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Safety diagnosis criteria—development and testing

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Abstract

Criteria for evaluating occupational safety in industrial organisations have been developed and tested. These criteria were designed for use in *safety diagnoses*, i.e. planned and systematic investigations of the organisation and the administrative procedures to control safety. The safety criteria were derived from previous performed safety management analyses and safety audit tools. A questionnaire survey was carried out in order to validate the criteria for evaluating safety in industrial organisations. Production personnel, safety professionals and line managers from 14 companies (aluminium production plants and meat production industry) answered the questionnaire. Strong correlation were found between the respondents' overall evaluation of safety and the evaluations of *safety specific factors* (management factors mainly to promote safety), while the injury frequency rate was strongly correlated to the evaluations of *general management factors* (management factors to improve the production system and organisation in general). The overall evaluation of safety correlated significantly with the injury frequency rate. This indicates that the proposed Safety Diagnosis Criteria can provide a valid measurement of safety in industrial organisations.

Keywords: Safety audit; Safety management; Diagnosis criteria; Internal control

1. Introduction

The main goal for this empirical study was to develop and validate a set of safety diagnosis criteria for evaluating safety in industrial organisations (Tinmannsvik, 1991). These criteria are to be used in safety assessment and control by the line management of the production systems. The safety diagnosis criteria were derived

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from previous performed safety analyses, and were developed within the framework of the so called SMORT method (*Safety Management and Organisation Review Technique*; Kjellén and Tinmannsvik, 1989; Kjellén, 1992, 2000). The empirical study thus provides a validation of the SMORT method.

The main question to be studied was; *Are the safety diagnosis criteria valid as safety measurements?* More specific hypotheses regarding validity were:

1. There is a significant correlation between the overall evaluation of safety, and the injury frequency rates.
2. There is a significant correlation between evaluation of safety management factors and the injury frequency rate.
3. There is a significant correlation between evaluation of safety management factors and the overall evaluation of safety.

Safety analyses and safety management have become more and more important. The MORT concept (*Management Oversight and Risk Tree*; Johnson, 1980) represented a new approach to the scientific management of safety, and has formed a basis for further development of safety analyses and safety assurance methodology in industry. MORT is a logic tree that provides a disciplined method of analysing an accident, and provides a format for safety program evaluation. The SMORT method is a further development of this systematic way of investigating safety in organisations intended for use in safety audits, as well as in accident investigations. SMORT provides a systematic and step wise means of unfolding relevant causal factors by starting with identification of risk influencing factors at the workplace level and proceeding through the various managerial levels of the organisation.

There are a growing number of well-known auditing methods, i.e. an inspection of the organisation and administrative procedures on a scheduled basis to determine their safety relative to a standard criterion. Among these, the *International Safety Rating System*; (ISRS, Bird and Germain, 1990) is widely used. ISRS is a safety auditing program for evaluating the different parts of the company's safety and health activities. In difference from SMORT and MORT, the safety management factors in ISRS are ranked and assigned a numeric value, based on a qualitative judgement of the relative importance or necessity of the elements.

Common for the majority of methods mentioned earlier is that the methods for safety analysis and the analysis process have only to a minor extent been scientifically validated (Eisner and Leger, 1988; Gaunt, 1989; Guastello, 1991; Rouhiainen, 1992; Hale and Hovden, 1998; Røer Ellefsen, 1998; Alteren, 1999). The methods have been developed and tested through pragmatic practical approaches, rather than a scientific approach.

2. Diagnostic tool development

The development work consists of; (1) clarifying different categories of safety measurements; (2) developing the safety diagnosis checklist.

2.1. Different categories of safety measurements

The term 'safety' is in this study defined as: to what extent the occupational accident risks from an activity are acceptable and as low as reasonable practicable, i.e. the ALARP principle (Reason, 1997). This definition makes the safety concept dynamic and a relative term, and implies systematic efforts in order to monitor and minimise risks. Safety perfomance indicators are the basis for any effort in feedback control of safety, and in obtaining the desired safety level in the organisation (Tarrants, 1980; Kjellén, 1984). The work in this study has been based upon the view that measurement is important, but not necessarily in a quantitative, technical manner. Qualitative criteria of properties may have better preconditions to generate adequate indicators of safety than quantitative measurements.

