IDENTIFICATION OF SAFETY CULTURE LEVEL USING QUESTIONNAIRE SURVEYS

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The aim of the present article is to provide information on the results of the safety culture assessment carried out in three engineering companies in the Czech Republic in 2017. Determining the level of safety culture helps to reveal the weaknesses in the work process from the point of view of safety in a particular company and, of course, it also allows to propose the necessary measures for improvement.

The article builds on the previous publications of the authors; therefore, it no longer announces the theoretical essence of the safety culture, but addresses the practical aspects of the subject based on factual examples. The article has two main parts. First, the issue of investigating the safety culture is described, including one of the selected approaches. The principles and techniques of questionnaire processing are analysed. The next part of the article introduces the results of the assessment.

The issues of safety culture are quite extensive; it is not possible to tackle all of them in a single article. In some areas, the safety culture is not systematically addressed in its complexity. This also applies to engineering. In our workplace, we intensively focus on the issues of safety culture; some partial approaches and results are the content of the present article.

Experience with the described assessment method can be useful or serve as a guide to analyse the level of safety culture in other industrial companies.

KEYWORDS

safety culture characteristics, questionnaire construction, safety performance, safety culture assessment

1 INTRODUCTION

The founder of the General Theory of Systems [Bertalanffy 1975], Ludwig von Bertalanffy, defined that the system is not only determined by its structure but also by rules, by interactions inside and outside the system, and by interactions with the ambient environment.

The human-machine system includes technical and human subsystems, depending on external business, regulatory, and other relationships. For defining the system's effectiveness, various criteria are used that describe the system's functions, the tasks performed, and the individual values. These criteria include structural and dynamic components of activity and are the basis for defining the requirement on the systems, functioning of processes and their participants. One of such criteria is reliability.

Recently, safety of technical aspects of reliability has been carried out at a high level, which is reflected in a statistically significant reduction in the number of hazardous events due to a failure of technology. The number of errors on the basis of various organizational deficiencies also increases. Therefore, in order to define the causes of systems inefficiencies, it is necessary to monitor not only the components of the system but also the structure of their activities as well as the characteristics of the activity subjects themselves. At present, in industrial practice, the importance of automation is growing; this is also often implemented with the aim to increase efficiency and safety, reduce workload and the impact of human error. However, human-automation interactions can have consequences for human work and safety as automation can create new errors and worsen their detection. [Lutzhoft et al. 2002].

Safety performance is a very complex and sensitive area of interest in the organization because it depends on the individual characteristics of the respective person, his/her abilities and competence, which also influences decision-making and performance [Enshassi et al. 2008].

Reports from major accident investigations confirm that the organizational aspect also has a critical impact on safety. Also, the safety culture affects the safety outcome and proves that most of the operational incidents are not only the result of a failure of human factor, a technical failure, or an environmental factor. Often, there are other systemic organizational errors (e.g. fatal combinations of managerial failures, ordinary in-company staff, and a collapse of systems) [ABC 2012].

In recent years, safety culture has been the subject of lively discussion. Previous research has explored various approaches, procedures and techniques in nuclear industry [IAEA 1991], [Ostrom et al. 1993], [Begun et al. 2012], Aviation [Stroeve 2007], Metal processing industry [Braunger et al. 2013], Constriction industry [Molenaar et al. 2002], [Slates et al. 2008], [Alasamri et al. 2012], [Choudhry et al. 2007], [Fang et al. 2013], Maritime industry [ABC 2012], [Ek, A., et al. 2014], Oil and gas industry [OGP 2013]. A complete list of researched methods is described in the previous article of [Fedorycheva et al. 2015].

It has been found out that the best choice for assessing the safety culture is a comprehensive analysis through interviews, questionnaires, observation and documentation checks-ups [Ignatchenko 2012].

This article presents the results of a questionnaire survey that was processed on the basis of a socio-psychological approach which was previously successfully applied in nuclear power engineering.

The article has two main sections. Firstly, we will examine the question of safety culture measurement by the questionnaire, where the principles and techniques of a questionnaire design will be considered.

