ECONTECHMOD. AN INTERNATIONAL QUARTERLY JOURNAL – 2014. Vol. 3. No. 2. 71–78

Mathematical models for occupational injuries analysis at the enterprises of the state forestry committee of Ukraine

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Received May 14.2014: accepted June 15.2014

Abstract. The paper focuses on the mathematical models for the study of occupational injuries at the enterprises of the State Forestry Committee of Ukraine over a period of ten years. The major conditions and causes of the accidents have been indicated. The relationship between individual pairs of variables that influence occupational injuries has been determined on the basis of correlation and regression analysis. The correlation dependences of the frequency of occupational injuries on individual factors have been obtained. Using the methods of multifactor analysis, the relationship between the number of injuries and workers' occupations as well as types of works has been established. The results obtained can be used for enhancing the efficiency of safety measures at the enterprises of forestry with the aim of reducing the rate of injury.

Key words*:* occupational injuries, correlation and regression analysis, methods of multifactor analysis.

INTRODUCTION

Every year two million people die on the planet Earth because of accidents and occupational diseases [1]. Annually 270 million accidents and 160 million cases of occupational diseases are registered. According to the data provided by the WTO such situation causes a 4 % loss of the gross national product of the world economy. From what has been mentioned above it follows that the study of the causes, consequences and circumstances of occupational injuries and formation on the basis of their results a set of measures to prevent and reduce the rate of injuries in any area of human activity is the task of particular importance. Following the recommendations given by the UNO and the WTO, each state forms its regional systems of administering labour protection. Conceptual foundations of administering labour protection and the national development concept in the field of administering labour protection are considered in the papers [1, 2].

The analysis of domestic and foreign scientific literature indicates quite clear tendency towards increasing the number of publications concerning the analysis of the causes and consequences of occupational injuries. In the publication [3] in particular the analysis of the occupational injuries causes conducted by the State Supervision Committee on Labour Protection is provided. The statistics of the causes of injuries in the anti-fire protection departments is presented in the paper [4]. Besides it should be noted that there exist many sectors of the national economy of Ukraine (forestry in particular), in which comparative dynamics of injuries and the mechanisms of their increasing or decreasing are not investigated enough.

Setting the problem and identifying the main causes of injuries. The aim of the paper is to investigate the state of occupational injuries at the enterprises of the State Forestry Committee of Ukraine and to develop mathematical models of the state estimation of labour protection in the field of forestry in general and the risk of damaging people’s health and the loss of working ability as a result of being injured at work in particular. In the article [5] the systematic analysis of the occupational injuries at the enterprises of the State Forestry Committee of Ukraine has been conducted. It is based on the annual state statistical observation form №7 RIW "Report on injuries at work (2000-2009). Besides the major causes and factors leading to the accidents have been singled out. The results of the statistical analysis are presented in Table 1.

Table 1. Statistical data on occupational injuries at the enterprises of the State Forestry Committee of Ukraine

Year	Number of injuries	With lethal outcome	Frequency coefficient	Number of the dead	Logging ths m^3	Total-expenses, hrv.	Expenses per person.	Number of workers	Total controls	Control per person.
2000	167	13	1,7	0,14	9559	3267337	34	95260	4747	14,2
2001	142	13	1,5	0,14	11026	7892286	83	94999	4984	14,9
2002	174	10	1,9	0,11	10153	8622998	95	91016	5358	16
2003	146	16	1,6	0,18	11048	10680591	119	89580	5894	17,6
2004	129	9	1,5	0,1	12117	13150914	149	88000	6696	20
2005	132	16	1,5	0,18	12094	15378119	177	87027	7661	23
2006	154	12	1,9	0,15	12747	17712303	221	80064	8156	25
2007	129	16	1,7	0,21	13403	22262021	297	74931	9411	28,1
2008	93	9	1,4	0,13	12393	22124869	330	67058	10336	30,7
2009	80	10	1,3	0,16	11475	22687737	374	60668	10399	31,1

