Safety Climate Assessment and Its Impact on the Productivity of Construction Enterprises

Krzysztof J. Czarnocki, F. Silveira, E. Czarnocka, K. Szaniawska

***Abstract*—**Research background: Problems related to the occupational health and decreasing level of safety occur commonly in the construction industry. Important factor in the occupational safety in construction industry is scaffold use. All scaffolds used in construction, renovation, and demolition shall be erected, dismantled and maintained in accordance with safety procedure. Increasing demand for new construction projects unfortunately still is linked to high level of occupational accidents. Therefore, it is crucial to implement concrete actions while dealing with scaffolds and risk assessment in construction industry, the way on doing assessment and liability of assessment is critical for both construction workers and regulatory framework. Unfortunately, professionals, who tend to rely heavily on their own experience and knowledge when taking decisions regarding risk assessment, may show lack of reliability in checking the results of decisions taken. Purpose of the article: The aim was to indicate crucial parameters that could be modeling with Risk Assessment Model (RAM) use for improving both building enterprise productivity and/or developing potential and safety climate. The developed RAM could be a benefit for predicting high-risk construction activities and thus preventing accidents occurred based on a set of historical accident data. Methodology/Methods: A RAM has been developed for assessing risk levels as various construction process stages with various work trades impacting different spheres of enterprise activity. This project includes research carried out by teams of researchers on over 60 construction sites in Poland and Portugal, under which over 450 individual research cycles were carried out. The conducted research trials included variable conditions of employee exposure to harmful physical and chemical factors, variable levels of stress of employees and differences in behaviors and habits of staff. Genetic modeling tool has been used for developing the RAM. Findings and value added: Common types of trades, accidents, and accident causes have been explored, in addition to suitable risk assessment methods and criteria. We have found that the initial worker stress level is more direct predictor for developing the unsafe chain leading to the accident rather than the workload, or concentration of harmful factors at the workplace or even training frequency and management involvement.

***Keywords*—**Civil engineering, occupational health, productivity, safety climate.

I. Introduction

THE safety climate is perceived value that ensures security in the organization at a specific moment. These perceptions and beliefs can affect the attitudes, values, opinions and actions of other employees in the organization and can change over time and circumstances. Positive safety atmosphere improves production, reduces compensation and insurance costs. Other results of positive safety atmosphere could be specified as follows [1]:

- increasing employees' knowledge about safety,
- motivation to behave in a safe manner,
- increasing the use of security policies and programs,
- better employee perception of support from the management team,
- risky activities decrease among employees exposed to dangerous environments,
- decreasing the frequency of occupational accidents.

The safety culture represents the value of security and the extent to which people take personal responsibility for security in the organization. Security culture is often referred to as the "Personality" of the organization, because it is a common value of security. Security culture is just one aspect of a wider organizational culture. Culture is formed naturally wherever there are groups of people cooperating to achieve a common goal. Organizational culture seems to be invisible because most employees do not realize that common views and assumptions affect not only their personal actions, but also the functioning of the entire organization [2], [3]. An example of how worker can experience a safety culture is to start working in a new organization. Initially, as a new employee one would like to understand the internships in the organization. In the initial phase, employees are introduced through written forms, procedures and training. They also try to teach from their colleagues and leaders, watching what they say and how they work. On the basis of this information and observation, they assimilate elements of organizational security culture. A positive safety culture exists when employees understand the importance of security and demonstrate positive safety behaviors. Examples of positive safety behaviors are wearing Personal Protective Equipment (PPE) without asking, assessing the risk of developing semi accident situation at workplaces [3], [4] and reporting all incidents. Organizations with the negative security culture usually find security and safety as unnecessary that consequently leads the staff to unsafe behaviors. Negative security behaviors include underestimating or choosing to ignore security threats. The safety climate is a perceived value in the safety of the organization at a specific point on time. That is why we can think of safety as the "mood" of the organization, based on what employees experience at a particular time. Because the safety climate is the illusion of security at some point, it can change daily or weekly. If this elevated safety climate is