In the study, two different measurements for safety have been used: the first measurement of safety is the *subjective evaluation of safety management factors*, measured by evaluating the perceived adequacy of a given set of safety management factors (work environment, human behaviour and administrative procedures to control safety). These are based upon evaluations on an ordinal scale of measurement. The other measurement of safety is expressed by the *injury frequency rate*.[1] In testing the validity of the safety diagnosis criteria, the consistency between those two parameters were analysed. Previous research has revealed a strong correlation between the two safety measurements (Marek et al., 1986; Rundmo, 1990).

Subjective evaluations of safety management factors have some advantages over accident data as a measurement for safety. Evaluation of the adequacy of safety management factors may be done in the absence of, or prior to mishaps and accidents, so that the organisation can be made aware of safety problems at an early stage. Furthermore, evaluation of safety management factors may be a more sensitive and accurate expression for safety than accident data; especially in small organisations and for measuring the effects of remedial actions. On the other hand, accident data will be a valuable corrective and a supplement to subjective evaluation of safety management factors, and is ultimately a criterion for validating them.

2.2. Developing the safety diagnosis checklist

Criteria in the safety diagnosis checklist were developed in two steps: (1) identifying safety management factors; and (2) identifying safety indicators, which correspond to single questions in the checklist.

Two main categories of safety management factors were defined: (1) *General management factors* are factors with purposes beyond safety, relevant to improving the production system and the organisation in general, i.e. safety aspects encompassed in general management functions. (2) *Safety specific management factors* are conditions and functions in the work organisation whose purpose is mainly to promote safety. Each safety management factor is supported by a number of safety

[1] Injury frequency rate is expressed as the number of lost time injuries (more than one day of absence) per 1 million work hours for the whole company, averaged over a period of 5 years.

indicators, which together indicate how satisfactorily the safety management factor is taken care of.

Safety indicators were derived from a survey of the literature, and developed within the framework of the SMORT method. There are two main reasons why the SMORT method was selected as a framework for reference in the study. Firstly, the SMORT method is a result of a thorough development and has been used in a variety of analyses; both safety audits and accident investigations. Secondly, the SMORT method is founded on the MORT concept (Johnson, 1980), which is a well-tested method for identifying unsafe conditions, unsafe practices and accident causes.

The following types of analyses formed the basis for deriving the indicators:

(a) SMORT analyses of different industrial organisations;
(b) analyses of the safety organisation and activities for controlling safety in companies of different sizes and from different trades;
(c) international empirical studies to identify characteristic features for companies with a low accident rate, as different from companies with a high accident rate; and
(d) analyses of causes and contributory factors to more than 2000 accidents in the chemical process industry.

The resulting checklist consists of a total of 140 safety indicators distributed among 13 safety management factors. The full list is shown in Tinmannsvik (1991). The 13 safety management factors are shown in Table 1.

As an example, the set of indicators for the management factor *Safety attitude* is shown below:

- Is safety a regular issue in work management meetings?
- Is there a positive attitude at the work site regarding:
  (a) use of personal equipment?
  (b) built-in safety in the production system (machinery defence, safety zones, warnings/alarms)?
- Do managers demonstrate commitment and personal involvement in safety issues through:

Table 1
General and safety specific management factors

General management factors	Safety specific management factors
Education and training	Safety attitude
Machines and technical equipment	Safety equipment and protective equipment
Maintenance	Emergency preparedness
Transportation and storage	Safety experience exchange
Housekeeping	Safety programme activities (safety objectives, safety organisation, safety representatives, inspections, safety meetings, accident investigation and safety action plan).
Procedures and activities	
Communication	
Leadership and work administration	

(a) measures to promote motivation and positive attitude to safety?
(b) give proof of the equivalence between safety and productivity in daily decisions?
(c) set a norm for safety by personal behaviour (e.g. use of personal equipment)?