Year	Occupations(positions)						Professional work experience				Types of works					
	Logger	Driver	Machine-tool operator	Hooker	Workman	Others	1-5 years	5-10 years	10-15 years	More than 15 years	Log-ging	Trans-porting	Low-storing	Wood-working	Repairing	Others
2000	58	35	33	18	9	14	77	35	22	33	56	34	18	31	15	13
2001	54	27	31	17	6	7	89	19	17	17	50	29	16	30	9	8
2002	59	31	33	19	13	19	90	34	21	29	59	33	18	41	15	8
2003	54	26	27	15	14	10	76	28	18	24	46	26	15	32	13	14
2004	44	25	23	13	9	15	62	29	17	21	44	20	12	36	6	11
2005	53	22	25	11	8	13	79	18	14	21	45	27	15	20	11	14
2006	57	29	26	14	13	15	96	25	16	17	55	32	17	18	13	19
2007	45	26	23	13	11	11	71	24	15	19	53	26	13	15	11	11
2008	25	19	10	10	16	13	58	13	10	12	39	21	10	10	7	6
2009	25	18	10	5	16	6	37	19	11	13	33	15	7	10	8	7

The analysis of the injuries dynamics during the period under investigation shows that the number of injuries has a wave-like character. It increases in 2000-2002, 2004-2006 and decreases in 2002-2004 and beginning since 2006. The recession in 2002-2004 is caused by the improvement of the normative base concerning safety measures at the national level in connection with the adoption of the Law of Ukraine "On Labour Protection" in a new wording. Also, the enterprises have begun to implement measures to fulfill the National Program of improving safety status, occupational health and working environment in 2001-2005, approved by the Resolution of the Cabinet of Ministers of Ukraine of October 10, 2001 № 1320.

From 2004 to 2006 under the condition of constant volume of logging and reducing the number of employees by 10% the occupational injuries were increasing including those with the lethal outcome. To some extent this can be explained by the emotional disturbance of society at that time.

And since 2006 we are noticing a gradual decreasing of occupational injuries and it is due to the arranging of the system of administering labour protection in forestry. In 2005 NRALP 02.0-1.04-05 "Rules for labour protection for the workers of forestry and forest industry" and NRALP 20.0-1.02-05 "Rules for labour protection in the woodworking industry" were developed. As a result they significantly increased financing of expenses on safety measures in general as well as financing per worker in particular. Besides the above mentioned, a number of additional measures to improve safety and reduce injuries at the industry enterprises had been conducted.

However, in spite of the measures taken at the enterprises injuries remain high. Also we should keep in mind the fact that human life is priceless.

Summing up the statistics mentioned above, it can be stated that every million cubic meters of wood harvested accounts for one human life and every seven hundred workers accounts for one accident at work. The major conditions that caused the occupational injuries at the enterprises of the State Forestry Committee of Ukraine are:

– in the process of logging operations: stalling trees, pruning branches, bucking wood whips, skidding and loading wood,

– in the process of transporting: transporting wood whips and assortments,

– in the process of low-stocking works: unloading and stacking wood,

– in the process of woodworking: cutting trees for their wood,

– in the process of ancillary works: metal-working, metal-forging, sharpening, welding, tire mounting works.

A detailed analysis of the impact of various factors (total work experience, seniority, profession, age of the injured people, time of year and time of day) on the coefficient of frequency of injuries is provided in the publication [5]. However, it should be noted that the processing and compiling information about the causes of occupational injuries is not yet allowing the assessment of the conditions and labour protection and to give a preference to particular measures and means or use them in a complex. In order to achieve this you must have some quantitative indexes of risk or safety assessment at workplace. Thus, the need to develop a certain integral criterion that would assess the impact of all production factors (organizational, technical, psychological, subjective, etc.) and give an idea of the scope of the social and economic losses of the enterprise because of injuries and occupational diseases. Currently, more and more often a professional risk is being chosen in the role of such parameter. The foundations of this approach are considered in the papers [6-10], in which the methodology and the identification assessment examples of the professional risks at workplaces and in the whole industry are presented.

