SAFETY CULTURE OF TRACK MAINTENANCE ORGANISATIONS AND ITS CORRELATION WITH ACCIDENT/INCIDENT STATISTICS

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ABSTRACT

The present paper reports the results of a questionnaire-based survey on safety culture in track maintenance organisations for a Japanese *high-speed railway* (*Shinkansen*). The survey was focused on operators' attitudes toward management, organisational issues, their perceptions of their own skills and competencies, and other aspects that impact on safety. The survey was conducted by using an adapted version of the shortened TMAQ questionnaire, which is based on Helmreich's FMAQ and its derivative, the SMAQ (Flight [Ship, Train] Management Attitudes Questionnaire. More than 1,500 responses were collected from all the operators working for *track maintenance* of the high-speed railway (yielding a response rate of 94%).

Principal component analysis was applied to the response data, and ten attitudinal factors were extracted, accounting for 55% of the cumulative variance, e.g., motivation, trust in their mother company's management, confidence in their own skills/competencies, teamwork with other organisations and ambition for skill development and obtaining higher licenses. The results suggested that each subsidiary company has its own safety culture since there were significant differences in most of attitudinal factors between the companies. Moreover, significant differences in perceptions and attitudes were also found among branches belonging to the same company, suggesting different "branch cultures". In addition, the independent "unit companies" working under contract with the branches turned out to differ in terms of either having developed their own specific culture or having adopted the culture of the branch to which they belonged. Finally, focusing on the effects of attitudinal factors on operation safety, we analysed correlations between the branch-based accident/incident rate for the last five years and the mean score of each of the attitudinal factors. Significant correlations were found between two factors and the accident/incident rate, namely, operators' motivation and their trust in the management of their mother company. Thus, branches which employed operators having lower motivation and lower trust in their management exhibited a higher accident/incident rate.

Based on the results of the questionnaire survey, we discuss potential risk factors for accidents during track maintenance and some implications for the improvement of operational safety.

KEYWORDS

Safety culture, attitudinal factors, questionnaire-based survey, track maintenance, accident/incident rate

INTRODUCTION

Organisational factors play a crucial role for safety in human-machine system operations such as aviation, ship handling and railways. It is well known that human error is the predominant cause of accidents in these domains and, moreover, that organisational problems are frequently latent causal factors that contribute to the occurrence of human error made by frontline personnel. Thus, it has been pointed out that the majority of contributing causes of major accidents may be attributed to the organisations themselves that shape the safety culture or climate within which the employees operate (Hee et al., 1999; Reason, 1997). For example, it was reported that 40% of incidents in the Dutch steel industry were caused

by organisational failures (van Vuuren, 2000).

There are many proposed definitions of safety culture or safety climate (e.g., ACSNI, 1993; Flin et al., 2000; Pidgeon and O'Learry, 1994; Zohar, 1980), and it is difficult to define or explain this concept precisely. One of the more succinct definitions was presented in a report by ACSNI (1993) stating that "it 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, e.g., fatigue, risk taking, violations of procedures (Andersen, 2001). Several approaches have been applied in investigations of the safety culture of particular organisations, ranging from safety audits, structured interviews with management and employees, behavioural observations to questionnaire surveys. The latter approach, which has been pursued in various forms by a number of investigators (e.g., Cox and Cheyne, 2000; Williamson et al., 1997; Zohar, 1980), may be termed the "measurement of individual perceptions and attitudes approach" in so far as it seeks to capture organisational culture or climate by eliciting the perceptions, norms and attitudes of employees to factors that impact on safety.

Applying this approach to uncovering night train operators' perceptions and attitudes to organisational issues, Itoh and Andersen (1999) and Itoh et al. (2000) reported a questionnaire-based survey collecting responses from the operators of track maintenance trains working for a Japanese high-speed railway, Tokaido Shinkansen, that runs between Tokyo and Osaka. In these studies, seven attitudinal factors were extracted by principal component analysis with cumulative variance of 60%: motivation, morale, satisfaction with working procedures, with own competence, and trust in management and organisation, and so forth. Using the statistics of accidents/incidents collected independently by the same companies, a close correlation was obtained between the levels of operators' motivation and morale and the accident/incident rates of the respective branches or companies to which they belonged. From these results, these attitudinal factors were proposed as potentially diagnostic factors for risk of accidents of track maintenance trains. In addition, it was also found that morale and motivation are highly related to operators' satisfaction with own competence and with management system as well as to their attitudes to organisation related factors.

