An increasement of general occupational safety level at food industry plants

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Abstract

Introduction. A purpose of research is to increase the occupational safety level through elaboration of general injury risk model at food processing.

Material and methods. Research object is an occupational traumatism at food industry plants. The research was carried out using method of the principal components for determination of main traumatism factors and work injury risk prognostication.

Results. We've improved the general injury risk model at food processing, which considers all the variety of industrial and socio-economical factors comprehensively, and is built upon the pattern of accident occurrence, wherein each accident is linked to its reason. This approach, based on data from the mandatory annual reporting forms, allows to perform the analysis of direct causal connections in traumation process and to detect both basic and hidden reasons of injuries, including types of events leading to accidents. It was found that the most efficient way to provide filtering of statistics and visualize results is the principal components method. Usefulness of this method in the analysis of data on occupational injuries is based on its capability to reduce the information amount and identify the most significant factors of industrial traumatism. Due to main properties of the principal components method, it is suited to prognostication of significant initial indications number, with relatively few auxiliary (latent) variables which display the reasons of traumatism, ensuring the smallest prognosis error.

Introduction

The problem of determining the causes of occupational injuries is crucial for effective prevention of unwanted effects at all levels of health and safety management. To solve this problem has been done a lot in the areas of investigation, recording and analyzing of the direct causes of occupational injuries [1–3]. However, there is no simple answer to the question of how the general characteristics of production, state of assets, and state supervision of safety and resource needs of safety affect on the occupational injuries. That is there are currently no external factors potentially able to influence the injuries (addition to the general considerations which are based on logic generalization and subjective perceptions). In the currently known research and practice analysis that focus on the impact of external factors on injury are used: comparison of the dynamics of gross domestic product and the injury levels [4], assessment of injury – rates of injuries per unit of production [5], expert assessment of the impact of external factors on occupational injuries [6] etc. That is taken into account only some of the characteristics of external factors that can not perform a comprehensive assessment of the impact on getting injuries of the entire range of industrial and socio-economic factors, which greatly impoverishes the results of analysis and does not take into account the trend of changes in external factors to correct for the prevention of occupational injuries.

A purpose of research is to increase the occupational safety level through elaboration of general injury risk model at food processing.

Research object is an occupational traumatism at food industry plants.

Material and methods

To analyze the direct cause-and-effect relationships that occur during injury, used the circuit of accidents that displays statistics about the immediate causes of occupational injuries [7]. Using this scheme, the tasks of improving informativeness of available statistics about the main causes of occupational injuries and kinds of events that lead to an accident were solved. The main source of information is acts of investigation of accidents and the results of their generalization in the form of mandatory annual statistical reports. In these forms stand out 16 major causes of accidents and 15 types of traumatic events that have traditionally been analyzed separately, independently one from the other.

To enhance the information content in the work investigates a binary mix (group) "cause of injury – type of traumatic event", that repeatedly increases the number of possible options (varieties) of causes of injury, hidden in the statistics form № 7-THB, and allows more specifically and purposefully determine how to prevent injuries.

The study of binary groups based on causal chain [7], shown in Fig. 1.

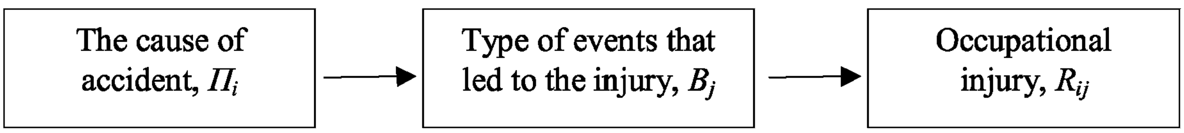

Fig. 1. Scheme occurrence of accidents

Assume that for the assessments of circuit components (Fig. 1) uses quantitative characteristics as the risk indicators. That is causes of traumatism assesse in terms of the risk of injury for each of the reasons $П_i$ (i – cause of injury index, i = 1,2,...,16), and the kinds of events that led to injury – in terms of risk that correspond to each traumatic event B_j (j - kind of traumatic event index, j = 1,2,...,15). Indicators of risk of injury in general R and for certain causes or kinds of events are determined by the frequency of accidents: $R^t = N^t / N_c$, N^t – number of injured with fatalities or no fatalities or the number of persons injured by certain causes $П_i$ or kinds of events B_j (with fatalities or no fatalities results), N_c – average number of employees. For ease perception of numbers accepted to multiply them by 100 000. Indicator risk in this case is interpreted as the number of injured or killed at work per year per hundred thousand workers (international practice).