The next section briefly outlines the examples of the results of investigation in 3 companies.

The conclusion section summarizes the main findings and the most important messages with regard to the assessment of the safety culture.

2 APPROACH TO QUESTIONNAIRE CONSTRUCTION

A large number of factors influencing the humans predetermines the need for an integrated approach to analysing the safety culture in a particular company.

The questionnaire described in this article and constructed by our research team was used in selected engineering companies. The questionnaire consists of five blocks.

Block 1 – Is focused on finding the employees' views on safety characteristics and safety behaviour at work. Based on this, the stages of safety culture development are defined.

Block 2 – Employees opinions on the most troublesome issues or areas of concern in which the employees have problems.

	External factors as a condition and means of work
Artefacts and symbols	• workplace ergonomics • ergonomics of technologies • ergonomics of regulatory documents • workplace hygiene • latent error of project and erection
Espoused Values	• social-psychological situation • social conditions
	External organizational factors • external communication • purpose and strategies • functions of management and control • resource assignment • human resource management • staff training • coordination of operations • communication • organizational knowledge • organizational culture
Basic underlying assumptions	**Internal factors** • motivation (personal values, priorities) • professionally important qualities • psychophysiological qualities • characteristics of thinking, memory, concentration • functional status • professional competency - skills, attainments

Figure 1. Interrelation between Schein's organizational culture levels and factors influencing the safety culture development

Block 3 - Positive factors that attract people to work in the respective company.

Block 4 - Identifies the area (s) of activity to improve the level of safety culture.

Block 5 - Identifies weaknesses in organizational safety factors according to respondents' views.

Here is a description of the individual parts.

2.1 Safety questions as a part of research (Blok 1 a 4)

Depending on the stage the company is being found in, the concept of safety culture development is defined. In the literature. there are three stages in the development of safety culture:

Stage 1 - Safety based on rules and regulations.

In this case, safety is seen as an external requirement. These requirements are, for example, governmental orders, standards or requirements of supervisory authorities. Safety is seen as an external problem and must "meet" the relevant regulations, standards, etc. Characteristics of the companies in the first stage are, for example, the following [IAEA 2002] problems are not predictable and the organization responds to the problems that have already arisen, comunication between the departments of the organisation and between the respective functions is weak, cooperation and co-decision-making is limited, people who make mistakes are blamed for inability to comply with regulatory requirements.

Stage 2 - Safety is considered to be the goal of organization.

At this stage, safety is no longer seen as an external requirement. However, the problem is that the management of the company always focuses only on technical and process solutions. Safety is taken as a necessity to meet the set goals. The characteristics of companies in Stage 2 are, for example, the following: [IAEA 2009]. There is a growing awareness of the impact of culture at the workplace, although it is unclear why the increased control and training do not seem to be expected to improve safety, the management promotes communication between departments and organization functions, a response of management to the mistakes consists in implementing additional inspections and procedures and ensuring further retraining; the organization is willing to learn from the experience of external groups, especially if it is a new technique and best practice.

Stage 3 - Safety can always be improved.

Companies at this stage put emphasis on continuous improvement with a strict focus on safety. The company places great emphasis on communication, training, managerial style, and increase in efficiency and effectiveness. The staff in the organization understand the impact of culture issues on safety. Some features of the organization in Stage 3 are as follows: [IAEA 2002]. Problems are anticipated and addressed before they have arisen, a cooperation between the departments and functions in the organisation is good, there is no conflict between the performance of manufacturing tasks and safety.

In order to identify the real characteristics of the company and determine the development stage, the questionnaire includes the questions about management policy, the attitude of the company towards development of safety as a priority, availability of safety measures, analysis of near misses, processing of corrective measures, tuning of communication in the company, and appropriate information for the employees on possible risks.

2.2 Social-psychological part of research (Bloks 2, 3, 5)

As consistent with previous study [Abramova 2009], three categories of factors which influence the safety culture development are correlated with the organizational culture levels (developed by E. Schein [Schein 2004]), as illustrated in Fig. 2.

