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# Expanding Resilience Indicators: A Case Study on Buffering Capacity Indicator in a Process Plant

Gholam Abbas Shirali,[1,*] Liela Mohammad Salahi,[2] and Mohammad Javad Zare Sakhvidi[3]

[1]Department of Occupational Health Engineering, School of Public Health, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, IR Iran
[2]National Iranian Oil Products Distribution Company, Ahvaz Region, Ahvaz, IR Iran
[3]Department of Occupational Health, Faculty of Health, Shahid Sadoughi University of Medical Sciences, Yazd, IR Iran

[*]*Corresponding author*: Gholam Abbas Shirali, Department of Occupational Health Engineering, School of Public Health, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, IR Iran. Tel: +98-6133738269, Fax: +98-6133738282, E-mail: Shirali@ajums.ac.ir

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## Abstract

**Background:** The complexity of modern sociotechnical systems has created new challenges for safety, so that traditional approaches are not able to cope with them. Resilience engineering (RE) is a good alternative to traditional approaches for safety management, however resilience is still a difficult concept to measure, and indicators such as buffering capacity, flexibility, and so on, which are thought to contribute to it, are undeveloped.
**Objectives:** This study aimed at expanding buffering capacity as one of the main indicators in order to facilitate measurement of resilience of a system.
**Materials and Methods:** We used the Delphi method in order to identify indicators, and data related to all the indicators were gathered by observation and interview. In this line, 32 of the experienced operators with at least 15 years of operational record were selected for semi-structured interviews. Gathered data was processed by the principal component analysis technique. The results were processed by the Minitab 15 software.
**Results:** In this study, 29 factors affecting this indicator were determined using the Delphi method; the scores of all factors were less than the scores of the best practice. On the other hand, the state of this indicator was poor in plant included in the study.
**Conclusions:** This was the first study that focused on expanding resilience indicators, and presents a new framework to simplify assessment of resilience and safety of a complex system.

*Keywords:* Buffering Capacity, Safety, PCA, Resilience Engineering

## 1. Background

The complexity of the current sociotechnical systems has created new challenges in safety systems (1); because the impracticability of having full control over and full knowledge of the complexity in these systems has not been clearly taken into consideration when designing safety systems dominate in the industry (2). Hence, limits and systemic impacts (2), such as complexity and variability of interactions are not usually assessed in safety practices. On the other hand, since risks can emerge as non-linear combinations of performance variability among the system components, traditional approaches of risk assessment are not able to capture these combinations and establish a false feeling of risk and control (3, 4). Such situation in turn may lead to brittleness of some or the entire complex system. This property is usually found in a tightly coupled system where one subsystem impacts other coupled subsystems immediately. Although propagation time in these systems is fast, yet they should be able to anticipate the main breakdowns in the design phase in order to provide engineering safeguards for safe operation and recovery of the system (5); in this state they are considered safe. In contrast, in sociotechnical systems, human performance cannot be described as if was bimodal (6). That is to say, most of the human-related systems in a modern organization normally have high response time and high flexibility in nature and intensity of responses-loosely coupled systems (5). These properties enable characteristics such as recovery from breakdowns and adaptation, giving proper (complex) information to cope with pressures for change, errors, and breakdowns in a more resilient way than tightly coupled systems that quickly respond to environment disturbance. Of course, the intrinsic resilient properties of loosely coupled systems do have limitations, especially when sudden changes in the environment transform a loosely coupled situation into a tightly coupled one (5).

In summary, the nature of things that go wrong are the same as the things that go right, i.e., there are several reasons for this, where root cause analysis cannot and should not, be used in such systems (6). However, it has become clear that traditional approaches such as risk analysis and probabilistic safety assessment (PSA) are not able to provide the much needed solutions (7). The need to develop new approaches or mechanisms is completely felt in these areas. In this light, resilience engineering (RE) is a good alternative to traditional approaches for safety management (8). Resilience Engineering, which is a new paradigm in safety management, is concerned with normal work, rather than emphasis on learning from accidents (9, 10); its aim is to identify, analyze and improve the resilience of systems. So far various definitions of resilience have arisen in the literatures. According to one of them, RE was defined as the intrinsic ability of a system to adapt its function before, during, or after a major mishap or change, so that it can continue the operations required under both expected and unexpected conditions (11).

