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Comparison of Safety Cultures between the Chemical and Power Industries

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We have defined a safety culture ontology and corresponding questionnaire, which includes 17 features and 51 statements. The statements specify an aspect of one or more features. Employees of organisations estimate the truth value of the statement in regard to their own organisation at that moment in time. The employees also specify how they would like the situation represented by that statement to be in the future. Responses are made through an Internet-based self-evaluation tool.
In our research project, we studied ten different organisations in a Finnish chemical industrial park. This covers all the major companies within the area, with 794 employees as potential respondents. We had 407 replies, giving a response rate of 51.3%. In addition, four companies from the power industry participated in our research. Some of these companies have their own power plants, build and maintain a power-distribution network and sell electricity. From the power companies, there were 158 replies with a response rate of 86.3%.
From the respondents' answers, we have firstly defined a collective understanding of each organisation's safety culture. Then, by combining the answers of the companies from the two separate industries, we have built up a picture of the overall safety cultures of the two industries.
The results of the comparisons show that the same kinds of points of interest and concern in both industries do exist. However, safety culture also varies greatly across both industries at some points, with significant differences in the current as well as in target states and proactive visions.

1. Introduction

We defined a safety culture questionnaire including 17 features and 51 statements (Porkka et al. 2013). The statements specify an aspect of one or more features. Employees estimate the truth value of the statement in regard to their own organisation at that moment in time. The employees also specify how they would like the situation represented by that statement to be in the future. Responses are made through an Internet-based self-evaluation tool. The answers provide us with a view, through the eyes of the employees, of what the safety culture features in the organisation really are in practice (Porkka et al. 2013).
In our research project, we studied ten different organisations in a large-scale industrial park located in Harjavalta (Porkka et al. 2010), which is one of the biggest chemical industry complexes in Finland. Our research covers all the major companies within the area with 794 employees as potential respondents. We had 407 answers so the response rate was 51.3 %. From the respondents' answers, we defined a collective understanding of each organisation's safety culture. Together, the answers build up a picture of the safety culture of the whole area, which is the focus of this paper.
Later, four companies in the power industry participated in our research. All these companies are located in the same western region of Finland. An identical questionnaire was used to gather comparable data from the power industry. In the four power industry companies, there were 183 employees of which 158 completed the questionnaire. Therefore, the response rate was 86.3%.

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The individual responses to a questionnaire are, according to the statistical theory of scales, on an ordinal scale (Conover 1999). This scale dictates the methods that are allowable for that data. Since rankings are a valid method for comparable group results with ordinal scale data, the responses of each individual were transformed into rankings (Porkka et al. 2010). From these rankings, group results were calculated for the whole industry.

In the analysis phase, we focused on a comparison of the results. We were interested in finding out in which features the industries shared the same opinion and in which they differed. Since the sample was not random and all the companies were from Finland, the results cannot be generalized. However, the results show some features and differences that might be of interest also outside Finland.

2. Safety Culture model and its implementation

Guldenmund distinguishes two different categories of safety culture research: purely descriptive academic research and practical case study (Guldenmund 2010). Our research is of the latter type. We have used Schein's and Cooper's models for the structure of safety culture. Cooper's trinity: person, job and organisation, forms the basis of our model. Cooper also makes the distinction between internal psychological factors and external observable factors (Cooper 1998). This same distinction between internal and external factors is also included in Schein's model (Schein 2004) and in Nonaka's SECI model (Nonaka & Takeuchi 1995). In Schein's model, the basic underlying assumptions are features of an individual including beliefs, feelings, values and attitudes. The espoused values are the organisation's strategies and goals. Schein states that artefacts are not only visible organisational processes and structures, but also the behaviour of persons, when it is a reflection of basic underlying assumptions (Schein 2004). A more precise description of the model can be found in (Porkka et al. 2013).

As mentioned above, a safety culture ontology was defined based on our model. The ontology includes 17 features and 51 statements. The statements specify an aspect of one or more features. In our model the features are divided up into eight sub-classes and sub-classes into two main classes. This division of sub-classes and main classes follows Tannenbaum's (Tannenbaum 1997) learning environment model (Paajanen 2012) and can also be found in (Porkka et al. 2013).

However, the two main classes can be expanded to three classes by extracting person related features from organisational ones. In Table 1, the features and corresponding example statements are sorted into three categories, which are separated by lines. In the first category, there are 10 organisational features. These are followed by two personal and job-related features, and five features related to Nonaka's SECI model.