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maintained, time can lead to changes in culture. Because the safety climate attracts attitudes to safety at a particular moment, it is a useful security indicator. The measurement of safety culture is usually performed using employee survey or team discussions. Security leaders demonstrate a strong commitment to security and engage and inspire others [5]. They have positive security behaviors. Security leaders can exist at all levels from senior executives, middle managers to informal leaders among employees. Leaders are important in any organization because they direct the staff in terms of planning and supervising their work. They also ensure employees' motivation to achieve goals by rewarding, inspiring and leading by example [6]. Safety leaders inspire others to be positive about security, setting good example of safety and rewarding staff for good safety behavior. The consistent security leaders can affect the climate of security and over time have an impact on security culture of the company or the industry. Thus, the leaders with a strong commitment to security, encourage employees and give positive personal example of safety, consequently will improve the climate of safety. Efforts over time will cause people to re-evaluate their deep beliefs and values about security and have a positive impact on safety culture [7]. Through the actions of security leaders, we can create a positive safety culture, giving better security results, which will help keep employees in a safe place. By investing in security-related leadership, we can start to influence the security climate and the long-term impact, building a positive security culture. The end product is to improve the safety and behavior of employees [8].

Fig. 1 Consolidation of Safety Model in the Enterprise

The safety climate can be measured in several ways depending on the needs and abilities of the organization. It can be measured formally, using survey tools designed to assess individual responses to key areas of security. Research results can be applied to the organization and many free online tools are available that measure safety [9]-[11]. For smaller organizations, the safety climate can be measured by focus groups, interviews with management and observation of normal operational procedures in the organization. The best practice approach would be a combination of these methods. Such research projects have been developed in the Construction companies sector in Poland 2015-2018. The consolidation of safety model in the enterprise is presented at Fig. 1.

The construction industry is rapidly developing sector of Polish economy, however, according to Eurostat [12], the industry is classified among the sectors of the economy presenting high occupational risks and an unsatisfactory level of occupational safety. Although some safety programs have been developed in the country the observed accident reduction rate seems to be rather weak. Employees within the construction sector are exposed to biological and chemical factors, as well as the effects of noise, vibrations, insufficient illumination and temperature. Moreover, the workload tendencies with particularly frequent changes of workload level have been observed in many investigations. More than 45% of workers in the construction sector say that their work has a negative impact on their health [12]. The construction industry is subjected to high occupational risk and high rates of occupational accidents, occupational diseases and absenteeism at work. In Europe, according to Eurostat data for 2011 (for 28 European Union [EU] countries), the fatal accident rate was 6.39 (per 100,000 persons in employment) in the construction industry [13]. The majority of serious accidents have taken place at the scaffolds or at the construction sites with scaffolds. Taking into consideration the frequency of accidents and high occupational risk in the construction industry with scaffold use, it is important to take the necessary steps to reduce this exposure. In these conditions the research project Scaffold Use RAM for Construction Process Safety "ORKWIZ" has been developed in Poland from early 2016. The project focused on the introduction of a system of new/additional procedures and tools for monitoring safety on construction sites [14]-[16]. This system built as model could imposes strict rules regulating the conduct of contractors in a comprehensive manner to ensure an elimination of hazards from the construction site or an effective reduction of associated risks.

The construction of SURAM is the core part of the ORKWIZ project. The research also shows that many accidents can be avoided by developing a proper concept of safety assurance at the preparation stage [17]-[19].

II. Methods

A. Population

The study was conducted in Poland. Five different regions of the country have been selected for the project research. The regions have been selected by virtue of economic development level, unemployment rate, technical culture of employees, construction processes intensity, and infrastructure level, among other factors. Accordingly, the study was conducted in the different construction sites, representing typical (more frequent) scaffold size, scaffold system types and technical equipment. Such a diversity of regions, sites and employee behaviors and customs is required to achieve universal safety climate for the proposed safety model. At least 120 construction sites with scaffold use will be examined during the research project period. Subsequently, a random sampling procedure was conducted to select individual workers at each construction site; 234 individual workers of those sites potentially exposed to occupational hazards were selected in the first year of the project. For the purpose of the SURAM 800 individuals should be interviewed. An original questionnaire for risk perception and safety climate assessment at the construction site has been developed. At the beginning of our investigation, we have verified several existing questionnaires including NOSACQ-50, Quality of Worklife Module (NIOSH), Contractor OH&S Evaluation, as well as some polish ones and we prepared original tool that better fit to the construction site occupational environment and construction workers perception. Before using the original questionnaire among the selected population, we ran a pilot study among 60 workers. The trial and first run exploratory factor analysis confirmed that the original 45-item questionnaire could be used as a risk perception and safety climate scale in polish construction industry. A 5-point Likert-type scale (1 = strongly disagree, 5 = strongly agree) was used to collect the workers' responses. Yes/no responses, lists of options, check-the-box responses, quantity choice etc., were used to self-report incident involvement and demographic data.

