Lecture W11

Application of Psychological factors to specific behavioural safety programs

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The core aim of this presentation is to determine the reliability and validity of the Safety Culture Survey Qestionnaire SCS-Q. SCS-Q is used to measure employee assessments of organisational factors, safety attitudes and risk behaviour. Dyno Nobel initiated the study because the company intends to include employee evaluations of safety, health and environment into their SHE-management systems.

Performance in these areas is regularly measured in all the plants belonging to the Company. The study is a part of Dyno Nobel's continuous systematic and structured safety, health and environment activity. Two questionnaires have been tested. Both of them measure the same main elements and sub-elements or dimensions.

SCS-Q is based on the multi-indicator perspective, which means that several questions or indicators measure employee assessments on each of the SCS-Q dimensions. For example, it may be ideal to include several questions to examine the respondents' attitude towards on-the job rule violations. The multi-indicator perspective makes it possible to fulfil two main demands of a measurement instrument, which is reliability and validity.

Reliability is internal consistency in subjective assessments. If safety measures have not been implemented during the time interval between a first and a second data collection the respondents' assessments should be identical when we ask the same persons identical questions on two occasions. Reliability can also be obtained by asking the same respondents similar questions, i.e. questions that measure the same underlying sub-element or index at the same point of time. It is the last-mention method that is applied in the present study.

The more questions or indicators which are included into each index, the more reliable is the index. Several questions about the same sub-element reduce the effect of misunderstanding of questions etc. Furthermore, asking several questions intended to measure the same sub-element also increase the validity of the measurement. The multi-indicator perspective increases the capability to measure several parts of the respondents' true assessments.

Validity is whether we measure what we intend to measure. *Criterion-related validity* is estimated by analysing whether or not a measurement instrument "behaves" as hypothesised. Made simple this implies that if an index measures what it intend to measure, it should also be related to other factors which theoretically should be associated with it. In the present study there are three criterion variables: *Risk Behaviour*, *Safety Status*, and *Accidents*. It is hypothesised that the more risky the single respondent's behaviour is, the more accident and near accident have he or she experienced personally, i.e. *Risk Behaviour* also enhance the risk of experiencing such an event. In addition, the study also expects to find a positive relationship between a bad *Safety Status* and *Accidents*. *Safety Status* include such elements as employee satisfaction with their own influence and communication with management, status of *Personal protection equipment*, status of *Rules and instructions*, and other people's *Safety involvement.* The status may have a direct influence on the number of injuries which does not depend on employee individual on-the-job *Risk Behaviour*. However, the extent to which the employees carry out risky behaviours may influence their evaluation of *Safety Status*, i.e. the extent to which they use *Personal protection equipment*, how well they communicate with the management and their colleagues about safety etc. The theoretical and empirical basis for this hypothesis is that there is a relationship between safety motivation and safety knowledge one the one hand, and risk behaviour and accident involvement on the other hand. Safety knowledge is the extent to which employees seek knowledge about safe working (Probst and Brubaker, 2001). Probst and Brubaker showed that safety motivation and as safety knowledge predicted accidents and near-accidents.

Further tests of criterion-related validity also include the following hypotheses. A positive relationship between *Attitude towards Accident Causation* and *Risk Behaviour* is expected. *Belief in accident prevention* as well as fatalism related to this, is hypothesised to be associated with *Risk Behaviour*. If people e.g. believe it is impossible to avoid accidents and that their own behaviour is unimportant or insignificant in accident causation, it is reasonable to expect this also to contribute to more risky on-the-job behaviour. Social cognition models, i.e. Theory of Reasoned Action (Ajzen and Fishbein, 1980) as well as Theory of Planned Behaviour (Ajzen, 1991) provides the theoretical basis for this hypothesis.

We also hypothesise that there is a positive relationship between Employee *Risk Judgements* and *Risk Behaviour*, i.e. the greater employees perceive the risk, the more risky are their behaviours. However, several hypotheses have been set forth about the association between risk perception and behaviour. It is often assumed that accidents happen because there is something "wrong" with individuals' perception of risk. "Misjudgement" of risk may cause inappropriate decisions as well as unsafe behaviour and "human error". Accordingly, several studies have been aimed at classifying such errors (Mashour, 1974; Miller & Swain, 1987; Rasmussen, 1981; Reason, 1994; Swain & Guttman, 1983; Taylor & Lucas, 1991). If the "real" risk is "misperceived" it should be corrected (Marek et al, 1985) and if the demands placed on the individual exceed some assumed "limits" in human "information processing capacity" (e.g. Shiffrin et al., 1973, Broadbent, 1958, Treisman & Geffen, 1967) the factors causing the problems should be removed. Therefore, to avoid accidents tasks have to be fitted to "human limitations" and taken care of in the design phase, e.g. of an industrial plant. Accordingly, information-processing approaches have frequently been included into models of accident causation (e.g. Mackay & Whittington, 1983; Saari, 1984; Hale & Glendon, 1987). However, is it true that perception of risk affects behaviour? Can misjudgements and human error be the core causal factor of accidents? The second hypothesis on the relation between perceived risk and behaviour is that the affective reactions may be seen as reactions to stress, i.e. a strain factor, which may reduce a person's ability to cope with risk and therefore cause enhanced *Risk Behaviour* (Glendon & McKenna, 1995: 203-242). "Stress" at work may cause "strain" and affect the capacity to cope. In addition, employees may know when he or she is exposed to a risk source, judge the probability of experiencing an accident to be enhanced, and hence he or she feels unsafe and worried. Consequently the risk causes affective reactions and strain (Ulleberg & Rundmo, 1997), which may enhance risk taking behaviour and the probability of experiencing accidents and near misses (Rundmo, 1992). When an employee is exposed to a risk source, an accident may happen because the perceived risk corresponds to the "real" risk. Consequently, to inform employees about "real" risk may enhance the probability of accidents. If so, we would expect a positive correlation between perception and behaviour.