Table 1: Features and examples of statements

Feature	Example statement
Safety training	Safety training is available in our organisation
Support and encouragement	Our superiors encourage safe working methods
Safety policy	In our organisation safety issues are paid attention to
Management	Safety relating development suggestions are met positively in our organisation
Organisation's openness to new ideas	Our organisation enables the questioning of working methods and procedures
Atmosphere	Stressfulness of work and excessive work load are noted in my organisation
Resourcing for safety:	Unclear assignment or guidance has affected my ability to work safely
Working environment	The working environment is monitored and improved
Risk management	Safety instructions are regularly updated
Efficacy of safety actions	Everyone performs according to safety instructions and regulations in our organisation
Attitudes towards safety	I breach safety instructions if it facilitates my work performance
Safety awareness and responsibility	I am aware of the safety related goals of our organisation
Co-operation	The employees in our organisation aid each other in working safely
Flow of information	The safety risks in my organisation are openly discussed
Safety rules and regulations	Safety instructions are easily accessible to all
Creation of new knowledge	I receive information which is not necessary considering my work
Learning by doing	My organisation makes "learning by doing" possible.

Respondents evaluate not only the current state of each statement, but also the target state. With the target state, they express their own opinion of what the status of the statement should be in the future.

Finally, the difference between the target and current states is calculated. This is called creative tension and expresses the wish for improvement (Senge 1990).

3. Analysis

In our study, the values of features given by an individual are ranked from 1 to 17. The rankings of all respondents of companies belonging to the same industry can then be calculated together and the sum is divided by the number of respondents. Therefore, the result is the average of responses, which is a statistically valid group result (Conover 1999).

Each of the participating 14 companies received a full report, which included group results calculated by rank but also with traditional and widely used means. Features were also analysed at the statement level in the reports. In this paper, we have combined these company level results into industry level results.

Figures 1-3 include both a table of data and a graph. The table shows averages of rankings for both industries. Column A contains the chemical industry data. The chemical industry data include results from 10 companies and 408 respondents. Correspondingly, the averages of the four companies and 158 respondents of the power industry are in column B. The third column A-B shows the difference between the industries, which is B subtracted from A. The grey colour in the cell indicates that the corresponding feature is amongst the best in the industry. The blue colour indicates that it belongs to the lowest part. We have used the minimum statistical difference when deciding which features form a class (Conover 1999; Porkka et al. 2013). The difference shows which features were valued higher in different industries. The interpretation of each figure is easy: the features that are valued higher in the chemical industry are at the top, and those of higher value in the power industry are at the bottom.

4. Results

The **current state** of the safety culture features indicates how respondents see certain safety features of their organisation at present. To be more precise, what has been done in the organisation and how the respondents view their own awareness, responsibility and attitudes towards safety. The current state shows how the employees consider the safety-related issues are dealt with in the organisation. Also in the organisation level analysis, we have seen that there might be opposing views of certain features. Management thinks that everything is in control, but employees have encountered some severe flaws.

One should be very careful when interpreting Figure 1. The graph only shows the similarities and differences between the industries, not the overall valuation of a certain feature. The value within the industry can be seen in the table. For example, the features of ‘safety policy’ and ‘atmosphere’ were quite similarly valued in both industries, the differences being 0.32 and 0.28. However, within both industries, the safety policy was ranked very highly, but the atmosphere belonged to the lowest valued.

A	B	A-B
8.15	5.49	2.66
11.75	9.86	1.88
10.72	9.10	1.62
12.25	11.46	0.79
13.47	12.71	0.76
11.76	11.44	0.32
4.60	4.32	0.28
8.94	8.74	0.20
8.93	8.90	0.04
6.47	6.58	-0.10
7.52	7.69	-0.17
8.63	9.35	-0.73
8.40	9.36	-0.97
8.24	9.21	-0.98
11.20	12.50	-1.29
7.72	9.61	-1.89
4.25	6.67	-2.41