In the phase of research and simulation of the model for construction companies in Poland and Portugal, presented in this study, methodological approach was used, analogous to researchers from the Technical Department in Bor University, Belgrade, Serbia [20]. As our questionnaire uses scaling responses using a 7-point Likert scale or, alternatively, a 10-point acceptance scale, an audit option has been added that allows entering information that the respondent could not choose or refuse to assign a weight to a given criterion. In order to ensure greater objectivity both questionnaire and model and mostly to increase flexibility of SURAM the control group has been recruited at the Portuguese construction sites, considering similarities and differences between countries. Characteristics of the study and control groups have been presented in Table I. The difference in the drug (including alcoholic beverages) use between groups seems to be the result of different level for acceptance of some alcoholic beverages use in the shift period between Polish and Portuguese workers. In the detail questions regarding type of drug and frequency of use, we find no significance except popularity of spirits in Poland and wine or beer in Portugal.

B. Questionnaire Validity and Reliability

In the implemented version of the questionnaire, the questions focused on six factors: S_{SOC} (life coherence and social associations): 11 questions; S_{LOC} (sense of control): 10 questions; S_{LKZ} (health state): 5 questions; S_{LWO} (value hierarchy): 11 questions; S_{IZZ} (occupational praxis and psychical attitude): 10 questions; S_{PR} (risk perception): 8 questions. There were also 7 predictors not involved to any of six scales. Sampling adequacy has been measured using the Kaiser-Meyer-Olkin test. Bartlett's test of sphericity was involved for evaluating correlations among safety climate items [21]-[23]. The reliability of the research tool created in this way was verified by factor analysis methods, and discriminatory validity was verified by comparing the perception in the area of safety culture among groups that differ in age, professional experience, participation in accidents, position in the company, education level and ownership of the organization. To evaluate the internal consistency of the questionnaire, Cronbach's α has been used, Speraman-Brown coefficient and Ω. The Cronbach's α was used as an indicator of mean correlations between positions, like other authors suggest, when responses were scored on the 7-point Likert scale, as was the case in this study [24], [25]. Spearman Brown coefficient represents the reliability coefficients that can be attained from possible combinations of split-half questions. The minimal proposed value of these coefficients is 0.70. The data obtained using our questionnaire were analyzed with Statistica 13.1 StatSoft Inc. The comparison of the difference in accident risk perception and safety climate scores among different demographic groups (age, work experience, occupational experience, position in the company, education, accident involvement, type of construction site) was done with the multiple analyses of variances (MANOVA).

TABLE I
GROUP CHARACTERISTICS

Variable	Polish Study Group		Portuguese Control Group		p
	N	%	N	%	
Monitored Subjects	243	100	38	100	>0.05
Gender					
Male	239	98.3	36	94.7	>0.05
Female	4	1.7	2	5.3	>0.05
Position in Company					
Construction Workers	177	72.8	28	73.7	>0.05
Other Workers	43	17.7	6	15.8	>0.05
Administrative Workers	9	3.7	2	5.25	>0.05
Managers and Supervisors	14	5.8	2	5.25	>0.05
Age (years)					
<25	38	15.6	6	15.8	>0.05
25-34	48	19.8	8	21.05	>0.05
35-44	59	24.3	9	23.7	>0.05
45-54	42	17.3	8	21.05	>0.05
>54	56	23.0	7	18.4	>0.05
Work Experience (years)					
≤1	28	11.5	4	10.5	>0.05
2-5	87	35.8	14	36.8	>0.05
6-10	65	26.8	10	26.3	>0.05
11-20	33	13.6	5	13.2	>0.05
≥21	30	12.3	5	13.2	>0.05
Drug Use	191	78.6	20	52.6	<0.05
Smoking	202	83.1	23	60.5	>0.05
Accident Involvement or Witness	107	44.0	11	28.9	>0.05