Risk perception contains a rational as well as an affective component (Rundmo and Sjöberg, 1998). The rational component consists of the respondents' probability assessment and the emotional component of the extent to which they are worried and concerned when thinking on the risks. In SCS-Q the rational judgements and the affective reactions are split and different measures are aimed at determining both the components. Individual perceptions and judgements are hypothesised to be the prime "causal" factors for behaviour.

For SCS-Q to "behave" as expected to be valid, we would also expect to find a direct relationship between Organisational Factors and *Safety Status* in addition to the indirect relation via *Risk Judgements* and Accident Causation. A direct relationship between Organisational Factors and *Risk Behaviour* is also hypothesised. A heuristic work model for these associations is shown in Figure 1.

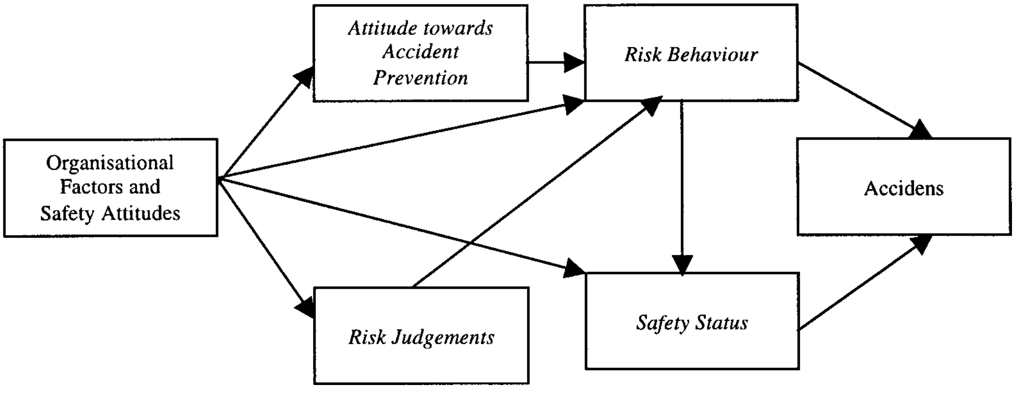


Figure 1: Heuristic working model for testing criterion validity

A final demand related to validity is that the questionnaire fulfils the demand for *discriminant validity*. In order to provide for such validity, respondents were asked about their own injury experience, and their job position. The study was carried out amongst employees at 18 different plants and the number of accidents varied according to which plant the respondents belonged. Therefore, for the SCS-Q to show satisfactory discriminant validity it should be possible to find significant plant differences in the employees' evaluations on the majority of the indices.

SAMPLE

A total of 18 plants participated in the main study and about 1250 respondents replied to the questionnaire. The plants were located in Norway, USA and Australia and covered varying producing divisions in Dyno Nobel.

A sample of employees at all the plants was asked to fill in the questionnaire. The total number of employees in each plant varied and the number of respondents at each plant varied accordingly. The lowest number of respondents at a single plant was 8 and the largest 210. The questionnaire was distributed, filled in and collected at the place of work. The response rate was near up to 100 per cent. A very few refrained from participation.

A total of 83 percent of the respondents were male, 78 per cent of the respondents were operators and 21 per cent supervisors.

QUESTIONNAIRE

The content of the questionnaire was divided into the following sections or main elements:

1) Element I: *Organisational Factors and Safety Attitudes*. The respondents were asked to rate on a five-point evaluation scale to which extent they agreed or disagreed with statements intended to measure different sub-elements of the safety climate.
2) Element II: *Attitude towards Accident Causation*. The respondents were asked to indicate whether they agreed or disagreed with different explanations as to why accidents take place. A five-point scale was also used for this assessment.
3) Element III: *Risk Behaviour*, i.e. the extent to which personnel ignore safety regulations in order to get a job done, carry out activities which are forbidden, perform their job duties correctly etc. The respondents were asked to rate whether they *very often, often, sometimes, seldom*, or *never* carried out these actions in their jobs. *Risk Behaviour* has to be distinguished from *risk-taking behaviour* (Zuckerman, 1979). Risk-taking behaviour refers to whether people like to take risks and are sensation seekers, i.e. a personality variable. The present measurement, which is an extended version of a measurement first applied by Rundmo (1994), is only intended to measure whether or not personnel take chances during work. A similar measurement was also used to measure traffic behaviour (Rundmo, 1991, 2001).
4) Element IV: Satisfaction with *Safety Status*. The subjects rated how satisfied they were with various safety measures. For this element a five-point rating scale was applied. The scale ranged from *very satisfied* to *very dissatisfied*. In addition, the respondents were asked how satisfied they were with their management, current supervisors, safety representatives and colleagues.
5) Element V: *Risk Judgements*, i.e. the employees' perception of risk. We measured probability assessments (rational judgements) as well as worry, concern and insecurity (affective reactions to risk). A seven-point bipolar scale was applied. It ranged from very probable to not at all probable, very unsafe to very safe, very worried to not at all worried, and very concerned to not at all concerned.
6) Element VI: *Environmental Issues*; which measured employee assessments of Dyno Nobel's perceived environmental profile and the respondents' *Environmental fatalism*.

All the statements are shown in the results' section below. In addition, the respondents were asked about their gender, whether they themselves ever had experienced an occupational accident where medical attention was needed and whether they *ever have had* an accident in their work and/ or a near accident during the *last month*. In addition, they were asked about their position in the company[1] .