### 1.1. Factors that Contribute to Resilience

Definitions of organizational resilience and the associated factors or attributes were found in numerous studies (12). Hollnagel (2005) proposed a set of factors that contribute to RE developed in an organization, including buffering capacity, flexibility, margin, tolerance, and cross-scale interaction (13). However, they did not explain what these factors themselves were comprised of. Therefore, as wood stated: we can only measure the potential for resilience but not resilience itself (14). In this line, he has presented the aforementioned factors, yet there are no specific criteria to assess them and thus it is very difficult for the managers to develop accurate numerical models to describe and predict these intangible factors.

### 1.2. Buffering Capacity

Buffering capacity relates to size or kind of disruptions, which a system is able to absorb or adapt to without a fundamental failure or breakdown in performance or in the system's structure (10). As previously mentioned, measuring and assessing the buffering capacity (like the other factors) is difficult because it is very hard to find examples of buffers, which absorb or adapt to disruptions (15) in the industries under study.

In this work, the authors tried to expand the buffering capacity indictor in a process industry, in order to simplify assessment of resilience of the industry. They identified 29 factors that directly and/or indirectly effected buffering capacity and assessed these effects through principal components analysis (PCA). The factors were identified by an expert team based on the Delphi method (16).

## 2. Objectives

This study aimed at expanding the buffering capacity, as one of the main indicators, in order to facilitate measuring the resilience potential of the mentioned plant.

## 3. Materials and Methods

### 3.1. Identification of Factors Contributing to Buffering Capacity

In order to obtain the most reliable consensus of a group of experts on the subject, experts in line with the guidelines of Okoli et al., (16) were selected and detailed information (by seminar, training) about resilience and its factors was given to experts during the communication process based on the Delphi method and expert panels. Accordingly, two expert panels with individuals from various specialties, such as chemical engineering, mechanical engineering, process engineering, industrial safety engineering, industrial management, operator, and shift operator were formed to determine the factors affecting each indicator using brainstorming, narrowing down and ranking (For more information see (16). The purpose of this formation was to determine whether the factors were able to measure and assess the desired indicators are appropriate or not? (17) Finally, the group selected 29 items, which may contribute to buffering capacity in the industry under study. They also allocated weights to each item from zero to one hundred in order to prioritize the factors.

### 3.2. Assessment of Effect of the Identified Factors on the Buffering Capacity

In order to assess the buffering capacity of the plant and the effect of the mentioned factors, 32 of the experienced operators with at least 15 years of operational record were selected for semi-structured interviews (in this method, the interviewer had a set of themes from which the questions were selected so that the interviewer was able to rate the responses on a five-point scale, i.e. from very negative = 1 to very positive = 5). These operators had been working in various operational units, i.e., they were selected among different units. After the interview, the research team processed the data through PCA. Because of the large number of variables, complex relationships, and elimination of data redundancy, in this study was used in the PCA method. This method due to its simplicity and straightforward interpretation is most suitable for such studies.

In this study in order to compare the obtained results from the PCA with a reference value, we also calculated the best practice (see (18) for more information). Because management of the plant was not able to identify their weaknesses, the research team solved this problem only with the PCA scores.

A reference value was designed using responses of the respondents. In order to design such reference, first, distribution of the data and its Skewness were determined. Then, the reference questionnaire as best practice was designed with regards to the data Skewness, safety experts and statisticians comments (18).

## 4. Results

### 4.1. Factors Affecting Buffering Capacity

As explained in section 4.1, the expert panel with consent could identify all factors, which influenced buffering capacity in the mentioned industry. These factors are presented in Table 1.