In the present study, the "measurement of individual perceptions and attitudes approach" is similarly applied to uncovering the safety culture of track maintenance organisations operating for the Japanese high-speed railway. While the former two studies of track maintenance organisations focused on track inspection (train drivers and supervisors) (Itoh and Andersen, 1999; Itoh et al., 2001), this study is targeted at employees doing track repairs and construction (supervisors and workers). Based on results of a questionnaire survey, we discuss whether the above-mentioned risk factors of the railway can be extended to a different type of jobs, i.e., track maintenance operations.

There is a four-level hierarchy for track maintenance organisations operating for the high-speed railway. The bullet train company will contract track maintenance in a specific area to one of its subsidiary track maintenance companies. Each subsidiary company has several branches each of which is responsible for contracted operations in a local area. Within each branch of a subsidiary, there are one or several small independent operational units, each of which employs 10 to 50 operators. This hierarchy is structured in an organisational tree: at the top of hierarchy, the bullet train company controls three subsidiary companies which in turn comprise a total of 22 branches which, finally, are divided into 54 units. Most of the operators are employed by the units, but a small number of operators (less than 3% of all operators) are employees of one of the three larger subsidiaries (and these operators thus work in particular branches).

Track maintenance operations are performed manually during night only when passenger trains are not running. These operations are usually carried out by a team of operators working under the supervision of one or a few senior operators, so-called "track maintenance supervisors". Operators are required to master several kinds of operational skills, and the bullet train company grants operators who are thought to have achieved a sufficient level of skills *license*. There are several ranks of licenses, the rank of "supervisor" being the highest for track maintenance operators. Most of the operators employed directly by any of the three subsidiary companies (rather than units) are supervisors whereas only a small proportion of unit operators have obtained this rank. This does not mean, however, that supervisors necessarily have superior skills in relation to ordinary operators. In fact, the rank of supervisor

is not necessarily an indication of a higher level of skills. For reasons that may have to do with complex bureaucratic processes, it turns out that supervisors are, as mentioned, nearly always from the subsidiary companies; but it is widely recognised that they may nevertheless well have lower levels of skills or competence than senior operators in their daughter units.

In addition, an operator's conditions of employment such as income, compensation and working schedule depend much more on the organisational level to which he belongs than on his skills or licensing rank. Accordingly, there may well exist a mismatch between an operator's skills/competence and his license, and thus, as perceived, an even more unwarranted mismatch between an operator's competence level and his conditions of employment. One may speculate, therefore, that these discrepancies may lead the majority of track maintenance operators, i.e., ones belonging to the units, to possess relatively lower morale and motivation and this in turn may cause a lower quality of track maintenance and a lower level of operational safety.

QUESTIONNAIRE

For the present study an adapted version of the TMAQ (Train Management Attitudes Questionnaire) was used. The TMAQ, which was developed for night train operators (Itoh et al., 2000), is based on the widely known FMAQ, developed by Helmreich and his associates (Helmreich et al., 1993) and its derivative, the SMAQ (Flight [Ship] Management Attitudes Questionnaire) (Andersen et al., 1999). (Confer Helmreich & Merritt, 1998, for results from extensive surveys using the FMAQ). As mentioned above, the adaptation of the TMAQ questionnaire was made in order to capture in particular operator's perceptions of their own skills and their views of the licensing system as well as related motivational issues. Thus, questions concerning these topics were added to the original TMAQ. The questionnaire used for the present study we have called the TMAQ II questionnaire, since it differs somewhat from its predecessor, the original TMAQ. The TMAQ II is shorter than the TMAQ and has just 45 questions (Likert-scale question items) as well as questions that prompt respondents to supply free-text comments on a range of factors: operational safety, productivity, work schedule, employment conditions and so forth. It seeks to elicit from respondents their views and attitudes concerning a range of safety related factors including morale, motivation, leadership and teamwork, skills and competence, management style and other organisational issues. Respondents are thus asked to rate each question on a five-point scale between 1 and 5 (from 'strongly disagree' to 'strongly agree'). It takes a respondent around 15-20 minutes to answer all the items in the questionnaire.

The survey was made in December of 2000, and the questionnaire was distributed to all the track maintenance operators employed by the unit companies, not including subsidiary operators. We obtained 1,525 response samples, and the response rate was 93.8%, reflecting the strong management and organisational support for this project. Of all the respondents, 461 operators had a supervisor license, 37 respondents had a "sub-supervisor" license, 287 a "watch operator" license, and 623 operators had no license. (i.e., they were non-licensed, hence "ordinary" operators). Mean age of respondents was 44.1 years and mean extent of working experience of track maintenance was 11.1 years.

TRACK MAINTENANCE OPERATOR'S ATTITUDES

Attitudinal factors

Principal component analysis was applied to TMAQ II response data collected from all the track maintenance operators. The purpose of this analysis was to compare track maintenance operators' attitudinal factors with those derived from the night train drivers (Itoh et al., 2000). Altogether, 37 organisational items of the questionnaire were used for the analysis, and 1,274 valid samples were obtained in total.