RESULTS

Reliability of the questionnaires

Table 1 shows the reliability of the indices of SCS-Q separately for the A-version (A-Q) and the B-version (B-Q) of the questionnaire. The number of test items in each of the fifteen indices are shown in the second column (for A-Q) and in the fifth column (B-Q).

Table 1. Scale reliabilities and corrected total inter-item correlation coefficients for each of the SCS-Q dimensions

SCS-Q dimensions	A-Q[1] Number of items	A-Q[1] α	A-Q[1] Corrected total inter-item correlation	B-Q[2] Number of items	B-Q[2] α	B-Q[2] Corrected total inter-item correlation
1. Acceptability of rule violations	3	.781	.62	3	.822	.67
2. Priority of safety versus production goals	4	.730	.52	3	.517	.32
3. Employee safety support	2	.813	.68	2		
4. Management safety support	2	.600	.42	2	.726	.57
5. Fatalism accident prevention	4	.648	.42	4		
6. Belief in accident prevention	2			2		
7. Risk Behaviour	7	.876	.65	6	.856	.65
8. Employee influence and communication with management	3	.837	.69	2	.824	.70
9. Personal protection equipment	3	.688	.49	2	.878	.78
10. Rules and instructions	4	.759	.56	4	.824	.67
11. Satisfaction with other people	4	.811	.62	4	.780	.60
12. Rational element of risk perception	2	.691	52	2	.723	.56
13 Affective element of risk perception	2	.650	.48	2	.880	.81
14. Company environmental profile	2	.652	.48	2	.815	.66
15. Environmental fatalism	2			3	.528	.34

[1] = A-version of the questionnaire, [2] = B-version of the questionnaire

As shown in Table 1 a is above 0.70 for the majority of the indices in both the questionnaires, indicating a satisfactory internal consistency (Nunally, 1978). The number of items is quite low for the majority of the indices and a is sensitive to the number of items. In addition, inter-item correlation coefficients (Pearson's r) were calculated for each of the indicators belonging to each of the indices. Thereafter, the total inter-item correlation for each of the indices was calculated. As shown in column four and seven (Table 1) they were all above 0.30, also indicating a satisfactory reliability of the indices in both the versions of the questionnaire. Consequently, the respondents could be compared on identical indices, intending to measure the same, however, with different questions. Thus, it was also possible to compare the respondents' assessments on the same set of indices and main element despite the fact that they answered different questions.

In addition, the total alphas for all the indicators making up each of the six main elements were calculated separately for A-Q and B-Q. For A-Q the alphas were as follows: 0.747 for *Organisational Factors and Safety Attitudes*, 0.694 for *Attitude towards Accident Causation*, 0.865 for satisfaction with *Safety Status*, 0.673 for *Risk Judgements*, and 0.561 for *Environmental Issues*. For B-Q the comparable figures were 0.832 for *Organisational Factors and Safety Attitudes*, 0.604 for *Attitude towards Accident Causation*, 0.864 for satisfaction with *Safety Status*, 0.604 for *Risk Judgements*, and 0.781 for *Environmental Issues*. To avoid the reliability to become unacceptably low in A-Q the indicator "accidents are unavoidable due to the shop floor employees" had to be removed before calculating the reliability coefficient for the second element, *Attitude towards Accident Causation*. Likewise, in B-Q, the indicator "there is little one can do to reduce the pollution from this plant further", should be removed from the sixth main element *Environmental Issues*. The number of responses related to *Attitude towards Accident Causation* was too few to examine the reliability on this element in the B-Q.

DISCRIMINANT VALIDITY

The correlation matrix in Table 2 shows that the coefficients are low enough to provide support for the argument that the fifteen SCS-Q dimensions all measures unique constructs. However, the dimension satisfaction with *Rules and instructions* was significantly related to two of the other dimensions or variables of satisfaction with *Safety Status*. The two dimensions were Employee influence and communication with the management, $r = 0.61$, and *Personal protection equipment*, $r = 0.68$. The correlation coefficient were also a bit higher than ideal between *Acceptability of rule violations* and *Priority of safety versus production goals*, 0.56.

Additional exploratory factor analysis of the indicators of *Organisational Factors and Safety Attitudes* amongst the respondents who replied on the A-version of the questionnaire (n=211), confirmed, however, that the four-factor solution and explained 69 per cent of the variance. The comparable figure for the main element Satisfaction with *Safety Status* was 65 per cent of the variance for this same sub-sample. This sub-sample was made up of respondents from three of the plants. The other respondents replied to the B-version (n=32). The percentage of explained variance for the items making up the elements *Organisational Factors and Safety Attitudes* and Satisfaction with *Safety Status* were 73 and 83 per cent, respectively. In the last analysis of *Safety Status* four dimensions emerged. This was due to the fact that indicators of *Satisfaction with other people* were included into the B-version, however, not in the A-version of the questionnaire.

To be valid we expected the plants to differ significantly on the great majority of the fifteen indices of SCS-Q. Consequently, the next step was to examine plant differences in SCS-Q measures as well as accidents and near accidents. As shown in Table 3 the plant differences were significant on all the measures except the following two: Dimension 4 of Satisfaction with *Safety Status*, which was *Satisfaction with other people*, $p > 0,05$, and dimension 2 of *Attitude towards Accident Causation*, i.e. *Belief in accident prevention*, $p > 0.05$. For the great majority of the indices the plant differences were highly significant, $p < 0.001$. This was the case for the following: *Acceptability of rule violations*, *Priority of safety versus production goals*, Employee as well as *Management safety support*, *Risk Behaviour*, *Employee influence and communication with the management*, *Personal protection equipment*, *Company environmental profile*, and *Environmental fatalism.*

