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Safety Culture Evaluation Model at Construction Site

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Abstract:

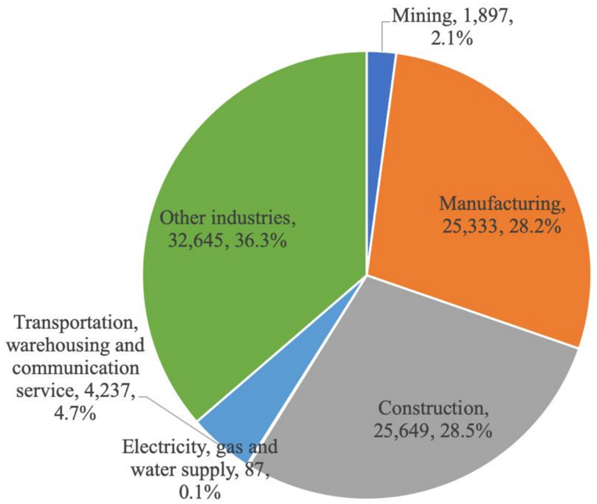
This study was conducted to develop a safety culture evaluation model for construction sites. To develop a safety culture evaluation model, M.D Cooper's model for safety culture was used as an evaluation method, and M. Fleming and D. Parker et al.'s safety culture maturity model was applied as an evaluation standard. In addition, the case study was able to evaluate the level of safety culture at the construction site. However, the evaluation results were expressed in different forms according to the areas of environment, person and behavior, and there was a limit in comprehensively determining the level of safety culture.

Keywords - Construction Industry, Safety Accident, Safety Management, Safety Culture.

I. INTRODUCTION

Many countries, including Korea, the United Kingdom, the United States, Singapore and Australia, are working to reduce safety accidents occurring at industrial sites. This is because disasters not only take valuable lives but also cause great economic losses. Estimates of economic loss due to industrial accidents in Korea increased steadily to KRW 19 trillion in 2013, KRW 19 trillion 600 billion in 2014, KRW 20 trillion 400 billion in 2015, KRW 21 trillion 400 billion in 2016 and KRW 22 trillion 200 billion in 2017 [1]. The number of casualties in the construction industry in 2017 was 25,649 (Figure 1). This represents 28.5% of all industrial accidents. Except for 'Other industries', construction is the most vulnerable industry of industrial accidents. In particular, the smaller the workplace, the greater the number of industrial accidents and deaths from industrial accidents (Table 1). Of these, 72.8% of all deaths occurred at workplaces with less than 50 employees [1]. W.S. Dester and D. Blockley say that 'unsafe behavior' is the biggest contributor to on-site accidents at construction sites, which is why the construction industry's safety culture is evaluated as undesirable [2]. And, in the UK's Health and Safety Executive report, about 90% of deaths on construction sites can be prevented through active management [3]. In addition, M. Kathryn et al. argued that the safety culture must be improved in order to expect desirable safety performance in the construction industry [4]. In the past, the performance criteria for safety were based on lagging indicators indicating the number of casualties, lost working hours and death toll. However, recent trends have shifted to leading indicators such as safety audits and measures of safety climate [5]. These changes are based on the awareness that the primary causes of safety accidents are organizational, managerial and human factors rather than technical problems [6].

Korea has recently begun to study safety culture. In Korea, the study for safety culture of the construction site was mainly conducted by examining the differences of perception in categories and classes through the survey method and analyzing the correlation with safety behavior. However, there is a lack of clear study on what are the problems of the safety culture in the construction site, how these problems are manifested and how to improve the safety culture. This study presented the model to evaluate the safety culture of the construction site using the Safety Culture Model of M.D. Cooper [7] and the Safety Culture Maturity Model of M. Fleming [8] and D. Parker et al. [9], which comprehensively reflect the existing evaluation methods of safety culture. And, the practical applicability was examined by applying the evaluation model to Korean construction sites.