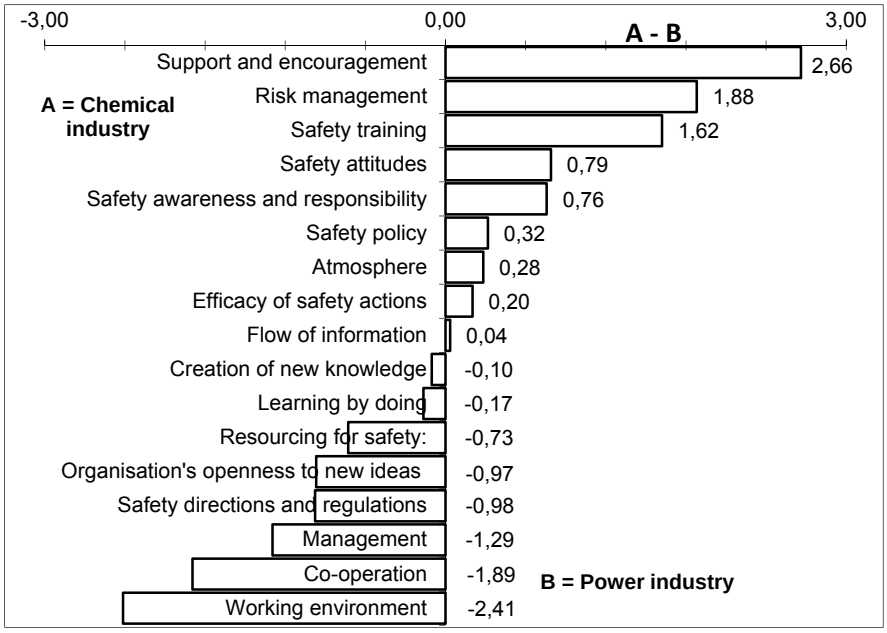

Figure 1: Differences of the current states between the industries ordered by size of difference

The similarities can be found in the middle section of Figure 1. The features that are more highly ranked in the chemical industry are shown in the upper part of the figure. It can be observed that especially ‘support and encouragement’ is valued more highly. Also ‘risk management’ and ‘safety training’ were ranked higher. The features related to the individual are also valued slightly higher. These features were ‘safety attitudes’ and ‘safety awareness and responsibility’.
The true nature of the chemical processing industry is much more risky and complicated. This may explain the high value of risk management and safety training. In addition, employees must be much more aware of the risks and this is revealed in the features linked to individuals. However, the feature ‘support and encouragement’ shows that the management level in particular in the chemical industry is much more aware of their responsibilities concerning safety.
In contrast, the working environment in the power industry in its current state is ranked higher. This is quite natural, since the working conditions in the Harjavalta industrial park are extremely hot and noisy in some places, and dusty everywhere. The features ‘co-operation’ and ‘management’ are regarded more highly in the power industry and there is no other explanation for this than that the management is simply considered to be better. In smaller companies, like the power companies, the directors are also usually more familiar with the employees. In general, in the power industry there are small working groups of for instance two electricians. This may explain why co-operation is highly valued in the power industry.

More often than not, only questions about the current state are asked in safety culture questionnaires. If intervention and change are the goals, the **target state** and especially the creative tension/proactive vision are more important. The target state indicates where the respondent would like to see the feature improve. When the current state shows how the organisation has managed, the viewpoint of the target state is purely individual. In the target state, respondents express their own desires and feelings, based on their own knowledge and constructs. In Figure 2, features are listed by the differences in target states.

A	B	A-B
9.35	7.49	1.86
10.49	9.18	1.31
10.77	9.61	1.16
12.26	11.19	1.07
7.81	7.18	0.63
10.58	10.34	0.25
9.91	9.98	-0.07
7.01	7.13	-0.12
10.46	10.80	-0.34
8.27	8.71	-0.44
10.11	10.66	-0.56
4.18	4.78	-0.61
10.95	11.62	-0.66
7.99	8.69	-0.70
8.34	9.05	-0.71
7.14	8.00	-0.86
7.38	8.59	-1.21