To define the usefulness of the questionnaire for a complete SURAM model, the main element of the analysis was carried out similarly as Milijic proposed [20] with a self-esteem greater than one. After separating the factors, Varimax rotation was performed. The analyses showed that the Kaiser-Meyer-Olkin measure of sampling adequacy was 0.81 indicating that these data were appropriate for factor analysis [26]. Bartlett's test of sphericity was significant (χ^2=1270.6, p<0.01), which indicated that there were correlations among safety climate items and the correlation matrix was not a unit matrix.

III. Results

The reliability of both the research method and the tool and, as a consequence, the accuracy of the model fit depends on the internal consistency of the method. The routine approach used also in other studies [20], [19], [27] was used, the consistency was assessed using the Cronbach-Speraman-Brown coefficient [25], [28], and according to Cronbach, the internal consistency was 0.79 for the entire population. Spearman Brown coefficient was 0.78 and W = 0.70. Most coefficients were higher than 0.70 and adequate for psychometric requirements for a measurement. Thus, the method for measuring occupational hazards, risk perception and the contractor safety climate was appropriate [29]. Table II shows each coefficient of the accident risk and safety climate scales. Fig. 1 presents the results of the SURAM structural analysis. To make it clearer, it shows only the values of the structural equation, but not the measuring models. Except the questionnaire scales the SURAM have been developed including worker psycho-physiological parameters monitoring before the shift as well as the part of the shift after a break corresponding to the workload during the shift (WL). The wide range of demographic factors (DF) collected both at the construction site as well as from local statistical offices have also been used for model construction. Environmental parameters at the construction site have been monitored on 2 up to 3 levels of the scaffold (depending of its size) during at least five days working week including sound level, illumination, microclimate (EF). Then the diversity from the standard levels has been evaluated as the measure for the matrix construction. To evaluate worker visual concentration on the critical areas or elements of working zone the mobile eye-tracking equipment have been used (ET). Stability and quality of scaffold set-up and maintenance have been evaluated ($C_{scaffold}$) as well as construction site organization level (CSO). The complementary element of SURAM especially for model teaching period was Historical Accident Analysis module (AHA). In the Aha module the accidents from past 10 years of the construction industry have been decomposed to the elementary factors. As the model presented at the Fig. 1 is a beta one prepared after first year of the projects some of the relations could not be calculated precisely *nd* values. Therefore, even in those partial data it shows potential for use in improving safety at the construction sites with scaffold use.

TABLE II
Questionnaire Scales Inter-Consistency Coefficients

Scale	No. of Items	Cronbach's α	Spearman-Brown Coefficient	Ω
S_{SOC}	11	0.763	0.771	0.703
S_{LOC}	10	0.694	0.712	0.614
S_{LKZ}	5	0.631	0.680	0.622
S_{LWO}	11	0.895	0.899	0.811
S_{IZZ}	10	0.744	0.752	0.728
S_{PR}	8	0.707	0.719	0.631

Legend: S_{SOC} - life coherence and social associations; S_{LOC} - sense of control; S_{LKZ} - health state; S_{LWO} - value hierarchy; S_{IZZ} - occupational praxis and psychical attitude; S_{PR} - risk perception

As to several authors, the goodness-of-fit (GF) model had to be considered first [30], [19], [31]. Within a GF model, it is required to consider three indicators: the measure of absolute fit, the measure of increased fit and the measure of decreased fit. Table III presents the results for the proposed model together with the recommended values for satisfactory fit [32], [33].

Due to the absolute correspondence of the models, the indicators that can be applied in an incompetent strategic analysis are GFI (goodness-of-fit index) and the index of corresponding values. In GFI, the higher the value, the higher the correspondence. In this case, the obtained value was 0.92. This indicator is acceptable since it is over 0.90 [34]-[36].