Imbalances in motivation and personal qualities are a potential source of inappropriate situations that could lead to dangerous events in life and operation. Work competencies of the employee are his/her individual data necessary for a safe and successful activity, such as psycho-emotional stability in respect to external negative influences, high-quality professional competence, psychological readiness to work under any production conditions and regimes, and the pursuit of high reliability. The developed work competencies of the employees characterize a high level of safety culture in the work environment. There is also the opposite, such as inadequate professional readiness, persistent anxiety that reduces the ability of humans to orient themselves and respond to situations; this characterizes a low level of safety culture.

	Agree	Neither	Disagree	I don't know
Do you think your strict compliance with the rules and standards can ensure production safety?				
Do you analyse your own mistakes in collaboration with colleagues or supervisors (even if these do not have a significant impact on safety)?				
Even if the system fails, we are still expected to achieve the targets that are set for us				

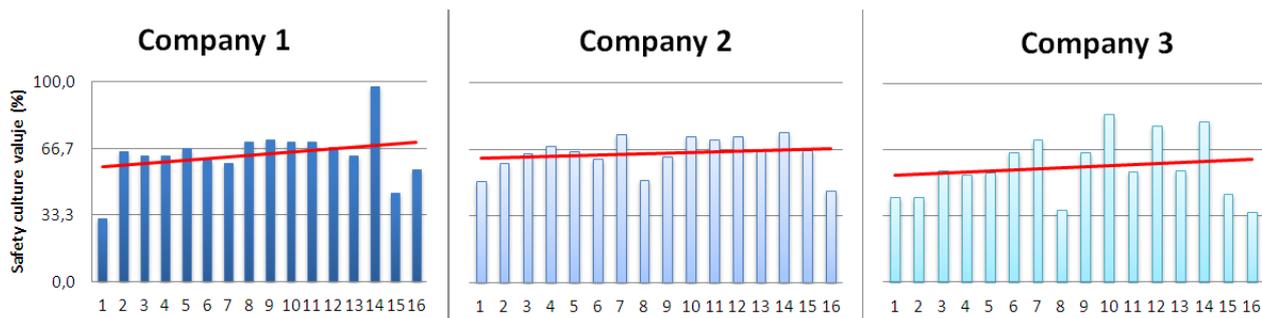**Table 1.** Example of safety culture questions

Figure 2. Results of safety culture assessment

Designed factors in system interaction affect the functional status and professional reliability of employees, which predestines the normal and stable operation of the company as a social system.

On the basis of the theory studied in literature, the questionnaire includes subjects of questions that give an overview of how much the symptoms of safety culture are manifested in the behaviour and activity of management and company staff in production.

As a result, the questionnaire survey is based on a combination of socio-psychological questions and questions arising from safety culture characteristics. These take into account not only the opinions of employees with regard to safety, but also their attitude to the existing sociological problems that could affect the overall status of the interviewed persons. The questionnaire was constructed and performed in the Czech language. For the purpose of his article, some questions were translated into English and are listed in Table 1.

3 RESULTS OF INVESTIGATION

Fig. 2 presents graphically the results of the safety culture assessment held in three different manufacturing companies in the Czech Republic.

3.1 Procedure and Sample

In 2017, three Czech companies were offered an anonymous survey to determine the level of their safety culture. During the survey, exclusively, the opinion of the employees themselves was taken into account. The safety of technical equipment, safety rules or their compliance with the personnel have not been checked. However, this information already shows the state of the psychological [climate in the company, helps to identify weaknesses and the areas that are not given a sufficient attention due to the routines, which creates a tense atmosphere in the mood of the employees in the monitored company [IAEA 2006], [Begun et al. 2012], [IAEA.org 2011].