CALCULATION MODEL OF CORRELATION AND REGRESSION ANALYSIS

It is clear that the overwhelming majority of the causes of occupational injuries are of random (scholastic) nature and therefore it is reasonable to use the methods of mathematical statistics [11-14]. In this case the frequency coefficient of injuries can serve as an example of the use of risk as the probability of an adverse event. Under such circumstances it would be recommended to use the methods of correlation and regression analysis, which can establish the existence of a certain quantitative or functional relationship between two random variables and its density. Here are the basic dependences concerning this problem.

Suppose that two random values *x*, *y* after conducting *n* independent tests assume the value (x_1,y_1), (x_2,y_2),…, (x_n,y_n). Hence the existence of correlations between these values are found by means of the correlation coefficient r determined in the following manner:

$$r = \frac{\overline{xy} - \overline{x}\cdot\overline{y}}{s_x \cdot s_y}, \tag{1}$$

where: $\overline{xy} = \frac{1}{n}\sum_{i=1}^{n} x_i y_i$ – the average value of the product of two correlated quantities,

$\overline{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$, $\overline{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$ – the average values of these quantities,

$s_x = \sqrt{\overline{x^2} - \left(\overline{x}\right)^2}$, $s_y = \sqrt{\overline{y^2} - \left(\overline{y}\right)^2}$ – the average square (standard) deviations of the corresponding quantities,

$\overline{x^2} = \frac{1}{n}\sum_{i=1}^{n} x_i^2$, $\overline{y^2} = \frac{1}{n}\sum_{i=1}^{n} y_i^2$ – the average value of the squares of the correlated quantities.

Let us notice that in the given case s^2 is the variance of a random quantity (measure of variance).

The correlation coefficient r is a characteristic of density connection between the investigated quantities and it changes within the range of $-1 \le r \le 1$. In case that $r=0$, there is no correlative connection between two random quantities, thus they are independent. In case that $r=\pm 1$, we observe linear functional connection between two random quantities. The direct connection exists when *r* obtains positive values, it means that with the increasing of the independent variable *x* the dependent random quantity y increases too. If r has negative values we observe reciprocal connection, thus with the increasing of the independent variable x the dependent random quantity y decreases.

If the independent variable X – factor causing occupational injuries, and Y – frequency coefficient of injuries, then there exists a certain functional relationship for non-zero correlation coefficients between these values Y = f(X). It is the most advisable to present this relationship as a polynomial of the fourth order, i.e:

$$y = f(x) = a_o + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4 . \tag{2}$$

Polynomial coefficients a_i (i = 0,4) are determined by means of the method of least squares. Its essence is that the most likely value of parameters gives the minimum function:

$$S = \sum_{i=1}^{n}\left[y_i - f\left(x_i, a_o, a_1, a_2, a_3, a_4\right)\right]^2 . \tag{3}$$

Under the necessary condition of the minimum functions of several variables:

$$\frac{\partial S}{\partial a_o} = 0; \frac{\partial S}{\partial a_1} = 0; \frac{\partial S}{\partial a_2} = 0; \frac{\partial S}{\partial a_3} = 0; \frac{\partial S}{\partial a_4} = 0 . \tag{4}$$

to determine five unknown coefficients of the polynomial a_i (i = 0,4) we obtain a system of five linear algebraic equations:

$$\begin{cases} a_o n + a_1\sum_{i=1}^{n} x_i + a_2\sum_{i=1}^{n} x_i^2 + a_3\sum_{i=1}^{n} x_i^3 + a_4\sum_{i=1}^{n} x_i^4 = \sum_{i=1}^{n} y_i, \\ a_o\sum_{i=1}^{n} x_i + a_1\sum_{i=1}^{n} x_i^2 + a_2\sum_{i=1}^{n} x_i^3 + a_3\sum_{i=1}^{n} x_i^4 + a_4\sum_{i=1}^{n} x_i^5 = \sum_{i=1}^{n} x_i y_i, \\ a_o\sum_{i=1}^{n} x_i^2 + a_1\sum_{i=1}^{n} x_i^3 + a_2\sum_{i=1}^{n} x_i^4 + a_3\sum_{i=1}^{n} x_i^5 + a_4\sum_{i=1}^{n} x_i^6 = \sum_{i=1}^{n} x_i^2 y_i, \\ a_o\sum_{i=1}^{n} x_i^3 + a_1\sum_{i=1}^{n} x_i^4 + a_2\sum_{i=1}^{n} x_i^5 + a_3\sum_{i=1}^{n} x_i^6 + a_4\sum_{i=1}^{n} x_i^7 = \sum_{i=1}^{n} x_i^3 y_i, \\ a_o\sum_{i=1}^{n} x_i^4 + a_1\sum_{i=1}^{n} x_i^5 + a_2\sum_{i=1}^{n} x_i^6 + a_3\sum_{i=1}^{n} x_i^7 + a_4\sum_{i=1}^{n} x_i^8 = \sum_{i=1}^{n} x_i^4 y_i. \end{cases} \tag{5}$$

Having solved the received system of equations, we obtain estimates a_i (i = 0,4) of the coefficients of approximating polynomial (2). In the publication [15] the expressions for the variance of all investigated values and confidence intervals for the coefficients of the interpolating polynomial are provided.

CALCULATION MODEL OF MULTIFAKTOR ANALYSIS

In practice, it often happens that one determining factor depends on several different factors, among which you can not set a clear connection. In this case it is advisable on the basis of the methods of multifactor correlation and regression analysis [16-20] to develop a mathematical model of the process or phenomenon, which would give an opportunity to assess the degree of influence on each studying resulting figure entered into the model of factors.

The construction of multifactor regression models presupposes the following steps:

1. Selecting all possible factors influencing the rate (or process) under investigation. If it impossible to determine the quantity of some factors or their statistics is not available, they are eliminated from further consideration.

2. Choosing a form of regression or multifactor model which consists in finding such an analytical expression which would best reflect the link between factor characteristics with the resultant one, i.e. the choice of function:

$$\hat{Y} = f(X_1, X_2, X_3, \ldots, X_n), \qquad (6)$$

where: $\hat{Y}$ – resultant variable function, $X_1, X_2, X_3, \ldots, X_n$ – factor variables.

An important issue in this case is the choice of the analytical form for the function f, which links existing factors with the resultant variable function. This function better than the others reflects the real relationships between the studied parameters and factors. Empirical study of such functions using a graphical analysis of relationships for multifactor models is unsuitable. Suppose that any function of many variables can be reduced to a linear form by logarithm or change of variables, then in practice the multiple regression equation assumes the linear form:

$$\hat{Y} = a_0 + a_1X_1 + a_2X_2 + \ldots + a_nX_n, \qquad (7)$$

where: $a_0, a_1, \ldots, a_n$– equation parameters to be determined.

If for each factor, including the resultant variable the values of n are known $\hat{Y}_j, X_{1j}, X_{2j}, \ldots, X_{nj}$, j=1,2,…,m then using the standard procedure of the least squares method to estimate the parameters of regression equations we obtain a system of linear algebraic equations:

$$\begin{cases} a_o m + a_1\sum_{j=1}^{m} x_{1j} + a_2\sum_{j=1}^{m} x_{2j} + \ldots + a_n\sum_{j=1}^{m} x_{nj} = \sum_{j=1}^{m} y_j, \\ a_o\sum_{j=1}^{m} x_{1j} + a_1\sum_{j=1}^{m} x_{1j}^2 + a_2\sum_{j=1}^{m} x_{1j}x_{2j} + \ldots + a_n\sum_{j=1}^{m} x_{1j}x_{nj} = \sum_{j=1}^{m} x_{1j}y_j, \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ a_o\sum_{j=1}^{m} x_{nj} + a_1\sum_{j=1}^{m} x_{nj}x_{1j} + a_2\sum_{j=1}^{m} x_{nj}x_{2j} + \ldots + a_n\sum_{j=1}^{m} x_{nj}^2 = \sum_{j=1}^{m} x_{nj}y_j. \end{cases} \qquad (8)$$