* Other industries are forestry, fishing, agriculture and financial insurance

Fig. 1. Accident status by industry (2017)

Table 1. Industrial accident status by workplace size in 2017

Classification	Fatality		Death rate (‰)
Number of workers	Death toll (Persons)	Rate (%)	
Less than 5 people	301	31.1	1.10
5~49 people	404	41.7	0.51
50~99 people	95	9.8	0.50
100~299 people	97	10.0	0.39
Over 300 people	72	7.4	0.22
Total	969	100.0	0.53

II. PRELIMINARY STUDY

II.I DEFINITION AND COMPONENTS OF THE SAFETY CULTURE

The term 'safety culture' was first used in the first report, "Summary Report on the Post-Accident Review Meeting on the Chernobyl Accident," announced by the International Atomic Energy Agency to identify the cause of the Chernobyl accident. Since then, various studies and definitions of safety culture have been conducted in various fields [10]. In the past, safety management methods have changed from safety technologies such as safety protection methods of facilities, inspection / management methods of dangerous machinery to safety systems such as safety policies, safety work standards, qualifications, capabilities and monitoring. And again, it is changing to a safety culture that emphasizes leadership, behavior, attitude and communication. As shown in Table 2, the terms of safety culture components of major organizations differ slightly. However, it is largely classified into leadership, system, and attitudes and behaviors of members. The first condition for the establishment of a safety culture requires the willingness of leaders to create a safety culture. Also, in order to conduct a safety culture evaluation, it should be classified as leadership, system and members. Evaluation indicators should be established to confirm the implementation of the safety culture for each category.

Table 2. Safety culture components of major organization

Major organization	Classification	Safety culture components
International Atomic Energy Agency, International Nuclear Safety Advisory Group (1999)	A. Policy level	Statement of safety policy, management structure, resources, self-regulation
	B. Management level	Responsibility regulation, definition / control of safety practice, qualification / training, compensation / punishment, audit / review / comparison
	C. Individual level	Problem awareness, through / careful approach, communication
Institute of Nuclear Power Operations (2004)	A. Leader's responsibility	Safety value driven leadership, leader's responsibility in decision making, environment establishment for mutual respect
	B. Member's responsibility	Member's safety responsibility, problem-conscious working attitude, effort for smooth communication
	C. Organization's responsibility	Learning-based organization operation, systematic problem management, free environment for problem raising, safety-first procedure
National Mining Association (2014)	A. Leadership	Responsibility, leadership, reporting, communication, empowerment, immersion
	B. System	Adaptation, trust, justice, awareness
	C. Culture	Attention, learning, training, capability

II.II REVIEW OF PREVIOUS STUDIES

The study for evaluating safety culture was theoretically founded by D. Zohar in 1980 [11]. Since then, many researchers have studied the safety culture evaluation method through a practical approach. In the 1990s, with the survey, a quantitative evaluation method, a study was conducted in parallel with in-depth interviews and behavioral observations to supplement the qualitative analysis [12].

In the 2000s, the necessity of linking of existing methods was emphasized.

Efforts have been made to integrate two or more evaluation methods [13] [14]. There are studies of D.P. Fang et al. [15] and S. Mohamed [16] as representative studies on the safety culture of construction sites. D.P Fang et al. identified factors affecting the safety culture of large construction companies in Hong Kong and analyzed the relationship between the safety atmosphere of the construction site and the safety behavior of the workers [15]. S. Mohamed conducted a study to explore the relationship between safety culture and safety working behavior in construction sites. He selected 10 independent variables including management commitment, safety rules and procedures, and worker's involvement. Safety culture plays a role in coordinating safety working behavior as a dependent variable [16].

III. HOW TO EVALUATE SAFETY CULTURE

III.I SAFETY CULTURE MODEL BY M.D COOPER

M.D. Cooper's model for safety culture establishes the conceptual scope of safety culture. M.D. Cooper's model for safety culture also categorizes the safety culture of the workplace into environment, person and behavioral areas in order to evaluate safety culture effectively [7]. This model focuses on the reciprocal relationships between psychological, environmental and behavioral factors that are commonly presented in Heinrich's accident cause model [17] and case studies of advanced safety firms [18] [19]. The environmental area evaluates the major aspects of the safety management system that are reflected in the safety culture of the workplace. The people area evaluates employees' perceptions and attitudes about shared safety using surveys or interviews. The behavior area uses behavior monitoring to measure the incidence of worker unsafe behavior. M.D. Cooper's model corresponds to triangulation using several methods. Triangulation can increase the reliability of the study results.