TABLE III
Model Fit Values

Statistics	Recommended Values	Achieved Level
χ^2/DF	<3.0	2.87
GFI	>0.90	0.91
AGFI	>0.90	0.92
NFI	>0.90	0.93
CFI	>0.90	0.93
IFI	>0.90	0.91
RFI	>0.90	0.92

Legend: GFI - goodness-of-fit index; AGFI - adjusted goodness-of-fit index

NFI - normed fit index, NNFI - non-normed fit index, CFI - comparative fit index, IFI - incremental fit index, RFI - relative fit index

In our model, this indicator has the value of 0.9 which, according to the above-mentioned academics, is an indicator of good correspondence. Table II shows inter-correlations among the six scales that were entered into the final model. Because of the comparatively small sample size, each correlation coefficient was significant at 0.05. As a step-in model construction this research focused on investigation whether there is any significant difference in risk perception and the safety climate in working teams as well as construction enterprises among the demographic subgroups [37], [38]. The significant differences in demographic subgroups in questionnaire scales have been observed. In particular, there were significant differences on all scales (S_{SOC}, S_{LOC}, S_{LKZ}, S_{LWO}, S_{IZZ}, S_{PR},), but for the education level there were significant differences on (S_{SOC}, S_{LOC}, S_{IZZ}, S_{PR},) scales and not for S_{LKZ} *and* S_{LWO} *scales*. Gender did not influence opinions on questions on analyzed factors as more than 97% of employees (94.7% and 98.3% in study and control groups respectively) were male. However, presenting all the results in this manuscript would require too much space. Therefore, they will be discussed in detail in another paper at the end of the project where we could observe larger subgroups. At this stage of the research and project development we have found the initial worker stress level (monitored by the bio-physical parameters at the beginning of shift and after the break + ET) [39] is more direct predictor for developing of the unsafe chain leading to the accident than the work load (WL), and concentration of harmful factors (EF) at the workplace.

IV. Conclusion

A study of risk perception, occupational hazards and safety climate at the construction sites with scaffolds in Poland, like the one in this paper, had never been conducted before. We have attempted to monitor the perception of risk, understand the values and beliefs about security among Polish workers or, properly, workers teams on Polish construction sites, because an increasing number of migrant workers (mainly Ukrainians) were noticed during the first phase of the research project.

The study presented evidence that the perception of the accident risk and safety climate in polish construction sites can be reliably measured with a 45-item questionnaire, involving six factors (S_{SOC} (life coherence and social associations), S_{LOC} (sense of control), S_{LKZ} (health state), S_{LWO} (value hierarchy), S_{IZZ} (occupational praxis and psychical attitude), S_{PR} (risk perception)).