### 4.2. The Results of Principal Components Analysis

Table 2 shows eigenvalues and eigenvectors obtained from the correlation matrix of indices. In the third line of the the the cumulative percent of the sample data is reported. As indicated, the amounts of the first ten component (PC1, PC2, PC3, ... and PC10) values are 94.2%, i.e., 94.2% of the data variability was comprised. Therefore, it was ignored from the other components. The scores of principal components and consequently their aggregated weights are presented in Table 2. The scores of PCA of best practice were also shown in the Table 3.

## 5. Discussion

Because directly measuring the buffering capacity of a system is difficult for researchers; thus it is required to identify factors, which directly or indirectly contribute to it. Based on this problem, the research team identified all factors, which may affect the buffering capacity of the plant under study. In line with this, they could identify 29 factors using the Delphi method (Table 1). Therefore, the authors could indirectly assess the buffering capacity of the plant with measure these factors.

Comparing between the PCA results of the data gathered through interviews and the best practice, showed that there existed a significant difference ($P < 0.017$) between the two groups. In other words, the results indicated that the buffering capacity of the plant was poor in comparison with best practice.

The analyses showed that in order to improve the buffering capacity of the system, changes should be done in the factors' status. These changes may be negative or positive. In other words, in order to improve the buffering capacity of the system, the score of factors of 12, 14, 15, 16, 17, 21 and 23 should be reduced, since these factors have a negative effect on the buffering capacity of the plant. In this light and for the purpose of improving the buffering capacity of the system, the management of the plant should try to increase the level of knowledge of the system in order to decrease the level of complexity and uncertainty of the system. The redundancy in the system should be decreased because it increases interactive complexity and opaqueness and encourages risk taking. The management can also enhance the buffering capacity using a suitable work design (hardware and software), because it in turn can lead to decreased work load, gap between imagined work and actual work, goals conflict, and stress at work.

Apart from the above factors, the score of the rest should be increased, because they have a positive effect on buffering capacity. The score of factors of 1, 3, 5, 9, 10, 18, 19, 20, 25, 28, and 29 are much less than the scores of the best practice. This means that the system's weakness in factors such as adaptation, training and instruction, management of change, monitoring, devoting resource, safety equipment, improving drift to danger, maintenance, sacrifice decision making, decentralization management, and production pressure is more considerable than the other factors in this group (Table 3). Of course, the rest of the factors of this group also had lower scores in comparison with the best practice scores, and their scores should also be improved in order to increase the buffering capacity of the plant.

### 5.1. Conclusion

The literature review indicated that studies have only focused on resilience indicators and the manner of measuring or estimating the potential of RE using these indicators. On the contrary, this paper aimed at expanding the resilience indicators in order to simplify measuring or estimating resilience in complex systems. In this light, buffering capacity as one of the resilience indicators was typically selected and assessed. Therefore, this paper can open a new window in the RE area in order to assess and measure resilience indicators and consequently, measure or estimate the potential of the RE.

However, one of the major limitations of this study was that it only expanded the buffering capacity and the rest of the indictors remained undeveloped. Therefore, future researches should be focused on other indicators in order to present a full paradigm for facilitating resilience assessment of complex systems.