From the analysis ten *attitudinal factors* were extracted, accounting for 55.4% of the cumulative variance. These factors are similar to the seven factors derived from the night train operators' responses (Itoh et al., 2000). There are, however, some minor differences that may be due to the hierarchical structure of track maintenance organisations and the additional items in the TMAQ II regarding skills, licensing system and subsidiary company's management.

For the first principal component, which explained 16.7% of variance, many items in the questionnaire were positively high loaded. Factor loadings of the following items were particularly high: "I am proud to work for this company", "I like my job", "I want to remain in this job for the rest of my working life", "Motivation in my company is high" and "I want to acquire various skills and competence required for my job" – for details see these and other items in Table 1.

Table 1 Attitudinal factors derived by principal component analysis

Factors/Highly loaded questions	% variance(Cum. var.) Loading
I: Motivation	**16.7% (16.7%)**
I am proud to work for this company	0.659
I like my job	0.601
I want to remain in this job for the rest of my working life	0.565
Motivation in my company is high	0.540
I want to acquire various skills and competence	0.508
I will report any unsafe condition to my senior	0.502
Morale in my company is good	0.484
My performance not poorer working with operators of other units	0.458
I am satisfied with regular feedback on my daily performance	0.454
My performance not poorer working under mother company's supervisor	0.450
II. Trust in mother company's management	**8.6% (25.3%)**
I am satisfied with the current working schedule	0.544
Salary system for an individual operator is appropriate	0.496
Operators and supervisors should be arranged responsibilities	-0.493
Mother company has a good understanding on operators	0.478
Operators having better competence must get higher income	-0.444
Operators should not question mother company's decisions	0.442
I am satisfied with my salary and income from my company	0.435
III. Confidence in own skills and competence (-)	**5.4% (30.7%)**
It makes no difference to me which company I work for	-0.513
I want to remain in this job for the rest of my working life	-0.457
I want to obtain a license of "track maintenance supervisor"	-0.406
I am often supervised by a senior having lower competence	-0.401
I like my job	-0.366
IV. Teamwork with other organisations	**4.6% (35.3%)**
I want to get a license of "track maintenance supervisor"	-0.418
Operators should not question mother company's decisions	0.410
My performance not poorer working under mother company's supervisor	0.349
My performance not poorer working with operators of other units	0.345
V. Ambition to obtain license	**4.0% (39.3%)**
I am satisfied with the licenses that I presently hold	-0.485
My performance not poorer working with operators of other units	-0.371
Operators having higher rank of license must get higher income	0.353
VI. Satisfaction with own company	**3.7% (43.0%)**
I am satisfied with the licenses that I presently hold	0.415
My performance not poorer working under mother company's supervisor	-0.389
My performance not poorer working with operators of other units	-0.376
I am satisfied with training that I have received	0.368
VII. Preference of competence-oriented evaluation	**3.4% (46.4%)**
Operators having higher rank of license must get higher income	0.512
Operators having better competence must get higher income	0.344
I am satisfied with the manuals and working rules	0.336
VIII: Hope to work for the present company (-)	**3.1 %(49.5%)**
It makes no difference to me which company I work for	0.620
Performance is not affected by inexperienced operators	-0.331
I am satisfied with the licenses that I presently hold	-0.301
Operators having higher rank of license must get higher income	-0.291
IX: Morale (-)	**3.0% (52.6%)**
Operators having higher rank of license must get higher income	-0.378
The organization's rules should not be broken	0.368
Morale in my company is good	-0.341
My performance not poorer working with operators of other units	-0.328
Motivation in my company is high	-0.308
X: Awareness of own skills/competence	**2.9% (55.4%)**
I am often supervised by a senior having lower competence	0.652
I want to remain in this job for the rest of my working life	-0.313
Performance is not affected by inexperienced operators	0.305

(-): 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 that reflect respondent's satisfaction with and attitudes to management and employment system as well as work planning and procedures, e.g., "I am satisfied with the current work schedule", "Salary system for an individual operator is appropriate", "Operators and supervisors should be assigned different responsibilities according to their ranks" (negatively loaded), "My mother company's management has a good understanding of operators" and "I am satisfied with my salary and income". Accordingly, the factor comprising these items was interpreted as "trust in mother company's management". All ten principal components derived by the analysis were considered in this way, based on factor loadings, and Factors III through X were interpreted as confidence in own skills and competence (III), teamwork with other organisations (IV), ambition to obtain a license (V), satisfaction with own company (unit) (VI), preference of competence oriented evaluation (VII), hope to work for the present company (VIII), morale (IX) and awareness of own skills/competence (X), 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.