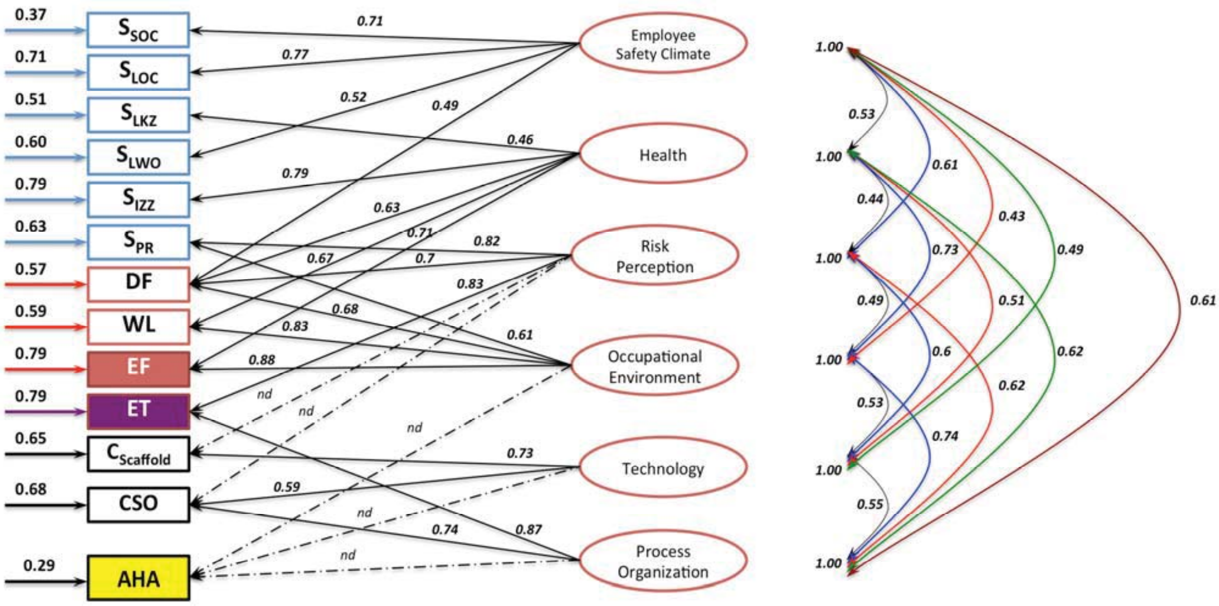

Fig. 2 Structural Model of SURAM. Legend: S_{SOC} - life coherence and social associations; S_{LOC} - sense of control; S_{LKZ} - health state; S_{LWO} - value hierarchy; S_{IZZ} - occupational praxis and psychical attitude; S_{PR} - risk perception; DF - demographic factors; WL - work load; EF - environmental factors; ET - eye tracking; $C_{scaffold}$ - scaffold construction; CSO - construction site organization; AHA - historical accidents analysis

The previous research results posited, construction workers put more emphasis on safety training, organizational environment, safety awareness and competency, and management support. Although, the previous theses are still valid, our recent study shows, that initial stress level could be crucial for developing risky or potentially prone to accident situation.

To establish a general model SURAM, our subjects came from several economically, historically and technologically diversified polish regions and the control group came from Portugal. Thus, the developed 45-item questionnaire can be used as a safety measurement tool for the whole construction sector with the scaffold use. This tool was based on the results from different parts of the world and then modified to fit polish construction sites [20], [40].

Further research will focus on a structural equation model, which will result from the structural analysis presented in this work. An additional factors), DF (demographic factors), WL (work load), EF (environmental factors), ET (eye tracking), $C_{scaffold}$ (scaffold construction), CSO (construction site organization), AHA (historical accidents analysis) will have to be included. It will determine the workers' attitude towards the risk level at their workplace, hazardous situations and real occupational accidents that took place there. Subsequently, the six factors from this study will be used to develop a hypothetical frame of the SURAM model.

Additionally, as already indicated, each demographic subgroup had strong influence on some of the six factors. This will be analyzed in detail and discussed in next project stages. This study considered workers from six regions (including Portugal), so the level of technical culture and type of organization was one of the variables (CSO). Consequently, the influence of this variable on all six scales will be studied in future.

The prognostic validity of the SURAM model developed in this work will be assessed in this way on next stages. Moreover, the results will have practical value for occupational health prevention in construction sector. The developed SURAM, even at this initial stage are found to be useful for predicting high-risk construction activities and thus preventing accidents to occur, based on a set of historical accident data. There is an example of construction sites analyze, presented as a 3D model of scaffolding (Fig. 3).

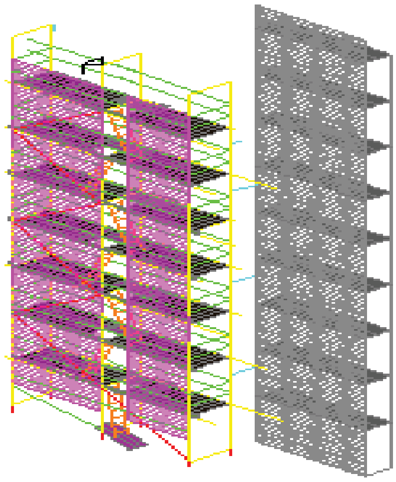

Fig. 3 3D model of scaffolding L-12 (Autodesk Software)

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