**Table 1.** Factors That Contribute to Buffering Capacity

| No. | Item | Description |
|---|---|---|
| $C_1$ | Adaptation | Knowledge in terms of anticipation, attention, and response to variability or change of things (13) |
| $C_2$ | Sense-making | What people do in order to decide how to act in the situations they encounter (19) |
| $C_3$ | Training and instruction | Helping employees learn how to do work (training), and what they should do (instruction) |
| $C_4$ | Competence | What a person is capable of doing (20) |
| $C_5$ | Management of change | Effects of change on the workforce/organization, product quality, including training requirements (21) |
| $C_6$ | Management and documentation of margins | Determining margins or boundaries and their erosions, and recording the information about them |
| $C_7$ | Self-reporting | Reporting incidents, errors, violations, failures, etc. by the workers |
| $C_8$ | Self-efficacy | The measure of one's own ability to complete tasks and reach goals (22) |
| $C_9$ | Continuous monitoring | The process and technology used to detect compliance and risk issues associated with an industry and operational environment (23) |
| $C_{10}$ | Resources | Hard wares and soft wares resources, which were utilized to perform work or function |
| $C_{11}$ | Feedback | A process in which information about the past or the present influences the same phenomenon in the present or future (24) |
| $C_{12}$ | Complexity | Something or process with many parts in intricate arrangement (25) |
| $C_{13}$ | Procedures | A set of rules that is used to control operator activity in a certain process (26) |
| $C_{14}$ | Uncertainty | Imperfect prediction of risk in safety management (27) |
| $C_{15}$ | Work as Imagined versus work as actually done | Gap between formal and actual images of work (28) |
| $C_{16}$ | Redundancy | Providing more than one means to accomplish something, where each mean is independent of the other (29) |
| $C_{17}$ | Work demands | Physical, psychological, social, or organizational aspects of the work (30) |
| $C_{18}$ | Safety equipment | Equipment which were used to protect the system and damp variability |
| $C_{19}$ | Drift to danger | Prediction of early warnings and drift to danger |
| $C_{20}$ | Repair and maintenance | Appropriate and timely Repair and maintenance |
| $C_{21}$ | Goals conflict | Interaction and conflict among multiple goals of a system |
| $C_{22}$ | Man-machine interference | The area of the human and the area of the machine that interact during a given task (31) |
| $C_{23}$ | Stress | Total response to an environmental condition or stimulus |
| $C_{24}$ | Job satisfaction | How content an individual is with his or her job (32) |
| $C_{25}$ | Sacrificed decision making | Making strong decision when goals are in conflict or when safety is at risk |
| $C_{26}$ | Situation awareness | The sum of operator perception and comprehension of process information and the ability to make projections of system states on this basis (33) |
| $C_{27}$ | Learning | Learning from failures, accidents, near miss |
| $C_{28}$ | Decentralization control | Distribution of authority throughout the organization and to all levels of management |
| $C_{29}$ | Production pressure | Placing safety at risk due to production pressure |