Results and discussions

For research and development of a general model of risk of occupational injuries at food industry enterprises we should define basic categories and concepts.
The risk of occupational injuries in the work will be understood as quantitative manifestation of risk of accident in the production. A common approach for risk assessment of occupational injuries foresees the analysis of industrial accidents by the totality of signs prescribed by law.

In general, the risk of industrial injuries can be defined as:

$$R = \sum_{i=1}^{n} S_i P_i , \qquad (1)$$

S_i – consequences of an accident, P_i – probability (frequency) of an accident, n – number of accidents.

To determine the consequences of an accident S_i can use economic indicators that can assess the risk of R in monetary units.

The risk of accidents at the enterprise using a single dimensionality when calculating the consequences can be represented as the sum of the components

$$R = R_1 + R_2 + R_3 + R_4 , \qquad (2)$$

R_1 – risk of death; R_2 – risk of disability; R_3 – risk of injury; R_4 – risk of micro injury.

At the same time if similar meanings of consequences of accidents or when they can not be estimated (eg in case of death of the victim), the calculation of risk can only be made for the likelihood of accidents. More topical for the definition of risk is to determine the causes of occupational injuries.

Specificity of statistical information on the causes of traumatism and kinds of events that led to the accident is if the condition performed [8]:

$$R^t = \sum_{i=1}^{16} P(\Pi_i^t) = \sum_{j=1}^{15} P(B_j^t) , \qquad (3)$$

that is the overall risk of traumatism R^t equal to the amount of risk (probability of injury) for the reasons or the amount of risk an accident (probability of injury) by the kinds of events.

Feature of statistics on the causes of injury at the enterprise is the fact that every accident is only responsible one reason and only one kind of traumatic event. That is the risk of injury for each of the traumatic event depends only on one of the reasons given in the statistical bulletins [9–10]:

$$P(B_j^t) = f\left[P(\Pi_i^t)\right]. \qquad (4)$$

Since the risk of an accident – it is likelihood of injury in the enterprise with indicators of risk can perform actions provided for the theory of probability. It is known that the conditional probability $P_A(B)$ called the probability of an event B, calculated under the condition that the event A has occurred [8, 11]. That is taking into account the scheme of cause-effect relationship [7], it is assumed that for the calculation of the probability (risk) of injury from a particular event in the manifestation of certain causes of injury can apply conditional probability. To calculate the conditional probability uses Bayes formula:

$$P_{П}(B_j) = \frac{P(B_j)P_{Bj}(П_i)}{P(П_i)}. \tag{5}$$

Given that the statistical base is structured with the condition (3) and (4) simultaneously, equation (5) takes the form:

$$P_{Пi}(B_j) = \frac{P(B_j)P(П_i)}{\sum_{i=1}^{n} P(П_i)}. \tag{6}$$

Formula (6) performed calculations of the matrix risk of injury in the enterprise. This matrix has the form:

$$R^t_{ij} = \begin{vmatrix} R_{П1B1} & R_{П2B1} & \dots & R_{П16B1} \\ R_{П1B2} & R_{П2B2} & \dots & R_{П16B2} \\ \dots & \dots & \dots & \dots \\ R_{П1B15} & R_{П2B15} & \dots & R_{П16B15} \end{vmatrix}, \tag{7}$$

$R_{П1B1},\dots,R_{П16B15}$ – value of risk of injury for binary systems "cause risk of injury – kind of traumatic event", $i = 1,2,\dots,16$ – amount of the main causes of injury in the production $П_i$ that is fixed in the currently valid form of classification mandatory statistical reporting №7-ТНВ [9–10], $j = 1,2,\dots,15$ – amount of the main kinds of traumatic events.

To check the results obtained using formula (7), the study uses two methods. The first method – comparing calculated by formula (7) matrices of risk with obtained by direct filling matrices by the results of analysis of acts of investigation of accidents. The second method – is a method analytical solution of the system of linear equations obtained using the method of principal components and regression analysis.

The essence of the second method is that performed component analysis of statistical information body on the causes of traumatism $П_i$.

