend to exhibit lower accident/incident rates.

6 Discussion

6.1 Improvement of operators' attitudes and accident rates

As mentioned in Sect. 2, we collected responses twice from operators working for Company P, separated by a two-year interval. Here, we discuss the change over two years in terms of operators' levels of the attitude factors for each branch within this company. The levels of each factor at the two different sampling periods (in 1997 and 1999) are shown in Table 8. The percentage agreements of each factor were calculated on the basis of the shortened TMAQ set of representative items for both

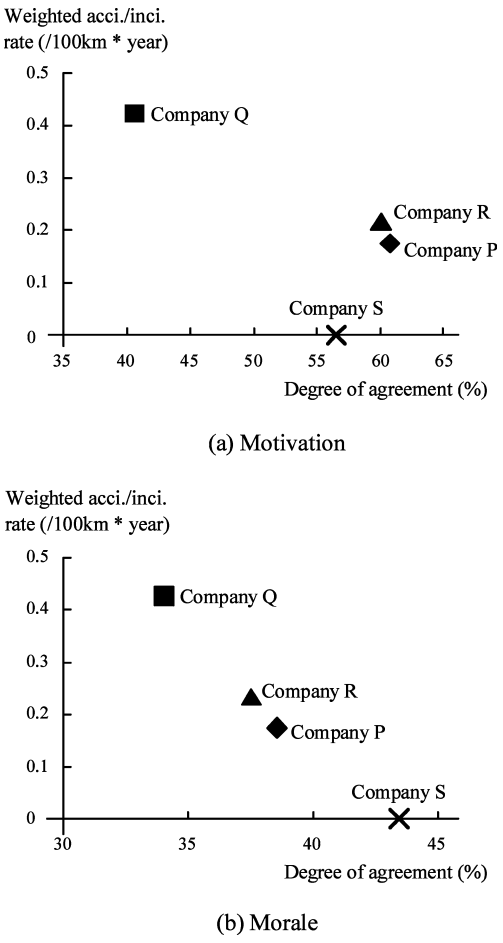

Fig. 4 Company based correlations of operators' motivation and morale with accident/incident rate

1997 and 1999 questionnaire samples. Therefore, values in the percentage agreement for the 1997 sample were changed for several factors from the ones shown in Table 2.

Table 8 shows that the overall tendency obtained from the responses in 1997 was maintained two years later. The relative ranking of branches within each factor has not changed very much over the two years although percentage agreements for most factors increased in all five branches surveyed in this study. In particular, operators' satisfaction with their own competence and their trust in management were largely improved in this interval. Such attitude improvements may possibly be mainly or partly due to a campaign of continuous company-wide initiatives and intervention aimed at improving railway safety over the two years in question. Since no unexpected changes happened between the two surveys, the data collected in the present survey seem to be sufficiently reliable to derive sound conclusions about operator attitudes and their relations to the risk of train accidents.

It should be emphasised that Branch B operators' motivation – as well as their scores on all other attitude factors except one – improved on the whole over the two-year period. The level of motivation has caught up with some of the other branches; on the other hand, the level of another critical factor, morale, was scarcely improved and was still the lowest of the five branches. The improved results of the "problem branch" were likely to reflect operators' improved attitudes, which may in turn be influenced by the safety enhancement activities inside the branch as well as by the above-mentioned, company-wide initiatives. The improvement of the operator attitudes in Branch B is supported by the fact that they had no big or small accidents/incidents during the entire year (1999) when the second questionnaire survey was made (in fact the other branches didn't have any either).

Considering the results of this two-year transition of operator attitudes and accident rates, it seems that a questionnaire-based survey like the one performed in this study can generate useful information when applied periodically to diagnose changes in morale, motivation and other attitude factors of employee groups. In particular, a questionnaire having a smaller number of questions like the shortened version of TMAQ developed in this study may be both cost-efficient and useful, since respondents' attitudes – that are critical to operational safety – can be easily and effectively elicited. This type of relatively focused safety culture survey may be especially applicable to measure the effects of safety enhancement programmes and initiatives – to the extent that other work factors such as tasks, environment, and staff do not dramatically change or are at least monitored and taken into consideration when interpreting the overall present survey results.