License-based analysis of attitudes

Percental agreement and disagreement as well as mean score - which is calculated by averaged score for all the related items – for each factor are shown in Table 2, based on the licensing ranks of track maintenance operations: supervisors, sub-supervisors, watch operators and ordinary operators. The percental [dis]agreement is defined as the rate of the total number of "strongly agree" and "slightly agree" responses [or "strongly / slightly disagree"] over the total number of responses for the specific items of each factor. The representative items of each attitudinal factor are indicated in italics in Table 1. These items were selected as highly loaded ones, i.e., more than 0.35 of factor loading in principle, by the principal component analysis, excluding some exceptional items from a set of representatives due to no direct associations with the factor in its meaning. 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 5 and 4 responses and vice versa.

In general, track maintenance operators' motivation is reasonably high. A significant difference was found in this factor between operators' type of license by the rank based Kruskal-Wallis test: motivation becomes higher

Table 2 Comparisons of attitudinal factors for operators having different licenses

		Superv.	Sub-sup.	Watch op.	Ordinary op.	Total	χ^2_0
I. Motivation	% agree.:	63.2%	66.7%	56.2%	59.0%	60.0%	
	% disagree.:	21.8%	21.0%	23.5%	22.7%	22.5%	34.03**
	Mean score:	3.67	3.74	3.51	3.60	3.61	
II. Trust in mother company's management		14.5%	15.6%	17.9%	19.7%	17.4%	
		70.8%	68.4%	68.1%	61.2%	65.9%	91.74**
		2.10	2.18	2.23	2.35	2.23	
III. Confidence in own skills/competence		45.2%	48.6%	34.4%	34.1%	38.6%	
		34.6%	36.1%	40.7%	41.3%	38.6%	52.63**
		3.21	3.26	2.95	2.93	3.04	
IV. Teamwork with other organisations		52.2%	56.5%	52.2%	49.9%	50.8%	
		33.8%	29.6%	31.2%	33.1%	32.9%	7.87
		3.27	3.43	3.30	3.27	3.27	
V. Ambition to obtain license		33.8%	34.3%	39.2%	43.4%	38.8%	
		50.7%	50.9%	40.8%	38.4%	43.2%	46.82**
		2.79	2.71	3.00	3.09	2.96	
VI. Satisfaction with own company		36.7%	33.6%	26.6%	31.1%	32.3%	
		48.2%	51.7%	51.7%	50.2%	49.3%	20.73**
		2.83	2.72	2.66	2.69	2.74	
VII. Preference of competence oriented evaluation		72.9%	62.5%	70.8%	69.5%	70.7%	
		15.5%	18.1%	16.2%	16.2%	15.8%	13.14*
		4.00	3.68	3.89	3.89	3.92	

Upper row: % combined response of 'agree strongly' and 'agree slightly'
Middle row: % combined response of 'disagree strongly' and 'disagree slightly'
Lower row: averaged score of 5 point responses of the related items
**: $p<0.01$. *: $p<0.05$

with the rank of license. A similar tendency can be identified for the third factor, i.e., confidence in one's own skills and competence. The higher the license rank of an operator, the more confident he is in his own skills. The levels of self-confidence was thus the highest among the supervisors and the sub-supervisors

In contrast, an operator's trust in his mother company's management is very low for any rank. But the level of this factor also depends significantly on the license rank. The most critical response (i.e., critical of management) within this factor was obtained from the supervisors, and in general, an operators' trust in his mother company's management is lower when his license rank is higher - contrary to motivation, where higher rank corresponds to higher motivation. In interviews conducted with several supervisors, we obtained similar statements of their dissatisfaction with their mother company's management and with organisational issues such as working conditions, imbalance or mismatch between responsibility and income and lack of proper communication channels from operators to the mother company. Many statements on such issues were also collected from all the ranks of operators as free-text comments in the questionnaire.

Compared to operators' attitudes to their mother companies, satisfaction with their own companies is higher, although not so high in absolute terms. Their dissatisfaction with income obtained from their unit companies was very strong, i.e., 65% expressed of dissatisfaction. However, they have a close relationship with their unit management in an old Japanese employment style which is characteristic of small companies, (a so-called family administration likened to the relation between a father and his children – a style which is rapidly disappearing).

Perceptions of and attitudes to teamwork with operators and supervisors from other units and their mother company seem to be rather positive. There is no significant difference in this factor among license ranks, and the mean percental agreement is over 50%.

Regarding operators' ambition or motivation to obtain a (higher) license, it is not surprising to see a dependency on the rank of license. Non-licensed operators and those having lower rank of license responded higher agreement on this factor. Its percental agreement exceeds disagreement for ordinary operators and train watch operators. This result may indicate that many operators are sufficiently motivated to obtain a higher license rank and, in turn, to develop their skills and competence.