3. Field test

To test the validity of the safety diagnosis criteria a questionnaire study was performed within the aluminium production industry and meat production industry. The field test was performed in the following steps: (1) questionnaire development; (2) sampling and data collection; and (3) data analyses—validation of the safety diagnosis criteria.

3.1. Questionnaire development

The questionnaire has a cascade design on three levels (see Fig. 1): Level I is evaluating *Safety indicators* (a number of single questions in the scheme related to 13 different safety management factors). Level II is an evaluation of *Management factors* (*general and safety specific*), and lastly, Level III is one single question about the *Overall evaluation of safety* (one of two dependent variables in the study). Evaluation of the different safety management factors was done *after* evaluation of the safety indicators concerning specific aspects within that safety management factor. The idea behind the cascade design is that evaluation of safety management factors and overall evaluation of safety are aggregations of a number of specific assessments of safety (Marek, 1963, 1985; Cohen, 1968). The questions on the first level were answered "adequate" or "not adequate" relative to documentation or a general norm for the trade. The other two levels were five-graded ordinal scale variables.

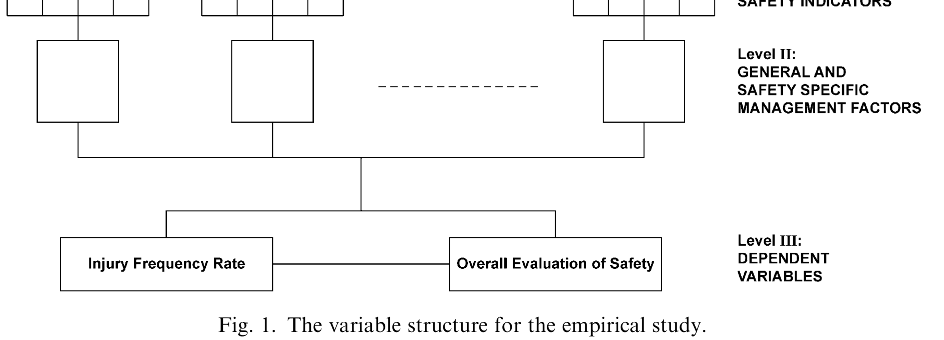

Fig. 1. The variable structure for the empirical study.

3.2. Sampling and data collection

The company sample was selected in accordance with the following analytic criteria: companies from two trades, trades with different risk levels and accident types, and companies of different size (number of employees). The questionnaire survey was performed in seven aluminium production companies and seven meat production companies. These were all the aluminium production companies in Norway, while the meat production companies were a representative, stratified sample of companies in the trade. The number of employees in the aluminium production companies varied between 560 and 1700, and in the meat production companies between 40 and 420.

Two representative production units from each company were analysed. The selection of these two units was done in proportion to the average value of injury frequency rate for the whole company. Production engineers, department managers, work supervisors, safety representatives and safety supervisors were informants. Between 8 and 12 persons answered the questionnaire from the aluminium production companies. The corresponding numbers from the meat production companies were 2 and 10. A total of 114 persons answered the questionnaire independently. The individual scores on the overall evaluation of safety were aggregated for the whole company to a company score, i.e. the average of scores over all respondents from each company, for the purpose of comparing with the injury frequency rate. The non-response share was equally distributed among company trade, company size and personnel category.

3.3. Data analyses—validation of the safety diagnosis criteria

Correlation analyses, calculating Pearson's coefficient of correlation were performed on questionnaire data and injury frequency rate data. These analyses ideally presuppose a continuous scale of measurement on an interval level. However, Labovitz (1970) and Marek et al. (1986) give references to several studies where correlation analyses have been done successfully with ordinal scale variables. To satisfy the condition for normal distribution, the ordinal scale variables were transferred into a logarithmic scale.