Table 2. Inter-correlation coefficients of the SCS-Q dimensions

SCS-Q dimensions	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Acceptability of rule violations														
Priority of safety vs. production goals	.56													
Employee safety support	.03	-.01												
Mng.ment safety support	.00	.08	.42											
Fatalism accident prevention	.36	.23	.10	.07										
Belief in accident prevention	-.05	-.02	-.03	-.05	-.38									
Risk behaviour	.57	.39	.29	.14	.26	-.05								
Employee influence and communication with management	.37	.45	.07	.24	.12	-.05	.44							
Personal protection equipment	.23	.29	.12	.11	.07	-.02	.34	.48						
Rules and instructions	.32	.39	.07	.16	.12	-.01	.39	.61	.69					
Satisfaction with other people	-.10	-.04	.12	.06	-.04	-.15	.08	.37	.24	.19				
Rational element of risk perception	.25	.23	-.05	.01	.04	-.03	.19	.26	.20	.26	.25			
Affective element of risk perception	.19	.17	.10	.10	.02	.04	.20	.26	.21	.22	.14	.35		
Company evironmental profile	.09	.10	.27	.27	.02	.10	.18	.24	.09	.22	.28	.08	.09	
Environmental fatalism	.16	.17	.12	.12	.16	.13	.24	.31	.30	.29	.15	.04	.02	05

For two of the indices, the affective element of *Risk Judgements* and Satisfaction with *Rules and instructions*, the plant differences were significant at the 0.01 – level. The differences were significant at the 0.05 – level for the dimensions *Fatalism related to accident prevention* and *the Rational component* of *Risk Judgements*.

Table 3. Descriptive statistics and plant differences – dimensions of SCS-Q

SCS-Q dimensions	Max. score	Mean	Standard deviation	F-value plant differences
1. Acceptability of rule violations	12	7.88	3.14	3.80***
2. Priority of safety vs production goals	16	7.00	3.48	13.42***
3. Employee safety support	8	7.21	1.34	5.28***
4. Management safety support	8	5.87	1.92	10.64***
5. Fatalism accident prevention	|6	10.84	3.17	2.50*
6. Belief in accident prevention	8	4.50	1.37	2.26
7. Risk Behaviour	28	21.51	4.73	5.49***
8. Employee influence and communication with management	12	6.85	2.89	5.62***
9. Personal protection equipment	12	7.79	2.21	14.05***
10. Rules and instructions	16	9.68	3.02	8.68**
11. Satisfaction with other people	16	11.29	2.90	0.67
12. Rational element of risk perception	12	6.13	3.08	3.04*
13 Affective element of risk perception	12	8.43	2.87	3.90**
14. Company environmental profile	12	5.94	1.68	16.07***
15. Environmental fatalism	12	3.35	2.18	43.51***

* = p < .05, ** = p < .01, *** = p < .001

CRITERION-RELATED VALIDITY

The SCS-Q indices are interesting only if they are related to accidents and near accidents and, accordingly, we would expect them to predict these consequences. T-tests showed that there were significant differences on ten of the fifteen indices in the respondents' assessments depending on whether they had been victimised themselves or not, $p < 0.05$. The mean score was higher on all the indices in the group of non-injured compared to injured respondents. However, when a person has experienced an accident and an injury himself or herself, this will also most probably affect attitudes as well as behaviour. Therefore, to be able to validate the measure, we would need prospective data on injury experience. To examine criterion validity we would need a pre- and post-designed study. However, there may be plant differences in the number of observed accidents.

Table 4. Plant differences in accidents and near accidents

Plant	Accidents		Near accidents		Total SCS-Q score
	Fobs	Fexp	Fobs	Fexp	
1 (n=72)	7	34	2	23	70
2 (n=210)	137	102	90	67	65
3 (n=46)	17	22	14	14	67
4 (n=19)	7	9	3	5	64
5 (n=8)	2	2	0	0	73
	$\chi 2=69.87$, $p < .001$		$\chi 2=38.86$, $p < .001$		

Table 4 shows the observed and expected number of accidents as well as the total SCS-Q scores for each of five of the plants. This analysis included only the five first plants that took part in the study. In three of the plants the expected number of accidents and near accidents was fewer than expected by statistical interference. This was true for plant 1, 3 and 4. However, in plant 3 the number of near accidents is equal to the expectancy value. In plant 2 the number of observed accidents as well as near accidents was higher than the expectancy value. The $\chi 2$-tests show that the differences were significant for accidents as well as near accidents, $p < 0.001$.

The Table also shows a tendency that the greater the number of observed accidents and near accidents compared to the expected number, the higher the SCS-Q-score. In plant 3, 4 and 5 there were no clear differences between observed and expected values when accident as well as near accidents were taken into consideration. The mean SCS-Q-score for these three plants were 68. It was also a greater number of observed accidents among operators compared to supervisors, $\chi 2 = 6.65$, $p < .01$. Comparable figures for near accidents were, $\chi 2 = 5.87$, $p < .05$.

To sum up, it was significant differences in the respondents' assessments on the majority of the indices of SCS-Q due to the respondent's position, and his or her injury experience. Consequently, additional discriminant and criterion-related validity evidence could be found if there are significant overall differences in the assessments between plants.

The results presented in this Table give rough estimates. Often, accident data lacks stability and statistical power. This is due to their infrequency and reliability of state accident records (Ranney, 1994). Studies have also shown that 14 per cent of people involved in injury-provoking road accidents ddi not remember the event a year later (Lofthus, 1993), and about 30 per cent of accidents are forgotten each year (Maycock, Lester and Lockwood, 1996). Near accidents are generally forgotten extremely rapidly, and studies show that 80 per cent of incidents are no longer reported after a delay up to two weeks (Chapman and Underwood, 2000). Therefore, in the present study, *Risk Behaviour* is used as a criterion variable. However, to be valid *Risk Behaviour* should predict accidents an near misses.