It is expected that such motivation for developing skills may be enhanced by adapting a licensing system that seeks to discard the present mismatch between license rank and competence level. Similarly, operators also wish to have an appropriate linkage between the employment conditions such as and the license rank. This is supported by the responses to Factor VII where the proportion of agreement is very high. A large number of operators, both among those who have a high license degree as well as among those with no license, express their preference for a competence-oriented evaluation and remuneration system.

SAFETY CULTURE IN ORGANISATIONAL HIERARCHY

Company cultures

Just as we grouped responses across different license ranks, we have grouped responses across the three subsidiary companies for which unit operators work. This company based grouping is shown in terms of proportion of agreement and disagreement in Table 3 in the same format as was used in the previous section on licence groups. As can be seen in this table, there are significant differences in most factors (i.e., motivation, trust in mother company's management, teamwork with other organisations, ambition to obtain a license and preference of competence-oriented evaluation) between the three companies for which unit operators work, and no differences in the rest of factors. This indicates that each of the three subsidiary companies has its own safety culture.

Regarding operators' motivation, the

Table 3 Company-based comparisons of percental (dis)agreement and mean score for attitudinal factors

Attitudinal factors		Company X	Y	Z	Total	χ_0^2
I. Motivation	% agree.:	56.0%	55.9%	65.5%	60.0%	
	%disagree.:	21.7%	27.6%	20.7%	22.5%	115.80**
	Mean score:	3.52	3.49	3.74	3.61	
II. Trust in mother company's management		16.5%	14.9%	19.5%	17.4%	
		61.8%	72.4%	66.6%	65.9%	26.91**
		2.29	2.14	2.23	2.23	
III. Confidence in own skills/competence		36.1%	37.9%	41.2%	38.6%	
		35.6%	42.9%	39.4%	38.6%	1.80
		3.03	3.01	3.07	3.04	
IV. Teamwork with other organisations		47.9%	49.6%	54.0%	50.8%	
		29.9%	37.3%	33.4%	32.9%	8.66*
		3.07	3.20	3.32	3.27	
V. Ambition to obtain license		33.9%	36.3%	39.6%	38.8%	
		41.9%	40.5%	45.6%	43.2%	7.85*
		2.93	3.08	2.93	2.96	
VI. Satisfaction with own company		29.3%	34.0%	34.0%	32.3%	
		46.4%	50.8%	51.2%	49.3%	2.07
		2.76	2.75	2.73	2.74	
VII. Preference of competence oriented evaluation		65.5%	74.9%	73.3%	70.7%	
		15.4%	15.9%	16.0%	15.8%	18.04**
		3.83	3.96	3.98	3.92	

**: $p<0.01$, *: $p<0.05$

percental agreement is very high for each of the three companies and is more than twice as great as the disagreement. In particular, operators working for Company Z exhibit a higher motivation than those from the other two companies by approximately 10 points. This strength of motivation seems to affect operators' ambition or motivation to obtain a license, i.e., Factor V. The percental agreement of Company Z for this factor is the highest of the three companies although its percental disagreement is also the highest. As far as these two factors are concerned, operators working for Company Z are the most motivated for their work and for developing their competencies.

Considering the multi-hierarchical structure of track maintenance organisations, the second factor may be of great importance to investigate safety culture of a specific organisation. There is a significant difference in operators' trust in their mother companies between the three subsidiary companies. The level of this factor for operators working for Company Y is slightly more negative than those for the other two companies. As can be seen in Table 3, however, the percental agreements are very low for operators working for all the three companies. This may suggest that low level of operators' trust in their mother companies can be a potential causal factor for reducing their motivation.

Finally, teamwork with other organisations and preference for competence-oriented evaluation may be critical factors that are affected by organisational culture. Concerning these factors, we can also identify significant differences between the three companies, and these two factors share a similar pattern. For both factors, operators' responses are fairly positive, and the agreements of Companies Y's and Z's are particularly high.

Branch cultures

In order to examine whether there was reason to refer to - and hence distinguish between branch-based cultures, we applied a rank based the Kruskal-Wallis test to identify differences in responses between branches of each subsidiary company. Results of this analysis are shown in Table 4 which contains the Chi square values for each attitudinal factor across each of the three companies. For instance, Company Z had eight branches, and there are significant differences in questionnaire responses for the seven factors between these branches. For the other companies, significant differences were also found in several factors between branches within each company.