Two aspects of validity of the safety diagnosis criteria were tested; *the content validity* and *the criterion validity*. The content validity explains to what extent the selected set of questions is relevant and representative to cover a specific matter, i.e. to what extent the questions are adapted to measure safety in industrial organisations. The cascade design of the questionnaire made it feasible to do multiple regression analyses on different levels; between indicators and safety management factors and between safety management factors and the overall evaluation of safety. Stepwise multiple regression analyses were done to assess the content validity of the safety diagnosis criteria, and to identify safety indicators and safety management factors that account for the greatest amount of criterion variance. The multiple regression analyses formed the basis for calculating the *raw contributions* (Pearson's $r^2 \times 100$), *unique contributions* ($\beta \times r \times 100$) and *total contributions* (Pearson's $R^2 \times 100$), expressed as percentages. The unique contribution is an abstract measure, where the contribution of each factor has been distinguished from the contributions of other factors. The total contribution (Pearson's $R^2 \times 100$) indicates to what extent the identified indicators (or safety management factors) explains the variation in the dependent variable, i.e. to what extent the identified indicators and safety management factors are suitable for safety measurements. Although 100% explanation is virtually unreachable, the higher the percentage, the more adequate is the choice of safety indicators (or safety management factors). All values over 30% are considered satisfactory (Marek, 1985). The analyses were performed separately for the two trades.

The criterion validity explains the correlation between different operational definitions of the theoretical concept of interest. The criterion validity tests have been done by correlation analyses (1) between the evaluation of each safety management factor and the injury frequency rate, and (2) between the overall evaluation of safety and the injury frequency rate.

4. Results

4.1. Content validity of the safety diagnosis criteria

The content validity tests were performed on two levels. Table 2 shows the total contributions from the evaluation of all the safety indicators within one single safety management factor to the evaluation of that safety management factor. Table 3 shows the unique contributions and the total contributions from the evaluation of 13 safety management factors to the overall evaluation of safety.

4.1.1. Contributions from the evaluation of safety indicators to the evaluation of safety management factors (Level I–Level II, see Fig. 1)

The average total contributions for the evaluation of safety management factors are 37.8 and 39.1% for the aluminium production industry and the meat production industry, respectively (see Table 2). This means that the established set of safety indicators for the aluminium production industry on average can explain 38% of the variance in the safety management factors; while 39% for the meat production industry. Compared to a satisfying correlation level at 30%, this indicates an adequate set of indicators in the majority of the safety management factors (Marek, 1985). For the aluminium production industry, however, 2 out of 13 safety management factors fall below 30%; correspondingly three factors for meat production industry.

The ranking is quite similar for the two trades. Roughly, the safety management factors with a high content validity for the aluminium industry also have a high content validity for meat production industry, and vice versa. The rank order correlation (Spearman's) between the two trades is 0.69; significant on level 0.01. The content validity shows however a higher variability for the meat production industry than for the aluminium industry.

The safety management factors with the highest content validity are "Communication", "Emergency preparedness", "Leadership and work administration",

Table 2
Total contributions (Pearson's $R^2 \times 100$) from evaluation of safety indicators to the evaluation of safety management factors (adjusted values, $P<0.001$)

Safety management factor	Total contributions from indicators	
	Aluminium (Rank)	Meat prod. (Rank)
Communication (G[a])	58.1 (1)	53.9 (2)
Emergency preparedness (S[b])	51.3 (2)	64.7 (1)
Education/training (G)	47.3 (3)	39.9 (7)
Leadership and work administration (G)	46.7 (4)	46.7 (4)
Safety experience exchange (S)	43.2 (5)	49.3 (3)
Safety attitude (S)	37.5 (6)	39.8 (8)
Maintenance (G)	36.0 (7)	28.3 (11)
Machines and technical equipment (G)	34.6 (8)	33.6 (10)
Procedures and activities (G)	31.8 (9)	41.1 (6)
Housekeeping (G)	31.5 (10)	18.2 (12)
Safety programme activities (S)	30.5 (11)	45.7 (5)
Safety equipment/protective equipment (S)	23.4 (12)	9.4 (13)
Transportation and storage (G)	19.7 (13)	37.2 (9)
Average	37.8	39.1

Sample size: Aluminium: 74, Meat production: 40.
[a] G, General management factor.
[b] S, Safety specific management factor.

