Forecasting the Level of Occupational Safety Culture on the Basis of Linear Regression of One Variable

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ABSTRACT

The article presents possibilities of forecasting increase of the level of occupational safety culture on the basis of models of linear regression for one variable for overall approach to safety culture as well as its particular fields, i.e. knowledge, skills, activity (analogically to synergy triangle). Conducted studies allowed identification of fields in which corrective proceedings would be the most effective for enterprises of a particular size. Research sample included manufacturing companies (micro, small and medium) from the section C of PKD (Polish Classification of Activity)—Industrial processing.

INTRODUCTION

The superior role in proper functioning of enterprises is played by maintenance of a proper level of occupational safety [1]. Every accident at work disturbs functioning of a company, it can cause a break in the production process, have a negative influence on the company's image, etc. [2]. In process of company existence, effective operation depends on reliability of fixed assets as well as human activities. Efficiency of a company depends on [3]:

- efficiency of particular elements of a company (state and quality of machines and devices, security procedures, profiles of employees),
- company structure (structure determines the efficiency of communication between company elements; we study whether there exists a flow of information between particular elements of company structure),
- efficiency of information flow, measured by the indicator of the level of safety culture (safety culture level is regarded as index of information distribution).

Having proper occupational health and safety service is a legal obligation of each company. Obligations of occupational health and safety service depend on the company size (according to Art. 237 of Polish Labour Code 11 [4] and Regulation of the Council of Ministers of 02.09.1997 on occupational health and safety service [5]:

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- below 100 employees—employer is obligated to form occupational health and safety service; in this case, these tasks can be entrusted to an employee hired at another work. Employer is allowed to perform these obligations on his own when employs up to 10 employees or up to 20 is the activity is not burden with a risk greater than the third category within the understanding of provisions about social insurance related with occupational accidents,

- from 100 to 600 employees—employer should form multi- or single-person body or employ a separate employee, at least as a half-time employee, who has proper qualifications in this field,

- over 600 employees—employer should hire one full-time employee per each 600 employees.

More conscious employers, who are aware of costs of accidents at work and occupational diseases, decide to introduce a System of Management over Occupational Health and Safety [6], [7], [8]. In the common practice, companies deciding to implement a System of Management over Occupational Health and Safety can realise this on the basis of norm ISO 45001:2018 Occupational health and safety management systems -- Requirements with guidance for use or norm OHSAS 18001 Occupational health and safety management systems—Specification. A fundamental distinction of a system based on norms is the scope of activities at implementing and maintaining a system [3]. These norms are focused on workstations of a particular company, while OHSAS broadens the scope by organization, i.e. a company along with cooperating parties etc. Having occupational health and safety service at a company has an influence on the safety, however, without a proper level of occupational safety culture, it will not be efficiently enough [9]. Similarly, implementing an Occupational Health and Safety Management System without a conviction of management and employees about its rightness will not bring expected results [10]. The level of occupational safety culture of a particular company is responsible for convictions and beliefs concerning justness of introduced norms, rules, and regulations [11]. A human being is a cause of accidents at work regardless the technical condition of a company, implemented management systems, or a socio-demographic structure of employees. In most cases, occupational accidents result from a bad organizational culture of a company [10], [11]. It has an influence on a low level of occupational safety culture. Occupational safety culture is understood as a measure of the level of implementation and regarding them as own, guidelines concerning safety [1], [12], [13]. A properly high level of occupational safety culture can compensate a bad technical condition of machines and devices or an improper organization of work. On the other side, the best technical background and meeting all legal and formal requirements can’t compensate low occupational safety culture [7], [8]. As a result, in order to evaluate a company in the scope of occupational safety, one should control technical and organizational conditions, as well as to verify the level of occupational safety culture [14], [15], [16]. On the basis of study results and analyzing references, a scheme of determining a path of improvement of occupational safety in the aspect of the level of occupational safety culture of a manufacturing company was proposed (Figures 1 and 2). Figure 1 presents a scheme of the course of studying the level of occupational safety culture along with three fields of issues (knowledge, skills, activity). Figure 2 presents an algorithm of studying and evaluation of fields of issues (considering branches of particular areas).
Figure 1. Algorithm of the course of studying the level of safety culture along with its fields.

The most important part of increasing the level of occupational safety is forecasting obtained results in respect to born expenditures on improvement of occupational safety. One of methods is forecasting the level of occupational safety culture on the basis of linear regression of one variable.