It is used such feature of principal components that are statistically unlinked, that by definition are orthogonal. This feature provides a regression relationship between the risk of injury due to traumatic events (dependent variables) and values of the principal components obtained in the analysis of risk of injury causes (independent variables)

$$B_j = f(Г_{Пp}) \tag{8}$$

Justification of the applicability of the method of principal component analysis of occupational injuries statistics. One of the tasks of the method of principal components is to find smaller subspaces in the orthogonal projection on which the deviation of the data (standard deviation from the mean) is maximized. At the same time raises the challenge of building such an orthogonal coordinate transformation, in which the correlation between individual coordinates are converted to zero.

The method of principal components based on the problem of best approximation of a finite set of points of straights and planes. Given a finite set of vectors $x_1, x_2, \dots, x_m \in R^n$. For each $k = 0,1,\dots,n-1$ among all k – dimensional linear subspaces in R^n necessary to find a such $L_k \subset R^n$ that the sum of squared deviations x_i from L_k will be minimal $\sum_{i=1}^{m} dist^2(x_i, L_k) \to \min$, where $dist(x_i, L_k)$ – Euclidean distance from a point to a linear subspace.

Any $k-$ dimensional linear subspaces in R^n can be defined as the set of linear combinations $L_k=\{a_0+\beta_1 a_1+...+\beta_k a_k \mid \beta_i \in R\}$, where the parameters β_i ranging over the real line R, $a_0 \in R^n$ and $\{a_1,...,a_k\} \subset R^n$ – orthonormalized vector set $dist^2(x_i,L_k)=\left\| x_i-a_0-\sum_{j=1}^{k} a_j\left(a_j,x_i-a_0\right)\right\|^2$, where $\|\bullet\|$ – Euclidean norm, (a_j,x_i) – Euclidean scalar multiplication.

Or, in coordinate form:

$$dist^2(x_i,L_k)=\sum_{l=1}^{n}\left(x_{il}-a_{0l}-\sum_{j=1}^{k}a_{jl}\sum_{q=1}^{n}a_{jq}\left(x_{iq}-a_{0q}\right)\right)^2 .$$

Solving the problem of approximation for $k=0,1,...,n-1$ has given by a set of nested linear subspaces $L_0 \subset L_1 \subset L_2 \subset ... \subset L_{n-1}$, $L_k=\{a_0+\beta_1 a_1+...+\beta_k a_k \mid \beta_i \in R\}$. These linear subspace defined by a set of orthonormal vectors $\{a_1,...,a_{n-1}\}$ (principal component vectors) and the vector a_0, which is sought by solving the minimization problem for $L_0: a_0=\arg\min_{a_0 \in R^n}\sum_{i=1}^{m} dist^2(x_i,L_0)$.

The usefulness of the method of principal components in the analysis of data of occupational injuries is based on possible reduction in information analysis and identification of the most significant factors of occupational injuries. At the same time principal component vectors can be found as the solution of optimization problems similar to the following algorithm:

1. Centering the data (by subtracting the mean values): $x_i := x_i-\overline{X}$ and $\sum_{i=1}^{m} x_i=0$;
2. Finding the first principal component as the solution of the problem: $a_1=\arg\min_{\|a_1\|=1}\left(\sum_{i=1}^{m}\left\|x_i-a_1(a_1,x_i)\right\|^2\right)$. If the solution is not unique, then choose one of them.
3. Calculate the data projection on the first principal component: $x_i := x_i-a_1(a_1,x_i)$.
4. Find the second major component as a solution to the problem $a_2=\arg\min_{\|a_2\|=1}\left(\sum_{i=1}^{m}\left\|x_i-a_2(a_2,x_i)\right\|^2\right)$. If the solution is not unique, then choose one of them. Find the projection on $(k-1)$-main component: $x_i := x_i-a_{k-1}(a_{k-1},x_i)$; 2*k*. Find *k*- principal components as a solution to the problem: $a_k=\arg\min_{\|a_k\|=1}\left(\sum_{i=1}^{m}\left\|x_i-a_k(a_k,x_i)\right\|^2\right)$. If the solution is not unique, then choose one of them.