The survey was attended by:
Company No. 1 - 30 employees (9 - administrative workers, 21 - operational personnel),
Company No. 2 - 81 employees (27 - administrative workers, 54 - operational personnel),
Company No. 3 - 63 employees (18 - administrative workers, 45 - operational personnel),

3.2 Processing of results

The questionnaires were constructed in accordance with the specific safety characteristics, and the socio-psychological part of the questionnaire described in the previous section. In blocks 1 and 5 of the questionnaire, the four-point Lakert scale

[Abramova 2009] was used. Depending on the meaning of the question, points were assigned to answers, "do not know" = 0 points, "Yes" = 1, "Yes and no" = 2, "No" = 3, "Yes and no" = 2, "No" = 1. In blocks 2 and 3, it was offered to rate each item according to its significance for the respondent at present (1 - most important), block 4 - it is possible to select several variants of safety development in the company. The last question is open, the respondent is offered the opportunity to leave a comment and his/her opinion about the safety in the company and how it can be improved.

The questionnaire rating was calculated using the following method [Reva 2012]:

1. For each question, the calculation will determine the number of points for respondents' answers. Next, the mean of points is determined, specifically for respondents - administrative workers (K_{adm}), and for operational personnel (K_{vr}).

2. For each question, the arithmetic mean of points is calculated (1), where N is the number of respondents.

$$K_{pr} = (K_{adm} + K_{vr})/N \qquad (1)$$

For questions on safety (Blocks 1 and 4), disagreement and agreement coefficients are determined.

$$K_{ns} = |K_{adm} - K_{vr}|/K_{pr} \qquad (2)$$

$$K_s = 1 - K_{ns} \qquad (3)$$

4. The rating of safety culture level (KB) is obtained according to the relationship where K_{max} is the maximum possible number of points per question (considering that KB ideal = 1).

$$KB = (K_{pr} \times K_s)/K_{max} \qquad (4)$$

For clarity, the rating of safety culture level (KB) is also given in percentage (KB%).

3.3 Results

As can be seen in Fig. 2, the overall level of safety culture is, within the stage 2, close to the stage 3, which characterizes the effort to improve the organizational conditions of the operation by an increase in control as an administrative function.

In Company № 2, the indicators are more stable, a decline of rating in other companies can indicate the uncertainty of respondents and weak areas that need to be compared with other questions and explored in detail using other methods.

As highly positive, the following factors were highlighted:
- the use of safety sheets for reporting of near misses is sufficiently supported,
- Specific analyses of errors, near misses and accidents are used during the safety training.

Half of the respondents in Company № 1 left a comment on the last open question, which reflects the employees' interest in

safety issues and confirms the high level of safety culture. Some of the views are as follows:
- It would be a good idea to have a computer program where you could write down the problems at the workplace that could be solved,
- Rather than tackling reliability, it would be better if there were no dangerous obstacles at the workplace.
- It would be appropriate to get a personal financial bonus for 0 injuries per year.

In other companies, problems were pointed out as for the ergonomics of individual workplaces, communication between employees, training on possible risks, etc.
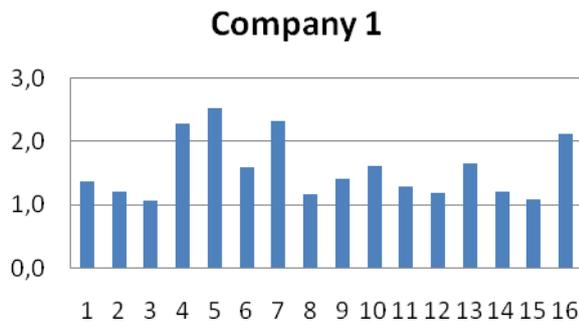
Company 1