**FORECASTING THE LEVEL OF OCCUPATIONAL SAFETY CULTURE ON THE BASIS OF LINEAR REGRESSION OF ONE VARIABLE**

Studies were conducted at manufacturing companies (Section C of Polish Classification of Activity—Industrial processing). Companies under the study run manufacturing activity and are classified as industrial plants, which, in their operation, use machines and devices of mechanical drive. Table 1 presents a list of companies studied on the basis of Polish Classification of Activity.

Table 1. Manufacturing companies at which studies were conducted (section c of Polish classification of activity—industrial processing).

| Section | % |
|---------|---|
| Section 16 – Manufacture of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials | 13 |
| Section 20 – Manufacture of chemicals and chemical products | 12 |
| Section 22 - Manufacture of rubber and plastic products | 4 |
| Section 23 - Manufacture of other non-metallic mineral products | 7 |
| Section 25 - Manufacture of fabricated metal products, except machinery and equipment | 30 |
| Section 26 - Manufacture of computer, electronic and optical products | 16 |
| Section 28 – Manufacture of machinery and equipment not elsewhere classified | 16 |
| Section 29 – Manufacture of motor vehicles, trailers and semi-trailers excluding motorcycles | 2 |
The total number of surveys was 1462. Due to formal reasons, 39 surveys were rejected. Thus, an analysis concerned 1423 surveys, conducted in companies divided as per their sizes: 214 micro, 436 small, and 773 medium (see Figure 3).

Figure 3. Criteria of analysis of research sample.

An important factor when selecting companies was the will of managements to cooperate, as well as the availability of data. Legal and organization form, as well as ownership were not essential. Field research technique was used for data collection. It was the most labour-intensive and time-consuming part of the studies. Approaching the necessary number of manufacturing companies took over 2 years. Data were collected through direct contact with enterprises. The original concept to send questionnaires by email did not prove to be efficient. For a particular number of sent emails asking for a possibility of conducting studies, no company replied. Only the direct contact enabled collection of enough amounts of materials for studies and analysis. Data were collected through a direct contact with companies. For this aim, an original survey on the level of safety climate in a company was used. The questionnaire was subject to evaluation of reliability of a research tool—Cronbach's Alpha. It determines the coherence of positions of a particular scale, i.e. specifies the extent to which positions included in a certain factor, scale, are similar to each other, and whether they study the same phenomenon [17]. The survey questionnaire used in the study has the Cronbach’s alpha factor equal to 0,93, what indicates a high level of the reliability of a study tool. This factor was calculated also for particular empirical areas of the questionnaire. Area 1 (Knowledge about occupational health and safety) includes 15 positions concerning “knowledge” in the field of occupational health and safety: Cronbach’s alpha = 0,813. Area 2 (Skills in the scope of occupational health and safety) includes 10 positions related with declared skills related with issues of occupational health and safety and towards co-workers: Cronbach’s alpha = 0,837. Area 3 (practical behaviours in the field of occupational health and safety) is composed of 20 positions relating to “activity” in the field of occupational health and safety: Cronbach’s alpha = 0,864

Micro Manufacturing Companies

Linear regression model is a method for data analysis that allows quantitative evaluation of relationships existing between various aspects of studied phenomena [wa18]. A formal way of approach to analyzed problem leads for formulating a one-way dependence in the form of function: \( S = f(P) \). This function is often written in the form: \( Y = f (X, \xi) \). Such form assumes that the real dependence of \( S \) from \( P \) is of stochastic character. In this model, \( Y \) denotes dependent or response variable, while \( X \) is independent or explanatory variable. In the classical regression analysis, it is
assumed that there is a stability of relationship \( f \) between analyzed phenomena and that
the model is linear in respect to parameters [18].

\[
Y = \beta_0 + \beta_1 + X + \xi
\]  

(1)

Where: \( \beta_0 \) and \( \beta_1 \) are structural parameters of the model, and the random component is a random variable of normal distribution \( N(0, \sigma^2) \).