Table 8 Comparisons of attitude factors for each branch at two different surveyed periods (1997 and 1999)[a]

Attitudinal factors	Branch A	B	C	D	E
I Motivation	60%, 60%	51%, 59%	59%, 65%	56%, 58%	66%, 69%
II Satisfaction with own competence	24%, 50%	20%, 38%	48%, 44%	23%, 31%	35%, 59%
III Safety awareness of operation	84%, 83%	77%, 79%	81%, 72%	79%, 81%	75%, 72%
IV Morale	37%, 39%	28%, 29%	37%, 47%	37%, 40%	36%, 43%
V Satisfaction with manuals & checklists	55%, 71%	42%, 74%	71%, 68%	43%, 60%	55%, 59%
VI Satisfaction with management system	39%, 46%	31%, 38%	47%, 45%	42%, 40%	33%, 37%
VII Trust in management	53%, 64%	40%, 53%	43%, 60%	56%, 69%	64%, 64%

[a]The result for each branch is presented in the format: % agreement in 1997, % agreement in 1999
%agreement: combined response of "agree strongly" and "agree slightly" in %

6.2 Implications to organisational supports

Train operators' motivation and morale were suggested to be key factors related to railway safety levels in both the branch-based and the company-based investigation. Changes in the level of each of these factors correlated the accident/incident rates. Such results of correlation analyses did not demonstrate a causal relationship between these two variables. However, it seems reasonable to consider these attitude factors to affect safety performance indices for the following reasons: firstly, the operators surveyed had at no time been informed about incidents in the other braches or companies, and therefore they had no means of knowing their own branch's relative level of safety performance; secondly, as was apparent from numerous interviews as well as from the comments added for the open-ended questions by operators (discussed later), they had demonstrated little concern about their branch's safety status itself, whereas their primary work-related interests were focused on income and working schedule (such as more days off on Saturdays and Sundays). Considering these facts, it is not likely that the causal link goes from incident rate to attitudes; therefore, we suggest that the most plausible interpretation of the correlation is to regard the attitude factors as causally involved in the behaviours that underlie the accident and incident statistics.

These factors – motivation and morale – were also found to be related to other attitude factors, particularly to respondents' satisfaction with their company's management system and their trust in management. These organisation-related factors include issues concerning training, manuals and checklists, and work schedule and procedures as well as management style and organisational rules. As noted in Sect. 3, there is ample evidence that an informal, tacit culture exists in each local organisation (branch) within a company. Therefore, these results suggest the necessity of changing or adapting training schemes, working procedures and management style, considering both formal and informal ways in which safety culture is shaped, as well as to critically review manuals and checklists in order to enhance operators' morale and motivation.

Regarding the requirement to consider changes in the management system, a number of comments were included in the questionnaire responses collected from train operators. For example, in responses to the original TMAQ, approximately 60% of the comments to the open-ended question on organisational actions for safety focused on improving work systems and work conditions such as shift and work schedule, working hours, and allocation of more employees appropriately to the daily task. Requests for more days off (that can also be taken regularly) occupied approximately 15% of all the responses on this question. There was also noticeable feedback (10%) regarding communication channels and human relations between managers and employees. Examples of statements on this issue are the following: ''Employee opinions should be collected to improve the work system,'' and ''Leaders should talk to their subordinates with an open mind so that operators are willing to submit suggestions and proposals for their jobs.'' In addition, a great number of operators (58% of the total responses to the open-ended question) remarked that increased payment or improvement of the payment scheme could contribute to higher satisfaction with their jobs and with their company. In contrast, only a few proposals about improvement of the work setting (4%) were presented.