Table 4 Differences in attitudinal factors between each subsidiary company's branches

	Company X	Y	Z
I. Motivation	15.55*	0.46	140.39**
II. Trust in mother company's management	103.39**	5.56	176.09**
III. Confidence in own skills/competence	32.26**	16.94**	50.53**
IV. Teamwork with other organization	8.13	12.87**	32.65**
V. Ambition to obtain license	3.55	9.24*	26.78**
VI. Satisfaction with own company	18.47*	7.63*	16.95*
VII. Preference of competence-oriented evaluation	23.89**	3.43	32.85**

Figures: χ^2. **: $p<0.01$, *: $p<0.05$

Each of the three subsidiary companies has its own formal management and employment system by which its branches are administrated. Thus, branches within the same company are entirely alike in terms of employment and management systems, operating procedures, training system, manuals and checklists and so forth. This means that all the branches belonging to the same company share the same organisational system in terms of all *formal* and *managerial* aspects. Therefore, in view of the above-mentioned results that show significant differences among branches within the *same organisational system* we conclude that each branch has developed its own *local* safety culture – we call it "branch culture" – that may differ in local ways in terms of operating procedures, training, daily briefings, communication channels between management and operators, and local management's commitment to safety activities and daily operations.

Types of "unit" culture

In this subsection, we analyse differences in operators' questionnaire responses between unit companies within each branch. Using the same format as above, Table 5 shows the Chi square values obtained by the Kruskal-Wallis test denoting differences or no differences between units within each branch. In this table, the results are indicated only for branches having multiple daughter units each of which had more than 15 responses due to considerations of reliability of analysis. So no branch appears in this table if we have failed to obtain more than15 responses from at lease two of its units or if contains just a single unit.

As noted in this table, all these branches can be classified into two types in terms of operators' responses for the attitudinal factors. A unit classified as Type "A" is referred to as a "homogeneous" unit. This type of unit is affected strongly by its super-ordinate branch in safety culture, and exhibits the same attitudes and perception as those of its parent branch, i.e., there is no significant difference in any attitudinal factors between all the units of the parent branch or at least only a single factor is significantly different.

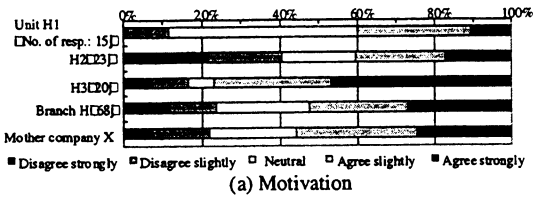
Table 5 Differences in attitudinal factors between each branch's units and their types of unit culture

	Company X						Y		Z	
	Branch C	D	E	F	G	H	J	K	L	M
I. Motivation	7.06*	0.93	1.59	0.36	2.50	51.71**	5.60*	1.19	3.39	1.13
II. Trust in mother company's management	3.77	8.66**	2.52	5.29	5.07	31.17**	0.19	6.46*	7.12	11.23**
III. Confidence in own skills/competence	19.23**	5.29**	0.30	0.13	0.04	22.90**	0.17	1.72	9.29*	4.10*
IV. Teamwork with other organisations	16.15**	0.50	1.85	2.64	1.67	0.16	0.42	0.30	17.55**	4.85*
V. Ambition to obtain license	1.62	6.41*	1.80	0.32	0.19	0.51	0.06	1.17	3.12	2.17*
VI. Satisfaction with own company	1.84	0.13	0.47	0.22	0.20	0.15	0.30	0.07	0.89	0.02
VII. Preference of competence oriented evaluation	0.38	0.24	4.36	2.99	0.30	5.86	0.22	0.28	1.93	3.32
Effect type of branch culture	B	B	A	A	A	B	A	A	B	B

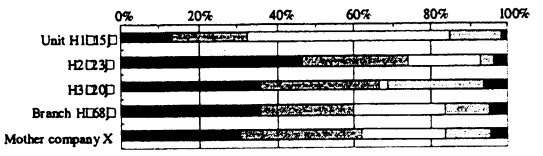
Figures: χ^2_0, **: $p<0.001$, *: $p<0.05$
Type of unit culture: A: "Homogeneous" type B: "Heterogeneous" type

In contrast, a unit company belonging to Type "B" has its own distinct "culture". In a branch having this "heterogeneous" type of daughter units, several attitudinal factors are significantly different between the unit companies, and their response to each factor is directed one and the same way. That is, a unit whose operators are more motivated exhibits more positive attitudes to most of factors among the units in the same branch. Charts of responses from Branch H are depicted for Factors I through III in Figure 1, as an example illustration of the "heterogeneous" type. In this branch, three units perform track maintenance operations in the same local area: Units H1, H2 and H3. Among these three units, operators from Unit H3 are much more motivated than operators from the other two units. Among the three units, the H3-respondents also exhibit the most positive attitudes both to their mother company's management (Factor II; although it is not high at the absolute level) and to their own skills and competence (Factor III). In contrast, the attitudes of the H2-operators are the most negative for these three factors.