"Safety experience exchange" and "Education/training". The safety management factors with the least content validity, which consequently have a potential for further development, are "Safety equipment/protective equipment", "Transportation and storage", "Housekeeping", and "Maintenance".

4.1.2. Contributions from the evaluation of safety management factors to the overall evaluation of safety (Level II–Level III, see Fig. 1)

The total contribution from evaluation of safety management factors to the overall evaluation of safety for the aluminium production industry is 76.1% (adjusted value, $P<0.0001$). The corresponding value for the meat production industry is 71.8% (adjusted value, $P<0.0001$; see Table 3). For both trades, safety specific management factors account for the majority of the contributions to the overall evaluation of safety. Safety programme activities account for more than 30% in both cases. Within safety programme activities the following indicators account for the strongest contributions to the overall evaluation of safety in the aluminium production industry (Tinmannsvik, 1991): "Safety action plan", "Accident investigation", and "Safety organisation". Correspondingly, the strongest contributions to the evaluation of safety programme activities in meat production industry are: "Safety inspections", "Safety action plan", and "Safety representatives".

One safety management factor for each trade show a significant negative unique contribution to the overall evaluation of safety. An explanation of this result is that in situations where there are non-observed explanatory variables (covariates), the regression coefficients may be unbiased. This will be the case when there is covariance between the non-observed and observed explanatory variables.

4.2. Criterion validity of the safety measurement

Like the tests on content validity, the criterion validity tests have been done on two levels; the correlation between the evaluation of each safety management factor and the injury frequency rate, and secondly, between the overall evaluation of safety and the injury frequency rate. These analyses were performed only for the aluminium production companies, due to lack of adequate injury frequency data in the majority of the meat production companies.

4.2.1. Correlation between the evaluation of safety management factors and the injury frequency rate (Level II–Level III, see Fig. 1)

The results from the correlation analyses between the evaluation of safety management factors and the injury frequency rate are given in Table 4. General

Table 3
Unique contributions ($\beta \times r \times 100$) and total contributions (Pearson's $R^2 \times 100$) from evaluation of the 13 safety management factors to the overall evaluation of safety (significance level <0.10)

Safety management factor	Unique contributions	Significance level
Aluminium		
Safety programme activities (S[a])	30.7	0.0001
Leadership and work administration (G[b])	16.3	0.0500
Safety experience exchange (S)	11.7	0.0100
Education and training (G)	7.6	0.1000
Emergency preparedness (S)	6.9	0.1000
Communication (G)	6.5	0.1000
Transportation and storage (G)	6.1	0.0500
Machines and technical equipment (G)	−6.7	0.0500
Total contributions from all safety management factors (Pearson's $R^2 \times 100$, adjusted value):	79.1 76.1 (adjusted)	0.0001
Meat production		
Safety programme activities (S)	31.8	0.0100
Safety experience exchange (S)	31.7	0.0100
Maintenance (G)	17.1	0.0500
Transportation and storage (G)	6.3	0.1000
Procedures and activities (G)	−10.3	0.0500
Total contributions from all safety management factors (Pearson's $R^2 \times 100$, adjusted value):	76.6 71.8 (adjusted)	0.0001

Sample size: Aluminium: 74, Meat production: 40.
[a] S, Safety specific management factor.
[b] G, General management factor.

management factors show a strong correlation with injury frequency rate, while safety specific management factors are less strongly correlated. "Procedures and activities" is the safety management factor correlating most strongly to the injury frequency rate.