Table 5 shows the results of a multivariate analysis of variance (MANOVA). In the analysis the fifteen dimensions of SCS-Q were used as criterion variables and plant as a factor. Accidents and near accidents served as covariates. This was due to the fact that the $\chi 2$-tests presented in Table 4 showed that there were significant differences between the observed and expected number of accidents and near accidents when the five first plants were compared. The Table shows that there were significant differences between the plants in the overall test for all the dimensions or variables entered as criteria in the analysis. These results are shown in the bottom of the Table. The overall main effect of plant is highly significant, Wilks' +l =0.30, d.f. (4,307), $p < 0.001$. The size effect was 0.258, which means that about 26 per cent of the variation of all the SCS-Q measures may be explained by the plant variances. The covariates had a much weaker effect. To examine further the interactions between the factor and the covariates, additional multivariate tests were carried out. No significant interaction effects were found, $p > 0.05$. This was the result for all the interactions.

The results of the univariate ANOVA analyses are also shown in Table 5. The relevant F-tests as well as ETA^2-tests are reported. We found significant main effects of plant for three of the dimensions measuring *Organisational Factors and Safety Attitudes*. The dimensions were *Priority of safety versus production goals*, F (3.308) = 11.35, $p < 0.001$, *Employee safety support*, F (3,308) = 6.11, $p < 0.001$, and *Management safety support*, F (3,308) = 8.76, $p < 0.001$. For the other measures, plant showed significant effects on the following: *Attitude towards Accident Causation*, F (3,308) = 3.16, $p < 0.05$, Self-reported *Risk Behaviour*, F (3,308) = 4.97, $p < 0.001$, Employee satisfaction with their influence and communication with the management, F (3,308) = 5.35, $p < 0.001$, Satisfaction with status of *Personal protection equipment*, F(3,308) = 10.06, $p < 0.001$, Satisfaction with status of *Rules and instructions* relating to safety and health, F(3,308) = 5.85, $p < 0.001$, *Company environmental profile*, F(3,308) = 9.75, $p < 0.001$, and *Environmental fatalism*, F(3,308) = 36.47, $p < 0.001$.

Measured by the ETA^2 statistics, plant explained about 13 per cent of the variance in *Priority of safety versus production goals*, 8 per cent of *Employee safety support*, 10 per cent of *Management safety support*. For *Attitude towards Accident Causation* and self-reported *Risk Behaviour* the identical figures were respectively 4 and 6 per cent. The corresponding figures for Employee satisfaction with their influence and communication with the management was 7 per cent, 12 per cent for Satisfaction with status of *Personal protection equipment*, 7 per cent for Satisfaction with status of *Rules and instructions* relating to safety and health, 11 per cent for *Company environmental profile*, and 32 per cent for *Environmental fatalism*. It should be noted that these effects were computed after the variation explained by the covariates had been removed.

Table 5. Multivariate analysis (MANOVA) of the SCS-Q scales by plant with accidents, near accidents and position as covariates

SCS-Q dimensions	F(4,323)	p-value	Eta^2	Means				
				1	2	3	4	5
1. Acceptability of rule violations	1.21	.304	.016	9.09	7.36	7.94	6.93	9.33
2. Priority of safety vs production goals	11.35	.000	.131	9.70	6.10	6.41	6.06	10.00
3. Employee safety support	6.11	.000	.075	6.66	7.51	7.16	6.80	6.66
4. Management safety support	8.76	.000	.104	4.83	6.30	5.91	4.53	7.00
5. Fatalism accident prevention	1.88	.113	.024	11.67	10.72	9.86	10.66	13.33
6. Belief in accident prevention	3.16	.014	.040	4.76	4.13	4.91	4.93	4.00
7. Risk Behaviour	4.97	.001	.062	22.10	21.47	22.61	16.93	20.66
8. Employee influence and communication with management	5.35	.000	0.66	7.55	6.85	7.50	3.86	5.33
9. Personal protection equipment	10.06	.000	.118	7.87	7.71	9.08	5.06	6.66
10. Rules and instructions	5.85	.000	.072	10.23	9.39	11.00	6.66	9.00
12. Rational element of risk perception	1.38	.241	.018	6.92	5.60	6.47	7.26	7.33
13 Affective element of risk perception	0.56	.686	.007	9.38	8.08	8.80	8.60	10.00
14. Company environmental profile	9.76	.000	.115	6.06	6.15	5.61	6.60	9.33
15. Environmental fatalism	36.47	.000	.326	2.75	2.89	3.52	8.20	5.66

* = $p < +.05$; *** = $p < 0.001$

Multivariate tests: Main effect of plant on SCS-Q measures of *Organisational Factors and Safety Attitudes*: Wilks'l =0.30, d.f. (4,307), $p < .001$, $ETA^2 = .258$ (Wilks).