Taking into account capabilities of modern modeling tools (Mathcad, Mathlab, Mathematica, Mapple, etc.) specified algorithm for statistical data series

$$X=\begin{bmatrix} x_{11} & \cdots & x_{1m} \\ \cdots & \ddots & \cdots \\ x_{n1} & \cdots & x_{nm} \end{bmatrix}$$ where there are signs of m and n observations can be written as follows:

1. Normalized the components of the vectors (rows) of the matrix X by an operation $z_i=\frac{x_{ji}-\bar{x}_i}{\sigma_{x_i}}, j=1,...,n, i=1,...,m$, σ_{x_i} – average deviation of a random variable X from the mean value for a column of the matrix X. We obtain the matrix Z size $n\times m$.
2. From the matrix Z finds correlation (covariance) matrix $R=\left[r_{ij}\right]_{m\times m}$
3. Finds the set of eigenvalues of the matrix R and organizes it by reducing components $\lambda_i, i=1,...,m$
4. Form a diagonal matrix with the eigenvalues of the matrix R $\Lambda=\begin{bmatrix} \lambda_1 & \cdots & 0 \\ \cdots & \ddots & \cdots \\ 0 & \cdots & \lambda_m \end{bmatrix}$
5. From the matrix R form a matrix of eigenvectors of the matrix $U=\begin{bmatrix} (u_{11},...,u_{1m}) \\ ... \\ (u_{n1},...,u_{nm}) \end{bmatrix}$
6. Finds the solution of the problem in a matrix $A=U\sqrt{\Lambda}$, where $\sqrt{\Lambda}$ is the matrix of roots on each element of the matrix Λ.

Found vectors $\{a_1,...,a_{n-1}\}$ are orthonormal simply as a result of solving the optimization problem, but to prevent due to error of calculation the violate of mutual orthogonality of vectors of principal components can be included $a_k \perp \{a_1,...,a_{k-1}\}$ in the conditions of the optimization problem.

The advantage of the described method to the analysis of statistics of injury is that it can almost always be used, regardless of the distribution of random variables – indicators of injury. However, this method is not always effective reduces the dimensionality of the given constraints on the accuracy. The straights and planes do not always provide a good approximation. For example, data can be described with sufficient accuracy by any curve, and the curve can be tricky located in the area of data. Also in the case of an isotropic distribution of data ellipsoid of scattering will be as hyper sphere and that is why will not be possible to reduce scattering by approximation methods.

Justification of the applicability of the method of principal components to predict occupational injuries. Due to the basic properties of the method of principal components is fairly successfully be used to predict the statistics of occupational injuries, while providing the smallest prediction error. Let us show that using the first p' principal components $z^{(1)},z^{(2)},...,z^{(p')}$ when $p'<p$, output signs $x^{(1)},x^{(2)},...,x^{(p)}$ are achieved the best prediction of these characteristics among all forecasts, which can be constructed using p' linear combinations of a set of p – random signs.

Let us explain in more detail aforementioned. Let it is necessary to replace the output researched p - dimensional vector of observations X on the vector $Z=\left(z^{(1)},z^{(2)},...,z^{(p')}\right)^T$ lower dimension p', in which each component would be a linear combination p output (or auxiliary) features without losing too much information. Informativeness of new vector Z depends on to what extent p' introduced auxiliary variables make it possible to "restore" p output characteristics by using the appropriate linear combinations $z^{(1)},z^{(2)},...,z^{(p')}$. One can imagine that the mistake σ forecast X on Z is determined by the residual dispersive matrix vector X by subtraction from it of the best prediction for Z that is matrix $\Delta=\left[\Delta_{ij}\right]$, and $\Delta_{ij}=E\left\{\left(x^{(i)}-\sum_{l=1}^{p'}b_{il}z^{(l)}\right)\left(x^{(j)}-\sum_{l=1}^{p'}b_{jl}z^{(l)}\right)\right\}$. $\sum_{l=1}^{p'}b_{il}z^{(l)}$ – best in the sense of least squares prediction $x^{(i)}$ by components $z^{(1)},z^{(2)},...,z^{(p')}$. Forecast error of X on Z is defined as some specified function of the matrix elements $\Delta=\left[\Delta_{ij}\right]$, that is $\sigma=f(\Delta)$, and $f(\Delta)$ defines some quality criterion prediction.