**Table 2.** The Results of Principal Components Analysis Related to Different Factors

| **Eigenvalue** | **6.298** | **4.418** | **3.560** | **3.065** | **2.470** | **1.919** | **1.759** | **1.602** | **1.257** | **0.978** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Proportion** | 0.217 | 0.152 | 0.123 | 0.106 | 0.085 | 0.066 | 0.061 | 0.055 | 0.043 | 0.034 |
| **Cumulative** | 0.217 | 0.369 | 0.492 | 0.598 | 0.683 | 0.749 | 0.810 | 0.865 | 0.909 | 0.942 |
| **Variable** | PC1 | PC2 | PC3 | PC4 | PC5 | PC6 | PC7 | PC8 | PC9 | PC10 |
| **$C_1$** | -.216 | -0.315 | 0.064 | 0.075 | -0.020 | -0.186 | 0.219 | -0.070 | 0.092 | -0.140 |
| **$C_2$** | 0.244 | -0.057 | -0.062 | 0.225 | 0.076 | -0.108 | -0.119 | 0.041 | -0.494 | -0.072 |
| **$C_3$** | 0.077 | -0.202 | -0.053 | -0.153 | -0.199 | -0.294 | -0.206 | -0.145 | 0.442 | -0.239 |
| **$C_4$** | -0.002 | -0.154 | 0.386 | 0.262 | -0.101 | -0.041 | -0.064 | 0.112 | -0.213 | -0.050 |
| **$C_5$** | 0.206 | -0.371 | -0.038 | 0.075 | 0.058 | -0.059 | -0.057 | 0.126 | -0.113 | 0.054 |
| **$C_6$** | 0.343 | -0.109 | 0.145 | 0.039 | -0.153 | -0.061 | 0.067 | 0.123 | -0.082 | -0.022 |
| **$C_7$** | 0.292 | -0.129 | 0.094 | -0.227 | 0.087 | -0.118 | -0.102 | 0.186 | -0.060 | -0.140 |
| **$C_8$** | 0.319 | -0.054 | 0.061 | 0.183 | -0.183 | 0.052 | 0.091 | 0.160 | 0.240 | -0.041 |
| **$C_9$** | -0.200 | -0.186 | 0.127 | -0.293 | 0.231 | -0.097 | -0.052 | 0.000 | -0.212 | -0.006 |
| **$C_{10}$** | -0.056 | -0.263 | 0.252 | 0.089 | -0.065 | -0.056 | 0.243 | -0.310 | 0.220 | 0.283 |
| **$C_{11}$** | 0.286 | -0.016 | 0.031 | -0.129 | 0.062 | -0.410 | -0.063 | -0.086 | -0.061 | 0.213 |
| **$C_{12}$** | 0.104 | 0.249 | 0.149 | 0.069 | -0.288 | -0.132 | -0.169 | -0.246 | 0.044 | -0.200 |
| **$C_{13}$** | 0.154 | 0.015 | 0.315 | -0.310 | -0.005 | 0.146 | 0.008 | 0.065 | -0.026 | -0.298 |
| **$C_{14}$** | -0.039 | 0.005 | 0.394 | 0.089 | 0.260 | 0.121 | -0.175 | 0.032 | 0.334 | 0.102 |
| **$C_{15}$** | 0.063 | 0.236 | 0.147 | -0.231 | 0.030 | -0.291 | 0.268 | -0.297 | -0.102 | -0.144 |
| **$C_{16}$** | 0.305 | -0.162 | -0.164 | -0.022 | -0.018 | 0.106 | 0.058 | 0.141 | 0.168 | 0.270 |
| **$C_{17}$** | 0.186 | -0.064 | -0.161 | 0.222 | 0.030 | 0.183 | -0.297 | -0.408 | 0.074 | 0.007 |
| **$C_{18}$** | 0.035 | -0.258 | -0.031 | -0.242 | -0.394 | 0.152 | -0.161 | -0.004 | 0.001 | -0.107 |
| **$C_{19}$** | -0.198 | -0.116 | -0.128 | -0.144 | 0.216 | -0.068 | -0.385 | 0.170 | 0.228 | -0.165 |
| **$C_{20}$** | 0.040 | -0.280 | 0.252 | -0.192 | -0.086 | 0.337 | 0.037 | -0.085 | -0.079 | 0.173 |
| **$C_{21}$** | 0.215 | 0.028 | 0.026 | 0.088 | 0.250 | -0.027 | 0.392 | 0.014 | 0.192 | -0.393 |
| **$C_{22}$** | -0.130 | 0.086 | 0.364 | 0.236 | -0.005 | -0.000 | -0.055 | 0.245 | 0.040 | -0.221 |
| **$C_{23}$** | 0.093 | 0.151 | 0.101 | -0.141 | -0.001 | 0.523 | -0.093 | -0.171 | -0.078 | -0.182 |
| **$C_{24}$** | -0.158 | -0.305 | 0.194 | 0.032 | 0.219 | -0.067 | -0.096 | -0.254 | -0.145 | 0.003 |
| **$C_{25}$** | -0.085 | 0.013 | 0.086 | 0.405 | -0.162 | -0.003 | -0.003 | -0.065 | 0.019 | 0.004 |
| **$C_{26}$** | -0.094 | -0.275 | -0.247 | 0.229 | 0.098 | 0.061 | 0.009 | 0.093 | -0.036 | -0.406 |
| **$C_{27}$** | 0.112 | -0.184 | -0.177 | 0.004 | 0.231 | 0.223 | 0.326 | -0.288 | -0.013 | -0.171 |
| **$C_{28}$** | 0.214 | 0.067 | 0.058 | 0.142 | 0.280 | -0.059 | -0.348 | -0.323 | -0.019 | -0.044 |
| **$C_{29}$** | -0.190 | -0.120 | -0.094 | -0.015 | -0.418 | -0.050 | -0.005 | -0.185 | -0.212 | -0.179 |