Figure 3. Socially significant areas in Company 1

Identified socially significant areas (the first three in descending order) in Fig. 3, brackets show the arithmetic means obtained from the points for each question.
Company № 1 - Relationships with managers (1.08), working atmosphere, relationships with colleagues (1.08), financial evaluation (1.16), self-education and personal development (1.18).
Company № 2 - Relationships with managers (1.30), Occupational health protection (1.32), Financial evaluation (1.32), Preference for occupational safety (1.35).
Company № 3 - Financial evaluation (1.46), occupational health protection (1.52), quality of in-company catering (1.54).
This block of questions is important for processing corrective measures and making changes in the organization. Satisfaction in the priority areas, identified during the survey, affects the overall satisfaction of employees [Crocker 1995]. According to the principle of Pareto-the impact on these 20 % significant areas will bring 80% efficiency.
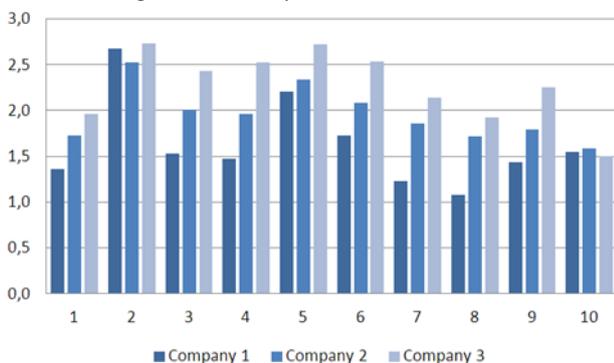

Figure 4. Rating of causes of devotion to the company

Rating of causes of devotion to the company (in other words, the company strengths from the employees' point of view) are shown in Fig. 4:
Company No. 1 - Trust and openness among employees and managers (1.08), career advancement (1.23), company prestige (1.36). During the interviews with some employees, it was found that the company employee-superior communication

system was very well worked out, the employees had the opportunity to address the top manager with a possible question, which was aptly worded "the director's door is open for everyone".
Company № 2 and Company № 3 (have the same rating) – distance of the company from the place of residence (1.58 and 1.50), trust and openness between the employees and managers (1.72 and 1.92), company prestige (1.73 and 1.97).
One of the strategies to improve the company (and also personalities) is to improve the strengths. Improving in the direction of strong points will improve the situation and the weak points. This must be taken into account when making corrective measures [Jebb 2015].
Measures needed to prevent dangerous actions at work, in the respondents' opinion, were almost the same in the three companies, and were the following:
- Modernization of equipment
- Purchasing better protective gear
- Staff training.
Organizational problems in the company that need to be improved (Fig.5):
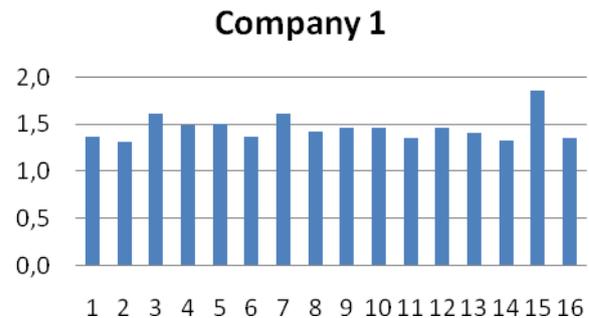
Company 1

Figure 5. Organizational problems in the company that need to be improved

Company № 1 - communication between departments (1.31), ergonomics of individual workplaces (1.33), division of responsibility (1.36). As mentioned above, the employee-supervisor communication system is very well worked out in the company. As can be seen from the rating, there is likely to be a problem in communication between departments.
Similar applications have recently gained popularity; they are commonly used in aviation [Stroeve 2007], nuclear and chemical industries, marine [ABC 2012]. There are examples of using special safety applications in large warehouses and shops. Regarding the ergonomics of workplaces, the following comment was made: "Rather than solving reliability, it would be better not to have dangerous mechanical obstacles in the workplace."
Company № 2 - Ergonomics of individual workplaces (1.20), solutions to everyday staff problems (1.32), monitoring of corrective measures (1.34). Rating is confirmed by respondents' comments. Regarding the ergonomics of the individual workplaces, the following examples have been given - cranes collide, poor table layout - no worktops can be rotated without the fear of injuring someone, we constantly knock on our colleagues when we transport the boards.
Company № 3 - Organization and planning of work (1.08), communication between departments (1.19), shortcomings in working documentation (1.28). The monitored company started to operate approximately two months before surveys were carried out, which explains the result of the point calculation. The company was in the stage of identifying and specifying the internal processes in the organization as a system[Samra et al. 2009]. However, specific cases of existing problems need to be

identified during the next stages of the survey (interviews, focus groups and others). Otherwise, a special internal anonymous line (telephone number) can be used to refer to an idea or a problem at work (there are large posters with all the information necessary in the production halls).