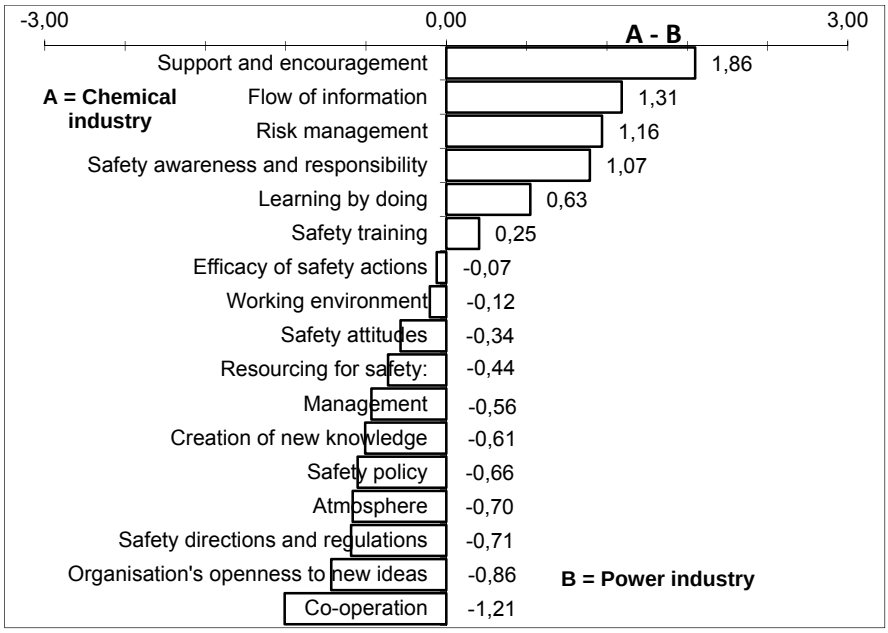

Figure 2: Differences of the target states of the industries ordered by size of difference

People in the different industries seem to value the features more highly in the target state than in the current state. For instance, ‘support and encouragement’ and ‘risk management’ are valued higher in the chemical industry and in the power industry ‘co-operation’ is ranked the highest. There are two possible explanations for this. Firstly, the current culture always favours things that are important to the culture. Culture is always trying to stay as it is (Schein 2004). On the other hand, features might have been amongst those most lately addressed, so they might just be clearer in people’s minds.
In the target state, the features that are valued equally are also interesting. The equal value means that the feature is valued similarly within the industries. Again the comparison does not indicate whether the feature was valued high or low. All we can see is the equality. Most of the features valued equally are

related to some kind of action on safety. These include ‘safety training’, ‘efficacy of actions’, ‘working environment’, ‘resourcing for safety’ and ‘management’. Also, ‘safety attitudes’ was given equal value within both industries.

Figure 3 shows a comparison of **creative tensions**. Creative tension is the difference between the target state and the current state. It describes the gap that exists between a person’s vision and the current reality. This gap works as the source of energy that motivates the individual to act to release the tension. It is the most interesting if there are plans for some kind of intervention. Creative tension shows exactly in what features the respondents see room for most improvement. Creative tension combines both the organisation’s viewpoint (current state) and the individual’s viewpoint (target state). It clearly shows the direction of desired improvement with a collective voice.

A	B	A-B
12.90	10.69	2.21
7.69	6.40	1.28
9.87	9.02	0.85
9.57	8.74	0.83
9.54	9.11	0.43
7.29	7.05	0.23
9.01	8.78	0.22
9.89	9.79	0.10
6.70	6.68	0.02
7.69	8.15	-0.45
7.17	7.62	-0.45
10.05	10.52	-0.48
12.49	13.14	-0.64
6.89	7.57	-0.68
7.81	8.82	-1.01
8.32	9.49	-1.17
10.14	11.43	-1.29