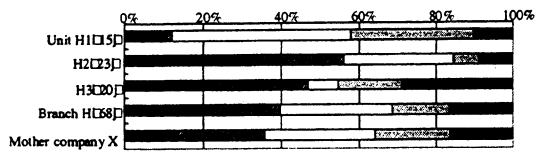
All the branches having "heterogeneous" units were found to share this pattern of "unit culture". It is interesting that the two branches belonging to Company Y fall into Type "A" while units in Company Z branches exhibit "homogeneous" culture. "Homogenous" and "heterogeneous" units are mixed in Company X.



(a) Motivation



(b) Trust in mother company's management



(c) Confidence in own skills and competence

Figure 1 Attitudinal factors of operators in a particular unit

EFFECTS OF SAFETY CULTURE

Accident/incident statistics

In this section, we discuss the relationship between, on the one hand, track maintenance operators' responses as they are aggregated in terms of several attitudinal factors such as their motivation and trust in their mother company's management and, on the other, the rate of operational accidents/incidents. A branch-based accident/incident statistics was collected from the three track maintenance companies surveyed, i.e., Companies X, Y and Z for the last five years (1996-2000). Table 6 shows aggregated accident and incident rates for these three companies (compare similar statistics in our former study, Itoh et al., 2000). In the Shinkansen high-speed railway company, accidents and incidents of track maintenance are classified into two types in terms of lost money and delay of the 'first' morning bullet train: big and small accidents/incidents (it is somewhat of a misnomer to talk about "accidents" in this connection: the Shinkansen has never had an accident involving casualties, serious injury or large material damage in its 37 year history). A 'big accident' is defined as one in which more than 500,000 Japanese yen is lost or a delay longer than 10 minutes is caused to the first bullet train. A 'small incident' involves a loss or a delay that is smaller or shorter. Table 6 shows the accident/incident rate that is indicated in terms of

Table 6 Averaged accident/incident rates of all the track-maintenance companies for the last five years (1996-2000)

	Company X	Y	Z	Total
Big accident	0.65	0.83	0.43	0.57
Small incident	0.39	0.41	0.72	0.57
Weighted total	0.73	0.91	0.57	0.68

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

the number of accidents/incidents per 100 km of railway track a year averaged for the last five years. Using a weight of 0.2 for "translating" a 'small' incident into a 'big' one - a figure obtained empirically by eliciting from railway employees as their "translation coefficient" - compare Itoh et al. (2000), a weighted total accident rate is defined, as follows:

Big accident rate + small incident rate * 0.2

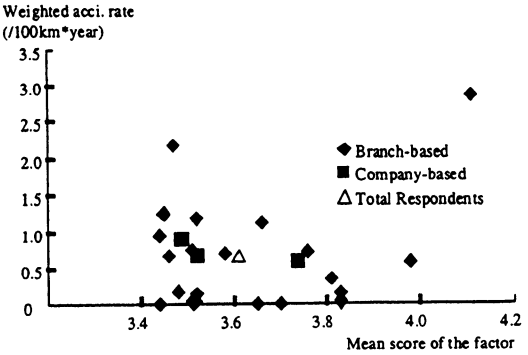
Table 6 also includes this one-dimensional, weighted total accident rate for each company. It can be seen from this table that there were very few accidents and incidents produced by these track maintenance companies. In many branches, no big accidents have been produced during the last five-year period, and therefore the weighted total accident rate of each company was not high, i.e., 0.68 incidents per 100 km of track a year on average.

Correlation with Accidents/Incidents

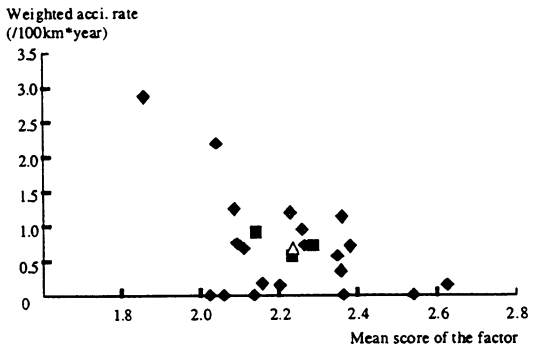
To represent the effect of attitudinal factors on operational safety quantitatively, each branch is mapped Figure 2 on the geometric plane of motivation (2a) and trust in mother company's management (2b) and the weighted total accident rate. As can be seen from this figure, both factors are negatively correlated with the accident / incident rate. The correlation coefficient between the latter factor and the weighted total accident rate is –0.485 ($p<0.05$).