Table 6: Plant differences in SCS-Q evaluations

SCS-Q dimensions	Plant comparisons									
	1-2	1-3	1-4	1-5	2-3	2-4	2-5	3-4	3-5	4-5
Acceptability of rule violations	1.71	1.06	2.14	-0.24	-0.64	0.43	-1.95	1.08	-2.38	2.38
Priority of safety vs production goals	3.55	3.18	3.65	-0.29	-0.37	0.09	-3.47	0.46	-3.47	3.94
Employee safety support	0.85	0.56	0.17	0.05	-0.29	-0.68	-0.85	-0.39	-0.55	-0.17
Management safety support	1.44	0.94	0.11	2.16	0.49	-1.33	0.72	-0.83	1.22	-2.05
Fatalism accident prevention	0.99	1.77	1.12	-1.65	0.78	0.12	-2.64	-0.65	-3.43	2.77
Belief in accident prevention	0.43	0.08	0.04	0.76	-0.51	-0.38	0.33	0.12	0.33	-0.72
Risk Behaviour	0.63	-0.66	4.71	1.44	-1.29	4.08	1.44	5.38	2.10	-3.27
Employee influence and communication with management	0.70	0.10	3.49	2.22	-0.60	2.78	1.51	3.39	-1.27	1.27
Personal protection equipment	0.17	1.22	2.59	1.21	1.39	2.42	1.03	3.82	2.43	-1.38
Rules and instructions	0.83	-0.74	3.39	1.23	1.61	2.52	0.35	4.14	1.97	-2.16
Rational element of risk perception	1.27	0.37	-0.29	-0.41	-0.89	-1.56	-1.68	-0.67	-0.78	0.11
Affective element of risk perception	1.29	0.48	0.71	-0.61	-0.81	-0.57	-1.91	0.23	-1.10	1.33
Company environmental profile	-1.11	-0.58	-1.32	-4.27	0.52	-0.21	-3.16	0.73	-3.68	-2.99
Environmental fatalism	-0.16	-0.87	-5.24	-2.91	-0.70	-5.08	-2.91	-4.37	-2.04	2.33

Tykey's HSD was used to examine between which of the plants there were significant differences (Table 6). The Table shows the mean differences between the plants on each of the fifteen indices. Group differences with an overall level of significance of 0.05 are underlined in the Table. It should be noticed that the number of respondents in the last two plants was small

Table 7. Associations between ***Attitude towards Accident Causation, Risk Judgements,*** *and* ***Risk Behaviour***

Predictor variables	β-value	r	t-value	Raw contribution	Unique contribution
Fatalism accident prevention	.28	.26	5.07***	7%	7%
Belief in accident prevention	-.06	-.05	0.92	0.25%	0.4%
Rational element of risk perception	.14	.19	2.47*	4%	2%
Affective element of risk perception	.14	.20	2.47	4%	2%

Adj. R^2 = 0.114, * = p < 0.05, *** = p < 0.001. Dependent variable: *Risk Behaviour*

It was hypothesised that *Attitude towards Accident Prevention* and employee risk judgement should be associated with self-reported *Risk Behaviour*. Thus, *Risk Behaviour* is the criterion variable in Table 7. Arguably, employees who take chances and violate safety rules should also report a fatalistic *Attitude towards Accident Causation*. Furthermore, employees are expected to know the risks they are exposed to well enough to avoid accident and take the necessary prevention measures. Therefore, it was hypothesised that there should be a positive correlation between self-reported *Risk Behaviour* and *Risk Judgements*. This is also in accordance with results of other studies (Rundmo, 1996, 2001). The results showed that *Risk Behaviour* was significantly predicted by fatalistic attitudes as well as perceived risk. *Fatalism related to accident prevention* was the most significant predictor, b = 0.28. The more fatalistic the attitude was the more risky behaviour. *Risk Behaviour* was also significantly associated with the variables measuring the employees' rational, b+= 0.19, as well as affective *Risk Judgements*, b+= 0.20. The results show that the more risky the work conditions were considered to be, the more often the respondents took chances and broke safety rules during work conduction. The four predictors explained about 11 per cent of the variance in the dependent variable. Table 7 also shows the raw as well as the unique contributions of each of the predictor variables on *Risk Behaviour*. The unique contribution uncovers the core contribution of each of the predictors and the raw contribution is r^2 x 100%. The two percentages together give on the intuitive level a good idea of the relative relevance of each factor (see Kerlinger and Pedhazur, 1973).

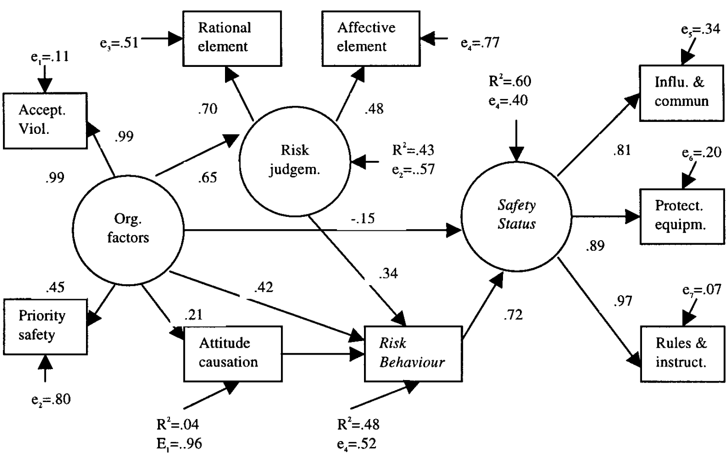
In the present study employee core *Attitude towards Accident Causation* and *Risk Judgements* were hypothesised to be associated directly with *Risk Behaviour*. *Organisational Factors and Safety Attitudes* were considered to exert an influence on these individual assessments. However, all these factors may also have a direct "effect" on *Risk Behaviour* and, consequently, all the three elements were entered in a hierarchical regression analysis (see Table 8). As can be seen in the Table, each of the single indicators in the first block had an insignificant influence. However, the two variables gave a significant contribution to explained variance in *Risk Behaviour* as a block, F change = 13.08, p < 0.001. The two other blocks contributed significantly to the change in R^2. The F change values were 9.83, p < 0.001, and 44.74, p < 0.01 for Organisational factors and *Safety Status*, respectively. In total the three blocks explained about 43 per cent of the variance in *Risk Behaviour*. The most significant predictors were *Acceptability of rule violations*, b = 0.51, and *Employee safety support*, b = 0.24. In an additional analysis *Safety Status* was also entered as a forth block, however, the R^2 increased with less than 1 per cent, indicating that *Safety Status* is not a predictor of *Risk Behaviour*.