4.2.2. Correlation between the overall evaluation of safety and the injury frequency rate

Correlation analyses between the overall evaluation of safety and the injury frequency rate were done on an individual level, as well as for aggregated data, i.e. the average of scores over all respondents from each company. The correlation between the individual evaluation of overall safety and injury frequency rate for the company is 0.31 ($P<0.01$), while the corresponding correlation on aggregated data, is 0.80 ($P<0.015$). The correlation analyses on aggregated data indicate a satisfactory correlation between the overall evaluation of safety and the injury frequency rate. However, Table 4 tells that six of the *general* management factors, but none of the safety specific management factors, reveal higher correlation with the injury frequency rate than the overall evaluation of safety. Tables from the thesis (Tinmannsvik, 1991, p 186) tell that, even a number of single questions (indicators—Level I) correlates higher with the injury frequency rate than the overall evaluation of safety. Those questions are listed in rank order related to maintenance, housekeeping, training and storage, i.e. all of them are within the domain of general management factors.

Table 4
Correlation between the evaluation of safety management factors and the injury frequency rate

Safety management factors	Correlation coefficient (Pearson's r)	Significance level
Procedures/activities (G[a])	0.49	0.001
Machines and technical equipment (G)	0.43	0.001
Housekeeping (G)	0.39	0.001
Education and training (G)	0.39	0.001
Maintenance (G)	0.37	0.001
Communication (G)	0.32	0.010
Safety/protective equipment (S[b])	0.28	0.010
Transportation and storage (G)	0.24	0.050
Emergency preparedness (S)	0.24	0.050
Safety experience exchange (S)	0.23	0.050
Safety attitude (S)	0.22	0.050
Safety programme activities (S)	0.18	>0.050
Leadership and work administration (G)	0.12	>0.050

Aluminium production companies. Sample size: 74.

[a] G, General management factor.

[b] S, Safety specific management factor.

4.3. The relationships between safety management factors, overall evaluation of safety and injury frequency rate

While Table 4 indicate a strong correlation between the evaluation of general management factors and injury frequency rate, the analyses performed to investigate the relationship between evaluation of safety management factors and the overall evaluation of safety, show another trend (see Table 5). Comparing Table 4 and Table 5 tells that those safety management factors correlating strongly to the overall evaluation of safety show a weak correlation with the injury frequency rate, and vice versa.

5. Discussion

The applied cascade design has some weaknesses and also some advantages to be aware of in the interpretation of the results. The variable structure of the questionnaire starting with safety indicators at the first level guides the respondents to use these indicators as a framework for evaluating more general management factors. Correspondingly, the general management factors form a basis for the overall evaluation of safety, and thus direct the respondents to apply a predefined common scope for understanding the contents of the evaluation questions. The design invites to inductive reasoning and thus avoiding the fallacies of hidden circular reasoning in a questionnaire with a more random structure of items and questions.

The research design results in multicollinearity between variables as subjective data is used both as independent and dependent variables. However, multicollinearity is quite common in social sciences and may not necessarily represent a serious fallacy (Schroeder et al., 1986). The aggregation of data for each company from the individual responses can be considered quite reliable, as the answers did not differ substantially between the positions of the respondents, i.e. very low within group variance.

As the factors are predefined by given indicators the use of factor analysis will not contribute to the main aims of the study, i.e. to look for the strength of the total contributions from the indicators to the explained variance of the factors, and the factors contribution to the overall evaluation of safety, as computed by stepwise regression analyses.

An analytical framework for the discussions of the hypotheses is illustrated in Fig. 2. The study design does not give the complete information for filling in the correlation coefficients at the individual level or the aggregated level for all the relationships in the figure. However, the correlation analyses give indications on some of the relations; others are identified as derived hypotheses for further studies.

H_1. There is a significant correlation between the overall evaluation of safety, and the injury frequency rates.

The analyses of aggregated data show that respondents from companies with a high injury frequency rate, on average are less satisfied with the safety management

Table 5
Correlation between the evaluation of safety management factors and the overall evaluation of safety

