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Safety Culture Research in a Finnish Large-Scale Industrial Park

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Safety culture ontology has been constructed, consisting of 17 features and 51 statements. The statements specify an aspect of one or more features. Employees of the organisations estimate the truth-value of the statement in regard to their own organisation at that point in time. The employees also specify how they wish the situation represented by that statement to be in the future. Responses are collected via an Internet-based questionnaire.
Ten different organisations were studied in the large-scale industrial park at Harjavalta, Finland. This research covers all the major companies within the area with 794 employees as potential respondents. We obtained 407 responses and the response rate was 51.3 %. From the responses, we have defined a collective understanding of each organisation's safety culture. Together, the answers provide an insight into the state of the safety culture of the whole area. The safety cultures of the various organisations have also been compared with each other and with the culture of the industrial park as a whole.

1. Introduction

An industrial park is a closed area, in which a group of independent organisations work in close co-operation. The organisations may be connected through their manufacturing processes, auxiliary systems, supplies, manufacturing areas or by some other activity, and therefore they may have common working areas. They may also share communal systems, such as sewerage systems or power production. Occupying the same enclosed area inevitably implies shared traffic lanes and passages. Due to this proximity, accidents in one company may well have severe effects on the others. Therefore, all organisations located in the same industrial park should have the same minimum requirements for their safety culture. In Finland, some legislative requirements also exist concerning safety, which companies in an industrial park must fulfil.
The Harjavalta large-scale industrial park is utilised by the metallurgical and chemical industries. It is generally considered to be one of the most dangerous places in Finland because of the nature of the industrial activity involving high pressure and high temperature processes, as well as toxic chemicals and poisonous substances. Chemicals manufactured or stored at the park include among others, ammonia, sulphur dioxide, sulphur trioxide, sulphuric acid, hydrogen and oxygen.
We have constructed a safety culture ontology to study 17 features, which we found to be important aspects of safety. Employees of the organisations were asked to evaluate the truth-value of certain statements with regard to their own organisation both at that moment in time and in the future. Evaluations were carried out by means of an Internet-based questionnaire, the responses to which provided us with a view of how the safety culture features in the organisation are in reality, through the eyes of the employees.
The research took place in the Harjavalta large-scale industrial park. All the major companies within the area participated in the research, amounting to 794 employees as potential respondents. We obtained 407 responses, thus the response rate was 51.3 %. From these responses, we defined a collective understanding of each organisation's safety culture. Together, the combined responses of all organisations provide an insight into the safety culture of the whole area.

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The research is still continuing and we are moving towards intervention. In one of the participating companies, a case intervention has been carried out, which will serve as a model for the rest of the organisations. We have plans to study the same companies later so that this research will evolve into longitudinal research.

2. Safety Culture model

According to Guldenmund (2010), two categories may be distinguished within safety culture research: purely descriptive academic research and practical case studies. The purpose of the former type is to define safety culture and the purpose of the latter is both to make an intervention and to improve the safety atmosphere or culture in the participating organisations. Our research is of the latter type.

Our model makes use of three other models, which have been widely used in organisational culture, in safety culture and in organisational knowledge creation research. Firstly, we draw upon some elements of Schein's model for organisational culture (Schein 2004), which distinguishes between internal psychological factors (basic underlying assumptions) and external observable factors (artefacts and espoused values). Secondly, Cooper's reciprocal safety culture model states that the safety culture consists of internal psychological factors of individuals and external observable factors, which can be related either to an organisation or to a particular job (Cooper 1998). Finally, Nonaka's and Takeuchi's SECI model for organisational knowledge creation provides a means for the externalisation of knowledge creation and tacit knowledge (Nonaka, Takeuchi 1995). We have named our model Serpentine.