The study resulted in 214 observations for micro-companies. Table 2 presents models of linear regression for three studied areas. The last column of Table 2 includes coefficient of determination (\( R \) squared = \(<0;1>\)), being a measure of what percentage of variability of dependent (response) variable is explained by independent variable (predictor).

| Studied area | Model of linear regression | R squared |
|--------------|----------------------------|-----------|
| KNOWLEDGE    | \( \hat{Y}_{mkn} = 0.034 + 0.38 \cdot x_w \) | 0.74      |
| SKILLS       | \( \hat{Y}_{mku} = 0.18 + 0.58 \cdot x_u \) | 0.70      |
| ACTIVITY     | \( \hat{Y}_{mkd} = 0.08 + 0.9 \cdot x_d \) | 0.90      |

According to models presented in Table II, the greatest influence on the level of safety culture in micro-companies is of “KNOWLEDGE”. Free term (“a”) in this model has the lowest value, which means that if the index of the level of knowledge (\( x_w \)) is zero, the safety culture level will amount to 0.034. The area with the least influence on the level of safety culture is micro-companies is “SKILLS”. Free term in this model has the greatest value (0.18). However, a manufacturing company can’t let negligence occur in any of these areas, as at a low index of one of them, the level of safety culture will not reach an acceptable level (0–0.49 unacceptable level, 0.5–0.69 average level, 0.7–0.83 good level, 0.84–1.0 very good level). When studying the level of safety culture one should be cautious in respect to too good results (over 0.95), as it may indicate insincere completion of the survey. A respondent could complete a questionnaire not in accordance to facts but in accordance to expectations of e.g. his superiors. Term “b” is coefficient of inclination of regression line. Its value shows how strong predictor is variable \( x \) in relation to variable \( y \). Thanks to it, we can estimate outlays to effects. The most effective correction proceeding shall be included in the area “ACTIVITY”. In this case, term “b” amount to 0.9. An increase of coefficient \( x_d \), (“ACTIVITY”) by 0.1 will increase the level of safety culture by 0.09. The least efficient corrective proceeding is in the area “SKILLS”. In this case, term “b” is 0.58. An increase of coefficient \( x_u \), (“SKILLS”) by 0.1 will result in increasing the level of safety culture only by 0.058. On the basis of obtained prognostic models, Table 3 presents predictions of influence of studied areas (knowledge, skills, activity) on the level of safety culture for assumed values for micro-manufacturing companies.

| \( X_u(x_w, x_d) \) | KNOWLEDGE | SKILLS | ACTIVITY |
|---------------------|-----------|--------|----------|
|                     | \( \hat{Y}_{mkn} = 0.034 + 0.88 \cdot x_w \) | \( \hat{Y}_{mku} = 0.18 + 0.58 \cdot x_u \) | \( \hat{Y}_{mkd} = 0.08 + 0.9 \cdot x_d \) |
| 0,0                 | 0.034000  | 0.180000 | 0.080000  |
| 0,1                 | 0.121568  | 0.235879 | 0.172594  |
| 0,2                 | 0.209461  | 0.293406 | 0.263205  |
| 0,3                 | 0.297354  | 0.350933 | 0.353816  |
According to prediction studies, in order to achieve an acceptable level of safety culture in micro-companies, coefficients for areas “KNOWLEDGE” and “SKILLS” should amount to at least 0.6, and 0.5 for “ACTIVITY”.

Small Manufacturing Companies

The study resulted in 436 observations for small companies. Table 4 presents models of linear regression for three analyzed areas; the last column includes determination coefficient. According to models presented in Table 4, the greatest influence on the level of safety culture in small companies is of “KNOWLEDGE”. Free term (“a”) in this model has the lowest value (0.03), what means that if the index of the level of knowledge ($x_w$) is zero, the safety culture level will amount to 0.03. The area with the least influence on the level of safety culture is small companies is “SKILLS”. Free term in this model has the greatest value (0.11).

| Studied area | Model of linear regression | $R$ squared |
|-------------|---------------------------|-------------|
| KNOWLEDGE   | $\hat{y}_{mlv} = 0.03 + 0.95 \cdot x_w$ | 0.84        |
| SKILLS      | $\hat{y}_{mlu} = 0.11 + 0.68 \cdot x_u$ | 0.81        |
| ACTIVITY    | $\hat{y}_{mid} = 0.05 + 0.93 \cdot x_d$ | 0.82        |

The most effective correction proceeding shall be included in the area “KNOWLEDGE”. In this case, term “b” amounts to 0.95. An increase of coefficient $x_w$, (“KNOWLEDGE”) by 0.1 will increase the level of safety culture by 0.095. The least efficient corrective proceeding is in the area of “SKILLS”. In this case, term “b” is 0.68. An increase of coefficient $x_u$ (“SKILLS”) by 0.1 will result in increasing the level of safety culture only by 0.068. Table 5 presents predictions of influence of studied areas (knowledge, skills, activity) on the level of safety culture.