In conclusion, the most important determinants for *Risk Behaviour* seems to be the attitude that it is acceptable to break rules and take changes when carrying out the work tasks and *Employee safety support*. However, all the three blocks contributed significantly to explaining variance in *Risk Behaviour*.

Table 8. Associations between ***Attitude towards Accident Causation, Risk Judgements,*** *Organisational Factors,* ***Safety Status*** *and* ***Risk Behaviour***

Predictor variables	**β-value**	**t-value**	**F Change**
Block I:			13.08***
Fatalism accident prevention	.03	0.67	
Belief in accident prevention	-.004	-0.09	
Block II:		9.83***	
Rational element of risk perception	.05	0.98	
Affective element of risk perception	.07	1.48	
Block III:		44.74**	
Acceptability of rule violations	.51	9.44***	
Priority of safety versus production goals	.06	1.19	
Employee safety support	-.24	-5.24***	
Management safety support	-.04	-0.04	

Adj. R^2 = 0.43, *** = p < 0.001. Dependent variable: *Risk Behaviour*



RMSEA = 0.029, GFI = 0..92, AGFI = 0.87, CFI = .0.99, NNFI = 0.99, $\chi 2$ (d.f. = 36) = 273.19

Figure 2. *Predictors of* ***Safety Status*** *- results of Structural Equation Modelling*

Figure 2 is a path model showing how *Organisational Factors and Safety Attitudes*, *Attitude towards Accident Causation*, or more specifically, *Fatalism related to accident prevention*, *Risk Behaviour* and *Risk Judgements* were associated to *Safety Status*. The hypothesised model showed a moderate fit to the data, RMSEA = 0.0 029, GFI = 0.92, AGFI = 0.87, CFI = .0.99, NNFI = 0.99, c2 (d.f. = 36) = 273.19. It was not considered necessary to carry out further modification of the model.

The results can be summarised as follows: *Risk Behaviour* was the most significant predictor of *Safety Status*, b = 0.72. *Organisational Factors and Safety Attitudes* seemed primarily to be indirectly related to *Safety Status* because it was closely associated with *Risk Behaviour*, b+= 0.42. However, the direct effect, b = 0.15 also had significant influence. The element entitled *Organisational Factors* was also closely related to the employees' *Risk Judgements*, b+= 0.65. However, these judgements seemed not related to *Safety Status*. The direct relationship between *Risk Judgements* and *Safety Status* was also examined. The D c2 for this model was -0.02, which is not an improvement. *Risk Judgements* did not contribute to an increased percentage of explained variance in the criterion variable, $R^2 = 0.60$.

CONCLUSION

The aim of the present study was to develop measures to determine employee assessments of some aspects of the safety culture. Based on the analyses it is argued that several conclusions can be drawn about the psychometric qualities of the scales. First, it is concluded that the reliability of all the indices included in the questionnaire was satisfactory. All the fifteen indices appeared to be unique from each other and consequently, they measure unique constructs.

Second, employee assessments of organisational factors, risk and attitudes were associated with safety status as well as risk behaviour. Risk behaviour and safety status were both used as criterion variables and the criterion validity of the other indices was tested and found to be good. Direct as well as indirect effects of the predictor variables were tested. The predictors were *Organisational Factors and Safety Attitudes, Attitude towards Accident Causation, and Employee Risk Judgements*. In total we were able to explain about 40 percent of the variance of the criterion variables.

Third, there were significant plant differences in the respondents' evaluations on the great majority of the indices. The number of accidents also varied significantly between the plants. Thus, the discriminant validity of the questionnaire was judged to be satisfactory.

The questionnaire was split into two questionnaires which measure comparable dimensions while applying different questions. The predictor variables in the two questionnaires (A-Q and B-Q) were able to predict an acceptable amount of variance in risk behaviour as well as safety status. During an audit in a plant, all the employees participating in the study must either respond to A-Q or B-Q. Preferably A-Q should be used. However, when audits are carried out frequently, B-Q could be applied for a second audit when there is a chance that some of the respondents in the sample have answered to A-Q on a previous occasion.