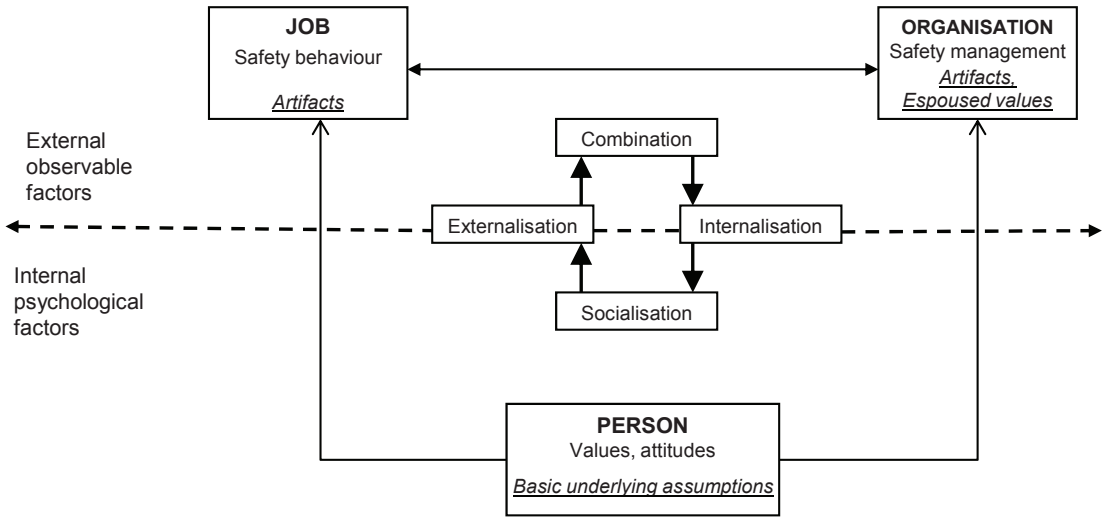

Figure 1: The Serpentine safety culture model

We have used Schein's and Cooper's models for the structure of safety culture. In Figure 1, the major features of Cooper's model, namely person, job and organisation, are written in bold capital letters. 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 and in Nonaka's SECI model. In Schein's model, the basic underlying assumptions are the features of an individual, including for example beliefs, feelings, values and attitudes. The espoused values are the strategies and goals of an organisation. Schein states that artefacts are not only visible organisational processes and structures, but also the behaviour of individuals, when it is reflection of basic underlying assumptions (Schein 2004).

The major problem with changing the safety culture is to find ways of affecting the internal psychological factors, which construct the true basis of a culture. If the underlying assumptions are not changed, then the visible changes will not be permanent. Nonaka and Takeuchi offer a means to change and share the internal world of individuals.

The purpose of our model is to study not only the features of safety culture, but also the organisational enablers that make the change of internal factors possible. The change in internal factors is dependent upon the ability of the organisation to support the creation of new knowledge (Paajanen 2012). In order to be able to change the underlying assumptions, the organisation must not only fulfil the environmental aspects, but also enable organisational knowledge creation activities.

3. Safety Culture Ontology

We have constructed a safety culture ontology based on our model (see Figure 2.). This ontology consists of 17 features, the hierarchy of these features (classes and main classes) and 51 statements. Each statement specifies an aspect related either to the organisation, or to an individual or organisational knowledge creation activities. All statements are related to either one or several features. The features are divided up into eight classes and then grouped into two main classes. This division of classes and main classes follows Tannenbaum's and Paajanen's learning environment model (Paajanen 2012, Tannenbaum 1997).