**Table 3.** The Scores of Principal Components Analysis and Best Practice Related to the Factors

| Code | PCA Score | Best Practice PCA Score | Code | PCA Score | Best Practice PCA Score |
|---|---|---|---|---|---|
| **1** | -0.085 | 0.186 | 16 | 0.056 | 0.186 |
| **2** | 0.024 | 0.186 | 17 | 0.007 | -0.174 |
| **3** | -0.086 | 0.193 | 18 | -0.100 | 0.193 |
| **4** | 0.030 | 0.193 | 19 | -0.083 | 0.193 |
| **5** | -0.003 | 0.193 | 20 | -0.072 | 0.174 |
| **6** | 0.074 | 0.186 | 21 | 0.103 | -0.193 |
| **7** | 0.032 | 0.193 | 22 | 0.409 | 0.186 |
| **8** | 0.096 | 0.186 | 23 | 0.057 | -0.174 |
| **9** | -0.080 | 0.174 | 24 | 0.095 | 0.186 |
| **10** | -0.006 | 0.193 | 25 | -0.080 | 0.186 |
| **11** | 0.029 | 0.193 | 26 | 0.009 | 0.193 |
| **12** | 0.032 | -0.174 | 27 | 0.173 | 0.174 |
| **13** | 0.043 | 0.193 | 28 | -0.431 | 0.186 |
| **14** | 0.087 | -0.193 | 29 | -0.443 | -0.174 |
| **15** | 0.015 | -0.174 | | | |

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## References

1. Qureshi ZH, Ashraf MA, Amer Y. Modeling industrial safety: A sociotechnical systems perspective. in Industrial Engineering and Engineering Management, 2007 IEEE International Conference on. 2007
2. Saurin TA, Carim Junior GC. A framework for identifying and analyzing sources of resilience and brittleness: A case study of two air taxi carriers. *Int J Indust Ergonom.* 2012;**42**(3):312–24. doi: 10.1016/j.ergon.2011.12.001.
3. de Carvalho PVR. The use of Functional Resonance Analysis Method (FRAM) in a mid-air collision to understand some characteristics of the air traffic management system resilience. *Reliab Eng Syst Saf.* 2011;**96**(11):1482–98. doi: 10.1016/j.ress.2011.05.009.
4. Woltjer R, Hollnagel. E. , editors. Functional modeling for risk assessment of automation in a changing air traffic management environment.. Proceedings of the 4th International Conference Working on Safety,. 2008; Greece. .
5. Carvalho PVR, dos Santos IL, Gomes JO, Borges MRS. Micro incident analysis framework to assess safety and resilience in the operation of safe critical systems: A case study in a nuclear power plant. *Loss Prevention in the Process Industries.* 2008;**21**(3):277–86. doi: 10.1016/j.jlp.2007.04.005.
6. Besnard D, Hollnagel DE. I want to believe: some myths about the management of industrial safety. *Cognition, Technol Work.* 2012:1–11.
7. Dekker S, Hollnagel E, Woods D, Cook R. Resilience Engineering: New directions for measuring and maintaining safety in complex systems. *Lund University School of Aviation.* 2008.
8. Hollnagel E, Nemeth CP, Dekker S. Resilience engineering perspectives: remaining sensitive to the possibility of failure. 1. Ashgate Publishing, Ltd; 2008.
9. Saurin TA, Formoso CT, Cambraia FB. An analysis of construction safety best practices from a cognitive systems engineering perspective. *Safety Sci.* 2008;**46**(8):1169–83. doi: 10.1016/j.ssci.2007.07.007.
10. Woods DD. Creating foresight: lessons for enhancing resilience from Columbia. *Organization at the limit: lessons from the Columbia disaster.* 2005.
11. Paries J, Wreathall J, Woods D, Hollnagel E. Resilience engineering in practice: a guidebook. Ashgate Publishing, Ltd; 2012.
12. Shirali GHA, Mohammadfam I, Motamedzade M, Ebrahimipour V, Moghimbeigi A. Assessing resilience engineering based on safety culture and managerial factors. *Process Safety Progress.* 2012;**31**(1):17–8. doi: 10.1002/prs.10485.
13. Hollnagel E, Woods D, Leveson N. Resilience engineering: Concepts and precepts. Ashgate Publishing, Ltd; 2007.
14. Hollnagel E, Woods D. Epilogue: Resilience engineering precepts. ; 2006.
15. Woltjer R, editor. Resilience assessment based on models of functional resonance. Proceedings of the 3rd Symposium on Resilience Engineering. 2008; .
16. Okoli C, Pawlowski SD. The Delphi method as a research tool: an example, design considerations and applications. *Inform Manag.* 2004;**42**(1):15–29. doi: 10.1016/j.im.2003.11.002.
17. Shirali GA, Motamedzade M, Mohammadfam I, Ebrahimipour V, Moghimbeigi A. Assessment of resilience engineering factors based on system properties in a process industry. *Cognition, Technol Work.* 2016;**18**(1):19–31.
18. Shirali GA, Mohammadfam I, Ebrahimipour V. A new method for quantitative assessment of resilience engineering by PCA and NT approach: A case study in a process industry. *Reliabl Engin Sys Safety.* 2013;**119**:88–94. doi: 10.1016/j.ress.2013.05.003.
19. Weick KE. Sensemaking in organizations. 3. Sage; 1995.
20. Eraut M. Concepts of competence. *Journal of Interprofessional Care.* 2009;**12**(2):127–39. doi: 10.3109/13561829809014100.
21. Hansen M.D., G.W. Gammel. Management of Change A Key to Safety Not Just Process Safety. *Professional Safety.* 2008;**53**(10):41–50.