Considering these open-ended comments and the characteristics of the task mentioned in Sect. 2.1, an imbalance between employment conditions such as income and compensation, and work factors such as workload and work schedule and conditions, may be the primary sources of operators' low satisfaction with management system. If this is true, it may be suggested that adaptation of the payment system and the work schedule is critically important to improve the operators' motivation in track maintenance organisations. In addition, efforts to enhance trust, openness and mutual understanding on the part of both operators and managers, as well as to improve formal and informal communication channels between the two sides seem to be crucial in developing a positive organisational culture within companies of the type targeted in this study.

Considering training issues, respondents' satisfaction with ''basic operation training'' and ''post-qualification training'' was not rated highly. Aggregating responses to these two training-related items, their level of satisfaction was 34%. In addition, supervisors' satisfaction (42%) was higher than that of drivers' (25%), and they were more satisfied with basic operation training (46%) than with post-qualification training (31%). These results were supported from a number of comments on training made to the open-ended question. The most frequent comment made by respondents was about the need for various kinds of training programmes and meetings such as safety training, post-qualification training, and approaches to handling emergencies. There were also several responses about requiring specific purpose training: training for detecting dangerous situations, safety meetings for obtaining relevant knowledge about safety procedures, and so on.

As can be seen from these comments, a substantial number of operators themselves recognised the necessity of training in order to enhance safety, and particularly they point to a greater need for post-qualification training. Table 3 showed the list of the present training programmes prepared for track maintenance train operators working for the high-speed railway. This table indicates that most time in training programmes were spent when drivers and supervisors start to work or when they receive qualification for their licenses. The other types of training in the list are not actually ''training'', but meetings or formal communications about safety issues that take from a few minutes to half an hour at the longest. Therefore, operators' opportunities for receiving training after obtaining their licenses

do appear to be somewhat limited. This seems to be a major reason why respondents were not satisfied with their present training programmes. Based on this result, it is natural to suggest that additional post-qualification training programmes are required to keep and improve employee's skills and competence at a satisfactory level and moreover, in turn to foster a greater motivation.

6.3 Work domain comparison

We compared the train operators' attitudes with those in the maritime domain. A similar survey was carried out for seafarers in two Japanese ship companies (Itoh and Andersen 1999) as well as in four Scandinavian companies (Andersen et al. 1999), using the SMAQ containing largely the same question items as the long-version TMAQ. Respondents to the maritime survey included both the officer and the non-officer groups. Since the social status of ship officers is higher than that of train supervisors, being comparable to that of airline pilots, we decided to compare responses of train operators to non-officer seafarers (able bodied seamen, ships assistants, electricians, catering personnel, and so on). Ship operations on board are performed not only by native staff but also by international employees, unlike in railway and track maintenance companies.

In the present paper, we compare the two work domains within the same national culture (Japanese seamen versus Japanese train operators) using responses from a sample of 83 Japanese non-officer seafarers. Their percentage of (dis)agreements on each attitude factor are shown in Table 9. This table also includes those of the track maintenance train operators that were calculated using response data from all four companies with the shortened version of TMAQ. This grouping procedure led to a more general trend with a larger number of samples. As can be seen in this table, we found relatively great differences for most of the attitude factors. As an overall trend of the attitudes elicited, in most attitude factors, percentage agreements among train operators were lower than those among seafarers. Only in regard to satisfaction with manuals and checklists did the level of satisfaction of train operators exceed that of the seafarers.

In contrast, the seamen's motivation as well as satisfaction with their own competence was quite a lot greater (approximately 25 points) than those of train operators. This may be due to the fact that seafarers seem to enjoy a higher status and moreover have a traditionally high professional pride. Compared to track maintenance train operators, seafarers also showed more "positive" attitudes towards their company and their management system: stronger trust in management and higher satisfaction with the management system, as well as higher morale. These factors may be largely affected by the hierarchical structure of track maintenance organisations: as mentioned in Sect. 2.1, the high-speed railway company controls four subsidiary companies, each of which in turn is comprised of several branches. Each branch of each subsidiary company has one or more daughter unit companies and most of the operators are employed by the unit companies, while a small number of operators (less than 15% of all the operators working for the high-speed railway) are employees of one of the subsidiaries. In contrast, all the seafarers were employees of top-level ship companies. To a certain extent, it can be stated that the hierarchical distance between management and workers could be considered to be much smaller in the ship companies sample than in the track maintenance organisations sample.