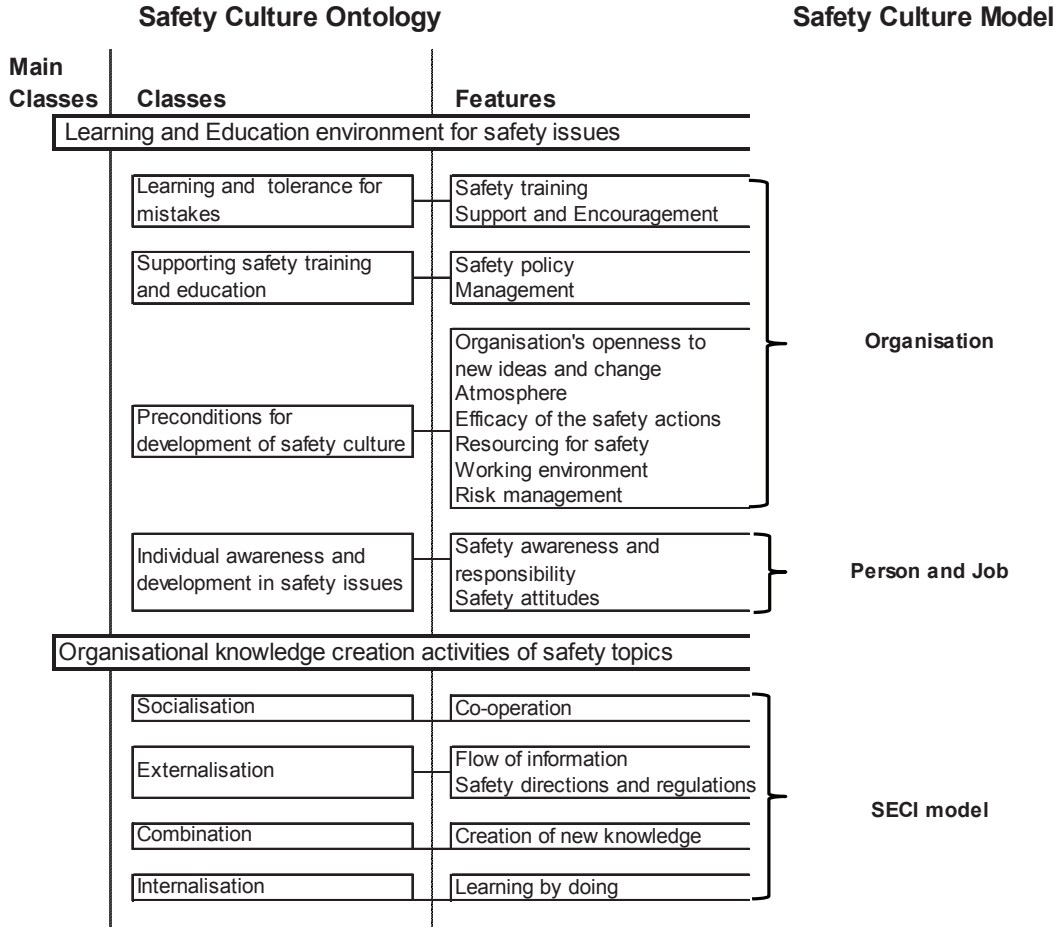

Figure 2: Serpentine safety culture ontology and model.

The features of our ontology were selected through an exhaustive literature review (Salo-Pihlajamäki, 2008). In addition to the literature review, social media has also been used to verify the relevance of the selected features. We have studied the LinkedIn's group, EHSQ Elite, which has more than 36000 followers worldwide (as of January 2013), the followers being mainly safety professionals. We discovered that all the features of our model were discussed in this group (Mäkinen et al. 2011). The safety managers of the organisations involved also participated in a seminar, where we discussed and altered our model. The relevance of our model has been checked in academia, social media and with working professionals in the participating organisations. Nevertheless, the features selected represent only our vision of the most important features and we do not claim that our model is the only truth. In this we follow Guldenmund: *"… safety culture is very much what a particular researcher wants to make of it."* (Guldenmund 2010).

Employees at the industrial park estimated the truth-value of each statement regarding their own organisation. They estimated the truth-value both at that moment in time, which revealed to us the current state, and also their estimation of the value in the future, which we call the target state. We also calculated the difference between the target state and the current state. This difference reveals how much (or little) the respondent wishes to improve the matter presented in the statement. We have used the notion of

creative tension from Senge (1990), when dealing with features of an individual. When the statements concern the organisation, the notion for tension is proactive vision.

4. Analysis

Data collected by means of a survey, with linguistic variables, is always personal and non-parametric. By personal we mean that each respondent literally speaks only for himself/herself. Consequently, the answers of different persons are not directly comparable. Two different people giving the answer “good” to the same question do not necessarily mean the same with their answers. The meaning of the response is dependent on the respondent’s own personal scale. If the respondent is negative-oriented, the answer “good” may be the highest and if the respondent is overly positive, the answer “good” may be the lowest.