III.II SATEFY CULTURE MATURITY MODEL

The safety culture maturity model presents the characteristics of the major categories that make up a safety culture, divided into grades. Representative safety culture maturity models were developed by M. Fleming and Hudson. M. Fleming's model consists of categories with management's visible safety willingness, communication, safety emphasis comparing with production, learning, safety resources, safety engagement, shared awareness of safety, trust, work satisfaction and educational training. D. Parker et al.'s model consists of categories with benchmarking, evaluation and reviewing, accident reporting and analysis, hazard factors and unsafe behavior reporting, work planning and permitting, supplier management, competency and educational training, site safety techniques, site safety management supervision, size and role of safety department, safety performance compensation, accident cause analysis, safety and health environment and benefits, safety meetings, safety communication between classes, and procedures. The safety culture maturity model consists of five grades of safety culture maturity.

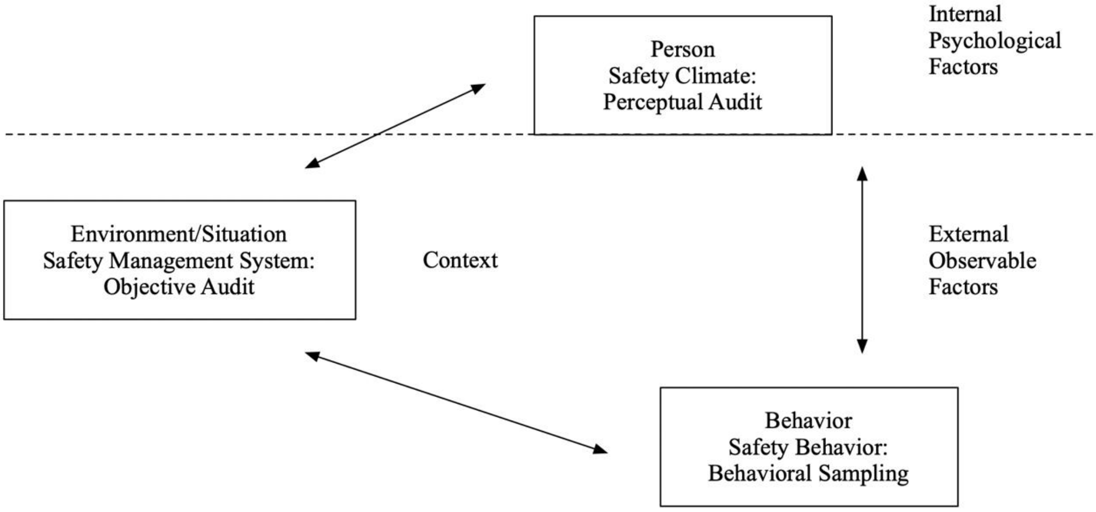


Fig. 2. shows M.D. Cooper's model for safety culture.

The main characteristics of the safety culture maturity model by grade are as follows.

Grade 1, the highest grade of safety culture maturity, is continuously improving / generative stage. Continuously improving / generative is valued in preventing all injuries to workers. In the cooperating / proactive stage of grade 2, most employees recognize that the safety and health is important in both moral and economical point of view. In addition, managers and site workers know that many factors cause an accident and that executive’s decisions are the root cause of an accident. The involving / calculative stage of grade 3 recognizes the importance of safety and health participation of site workers. Managers also know that the factors that cause an accident vary and often executive’s decisions have become the root cause of an accident. The management / reactive stage of grade 4 recognizes the safety as a business risk factor and invests time and effort to prevent accidents. However, at this stage, manager attempts to manage the safety only technically, simply by following regulations and procedures. In grade 4, the safety performance is measured by a lagging indicator such as labor loss time. The emerging / pathological stage of the lowest fifth grade attempts to manage the safety with technical and procedural aspects and compliance. The emerging / pathological stage of grade 5 takes accidents as part of the work. And, most employees are not concerned about safety. The characteristics of safety culture maturity by grade may be somewhat abstract. However, it can be a useful criterion for objectively evaluating a person's perceptions, attitudes and values.

IV. CASE OF SAFETY CULTURE EVALUATION

IV.I OVERVIEW OF SAFETY CULTURE EVALUATION

The safety culture evaluation was conducted on construction sites with about 208 employees. The classes and occupational groups included 182 site managers and workers except office workers.