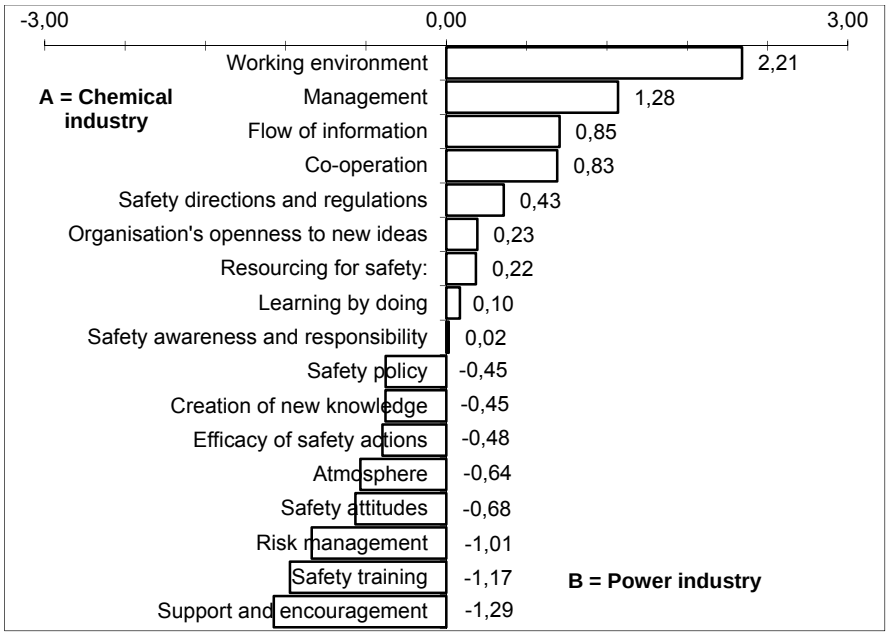

Figure 3: Differences of the creative tensions of the industries ordered by size of difference

Not surprisingly, in the chemical industry, the ‘working environment’ showed the biggest difference. As we saw in Figure 1, it also had the biggest difference in the current state. Also ‘management’, which was better in the power industry, had a bigger creative tension in the chemical industry.

On the other hand, in the power industry the biggest difference was in the features that were better in the chemical industry. In the current state, the chemical industry was higher in ‘support and encouragement’ and ‘risk management’ and both of these were amongst the three features with the biggest gap. The feature ‘safety training’ also belonged to this category. Safety issues are very important in both industries but probably safety issues in general and safety training have received more attention in the more dangerous environment of the chemical industry.

The person-related features were quite alike in both industries. There was almost an equal amount of improvement needed for ‘safety consciousness and responsibility’ and ‘safety attitudes’. In the power industry, slightly more improvement was needed in ‘safety attitudes’.

5. Conclusions

Figures 1-3 show clearly that there are similarities and differences between the industries when evaluated with our model of safety culture. It is important to emphasize that this comparison only concerns our model and there are most certainly other differences amongst the features, which are not included in our model. Additionally, these results are not necessarily transferable to other countries or to other industries. When interpreting the results, one should also bear in mind that the values are actually rankings. Comparison of values of different features within an industry is meaningless.

There is an important difference between the infrastructures of the companies, which makes a difference when interpreting the results. All employee groups of all the companies were given a chance to reply. However, in the chemical industry, the office workers were also located in the industrial park area, which

was in the danger zone of major accidents. With the power industry, only a small number of workers were under direct threat of a life-threatening accident. Normally, electricians work in the field where they build and maintain the power-distribution network. This may partly explain why safety seemed to be more valued in the chemical industry.

Almost all features that were related to Nonaka's SECI model were evaluated at the same level in both industries (Nonaka & Takeuchi 1995). These features were: 'co-operation', 'flow of information', 'creation of new knowledge' and 'learning by doing'. However, there was one feature that was evaluated differently. 'Safety directions and regulations' was ranked higher in the current and target states in the power industry. In contrast, creative tension was higher in the chemical industry.

Due to the differences in the nature of the industries, the highest gap was seen in the 'working environment' feature. The environment in the process industry is quite complex and also the number of different potential risks is much higher. After this research and tens of interviews within the chemical industry and a few in the power industry, it became clear that the level of overall safety is also higher in the chemical industry. This can partly be explained by the threat of a major accident looming above all employees in the chemical industry. Therefore, safety issues were in everybody's mind. The amount and quality of protective equipment is very high and there are also more legislative restrictions to be followed. Therefore it was a slight surprise that the 'safety directions and regulations' feature was so much higher in the power industry. There may be fewer points of danger, but instructions for these points were better produced. In the power industry, there are strict regulations related to safety issues. It is not possible to work as an electrician before you are familiar with these regulations. This explains why safety training is seen as important.

There was an interesting difference between 'management' and 'support and encouragement'. In the questionnaire, 'management' was more connected to directors than to managers. 'Support and encouragement' is a duty for managers. So in the chemical industry, due to the bigger scale of the companies, directors were less visible and managers were supportive and encouraging. On a smaller scale, the power industry directors had a bigger role, but there was a big need for 'support and encouragement'. This can be partly explained by the features related to the working environment in the power industry. Electricians work in the field and managers are not present all the time on the sites.

Gambetti emphasises the importance of the human factor in process safety (Gambetti et al. 2012). The features related to people were valued much more highly in the chemical industry. In contrast, 'safety attitudes' had a bigger creative tension in the power industry.

In the future, it would be interesting to study safety culture related issues between different countries. This would enable the study of how the cultures of different countries might affect the results in the chemical and power industries.

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