The received system of n +1 equations with n +1 unknowns $a_0, a_1, \ldots, a_n$ can be solved by linear algebra. For a large number of equations it is recommended to use the Gauss' method of main element choice [21] the procedure of which is well algorithmizated. Since the matrix of this system of linear algebraic equations is symmetric , there is always a solution, and the only one. If the number of equations is small, it can be successfully used for solving the reciprocal matrix method [22].

3. Checking the adequacy of the received model. You must calculate:

– the remains of the model, i.e. the differences between the observed and calculated values:

$$u_i = y_i - \hat{y}_i = y_i - (a_0 + a_1X_{1i} + a_2X_{2i} + \ldots + a_nX_{ni}), \quad i=1,2,\ldots,m, \qquad (9)$$

– relative error of the remains and its average value:

$$\delta_i = \frac{u_i}{y_i} \cdot 100\%, \qquad \delta = \frac{\sum_{i=1}^{m} d_i}{m}, \qquad (10)$$

– the average error variance of disturbances:

$$\sigma_u = \sqrt{\frac{\sum_{i=1}^{m} u_i^2}{m-n-1}}, \qquad (11)$$

– coefficient of determination:

$$R^2 = 1 - \frac{\sum_{i=1}^{m} u_i^2}{\sum_{i=1}^{m} (y_i - \bar{y})^2}, \qquad (12)$$

– multiple correlation coefficient R, which is the main indicator of the density correlation of the generalized index with the factors:

$$R = \sqrt{1 - \frac{\sum_{i=1}^{m} (y_i - \hat{y}_i)^2}{\sum_{i=1}^{m} (y_i - \bar{y})^2}}. \qquad (13)$$

If the value of R is close to 1, the relationship between the indicator and the factors is considered to be dense. Multiple correlation coefficient R is the main characteristic of the density of the relationship between the resultant variable and the set of factor variables . Note that we consider the correlation coefficient in the cases when the regression equation is a linear function. In the case of a nonlinear regression function the concept of correlation ratio is introduced, which is given by the same equation, but characterizes the degree of approximation of the regression equation to the data of observation.

In some cases in the course of the study of multifactor processes it is recommended to investigate in advance the degree connection between individual factors in pairs. If all paired connections are close to an average linear, then there is every reason to believe that the multiple connection is linear too. To determine the density of the link between two of the factors under investigation (excluding their interaction with other variables) paired correlation coefficients are used. The method of calculation of these coefficients and their interpretation is similar to the one used for calculating the linear correlation coefficient for the case of one-factor connection. However, in the real world all values are usually interrelated. The density of such a relationship is determined by partial correlation coefficients that characterize the extent and impact of one of the arguments on the function, provided that the other independent variables remain constant. Depending on the number of variables whose influence is excluded, the partial correlation coefficients can be of a different order: with the exclusion of the influence of one variable we obtain a partial correlation coefficient of the first order, with the exclusion of the influence of two variables – the second order, etc. However, as a rule, the pair correlation coefficient between the function and the argument is not equal to the corresponding partial coefficient.

Expressions for calculating the correlation coefficients of arbitrary order are provided in the paper [23].

4. Verifying the statistical significance of the obtained results:

– checking the adequacy of the model as a whole: but check the original hypothesis H_o: all coefficients of the multiple regression equation (7) are equal to zero:

$$a_i=0 \qquad (i=1,2,\ldots,n).$$

For alternative H_i exists at least one coefficient ai which is non – zero.