IV.II SETTING EVALUATION METHOD

(1) Environment area

The environmental area evaluated the level of effective operation of the safety management system presented in M. Fleming's model. The safety manager (site chief and site manager) at the construction site was interviewed to figure out the current status and performance of safety management. In order to figure out the status of safety management, 'Report on the site's risk factors and unsafe behavior of site', 'Communication and safety and health participation', 'Educational training and safety and health capability' and 'Management of safety regulations and procedures' were evaluated. Also, in order to figure out the performance of safety management, ‘Evaluation and reviewing’ and ‘Accident reporting and investigation / analysis’ were evaluated.

(2) Person area

The safety manager (site chief and site manager) and workers at the construction site were surveyed in person area. The evaluation items included the categories presented in the safety culture maturity model and the categories and questions presented in the 'Safety Climate Measurement Toolkit (SCMT)' developed by Loughborough University, UK [20].

This led to 9 categories and questions by category. Categories include 'Importance of safety and health', 'Awareness of hazard factors at construction sites', 'Attitude of safety manager (site chief and site manager)', 'Communication', 'Educational training', 'Compliance' ',' Safety and health capabilities of safety manager (site chief and site manager), 'Safety and health support of the head office' and 'Participation in safety and health activities'. Factor analysis was not conducted because the selected items used the tested evaluation categories and questions as they are. However, the internal reliability was analyzed to determine the correlation between the questions in the same category. As shown in Table 3, all Cronbach α values were calculated to be 0.6 or more. Therefore, it was confirmed that the reliability among the questions in the same category was secured.

Table 3. Reliability verification data for survey

Category	Number of questions	Cronbach α	
		Safety manager	Worker
Importance of safety and health	8	0.77	0.84
Awareness of hazard factors at construction sites	5	0.82	0.71
Attitude of safety manager (site chief and site manager)	5	0.75	0.71
Communication	4	0.74	0.75
Educational training	5	0.82	0.81
Compliance	5	0.82	0.83
Safety and health capabilities of safety manager (site chief and site manager)	4	0.80	0.81
Safety and health support of the head office	4	0.78	0.65
Participation in safety and health activities	3	0.79	0.76

The questions in each category used a five-point scale ranging from "very so" to "not at all".

The scores by scale were assigned as follows.

The most negative response was 1 point and the most positive response was 5 points. In the case of positive questions, 5 points were given to 'very so' and 1 point to 'not at all'. In the case of negative questions, 1 point was given to 'very so' and 5 points to 'not at all'. Next, the average of each question was calculated, and the calculated average value was converted into a percentage.

(3) Behavior area

The selection of subjects for the evaluation of behavioral areas was decided in consultation with the safety manager (site chief and site manager) at the construction site. Considering the progress of the construction, the reinforced concrete construction was decided as the subject of evaluation of the behavior area. Reinforced concrete construction consists of the work of 'rebar processing and assembly', 'formwork manufacture and installation / removal' and 'concrete pour'. The safety rules for reinforced concrete construction were applied four to seven safety rules for each work as shown in Table 4. Behavior monitoring cameras were installed at the reinforced concrete construction site on one floor for 5 days. The average daily number of workers was 18. The occurrence rate of unsafe behaviors among workers' overall behaviors was analyzed.

Table 4. Safety rules of reinforced concrete construction

Name of work	Safety rules
Rebar processing and assembly	A. Wearing protective gear
	B. Prohibition of rebar cutter use by untrained worker
	C. Use of standard salvage wire rope
Formwork manufacture and installation / removal	A. Wearing protective gear
	B. When using a round saw, attaching saw blade contact prevention device
	C. Prohibition of one-person working
	D. Prohibition of up and down simultaneous working
	E. Installation of work plate
	F. Installation the inside step of elevator PIT
	G. Compliance of formwork support installation standard
Concrete pour	A. Wearing protective gear
	B. When using vibrator, wearing electric shock protection gloves
	C. Installation of work plate
	D. Installation of handrails in openings
	E. Installation of slab end fall prevention

IV.III. EVALUATION RESULTS

Environment area: In the environment area, the operation status of safety management was evaluated through interviews with safety manager (site chief and site manager) at the construction site.

The evaluation results by category in the environment area are as follows.

The category of 'Report on the site's risk factors and unsafe behavior of site' reported both potential hazard factors and hazard factors that had been improved on the site.