Consider the following measures of forecast error:

1. $f(\Delta)=Tr(\Delta)=\Delta_{11}+\Delta_{22}+...+\Delta_{pp}$ – based on the trace of the matrix $\Delta=\left[\Delta_{ij}\right]$;
2. $f(\Delta)=\|\Delta\|=\sqrt{\sum_{i=1}^{p}\sum_{j=1}^{p}\Delta_{ij}^2}$ – based on the Euclidean norm of the matrix $\Delta=\left[\Delta_{ij}\right]$.

It is proved that both measures are achieved simultaneously a minimum if and only if when as $z^{(1)},z^{(2)},...,z^{(p')}$ elected the first p' major components of the vector X, and the value of forecast error $\sigma=f(\Delta)\ \sigma=f(\Delta)$ explicitly expressed by the last $p-p'$ eigenvalues of the original covariance matrix C or approximately by the last $p-p'$ eigenvalues $\lambda_{p'+1},...,\lambda_p$ covariance matrix $\hat{C}$ constructed from observations $X_1,X_2,...,X_n$ [11].

In particular,

if $f(\Delta)=Tr(\Delta):\sigma\approx\lambda_{p'+1}+\lambda_{p'+2}+...+\lambda_p$;

if $f(\Delta)=\|\Delta\|:\sigma\approx\sqrt{\lambda_{p'+1}^2+\lambda_{p'+2}^2+...+\lambda_p^2}$.

Let us explain by the example the idea of predicting the initial signs $x^{(1)},x^{(2)},...,x^{(p)}$ with a help of smaller than p number of linear combinations.

Example. When forming typical forming signs of causes of occupational injuries was studied statistics per 24 years (n = 24) of three main groups of conditions: the technical factor $x^{(1)}$, the organizational factor $x^{(2)}$ and the human factor $x^{(3)}$. According to the observations $\left(x_i^{(1)},x_i^{(2)},x_i^{(3)}\right), i=1,...,24$ was defined sample covariance matrix

$$\hat{C}=\begin{bmatrix}451{,}39 & 271.17 & 168{,}70\\ 271{,}17 & 171{,}73 & 103{,}29\\ 168{,}70 & 103{,}29 & 66{,}65\end{bmatrix}$$

Own radical of this matrix C will be: $\lambda_1=680{,}0$, $\lambda_2=6{,}5$, $\lambda_3=2{,}86$.

The matrix of eigenvectors will be:

$$U=\begin{bmatrix}-0,813 & -0,495 & -0,307\\ 0,545 & -0,832 & -0,101\\ -0,205 & -0,249 & 0,946\end{bmatrix}.$$

As a result, as the main components we obtain:

$$z^{(1)}=-0,81x^{(1)}-0,50x^{(2)}-0,31x^{(3)},$$
$$z^{(2)}=0,55x^{(1)}-0,83x^{(2)}-0,10x^{(3)},$$
$$z^{(3)}=-0,21x^{(1)}-0,25x^{(2)}+0,95x^{(3)}.$$

Here $x^{(1)}$, $x^{(2)}$, $x^{(3)}$ are the deviation of the number of accidents due to technical factors $x^{(1)}$, organizational factors $x^{(2)}$ and human factors $x^{(3)}$ from their mean values.

In this example $p=3$. Let us define as the goal of reducing the dimension of the output factor space to unity ($p'=1$) that is to describe all three groups of features by using linear combinations of just one auxiliary variable.

According to the above property "auto forecast» of principal components let us take as this one secondary variable the first principal component, ie variable $z^{(1)}=-0,81x^{(1)}-0,50x^{(2)}-0,31x^{(3)}$.

By the method of least squares unknown coefficients b_{i1} calculated by the expression:

$$b_{i1}=\frac{\operatorname{cov}\left(x^{(i)},z^{(1)}\right)}{Dz^{(1)}}=\frac{-0.81\operatorname{cov}\left(x^{(i)},x^{(1)}\right)-0,50\operatorname{cov}\left(x^{(i)},x^{(2)}\right)-0,31\operatorname{cov}\left(x^{(i)},x^{(3)}\right)}{Dz^{(1)}}.$$

Substituting in this formula values $\operatorname{cov}\left(x^{(i)},x^{(j)}\right)$ taken from the covariance matrix C for our example we obtain

$$x^{(1)}=b_{11}z^{(1)}+\varepsilon^{(1)}=-0,81z^{(1)}+\varepsilon^{(1)},$$
$$x^{(2)}=b_{21}z^{(1)}+\varepsilon^{(2)}=-0,50z^{(1)}+\varepsilon^{(2)},$$
$$x^{(3)}=b_{31}z^{(1)}+\varepsilon^{(3)}=-0,31z^{(1)}+\varepsilon^{(3)},$$

$\varepsilon^{(i)}$ – random (residual) forecast error of output component for the first principal component $z^{(1)}$.