Table 5. Prediction of the level of safety culture depending on the level of coefficients in particular analysed areas for small companies.

| $x_w(x_u, x_d)$ | KNOWLEDGE | SKILLS | ACTIVITY |
|-----------------|-----------|--------|----------|
| 0.0             | 0.030000  | 0.110000 | 0.050000 |
| 0.1             | 0.128358  | 0.177974 | 0.143237 |
| 0.2             | 0.223184  | 0.245493 | 0.236221 |
| 0.3             | 0.318010  | 0.313013 | 0.329205 |
| 0.4             | 0.412836  | 0.380532 | 0.422189 |
| 0.5             | 0.507661  | 0.448052 | 0.515173 |
| 0.6             | 0.602487  | 0.515571 | 0.608157 |
| 0.7             | 0.697313  | 0.583091 | 0.701141 |
| 0.8             | 0.792139  | 0.650610 | 0.794125 |
| 0.9             | 0.886964  | 0.718130 | 0.887109 |
| 1.0             | 0.981790  | 0.785649 | 0.980092 |
According to prediction studies, in order to achieve an acceptable level of safety culture in small companies, coefficients for areas "KNOWLEDGE" and "ACTIVITY" should amount to at least 0,5, and 0,6 for "SKILLS".

Medium Manufacturing Companies

The study resulted in 773 observations for medium companies. Table VI presents models of linear regression for three analyzed areas; the last column includes determination coefficient.

According to models presented in Table 6, the greatest influence on the level of safety culture in medium companies is of “KNOWLEDGE”. Free term (“a”) in this model has the lowest value (0,07), what means that if the index of the level of knowledge ($x_w$) is zero, the safety culture level will amount to 0,07. The area with the least influence on the level of safety culture is small companies is “SKILLS”. Free term in this model has the greatest value (0,14).

Table 6. Model of linear regression for medium companies (from 50 to 249 employees).

| Studied area | Model of linear regression | $R$ squared |
|--------------|----------------------------|-------------|
| KNOWLEDGE    | $\hat{y}_{iw} = 0.07 + 0.84 \cdot x_w$ | 0.74        |
| SKILLS       | $\hat{y}_{iu} = 0.14 + 0.62 \cdot x_u$ | 0.68        |
| ACTIVITY     | $\hat{y}_{id} = 0.13 + 0.83 \cdot x_d$ | 0.85        |

The most effective correction proceeding shall be included in the area “KNOWLEDGE”. In this case, term “b” amounts to 0,84. An increase of coefficient $x_w$, ("KNOWLEDGE") by 0,1 will increase the level of safety culture by 0,084. The least efficient corrective proceeding is in the area of “SKILLS”. In this case, term “b” amount to 0,62. An increase of coefficient $x_u$, ("SKILLS") by 0,1 will increase the level of safety culture only by 0,062. Table 7 presents predictions of the areas: knowledge, skills, activity, on the level of occupational safety culture.

Table 7. Prediction of the level of safety culture depending on the level of coefficients in particular analysed areas for medium companies.

| $x_w$ | $x_u$ | KNOWLEDGE | SKILLS | ACTIVITY |
|-------|-------|-----------|--------|----------|
| 0.0   | 0.0   | 0.070000  | 0.140000 | 0.130000 |
| 0.1   | 0.1   | 0.157223  | 0.204144 | 0.212727 |
| 0.2   | 0.2   | 0.241632  | 0.265667 | 0.295728 |
| 0.3   | 0.3   | 0.326041  | 0.327191 | 0.378290 |
| 0.4   | 0.4   | 0.410450  | 0.388714 | 0.461730 |
| 0.5   | 0.5   | 0.494859  | 0.450237 | 0.544731 |
| 0.6   | 0.6   | 0.579268  | 0.511761 | 0.627732 |
| 0.7   | 0.7   | 0.663677  | 0.573284 | 0.710733 |
| 0.8   | 0.8   | 0.748086  | 0.634807 | 0.793734 |
| 0.9   | 0.9   | 0.832495  | 0.696330 | 0.876735 |
| 1.0   | 1.0   | 0.916904  | 0.757854 | 0.959736 |
According to prediction studies, in order to achieve an acceptable level of safety culture in medium companies, coefficients for areas "KNOWLEDGE" and "SKILLS" should amount to at least 0.6, and 0.5 for "ACTIVITY".