Due to the use of linguistic variables, the scale of measure is said to be ordinal. An ordinal scale means that all a researcher can conclude from a single respondent’s answers is the order of his/her answers (ranking), nothing more. Therefore, calculating means, variances and other interval scale methods are not possible.

However, there are several suitable analysis methods for ordinal scale data. All these methods use rankings rather than the actual input values. With rankings, it is legitimate to calculate totals as group results, which are statistically valid. The transformation of data into rankings is straightforward. Original values are sorted into ascending (or descending) order, and the values are substituted with rankings. With the use of rankings, the personal degrees of scale of the respondents are removed, and the results (and the group results calculated from these values) become comparable. This can be seen in Table 2, where the sums of all the rankings within an organisation are always 153.

In our study case, there are several related samples in the data. The most powerful test for several related samples, where the number of different variables is more than six, is the Friedman test (Conover 1999). In Friedman’s test, the actual input values of a single respondent are transformed into rankings (Friedman 1937). In our case, the values of features from a single person are ranked (from 1 to 17). The rankings of several respondents can then be added together, producing valid group results.

The Friedman test also gives one extra benefit compared to sums and averages. With the Friedman test, one can calculate the minimum statistical difference (MSD), which is the difference the sums must have to be regarded as unequal (Conover 1999). This difference can be calculated with different significance levels. We have used the significance level $\alpha=0.05$. The MSD was used to cluster the results. The value of the minimum difference depends on the actual input values and on the number of respondents. Therefore, it is different in every organisation. The highest value and all other values within the MSD belong to the group of the best. The lowest value and all the others within the MSD belong to the group of the lowest. We have used colour coding to separate these groups. The grouping and the colouring are a great asset in the analysis phase.

5. Results

We have calculated group results for the whole industrial park, with a total number of 408 respondents. The number of respondents in each organisation ranged from eight to 132. Each of the participating organisations has been given a full report and analysis (50-100 pages) on the state of their safety culture. In these reports, organisational level results, some section level results and comparisons have also been made between workers and clerical workers.

In a few organisations, interventions have already taken place. Our reports have been a great help and guidance in intervention planning. These reports and interventions have shown that our method is usable. According to the constructive research approach, we have passed the weak market test, since the method was found to be useful and has been employed in some of the organisations (Kasanen et. al 1993).

The ten participating organisations can be divided into four groups by industry. Table 1 shows the industries of the participating organisations.

Table 1: Industries of participating organisations

Industry	Definition	Organisations
Production	Producers of chemicals and metals	A, B
Production suppliers	Suppliers of energy and chemicals	C, D
Engineering	Engineering services	E, F
Maintenance and services	Maintenance, transportation and cleaning	G, H, I, J

The current state of the safety culture shows what has been done in the organisation and what are the respondents' current awareness and attitudes towards safety. Or more precisely, what the respondents think has been done in the organisation. It should be noted that the group results do not tell the objective truth, but a collective understanding within the organisation. In some companies, it turned out that the impressions of workers and management about some features were quite different. However, the current state offers a collective understanding of the organisation.

Table 2. Current states of the whole park (All) and of the participating organisations.