7 Conclusions

This paper reported the integrated results from a questionnaire-based survey and the analysis of the accident/incident statistics in track maintenance train operations. The objectives of this investigation were, first, to uncover night train operators' perceptions and attitudes concerning their jobs, their organisation, their own competence, the management system of their company, their safety awareness and perception of human limitations. Secondly, we aimed to assess the connection between operators' attitudes and perceptions with railway safety. To fulfil these objectives, we collected two data sets of questionnaire responses from track maintenance train operators working for the Japanese high-speed railway: a branch-based sample within a single com-

Table 9 Comparisons in each attitude factor[a] between train operators and seafarers

Attitudinal factors	Train operators			Seafarers (non-officers)
	Drv.	Spv.	Total	
I Motivation	51%, 21%	63%, 14%	57%, 17%	84%, 5%
II Satisfaction with own competence	30%, 22%	49%, 15%	40%, 18%	63%, 9%
III Safety awareness of operation	76%, 9%	83%, 8%	79%, 8%	82%, 6%
IV Morale	32%, 41%	36%, 43%	34%, 42%	44%, 43%
V Satisfaction with manuals & checklists	60%, 7%	67%, 7%	63%, 7%	48%, 18%
VI Satisfaction with management system	40%, 25%	38%, 35%	39%, 30%	44%, 37%
VII Trust in management	54%, 20%	62%, 17%	58%, 18%	87%, 6%

[a]The result for each work group is presented in the format:
% agreement: combined response of "agree strongly" and "agree slightly" in %
% disagreement: combined response of "disagree strongly" and "disagree slightly" in %

pany, and a company-based sample from all of the track maintenance companies operating under the large high-speed railway company.

We first extracted a set of attitude factors by principal component analysis: motivation, morale, satisfaction with one's own competence, with the management system and with manuals and checklists, trust in management, and safety awareness of operations. Then, a number of correlation analyses were performed between attitude factors and accident/incident rates, using both branch- and company-based data sets. The two sets of data yielded substantially identical results and it was suggested that operators' motivation and morale are key factors for railway safety and, therefore, are potential risk factors that may be identified before accidents occur. It was also shown that these two attitude factors are highly related to the respondents' satisfaction with their company's management system and their trust in management. Based on these results, we suggested that it is necessary to change or adapt the management system, both in its formal and informal aspects, in order to enhance operators' morale and motivation contributing to railway safety.

At the same time, it was shown that respondents from the track maintenance companies had little awareness of the effects of fatigue and stress (only about 25% of operators agreed on an item on the effects of stress and emergency situation). This may be a common characteristic of Japanese workers since we detected a similar, and even stronger, tendency for Japanese seafarers. Therefore, it is also suggested that railway and maritime operators could benefit from appropriate training programmes to educate operators about stress, fatigue and sleep, for example, to provide knowledge concerning how they can affect work performance and safety and how they must be coped with (Helmreich and Merritt 1998; Helmreich et al. 1999).

Finally, when further results on correlations are obtained between incident risks and operators' responses to specific items involving motivation and morale, the questionnaire-based method employed in this study may be a useful supplement to accident/incident data in order to identify high-risk and low-risk work units. This is of particular importance whenever there is a possibility that accident/incident reporting is incomplete or when it contains scant and rare events; and, equally, while accident/incident reporting systems are applied as *retrospective* indices of safety levels, the attitude survey methods described above can be used *prospectively* and may therefore be used in designing more focused campaigns to improve safety.

8 Appendix A: Original TMAQ items used for analysis

8.1 General questions

Please indicate how satisfied you yourself are with each of these aspects of track maintenance train operations. Please rate each item from the corresponding scale between 1 (very low satisfaction) and 5 (very high satisfaction).