Regarding the former factor, i.e., motivation, its coefficient is –0.307, and this does not mean a significant correlation. There is an exceptional branch which produced the highest accident rate despite the highest motivation of operators. This branch produced a "big" accident three years ago, and since then management of this branch has been intensively tackling safety activities, including improved communication channel and emergency training programme. One of the units working for this branch adopted a competence oriented income system that is very unusual in track maintenance operational units although it is supported by most of unit operators as mentioned previously. That is the reason why the operators working for this branch has higher motivation at the present day. In addition, this branch won the best branch award of so-called hazard preventive training last year , i.e., 2000.

Besides this branch, in Figure 2(a), there are three branches producing no accident or very few accident but exhibiting relatively lower motivation. All these branches were located in urban areas and managers of the track



(a) Correlation with motivation



(b) Correlation with trust in mother company's management

Figure 2 Effects of attitudinal factors on accident/incident rates for all the branches and companies

maintenance section in the bullet train company expressed (independently of the present analysis) their suspicion that these three branches might have produced some "small" incidents which branch management had not reported to the bullet train company. Thus, removing these braches from analysing data, we obtain a significant correlation between motivation and the weighted total accident rate (r=–0.545; $p<0.05$).

To identify effective questions that can explain higher accident/incident data, we also applied the correlation analysis between each question in the questionnaire and the weighted total accident rate. As a result, we obtained a single question having a significant correlation with the weighted total accident rate (r=–0.486; $p<0.05$): "Operators should not question their mother company's and the bullet company's decision". In addition to this item, excluding several exceptional branches (three or four branches), three questions connecting to trust in mother company's management were identified as the ones having significant correlations with the one-dimensional accident/incident rate: "I am satisfied with my salary and income from my company" (r=–0.791; $p<0.01$), "The mother company and the bullet train company have a good understanding of operators" (r=–0.680; $p<0.01$) and "A standard to decide an individual

operator's income is appropriate" (r=–0.613; p<0.01).

Investigating effects of the "unit culture" mentioned in the last section on the operational safety, a rough, qualitative correlation can be found between the type of "unit culture" and the accident rate. The weighted total accident rates of the branches having a single unit – which did not appear in Table 5 – are relatively low: 0.00, 0.00, 0.67, 0.35, 0.70, 0.13, 0.57, 0.00, 0.14, 0.00 and 0.00. This may suggest that operations performed by teamwork within a single unit could be avoided from accident risks. Those of branches having "homogeneous" units are relatively high: 1.13, 2.18, 1.25, 1.19, and 0.76. In contrast, some branches whose daughter units are "heterogeneous" type "produced no or very few accidents: 0.00 and 0.00, and the others of this type produced more accidents: 0.95, 0.73, and 2.86. However, we did not find dependency of these two groups of the accident rate in the "heterogeneous" type with the levels of operators' motivation and trust in mother company's management.

CONCLUSION

This paper reported the results from a questionnaire-based survey and analysis of the accident/incident statistics in track maintenance operations. The purpose of this investigation was to examine whether risk factors of accidents and operators' attitudinal factors uncovered in the former study (Itoh et al., 2000) can be extended to a different type of job. we also aimed at finding the essence of safety culture in the hierarchically structured track maintenance organisations.

First, we extracted a set of attitudinal factors similar to the one obtained by night train operators' responses by principal component analysis (confer Itoh and Andersen, 1999, and Itoh et al., 2000), but slightly different due to, we hypothesise, the hierarchical structure of the organisations and due to the new questionnaire items that focus on operators' skills and their relation to a licensing system. Then, the correlation analyses were performed between the levels of the attitudinal factors and the accident/incident rates. From these analyses, we derived results similar to those of the former study (Itoh et al., 2000) and it was shown that operators' motivation and trust in the management of their mother company are key factors for operational safety.

In analysis of the safety culture of track maintenance organisations, a level-by-level approach was applied and differences were identified between the subsidiary companies as well as in the local culture between their branches. Two types of "unit" culture were identified: a "homogenous" type that is similar among daughter units within a branch having strong dependency on the "branch culture" and a "heterogeneous" type having its own culture with one-way effects among the attitudinal factors. These types of "unit culture" were found to have an association with the accident/incident rate in track maintenance operations.

Finally, we would like to hypothesise that a management strategy which explicitly and effectively seeks to link competence with professional ranking (degree of license) and remuneration and working conditions would engender a greater satisfaction on the items that have a correlation with safety. Thus, such a hypothetical management strategy is partly supported by the following results: Most operators had sufficient motivation to obtain a higher license as well as to develop their own skills and competence. In addition, almost all the operators employed by unit companies desired to change an employment system which formally and in practice would link competence with remuneration and professional rank.

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