22. Pfister D, Markett S, Muller M, Muller S, Grutzner F, Rolke R, et al. German nursing home professionals' knowledge and specific self-efficacy related to palliative care. *J Palliat Med.* 2013;**16**(7):794–8. doi: 10.1089/jpm.2012.0586. [PubMed: 23701034].
23. Campbell C. Wikipedia: The Free Encyclopedia. http://en. wikipedia. org/wiki, s. vv. Theatre, Performance, and Performance Studies. *TDR/The Drama Review.* 2009;**53**(4):185–7.
24. Wikipedia, Feedback. Wikipedia, the free encyclopedia 2013. http://en.wikipedia.org/wiki/Feedback/.
25. Wikipedia, Complexity. Wikipedia, the free encyclopedia 2013. http://en.wikipedia.org/wiki/Complexity/.
26. Antonsen S, Almklov P, Fenstad J. Reducing the gap between procedures and practice–lessons from a successful safety intervention. *Safety Sci Monitor.* 2008;**12**(1):1–16.
27. Markowski AS, Mannan MS, Kotynia A, Siuta D. Uncertainty aspects in process safety analysis. *Journal of Loss Prevention in the Process Industries.* 2010;**23**(3):446–54. doi: 10.1016/j.jlp.2010.02.005.
28. McDonald N, Corrigan S, Ward M, editors. Well-intentioned people in dysfunctional systems. Keynote Presented at Fifth Workshop on Human Error, Safety and Systems Development, Newcastle, Australia. 2002; .
29. Brauer RL. *Safety and health for engineers.* 2006.
30. Van den Broeck A, Vansteenkiste M, De Witte H, Lens W. Explaining the relationships between job characteristics, burnout, and engagement: The role of basic psychological need satisfaction. *Work Stress.* 2008;**22**(3):277–94. doi: 10.1080/02678370802393672.
31. Eckl R, MacWilliams A. Smart Home Challenges and Approaches to Solve Them: A Practical Industrial Perspective. 2009 ;**53**:119–30. doi: 10.1007/978-3-642-10263-9_11.
32. Chimanikire P, et al. Factors affecting job satisfaction among academic professionals in tertiary institutions in Zimbabwe. *African Journal of Business Management.* 2007;**1**(6):166-175.
33. Kaber DB, Endsley MR. Team situation awareness for process control safety and performance. *Process Safety Progress.* 1998;**17**(1):43–8. doi: 10.1002/prs.680170110.