- Your own basic train operation training.
- Your own basic train operation instructor's skills.
- Your own post-qualification training.
- Your own post-qualification training instructor's skills.
- Current checklists.
- Operation manuals (including standard operational procedures).
- Safety manuals.
- Shift schedule.
- My ability in handling normal operations.
- My ability in handling emergencies.
- Regular feedback on my daily performance.
- Operation planning (if relevant).
- The way my company evaluates performance (if relevant).
- Crew resource management training (if relevant).

8.2 Organisational issues

Please rate each item from the corresponding scale between 1 (strongly disagree) and 5 (strongly agree).

- Checklists are essential for safety
- I am sure management will never compromise safety for profitability.
- Morale in the company is good.
- My suggestions about safety will be acted upon if I express them to management in the company (if relevant).
- I am proud to work for this company.
- My colleagues are adequately trained in emergency procedures.
- I am encouraged by my seniors to report any unsafe conditions I may observe.
- I know the proper channels through which questions regarding safety procedures should be routed.
- Emergency drills are conducted as prescribed.
- When I enter a new train I always receive a proper hand-over.
- Our training has prepared the crew to work as a well-coordinated team in an emergency.
- I like my job.
- This company practices the highest maintenance standards.
- Task assignments are always cross-checked and verified.
- My colleagues frequently carry out secondary tasks during task.
- It is the practice to report colleagues who cannot perform their duties due to alcohol or drugs.
- Crewmembers are well trained to cope with fatigue.
- It makes no difference to me which company I work for.

- The company deals constructively with problematic crewmembers.
- Many junior train drivers are reluctant to assume full responsibility for their assigned tasks.
- It is not uncommon to abandon the performance briefly if there appears to be no danger.
- Crewmembers visibly impaired by alcohol or drugs will be kept from going on duty.
- On train, open discussion is a common way of solving problems.
- Alcohol presents a safety problem on my company's trains.
- I support attempts to reduce the manning level on trains.
- Accidents and emergencies are always reported according to company orders.
- More attention should be paid to sleep and sleeping possibilities before performing a task.

8.3 Train management

Please rate each item from the corresponding scale between 1 (strongly disagree) and 5 (strongly agree).

- Supervisors should encourage crewmember questions during normal operations and in emergencies.
- Even when fatigued, I perform effectively during critical times of operation.
- Asking for assistance makes one appear incompetent.
- People should be aware of and sensitive to the personal problems of other crewmembers.
- The organisation's rules should not be broken – even when the crewmember thinks it is in the company's best interest.
- I am normally consulted on matters that affect the performance of my duties.
- When my workload is high I ask for assistance.
- Leaders who encourage suggestions from crewmembers are weak.
- My decision-making ability is as good in emergencies as in routine conditions.
- A debriefing and critique of procedures and decisions after critical situations is an important part of safety.
- Leaders make sure that relevant operational intentions and actions are understood.
- Train drivers should not question their supervisor's and management's decisions.
- Briefings are important for safety.
- I am more likely to make errors in an emergency.
- Supervisors ensure full cooperation between all onboard departments.
- When I detect an error I speak up.
- I am ashamed when I make a mistake in front of other crewmembers.
- I am less effective when stressed or fatigued.
- My performance is not adversely affected by working with inexperienced crewmembers.
- Crewmembers should monitor each other for signs of stress or fatigue.
- A truly professional crewmember can forget personal problems while on duty.
- Effective team co-ordination requires team members to take into account the personalities of the other participants.
- I am reluctant to disagree with my superiors.
- Socialising among the crew can help reduce stress.
- Seniors should delegate responsibilities to junior crews as parts of their training.

8.4 Open-ended questions

- What can the company do to increase (1) safety, (2) efficiency, and (3) job satisfaction?
- What is your perception of (4) the Bullet Train Company, (5) other safety related issues, and (6) fatigue and work cycles?

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