SUMMARY

The presented approach enables determination of the level of occupational safety culture using obtained prognostic models, which were built on the basis of results of the survey conducted on the sample of 1423 physical workers employed at manufacturing companies. Thanks to implementation of accepted models, there took place a prediction of the influence of the analysed areas (knowledge, skills, activity) on the level of occupational safety culture in manufacturing companies. Results of conducted research experiments in the field of predicting the level of safety culture can be used by managerial staff at manufacturing companies, depending on their size, in order to:
- determine the weakest points in the structure of occupational safety,
- determine activities that should be undertaken to achieve the best results,
- make a decision concerning realisation of training and undertaking other activities for particular groups of employees.

Research works aimed at decreasing threats are not able to provide indispensable outlays for the maintenance of proper functioning of an enterprise. However, even at small resources (what we often face in case of small companies), multi-directional analyses of the level of safety culture can have an influence on a decrease of threats, mainly by shaping proper attitudes of employees and increasing their awareness. Such shaping should be preceded by diagnostics in order to be effective. Purposeful activities directed at specific groups of employees (considering socio-geographic characteristics) shall result in an improvement of occupational safety culture at manufacturing companies.

REFERENCES

1. Pidgeon, N. F. 1998. Safety Culture: a Key Theoretical Issues. Work & Stress, 12(3):202-216.
2. Zohar, D. 1980. Safety Climate in Industry Organizations: Theoretical and Applied Implications. Journal of Applied Psychology, 65(1).
3. Kalndyk, B. Zapala, R., and Maj, M. 2010. Systemy Zarządzania BHP w Przedsiębiorstwach, Archives of Foundry Engineering, 10:83-96.
4. Act of 26.06.1974 Labour Code (Journal of Laws 1974 no. 24 item 141).
5. Regulation of the Council of Ministers of 02.09.1997 on Occupational Health and Safety Service (Journal of Laws no. 109, item 704, as amended).
6. ISO 45001:2018 Occupational Health and Safety Management Systems -- Requirements with Guidance for Use.
7. PN-N-18001:2004 Occupational Health and Safety Systems. Requirements.
8. PN-N-18002:2011 Occupational Health and Safety Systems—General Guidelines for Occupational Risk Evaluation.
9. Ejdys, J. 2010. Kształtowanie Kultury Bezpieczeństwa i Higieny Pracy w Organizacji. Oficyna Wydawnicza Politechniki Białostockiej.
10. Schein, E. H. 2010. Organizational Culture and Leadership. 4th edition, Jossey-Bass.
11. Schein, E. H. 2009. The Corporate Culture Survival Guide. New and Revised Edit. Jossey-Bass.
12. Cooper, M. D. 1998. Improving Safety Culture. A practical Guide. Wiley.
13. Cooper, M. D.2000. Towards a Model of Safety Culture. Safety Science, 36:111-136.
14. Gabryelewicz, I. 2016. Badania Ankietowe jako Czynnik Wspomagający Zarządzanie Bezpieczeństwem Pracy. Acta Universitatis Nicolai Copernici. Zarządzanie, 43(2):17-25.
15. Gabryelewicz, I. 2016. Czynnik Ludzki i Warunki Techniczne W Procesie Kształtowania Bezpieczeństwa Pracy—efekt synergii. Zeszyty Naukowe Małopolskiej Wyższej Szkoły Ekonomicznej w Tarnowie.
16. Gabryelewicz, I., and Krupa, P. 2015. Poziom Klimatu Bezpieczeństwa jako Element Zarządzania Bezpieczeństwem w Przedsiębiorstwie. Zeszyty Naukowe Politechniki Częstochowskiej. Zarządzanie, 19:183-192.
17. Cronbach, L.J. 1951. Coefficient Alpha and the Internal Structure of Tests. Psychometrika, 16(3):297-334.
18. Wątroba, J. 2011. Prosto o Dopasowaniu Prostych, czyli Analiza Regresji Liniowej w Praktyce. StatSoft Polska.