If as a relative forecast error of output characteristics $x^{(i)}$ for the first principal component $z^{(1)}$ select a value $\delta_i=100\left(\frac{D\varepsilon^{(i)}}{Dx^{(i)}}\right)$ the forecast error in this example would be $\delta_1=2\%, \delta_2=1,2\%, \delta_3=0,8\%$.

The total relative forecast error of features $x^{(1)}$, $x^{(2)}$, $x^{(3)}$ by $z^{(1)}$ can be calculated by the expression $\delta_{сум.}=100\left(\frac{Tr(\Delta)}{D\left(x^{(1)}+x^{(2)}+x^{(3)}\right)}\right)=100\frac{\lambda_2+\lambda_3}{\lambda_1+\lambda_2+\lambda_3}=1,36\%$, which confirms sufficient efficiency of the method of principal components to predict the statistical characteristics, including and for the prediction of risk of occupational injuries.

This example shows the applied orientation of component analysis, in particular for forecast tasks (auto forecast) of a large number of initial indicators for occupational injuries with a small number of auxiliary (latent) variables that express the reasons for this phenomenon, visualization of multidimensional data and the selection of typically formed signs of injury.

To solve research problems associated with obtaining accurate statistical solution of the problem for injury risk values for binary groups "cause an accident - a kind of traumatic event" can use not only the principal components (which account for the bulk of the total variance of the array input data), but the whole components, covering the entire total variance of causes of risk of injury at the workplace. The system of regression equations for B_j then will look like:

$$\left.\begin{aligned} B_1 &= a_1^1 + b_1^1 \Gamma k_1 + b_2^1 \Gamma k_2 + b_3^1 \Gamma k_3 + \ldots + b_{16}^1 \Gamma k_{16}; \\ B_2 &= a_1^2 + b_1^2 \Gamma k_1 + b_2^2 \Gamma k_2 + b_3^2 \Gamma k_3 + \ldots + b_{16}^2 \Gamma k_{16} \\ B_3 &= a_1^3 + b_1^3 \Gamma k_1 + b_2^3 \Gamma k_2 + b_3^3 \Gamma k_3 + \ldots + b_{16}^3 \Gamma k_{16} \\ &\ldots \\ B_{15} &= a_1^{15} + b_1^{15} \Gamma k_1 + b_2^{15} \Gamma k_2 + b_3^{15} \Gamma k_3 + \ldots + b_{16}^{15} \Gamma k_{16} \end{aligned}\right\}, \quad (9)$$

The main components are determined through the input set of risk indicators for causes of injury by a system of equations

$$\left.\begin{aligned} \Gamma k_1 &= d_1^1 + c_1^1 \Pi_1 + c_2^1 \Pi_2 + c_3^1 \Pi_3 + \ldots + c_{16}^1 \Pi_{16}; \\ \Gamma k_2 &= d_1^2 + c_1^2 \Pi_1 + c_2^2 \Pi_2 + c_3^2 \Pi_3 + \ldots + c_{16}^2 \Pi_{16} \\ \Gamma k_3 &= d_1^3 + c_1^3 \Pi_1 + c_2^3 \Pi_2 + c_3^3 \Pi_3 + \ldots + c_{16}^3 \Pi_{16} \\ &\ldots \\ \Gamma k_{16} &= d_1^{15} + c_1^{15} \Pi_1 + c_2^{15} \Pi_2 + c_3^{15} \Pi_3 + \ldots + c_{16}^{15} \Pi_{16} \end{aligned}\right\}, \quad (10)$$

Substituting the values of the principal components of the system of equations (9) into the equation system (10) and equating all but one value of Π_i to zero we obtain the value of risk of injury for a particular binary group "cause an accident – the kind of traumatic event".

For example, a binary value $B_1\Pi_1$ "accident due to design flaws, imperfections and lack of reliability of the production, vehicles" equation to determine the risk of injury is:

$$P(B_1\Pi_1) = a_1^1 + b_1^1 (d_1 + c_1^1 + \Pi_1 + d_2 + c_1^2 + \Pi_2 + \ldots + d_{16} + c_1^{16} + \Pi_{16}). \quad (11)$$

Coefficients a, b, c, d calculated using component and regression statistics injuries.