Therefore, the category of 'Report on the site's risk factors and unsafe behavior of site' was evaluated as being at the involving / calculative stage. In the category of 'Communication and safety and health participation', the site manager performed the risk evaluation alone, without the participation of workers. Therefore, the category of 'Communication and safety and health participation' was evaluated as being at the managing / reactive stage. The category of 'Educational training and safety and health capability' provided that site managers had a good understanding of the risk evaluation and the quality of the evaluation was good. Therefore, the category of 'Educational training and safety and health capability' was evaluated as being at the involving / calculative stage. In the category of 'Management of safety regulations and procedures', the types of disasters that are the basis for managing accident statistics and analyzing the causes of accidents, the direct causes of accident and the types of original causes are not specified. Therefore, it was found that there was a limit to in-depth accident investigation. The category of 'Management of safety regulations and procedures' was evaluated as being at the managing / reactive stage. In the 'Evaluation and reviewing' category, improvement plans of safety willingness and safety activity participation of site chiefs and site managers, safety activity participation of workers and communication regarding to safety and health were established (involving / calculative stage). Therefore, the category of ‘Evaluation and reviewing’ was evaluated as being at the involving / calculative stage. In the category of ‘Accident reporting and investigation / analysis’, the results of identifying and improving the cause of unsafe conditions affecting accidents were good. Therefore, the category of ‘Accident reporting and investigation / analysis’ was evaluated as being at the involving / calculative stage. Of the six categories, the four categories of 'Report on the site's risk factors and unsafe behavior of site', 'Educational training and safety and health capability', 'Reporting and investigation / analysis of accidents' and ‘Evaluation and reviewing’ are evaluated as being at the involving / calculative stage, the third grade. 'Communication and safety and health participation' and 'Management of safety regulations and procedures' were evaluated as being at the managing / reactive stage, the fourth grade.

Person area: As a result of the survey analysis, as shown in Table 5, the safety awareness level of safety manager (site chief and site manager) and workers is 78.0%. The safety awareness level of safety manager (site chief and site manager) is 81.7% on average. On the other hand, the safety awareness level of workers is 74.2%. The awareness level of the nine categories was higher than the 60.0% standard of SCMT. Therefore, the safety awareness of the case site was evaluated as good. The awareness level by category was the highest with 85.1% of 'Awareness of the importance of safety and health'. Next, ‘Attitude of safety manager (site chief and site manager)’ was high at 82.5%. On the other hand, the category of ‘Communication’ was the lowest at 74.5%. Next, the category of ‘Compliance’ was 75.2%.

Table 5. Survey analysis results for person area evaluation

Category	Awareness level (Average value, %)		Total average (Average value of A+B, %)
	Safety manager (Site chief and site manager, A)	Worker (B)	
Importance of safety and health	86.4	83.8	85.1
Awareness of hazard factors at construction sites	80.7	71.5	76.1
Attitude of safety manager (site chief and site manager)	87.0	77.9	82.5
Communication	78.7	70.2	74.5
Educational training	80.7	73.5	77.1
Compliance	78.8	71.5	75.2
Safety and health capabilities of safety manager (site chief and site manager	82.2	72.5	77.4
Safety and health support of the head office	81.5	73.1	77.3
Participation in safety and health activities	79.7	73.6	76.7
Total average	81.7	74.2	78.0

Behavior area: The average rate of violations of safety rules during reinforced concrete construction was 19.3%. The rate of violations of safety rules by work is as follows. In the work of ‘Rebar processing and assembly’, violations of the safety rules of 'Wearing protective gear' and ‘Prohibition of rebar cutter use by untrained worker’ occurred. Violation of the safety rule of ‘Wearing protective gear’ during ‘Rebar processing and assembly’ was investigated without wearing a safety helmet. The violation rate of the safety rule of 'Wearing protective gear' during ‘Rebar processing and assembly’ is 28.2%. The violation rate of the safety rule of ‘Prohibition of rebar cutter use by untrained workers’ during ‘Rebar processing and assembly’ is 5.8%. In the work of ‘Formwork manufacture and installation / removal’, violation of the safety rule of ‘Prohibition of one-person working’ occurred. The violation rate of the safety rule occurred in ‘Formwork manufacture and installation / removal’ is 16.4%. In the work of 'Concrete pour', there was a violation of the safety rules of 'Wearing protective gear’. Violation of the safety rule of ‘Wearing protective gear’ during ‘Concrete pour’ was investigated without wearing a safety helmet. The violation rate of the safety rule of ‘Wearing protective gear’ during ‘Concrete pour’ is 26.6%.