4 CONCLUSIONS

Finally, we can say that, using questionnaires, we can obtain some benefits, such as obtaining information that is representative of the whole or part of the organization. Information can be quantified and the results compared between the groups over time. Questionnaires provide a higher degree of anonymity and make the respondent less stressful. However, questionnaire investigations can identify only some of the symptoms; another study is needed to identify the causes of the answers. To properly formulate the questions is very important to avoid the risk of misunderstanding. It is also difficult to obtain information on various aspects of the situation [IAEA 1991]. We can increase the number of completed questionnaires by making the questionnaire proposal attractive, short, and concise.

In addition, safety culture research is one of the ways of feedback between the management and the employees. Even the present study, as described here, has highlighted the need to identify subjects that have a direct impact on the staff productivity.

Performing the questionnaire survey was the first step in assessing the company's safety culture and defining the current state of the safety culture, identifying the factors that affect the company's safety culture. To analyse the values of the company under monitoring and how it is all reflected in safety, the following additional methods and steps are appropriate:

• Interviews with employees, with lower and middle management, with top management of the company.

• Analysis of documents (policies, standards, results of safety audits, annual reports).

• Analysis of safety reports (frequency of reports of near misses, identification of problems and areas of interest as indicators of employees' interest in the development and improvement of production).

• Sociometric survey (as needed).

In cooperation with the company management, it is necessary to implement specific measures. Over a period of time (1-1.5 years), it is necessary to carry out a reassessment of the state of safety culture, assessment of effectiveness of the measures taken, and reimplementation of new specific measures.

REFERENCES

[ABC 2012] ABC, Guidance notes on safety culture and leading indicators of safety. (Updated February 2014). Houston: American Bureau of Shipping Incorporated (ABS), 2012.

[Abramova 2009] Abramova, V. Organizational psychology, organizational culture and safety culture in the nuclear power industry. Part 1: psychology and methods of evaluation of organizational culture and safety culture at nuclear power plants (in Russian). Moscow: IG-SOCIN, 2009. ISBN 978-5-91070-040-0.

[Alasamri et al. 2012] Alasamri, H., Chrisp, M., Bowles, G. A framework for enhancing and improving the safety culture on Saudi construction sites. In: Proceedings of the 28th Annual ARCOM Conference, Association of Researchers in Construction Management, Edinburgh, September, 2012. pp. 475-485.

[Bertalanffy 1975] Bertalanffy, L. von, Perspectives on general system theory: scientific-philosophical studies. New York: G. Braziller, c1975. ISBN 08-076-0797-5.

[Begun et al. 2012] Begun, V. V., Shirokov, C. V., Begun, C. V., Pismennyj, E. N., Litvinov, V. V. and Kazachkov, I. V. Safety Culture in nuclear power engineering industry (in Russian). Kiev: NAEK "Energoatom", 2012. ISBN 978-966-2726-12-1.

[Braunger et al. 2013] Braunger, P., Frank, H., Korunka, Ch., Lueger, M., Kubicek, B. Validating a Safety Climate Model in Metal Processing Industries: a Replication Study. International Journal of Occupational Safety and Ergonomics (JOSE), 2013, Vol.19, No.1, pp 143-155.

[Choudhry et al. 2007] Choudhry, R., Fang, D., Mohamed, S. Developing a Model of Construction Safety Culture. Journal of Management in Engineering, 2007, pp. 207-212.

[Crocker 1995] Crocker, M., The Economics of Safety Management. Internal publication. London: Travers Morgan Ltd at Watford, 1995.

[Ek, A., et al. 2014] Ek, A. et al. Relationships between safety culture aspects – A work process to enable interpretation. Marine Policy [Online]. 2014, Vol.44, pp. 179-186. [Accessed: 19-May-2016]. Available from http://linkinghub.elsevier.com/retrieve/pii/S0308597X13001784.

[Enshassi et al. 2008] Enshassi, A. et al. Safety Performance of Subcontractors in the Palestinian Construction Industry. Journal of Construction in Developing Countries, 2008, Vol.13, No.1, pp 51-62.