Using the method of principal component for analysis of the main causes of accidents are more appropriate m output variables $X_1, X_2, X_3, \ldots, X_m$ replace their p linear combinations [12]

$$Y_k = a_{1k} X_1 + a_{2k} X_2 + a_{3k} X_3 + \ldots + a_{jk} X_j + \ldots + a_{mk} X_m, \quad (12)$$

$k = 1, 2, 3, \ldots, p$; $j = 1, 2, 3, \ldots, m$.

Amount of p new variables that explain the bulk of the variance of input variables (indicators) are usually much smaller than the number of m – variables X_j. Coefficients a_{jk} from equations (12) are calculated under the following conditions [12]: 1) the amount of variance of variables Y_k $(k = 1, 2, 3, \ldots, p)$ equals the sum of variances of the input parameters $X_j\,(j=1,2,3,...,m)$; 2) The variable Y_k is ordering largely by reducing their variance; 3) all Y_k are mutually independent.

New variables $Y_k\,(k=1,2,3,...,p)$ that meet these conditions are the main components.

Algorithm for the principal components is as follows [12]:

1. Using the input parameters calculated covariance or correlation matrix S and the vector of average values $\bar{x}$ of these parameters.

2. Identified the eigenvalues $\lambda_1, \lambda_2, \lambda_3, ..., \lambda_j, ..., \lambda_m$ of the matrix, for that is solved the equation

$$|S-\lambda I|=0, \qquad (13)$$

where $I-$ identity matrix of size $m \times m$.

The eigenvalues λ_j are the variance of principal components, they are placed in a row from largest to smallest.

3. Calculated the fate variances of principal components in their sum. The main components of the fate of the contribution which the small amount of variance, are excluded from further analysis, using only the p first component.

4. Calculated the coefficients a_{jk} of the first p – eigenvectors of covariance or correlation matrix. Using these coefficients are recorded equation of each p component. In particular for the main k components of the equation takes the form (12), but the input variables are normalized.

5. The transition from the fixed to the input variables by substitution $X_{jн} = \frac{X_j - \bar{x}_j}{\sigma_f}$ are performed.

6. Calculated the value of the principal components for each measure for each facility or research. Data are entered into the table, for example:

7. The interpretation of the principal components of the position of the object and tasks of research and a comprehensive analysis of certain components is performed.

Thus, based on the methods of regression and factor analysis formed a general model of risk of occupational injuries (3-11), which comprehensively links likelihood of an accident with a frequency of accidents in the enterprise with the full range of reasons.

Signs	**Factors**					
	F_1	F_2	. . .	F_m	. . .	F_n
1	α_{11}	α_{12}	. . .	α_{1m}	. . .	α_{1n}
2	α_{21}	α_{22}	. . .	α_{2m}	. . .	α_{2n}
. . .	. . .	. . .	. . .	. . .	. . .	. . .
j	α_{j1}	α_{j2}	. . .	α_{jm}	. . .	α_{jn}
. . .	. . .	. . .	. . .	. . .	. . .	. . .
n	α_{n1}	α_{n2}	. . .	α_{nm}	. . .	α_{nn}
V_r						
Percentage of summarily dispersions						

Conclusions

The general model of risk of occupational injuries at food industry enterprises should be comprehensively consider the influence on traumatism of the full range of industrial and socio-economic factors and be based on the scheme of occurrence of accidents in which every fact of an accident associated with the prerequisite of its occurrence. This approach allows for the analysis of direct causal relationships that occur during getting injury and identify both basic and hidden cause of occupational injuries, as well as types of events that lead to accidents on the basis of a form of mandatory annual reporting.

To provide filtration of statistical data and visualization of results for handling existing statistics of occupational injuries is the most appropriate method of principal components. The usefulness of the method of principal components in the analysis of data of occupational injuries is based on possibilities of reduction in information analysis and identification of the most significant factors of occupational injuries. Due to the basic properties of the method of principal components is fairly successfully be used to predict the statistics of occupational injuries with a small number of auxiliary (latent) variables that express the reasons for this phenomenon, while providing the smallest prediction error.

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