Verification is performed by means of Fisher's statistics n and m-n-1 degrees of freedom:

$$F= F=\frac{R^2}{1-R^2}\frac{m-n-1}{n}, \qquad (14)$$

where: n – the number of factors included in the model, m – total number of observations, R – coefficient of multiple correlation.

Using the Fisher's tables we find critical value F_{kr} of n and m–n–1 degrees of freedom, setting in advance the confidence level (1–α) 100%. If $F> F_{kr}$, then a built model is adequate. If the model is inadequate, it is necessary to return to the stage of model building and probably introduce additional factors or switch to a non-linear model.

– verifying the significance of the coefficient of multiple correlation R.

Check the performance of the null hypothesis H_o: R=0 by means of t–statistics:

$$t=\frac{R\sqrt{m-n-1}}{\sqrt{1-R^2}}. \qquad (15)$$

The calculated value of statistics is compared with the tabulated one t_{tabl} (α/ 2; m–n–1), were α – chosen level of significance , m–n–1 – the number of degrees of freedom. If $| t |> t_{tabl}$ it is possible to conclude about the reliability of the correlation coefficient.

– calculation and interpretation of regression parameters dependence.

The regression equation being known one can not determine which of factors most affect the resultant variable, since in most cases the coefficients of the regression equation have different dimensions and therefore are not comparable. On this basis one can not determine which of the factor variables has the greatest scope for changing the effective rate, because the regression coefficients do not take into account the variation factor variable.

In order to identify comparative connection and influence of individual factors and the provisions they contain, calculate the partial elasticity coefficients ε, and β (beta) and (delta) – coefficients [23].

Partial elasticity coefficient indicates the average percentage by which the resultant variable with the factor shift by 1% for the fixed values of other parameters is changed.

β– coefficient (standardized regression coefficient) is used to determine the factors that have the greatest scope for improving the resultant variable.

Δ– coefficient shows the share of contribution of the factor under consideration into the total effect of all selected factors.

Notice that increasing the number of factors that are introduced in the multiple regression model allows you to determine additional resources of the resulting variable.

ANALYSIS OF OCCUPATIONAL INJURIES AT THE ENTERPRISES OF THE STATE FORESTRY COMMITTEE OF UKRAINE

Using the above described mathematical tools of statistical modeling and modern tools of Microsoft Excel spreadsheet [24-26] the analysis of occupational injuries at the enterprises of the State Forestry Committee of Ukraine has been conducted.

The methods of one-factor correlation and regression analysis were mainly employed to investigate the relationship between injuries frequency coefficient (including those with the lethal outcome) and the main factors that determine the state of injury in the field, namely: the volume of harvested wood, the costs of labor protection per worker and the number of inspections, surveys (prescriptions) per worker in labour protection.

As an example the relationship between the frequency coefficient of occupational injuries and costs per worker was analyzed. The correlation coefficients in this case are quite small (0,439 – for general injuries, 0,3298 – injuries with the lethal outcome), indicating the absence of a linear relation between the studied variables. It is shown that in the considered case it is recommended to present the correlation curve in the form of a polynomial of fourth order (Fig. 1, 2).