[Fang et al. 2013] Fang, D., Wu, H. Development of a Safety Culture Interaction (SCI) model for construction projects. Safety Science, 2013, pp. 138-149. ISSN 09257535.

[Fedorycheva et al. 2015] Fedorycheva, I., Hammer, M. A description of methods and techniques of safety culture research. MM Science Journal [online], 2015. [Accessed: 19-May-2016]. Vol.2015, No.04., pp 756-759. DOI: 10.17973/MMSJ.2015_12_201556. Available from http://www.mmscience.eu/content/file/MM_Science_201556.pdf.

[IAEA 1991] IAEA. Safety series. Safety Culture: A report by the International Nuclear Safety Advisory Group. 75-INSAG-4. Vienna: International Atomic Energy Agency, 1991. ISBN 92-0-123091-5. ISSN 10252169.

[IAEA 2002] IAEA. Self-assessment of safety culture in nuclear installations: highlights and good practices. IAEA-TECDOC-1321. Vienna: International Atomic Energy Agency, 2002. ISBN 920117702X.

[IAEA 2006] IAEA, The management system for facilities and activities: safety requirements. GS-R-3. Vienna: International Atomic Energy Agency. 2006. ISBN 92-010-6506-X.

[IAEA 2009] IAEA. The management system for nuclear installations: safety standards. GS-G-3.5. Vienna: International Atomic Energy Agency, 2009. ISBN 978-920-1034-090.

[IAEA.org 2011] IAEA.org. Safety Culture: After the Fukushima accident. International Atomic Energy Agency, 2011, [online]. [Accessed: 19-May-2016]. Available from http://www-ns.iaea.org/tech-areas/operational-safety/safety-culture-home.asp..

[Ignatchenko 2012] Ignatchenko, A. Safety culture assessment methods: report (in Russian). In: Proceedings of the IV International scientific-practical conference of safety culture from NAEC "Energoatom", Kiev, 2012.

[Jebb 2015] Jebb, S. Reducing workplace safety incidents: bridging the gap between safety culture theory and practice.

Doctoral Thesis. Queensland: Queensland University of Technology, 2015.

[Lutzhoft et al. 2002] Lutzhoft, M. H. and Dekker, S. W. A. On your watch: automation on the bridge. Journal of Navigation, 2002, Vol.55, No.1., pp 83–96.

[Molenaar et al. 2002] Molenaar, K., Brown, H., Caile, S., Smith, R. Corporate Culture: A study of firms with outstanding construction safety. ASSE Journal of Professional Safety, 2002, pp. 18-27.

[OGP 2013] OGP, Shaping safety culture through safety leadership: Report No. 452. UK: International Association of Oil & Gas Producers, 2013.

[Ostrom et al. 1993] Ostrom, L., Wilhellmsen, C., Kaplan, B. Assessing safety culture. Nuclear Safety, 1993, Vol. 34, No 2, pp. 163-172.

[Reva 2012] Reva, N. Analysis of the Safety Culture survey results and suggestions for improving questionnaires. In: Proceedings of the IV International scientific-practical conference of safety culture from NAEC "Energoatom", Kiev, 2012.

[Samra et al. 2009] Samra, J., Gilbert, M., Shain, M., Bilsker, D. The Business Case for Psychological Safety & Health. Consortium for Organizational Mental Health Care (COMH), 2009.

[Schein 2004] Schein, E.H. Organizational culture and leadership, 3rd ed. San Francisco: Jossey-Bass, 2004. ISBN 07-879-6845-5.

[Slates et al. 2008] Slates, K., The Effects of Leadership in the High Hazard Construction Sector. Leadership and Management in Engineering, 2008, pp. 72-76. ISSN: 1532-6748.

[Stroeve 2007] Stroeve, S.H., Sharpanskykh, A., and. Blom, H.A.P. National Aerospace Laboratory NLR. Literature survey of safety modeling and analysis of organizational processes: Eurocontrol CARE Innovative Research III, NLR-CR-2007-156. Eurocontrol, 2007.

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