Current State	**All**	A	B	**C**	**D**	E	F	**G**	**H**	**I**	**J**
Feature msd =	**0,59**	1,02	1,18	3,65	4,44	3,83	2,76	1,62	2,45	2,29	1,88
Safety awareness and responsibility	13,47	13,0	13,9	13,5	14,4	13,2	12,5	14,0	14,3	12,7	13,5
Safety attitudes	12,25	12,6	11,7	12,3	10,1	10,2	13,1	12,6	11,7	11,3	13,0
Safety policy	11,76	12,3	12,6	9,3	8,5	10,6	9,8	11,9	12,0	13,0	9,5
Risk management	11,75	11,8	13,0	11,6	10,8	12,4	10,2	10,9	10,9	11,2	11,7
Management	11,20	11,5	11,2	10,3	8,3	12,9	10,9	12,2	10,7	12,1	9,3
Safety training	10,72	10,6	12,3	12,2	11,4	10,6	8,8	9,6	8,8	12,0	10,1
Efficacy of the safety actions	8,94	8,1	9,0	9,5	11,7	7,4	11,9	9,1	7,5	10,5	9,6
Flow of information	8,93	8,2	9,2	10,4	10,9	11,1	9,2	9,2	9,5	9,2	8,6
Resourcing for safety	8,63	9,5	8,2	4,7	10,9	10,2	10,3	9,0	6,6	8,4	7,1
Organisation's openness to new ideas	8,40	8,0	8,3	9,3	7,9	11,7	9,3	8,4	7,6	8,3	8,9
Safety directions and regulations	8,24	8,3	8,6	8,9	10,4	5,1	7,3	8,2	7,1	7,8	8,7
Support and encouragement	8,15	10,5	7,7	6,6	4,7	8,4	5,7	5,3	6,6	7,6	9,0
Co-operation	7,72	7,1	6,4	9,7	8,2	9,2	9,6	8,8	8,2	7,1	9,3
Learning by doing	7,52	7,0	7,2	9,2	8,3	5,3	7,4	7,1	11,3	6,3	8,9
Creation of new knowledge	6,47	6,4	5,9	5,6	6,8	6,2	6,2	7,0	8,3	7,2	5,9
Atmosphere	4,60	4,5	2,3	2,6	6,7	5,8	7,0	5,8	6,4	4,2	6,3
Working environment	4,25	3,7	5,3	7,3	3,1	2,7	3,8	3,9	5,5	4,0	3,8
SUM	153	153	153	153	153	153	153	153	153	153	153

Table 2 shows the current states of the whole park (All) and of each participating organisation. The organisations are ordered by industry and to clarify this division, bold and underline are used. A higher value means more appreciation. In all companies, the highest value was given to safety awareness and responsibility. Also, the second highest, namely safety attitudes, is a feature of an individual. Atmosphere and working environment had the lowest values. However, in companies B and C, the working environment was not in the poorest class. Interesting results can be seen in the middle section of the table. Resourcing for safety belongs to the poorest class in C, but in the best class in D and E.
In several other safety culture questionnaires, only the current state is asked about. If intervention and change are goals, the target state and especially the creative tension / proactive vision are more important than the current state. The tension reveals exactly what the respondents wish to improve and how much.

In Table 3 we can see that the two features related to individuals, i.e. safety awareness and attitudes, have the smallest creative tension. This means that people think they have reached the top and there is little to improve. On the other hand, this might mean that there are better targets for development in the organisation.
Working environment had the highest proactive vision. This is quite understandable, since the environment is dirty, noisy, and temperatures vary. All this is due to the nature of the process and environment itself and there is not that much that can be improved. Also, in most organisations the atmosphere requires improvement, except in company D, where it belongs to the group of less improvement needed.

6. Conclusions

Table 2 shows clearly that in the industrial park there is a mutual understanding of which features belong to the group of the best and which to the group of worst. In addition, Table 3 shows that the understanding of what features need most and less enhancement is shared. This provides a good starting point when trying to organise joint safety training and education.

In both tables the differences between organisations and industries can be found in the middle section. In Table 2, resourcing for safety shows that differences do exist within the industry (C and D) and between industries (C and E). This can also be observed in Table 3 in learning by doing, where there are differences within the industry (E and F) and between industries (E and H). These results show that some safety training should also be organisation-specific.

Gambetti et. al (2012) emphasise the importance of the human factor in process safety. Our research shows that the safety culture features of the individual are in a healthy state at the industrial park studied, at least when the employees were asked about it. Employees understand their own importance as a vital part of safety culture.

Table 3. Proactive visions of the whole park (All) and of the participating organisations.