Table 6. Violation rate of the safety rule for evaluating of behavior area

Name of work	Violation of safety rule	Rate
Rebar processing and assembly	Wearing no protective gear	28.2%
	Prohibition or rebar cutter use by untrained worker	5.8%
Formwork manufacture and installation / removal	Prohibition of one-person working	16.4%
Concrete pour	Wearing no protective gear	26.6%
Average		19.3%

V. CONCLUSION

This study was conducted to evaluate the level of safety culture at construction sites.

The safety culture of the construction site was evaluated using evaluation methods and evaluation criteria based on the existing model. The evaluation method used M.D. Cooper's model. The evaluation criteria used the safety culture maturity model proposed by M. Fleming and D. Parker et al. The results of safety culture evaluation, which combines M.D. Cooper’s model, M. Fleming’s model and D. Parker et al.’s model, were more objective when using survey only. However, the evaluation results of the environment area, the evaluation results of the person area, and the evaluation results of the behavior area were expressed in different forms, and there was a limit in comprehensively determining the level of safety culture. Therefore, it is necessary to study how to integrate the evaluation results in the environment, person and behavior areas to quantitatively express them. Through quantitative study, if the safety culture evaluation results are quantitatively expressed, it is possible to objectively evaluate the current level of safety culture and the degree of future improvement.

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REFERENCES

[1] Ministry of Employment and Labor Reserved, The status of industrial accidents, 2017, 2018.

[2] W.S. Dester & D. Blockley, “Safety behavior and culture in construction”, Engineering Construction and Architectural Management, 2(1), 1995, 17-26.

[3] European Construction Institute, Guideline for Management of Major Construction Projects, London: HMSO, 1991.

[4] M. Kathryn, W. Sean and F. Rhona. “Safety climate, safety management practice and safety performance in offshore environments”, Safety Science 41, 2003, 641-680.

[5] F. Rhona, M. Kathryn, O. Paul & R. Bryden, “Measuring safety climate: identifying the common features”, Safety Science 34, 2000, 177-192.

[6] K.E. Weick, K. Sutcliffe, D. Obstfeld, “Organizing for reliability: process for collective mindfulness”, Research in Organizational Behavior 3, 1999, 81-123, 1999.

[7] M.D. Cooper, “Towards a Model of Safety Culture”, Safety Science, 36(2), 2000, 111-136.

[8] M. Fleming, Safety Culture Maturity Model, HSE Books, 2001.

[9] D. Parker, M. Lawrie and P.T.W. Hudson, “A Framework for Understanding the Development of Organisational Safety Culture”, Safety Science, 44(6), 2006, 551-562.

[10] International Atomic Energy Agency, Summary Report on the Post-Accident Review Meeting on the Chernobyl Accident, IAEA Safety Series No. 75-INSAG-1, 1986.

[11] D. Zohar, “Safety Climate in Industrial Organizations: Theoretical and Applied Implications”, Journal of Applied Psychology, 65(1), 1980, pp. 96-102.

[12] R. Buchan, “Safety Can't Wait: A Global Campaign for Transformational Change”, In Proceedings of the SPE / IADC Drilling Conference, Amsterdam, Netherlands, 1999, 281-292.

[13] S. Antonsen, “Safety Culture Assessment: A Mission Impossible?”, Journal of Contingencies and Crisis Management, 17(4), 2009, 242-254.

[14] F. Guldenmund, Understanding and Exploring Safety Culture, doctoral diss., Delft University, Netherlands, 2010.

[15] D. P. Fang, Y. Chen & L. Wong. Safety Climate in Construction Industry: A Case Study in Hong Kong. Journal of Construction Engineering and Management, 132(6), 2006, 573-584.

[16] S. Mohamed, Safety Climate in Construction Site Environments. Journal of Construction Engineering and Management, 128(5), 2002, 375-384.

[17] H.W. Heinrich, Industrial Accident Prevention (New York: McGraw-Hill, 1931), 62-92.

[18] A. Cohen, Factors in Successful Occupational Safety Programs, Journal of Safety Research, 9(4), 1977, 168-178.

[19] M.J. Smith, H.H. Cohen, A. Cohen and R.J. Cleveland, “Characteristics of Successful Safety Programs”, Journal of Safety Research, 10(1), 1978, 87-88.

[20] Loughborough University, Safety Climate Measurement Toolkit, 1999, 42-45.