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NOTE

1 To determine the dimensionality of the *Organisational Factors and Safety Attitudes*, *Attitude towards Accident Causation*, *Risk Behaviour*, *Safety Status*, *Risk Judgements* and *Environmental Issues*, principal component analysis with iteration and varimax rotation was applied. One analysis was carried out for each of these six elements. The dimensions are entitled indices. For each element there can be one index or more indices intended to measure different sub-elements of the element. The indices are made up of one or more indicators, which are the statements or questions included. The principal component analysis determines the underlying structure of the evaluations, i.e. more general dimensions. The latter are more general than the direct evaluations on single questions or indicators because they represent clusters of original direct evaluations. The latent dimensions make it easier to understand how the respondents view their own work conditions. The structure of evaluations shows which sub-elements that go together. These indicate which safety, health and environment improvements ought to be implemented. Cronbach's Alpha was used to determine the reliability or the internal consistency of the indices. The reliability was assessed on all the dimensions or sub-elements/ indices. In addition, total inter-item correlation coefficient was calculated for each of the indices. The results of the exploratory factor analysis are not shown, only the summary statistics related to inter-item correlations and alpha coefficients. A nearly identical structure of dimensionality was observed amongst the employees in the present study and a study carried out previously (Rundmo, 1998). This is ideal because it makes comparisons between plants possible. The indicators belonging to each of the single dimensions are added to determine the respondent's assessment. The indicators were added without differential weighting, i.e. not weighted according to their factor loading. Weighting would have given a more correct picture of the indicator's relative importance for the dimension it belonged to. However, it would be rather complicated to carry out such calculations. This is especially true when individual scores are going to be calculated regularly as part of ordinary SHE-audits. To examine the discriminant validity of each of the indices or dimensions, Pearson's r (correlation coefficient) was applied. It was expected that the fifteen indices should be correlated, however, not too strongly. This is to be sure that they really represent different dimensions. To test the plant differences in the number of self-reported accidents and near accidents the c2-test was applied. This test examines whether or not there are significant more or significant less observed number of accidents compared to the expected number by statistical interference in any of the plants, i.e. in the case that there were no plant differences in the number of self-reported accidents. Both the versions of the SCS-Q questionnaires aim at keeping the number of indicators as low as acceptable, but still keep the power of all the measurements included in the questionnaire. This was because it would be very time consuming for employees to fill in a questionnaire with a lot of questions, especially if subjective assessments are going to be used as a part of Dyno Nobel's Risk Management System. Therefore, each index was split into two indices by random by selecting indicators to belong to the A-version and to the B-version. Both the indices were intended to measure an identical underlying dimension. Only indices, which were sufficiently reliable, were included in the questionnaires, and the indices also had to satisfy this criterion. Another demand was that it should be possible to find significant differences in employee evaluations among the plants. One-way analysis of variance (ANOVA) as well as multilevel analysis of variance (MANOVA) was used to test the significance of plant differences. There are two reasons why this is preferable to fifteen separate ANOVA analyses, one for each of the SCS-Q dimensions. First, MANOVA give overall tests of the effects of dimensions and covariates. This may serve to protect against inflation in the probability of Type I errors as the number of criteria increase. Second, the MANOVA estimates takes into account the association amongst the criterion variables, which in the analysis are the fifteen indices of SCS-Q. MANOVA also makes it possible to estimate discriminant functions that can be interpreted as latent variables tapped for the individual SCS-Q scales. The analysis was carried out in the following steps: First, a multivariate test of the effects of which plant the respondents belonged to for their SCS-Q assessments was carried out. If the test turned out to be significant, the next step was to carry out individual univariate ANOVA analyses for each scale. Thereafter, the adjusted means were calculated after controlling for covariates and then we tested the differences between the plants by applying Tykey's Honest Significance Difference (HSD) adapted for unequal numbers (see Bray and Maxwell, 1985). Further tests of criterion validity were also carried out. First, the indices of *Attitude towards Accident Causation*, and Employee *Risk Judgements* were hypothesised to be associated with *Risk Behaviour*.

Regression analysis was carried out to test the significance of the predictors on behaviour. In addition, hierarchical regression analysis was carried out applying the dimensions belonging to each of the elements *Organisational Factors and Safety Attitudes* as predictor variables for *Risk Behaviour*. In this analysis *Attitude towards Accident Causation* was entered as the first block, Employee *Risk Judgements* as the second and *Organisational Factors and Safety Attitudes* as the third. *F-change* statistics was applied to examine whether or not the variables in each block together contributed to a significant increase in R2. In addition, the same variables as entered into the hierarchical regression analysis were hypothesised to predict *Safety Status*.An index may be important for safety without having a direct effect on *Risk Behaviour*. Some of the effects may be indirect; i.e. a predictor variable can have an effect on another variable, which in turn directly affects *Risk Behaviour*. To analyse such a possibility path analysis with latent variables was carried out applying the LISREL (LInear Structural-RELation)-analysis program. The predictors were included in the questionnaires as far as they significantly affected the criterion variable. LISREL-analysis can be used for comparing the magnitude of direct and indirect effects between a set of variables. The higher the path coefficient, the stronger is the effect that one variable has on another variable. Path coefficients vary between -1 and +1, being analogous to standardised partial regression coefficients. The standardised regression coefficient expresses the change, measured in relation to standard deviation, s, in the expected value of the effect variables, *y*, when the cause variables are changed according to their standard deviation, s_x. Error terms in the path model are termed *e*. Complete LISREL-analysis consists of two parts; the structural equation model and the measurement model. The first mentioned model specified "causal" relationships amongst the latent variables and gives a description of the relations. The latent variables in a model are designated ETA-variables (h).+Effects of an h variable on another h+-variable are expressed in the beta matrix (b).+An assignment of the explained as well as the unexplained variance is given. R2 indicates the proportion of variance in the endogenous variable that is explained by the exogenous and intermediate variables, i.e. 1 - e. The error term or the variation in an endogenous variable, which can not be attributed to other variables in the model, is designated z. The measurement model specifies how the latent variables depend upon the observed variables. The measurement model for the y-variables, which are indicators of the unobserved variables, is designated by the lamda y matrix (l_y). To avoid the models to become too complex, the dimensions that emerged as the results of the principal component analyses and the reliability tests, were entered as directly measured variables in the model, and the element as the unobserved variable. By this procedure it was possible to study the associations between the SCS-Q elements. Correlations between each indicator (or dimension) and the element it measures, is interpreted in the same manner as ordinary factor loadings. As a rule, the indicators contain measurement error, which is unexplained variance which can not be attributed to the latent variables. Epsilon (e_n) designate measurement errors in the l_y - indicators. Theta epsilon (q_e) is the co-variance matrix for measurement errors in the y-variables. The LISREL analysis can be used to search for causal relationships only indirectly, by eliminating or modifying poor models that give predictions which are inconsistent with the data. Correlations between the theoretical model and the data are expressed by means of the Goodness of Fit (GFI), the Adjusted Goodness of Fit Index (AGFI), the Root Mean Square of Approximation (RMSEA), the Comparative Fit Index (CFI), and the Non-Normed Fit Index (NNFI). A GFI, AGFI and CFI above 0.90 have been agreed upon as an indicator of good fit between the theoretical model and the data (Hu and Bentler, 1995; Loehlin, 1992). An RMSEA less than 0.07 is likewise indicating a satisfactory fit.