Creative Tension	**All**	A	B	**C**	**D**	E	F	**G**	**H**	**I**	**J**
Feature msd =	**064**	**1,10**	**1,36**	**3,96**	**4,68**	**4,4**	**2,93**	**1,62**	**2,50**	**2,57**	**2,02**
Working environment	12,90	13,9	12,3	10,1	14,4	11,7	13,4	12,8	13,2	11,5	12,3
Atmosphere	12,49	13,2	14,1	15,7	7,3	11,4	10,0	10,6	12,1	11,0	12,3
Support and encouragement	10,14	8,0	9,9	12,2	11,4	10,7	11,6	12,4	12,5	12,1	10,0
Efficacy of the safety actions	10,05	10,6	10,0	9,8	8,5	11,1	7,5	10,6	9,6	9,6	9,5
Learning by doing	9,89	10,8	10,2	9,4	11,4	12,4	8,6	9,8	6,6	9,3	8,8
Flow of information	9,87	10,5	10,2	8,3	6,9	9,2	9,6	8,5	10,0	11,1	9,6
Co-operation	9,57	10,3	10,0	8,8	9,4	9,4	8,7	8,9	9,1	8,4	8,8
Safety directions and regulations	9,54	9,7	9,6	9,5	8,3	9,7	11,1	9,3	9,8	9,9	8,7
Resourcing for safety	9,01	8,0	10,0	9,1	9,1	9,6	7,9	9,6	10,9	8,2	8,7
Safety training	8,32	8,7	6,6	7,1	7,4	6,4	9,9	8,9	9,2	8,5	9,5
Risk management	7,81	6,9	6,8	7,6	8,6	7,5	9,4	8,7	9,0	9,1	9,3
Safety policy	7,69	7,2	6,8	9,7	10,1	7,6	9,0	7,5	7,6	8,4	9,4
Management	7,69	7,7	7,4	8,4	10,3	6,1	6,0	7,2	8,0	7,4	9,0
Organisation's openness to new ideas	7,29	8,3	6,7	6,3	8,8	5,4	6,2	7,5	6,3	6,8	7,0
Creation of new knowledge	7,17	7,2	8,2	9,5	4,8	11,6	8,9	6,5	6,0	4,7	6,6
Safety attitudes	6,89	5,8	7,6	6,4	10,6	6,6	6,8	7,6	7,1	8,0	6,3
Safety awareness and responsibility	6,70	6,3	6,4	5,0	5,9	6,6	8,7	6,7	5,8	8,8	7,3

References

Conover, W.J. 1999, Practical nonparametric statistics. New York, NY, USA, Wiley.

Cooper, D., 1998, Improving safety culture : A practical guide. Chichester, UK, Wiley .

Friedman, M. 1937, The Use of Ranks to Avoid the Assumption of Normality Implicit in the Analysis of Variance, Journal of the American Statistical Association, 32(200), 675-701.

Gambetti, F., Casalli, A., Chisari, V. 2012, The Human factor in Process Safety management. Chemical Engineering Transactions, vol. 26, 279-284.

Guldenmund, F. 2010, Understanding and Exploring Safety Culture. PhD thesis, Technical University of Delft, Netherlands.

Kasanen, E., Lukka, K., Siitonen, A. 1993, The constructive approach in management accounting research. Journal of Management Accounting Research, vol. 5, 243-264.

Mäkinen, E., Porkka, P.L., Vanharanta, H., Tappura, S., Piirto, A. 2011, Using social media in developing proactive safety culture. Global Partnership Management Journal, vol. 2, no. 1-2, 32-39.

Nonaka, I., Takeuchi, H. 1995, The knowledge-creating company : How Japanese companies create the dynamics of information. New York, USA, Oxford University Press.

Paajanen, P. 2012, Managing and Leading Organizational Learning and Knowledge Creation. PhD thesis, Tampere University of Technology, Tampere, Finland.

Salo-Pihlajamäki, M. 2008, Serpentine – Evaluation method of the organization's safety culture. MSc. thesis, Pori, Tampere University of Technology, (In Finnish), Finland.

Schein, E.H. 2004, Organizational culture and leadership. San Francisco, USA, Jossey-Bass.

Senge, P.M. 1990, The fifth discipline: the art and practice of the learning organization. New York, USA, Doubleday/Currency.

Tannenbaum, S. I. 1997, Enhancing continuous learning: Diagnostic findings from multiple companies. Human resource management, 36(4), 437-452.