Safety management factors	Correlation coefficient (Pearson's r)	Significance level
Aluminium		
Safety programme activities (S[a])	0.74	0.001
Safety experience exchange (S)	0.71	0.001
Safety attitude (S)	0.58	0.001
Education and training (G[b])	0.56	0.001
Safety/protective equipment (S)	0.51	0.001
Leadership and work administration (G)	0.51	0.001
Emergency preparedness (S)	0.51	0.001
Communication (G)	0.48	0.001
Procedures/activities (G)	0.43	0.001
Transportation and storage (G)	0.43	0.001
Maintenance (G)	0.42	0.001
Machines and technical equipment (G)	0.35	0.010
Housekeeping (G)	0.22	0.050
Meat production		
Safety experience exchange (S)	0.77	0.001
Safety programme activities (S)	0.68	0.001
Safety/protective equipment (S)	0.66	0.001
Leadership and work administration (G)	0.52	0.001
Communication (G)	0.48	0.001
Safety attitude (S)	0.48	0.001
Housekeeping (G)	0.46	0.010
Education and training (G)	0.46	0.010
Maintenance (G)	0.45	0.010
Machines and technical equipment (G)	0.41	0.010
Procedures/activities (G)	0.37	0.050
Emergency preparedness (S)	0.34	0.050
Transportation and storage (G)	0.33	0.050

Sample size: Aluminium: 74, Meat production: 40.
[a] S, Safety specific management factor.
[b] G,General management factor.

factors than the respondents from companies with a low injury frequency rate. The correlation is 0.80, $P<0.015$.

The correlation between the overall evaluation of safety and the injury frequency rate is significant, but not really strong using the individual respondents as unit in the analyses. In fact, the injury rate has stronger correlation with some of the general management factors and a few single questions on indicators, compared with the overall evaluation of safety. The relatively weak correlation on an individual level (0.31, $P<0.01$) could be associated with the fact that injury frequency rate is a contextual variable, referring to the company in general, and not to a single department within the company.

A question to be asked is to what extent the overall evaluation of safety is reflecting the respondents' knowledge about the injury frequency rate of their own company compared to the trade in general? This impact is thought to be minor, since the overall evaluation of safety has been given within the frame of safety indicators and safety management factors (general and safety specific) within a single department of the production system (see the cascade design in Fig. 1). It is reasonable to believe that the evaluations within the frame of a limited part of the organisation have influenced the overall evaluation of safety more than the knowledge about the injury frequency rate for the whole company.

The validity of the correlation coefficients discussed earlier depends on a comparable injury frequency registration among the companies, and on representative samples of production units. The validity of injury frequency rate as a safety measure depends on the reporting reliability, i.e. the number of reported incidents in relation to the "true" number of incidents meeting the defined reporting criteria. It also depends on to what extent the reporting criteria are well defined and easily understood (Kjellén, 2000). Another validity problem is that the injury frequency rate might not necessarily be a valid safety measure for organisations with a major accident risk, due to the fact that there are different causal factors (Hale, 2000). These uncertainties might be an explanation of the relatively weak correlation on an individual level, between the overall evaluation of safety and the injury frequency rate.

Another aspect of concern is whether the respondents are using a common frame of reference. It is reasonable to believe that the aluminium production industry has nearly obtained such a common frame of reference, and that the respondents in the study had a basis for evaluating the different safety management factors in relation to the general situation in the trade. This is due to the fact that the aluminium production industry appears to be relatively homogeneous, i.e. same production system, same size of the companies and the existence of a trade organisation, promoting safety information and experience exchange. If it had been possible to observe the companies over some years, and to make safety diagnoses repeatedly, the correlation between the overall evaluation of safety and the injury frequency rate might have been still stronger. In that case it would have been possible to control for some of the uncertainties mentioned earlier.

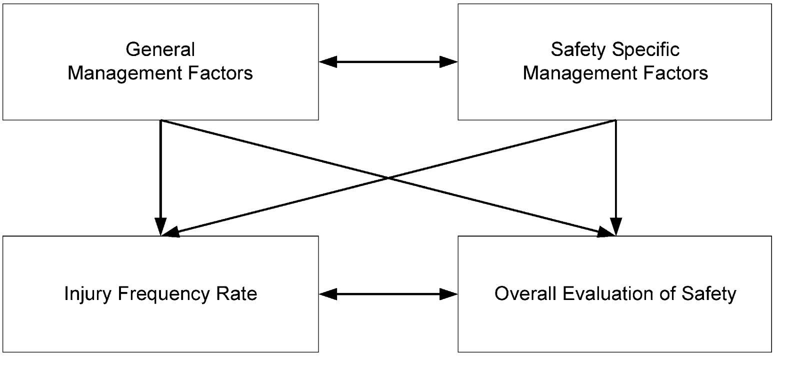

Fig. 2. An analytical framework for the discussion of the relationships between safety management factors, overall evaluation of safety and injury frequency rate.

H_2. There is a significant correlation between the evaluation of safety management factors and the injury frequency rate.

The analyses show a strong correlation between the respondents' evaluation of the general management factors and the injury frequency rate. A question to ask is why there is such a weak correlation between the injury frequency rate and the safety specific management factors? One possible explanation could be a hierarchical relationship between safety management factors. This interpretation is in agreement with Decker (1984) and Lepistö and Mattila (1988). Correlation analyses indicate a strong correlation between general and safety specific management factors. Safety specific management factors may affect the injury frequency rate mainly through the general management factors, and may be a necessary precondition for the influence of general management factors, on safety performance in an organisation.

An alternative interpretation is to suggest that the general management factors affect the specific safety factors, which in turn affect the overall evaluations and the injury rate. In other words, the general management attributes would encourage attention to safety, and hence good performance.

However, the data from this study give no empirical evidence regarding the direction of influences and causal chains. Derived hypotheses for further research and testing can be:

- Safety specific management factors have low influence on the injury frequency rate, both directly and indirectly.
- General management factors are determining the safety level, as demonstrated in this study, and their effect is: (1) conditioned by the safety specific management factors, or (2) is independent of the safety specific factors.

The last alternative, a H_0 hypothesis telling that the injury rate is *independent* of the safety specific management factors is specially interesting. It contradicts commonly held beliefs in safety science and practice. An improved research design and the use of structural models and LISREL analysis (Jöreskog and Sörbom, 1984) might reveal the empirical basis for the alternative interpretations of the results of this study.

H_3. There is a significant correlation between evaluation of safety management factors and the overall evaluation of safety.

The analyses show a strong correlation between the respondents' overall evaluation of safety and the evaluation of the safety specific management factors.

One reliability problem that could have had an effect on this result is the order of safety management factors in the questionnaire. Questions concerning safety specific management factors were in the final part of the questionnaire. This could have the effect that the overall evaluation of safety, which came just after them, was more influenced by specific safety management factors than by general management factors. Thus, the correlation between safety specific management factors and overall evaluation of safety could be somewhat weaker than implied in this study. Had the structuring of the questionnaire changed the order of the management factors, the overall evaluation may have been more influenced by the general management factors. This illustrates some of the sensitivity problems of the cascade design. On the other hand, most alternative designs of questionnaires do not solve the dilemmas of ordering the contents. The advantage of the cascade design is that it provides the respondents with a systematic framework and a common understanding for assessing the management factors.

6. Conclusions

The study described in this paper supports the conclusion that the proposed criteria for decentralised safety diagnoses, based on subjective evaluation of a number of safety indicators and safety management factors, provide a valid measurement of safety in industrial organisations. The study also supports that the SMORT method is a valid method for safety performance measurement. However, the results and discussions reveal some problems in applying a cascade design in the questionnaire.

Because of different frames of reference between trades, one should be cautious in doing comparisons between companies across industries on the basis of safety diagnoses. Comparisons between companies within the same trade may, however, be justified, if the trade appears to be homogeneous.

One interesting subject for further development is to gain knowledge about the respondents' criteria to evaluate a safety indicator as adequate, or not adequate, respectively. One question to ask is whether personnel in an organisation with a low injury frequency rate tend to use more strict criteria for adequacy. This knowledge is of great importance if safety diagnoses should be a basis for comparisons between companies. Another challenge is investigating any hierarchical relationship between general and safety specific management factors; i.e. the proposed hypotheses in the earlier discussion, including the question whether certain safety management factors need to be satisfied before there can be any positive effects from other safety management factors.

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