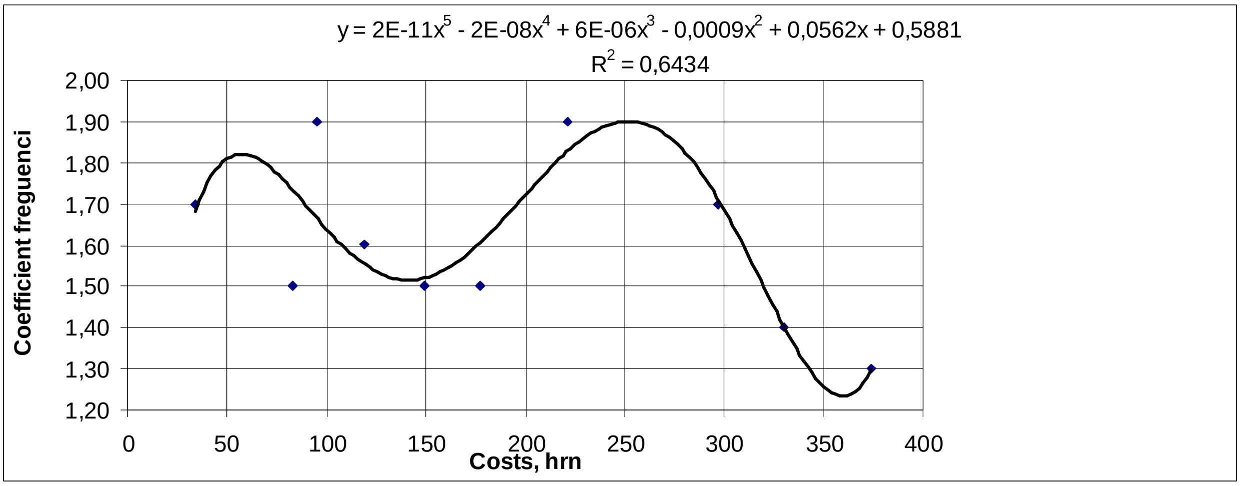

Fig. 1. Dependence of the frequency coefficient of injuries on the costs spent per worker

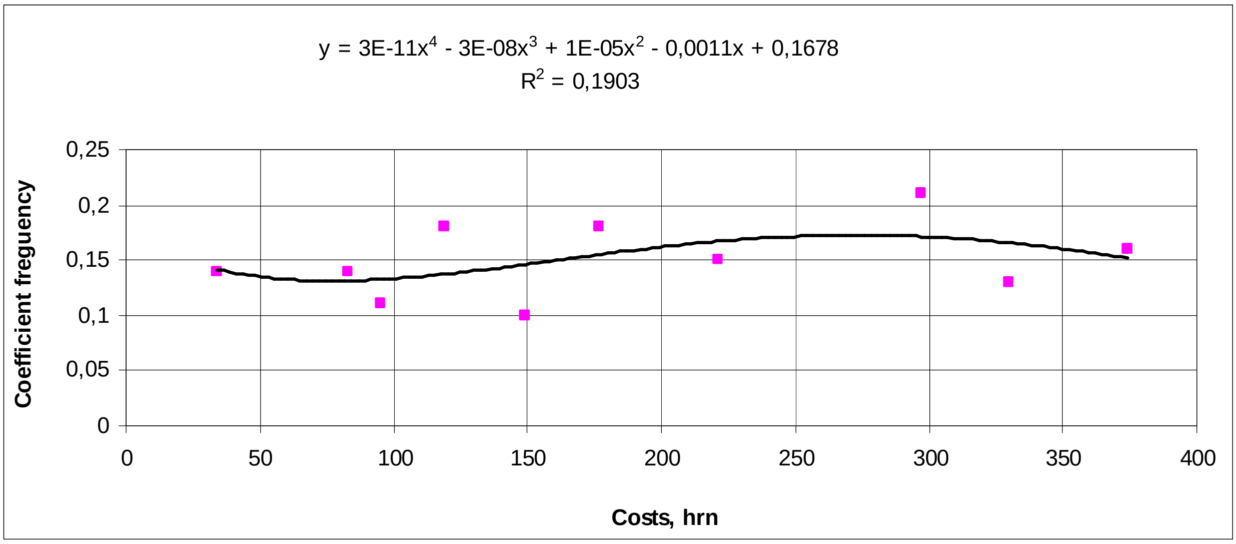

Fig. 2. Dependence of the frequency coefficient of injuries with the lethal outcome on the costs spent per worker

The dependence of the frequency coefficient of injuries on the amount of the harvested wood and the number of inspections, surveys (prescriptions) per specialist in labour protection were also investigated.

It is obvious that in real production environment the level of injuries rarely depends on one cause. In this case it is recommended to use the methods of multifactor correlation and regression analysis, which allow us to estimate the degree of influence on the studied resultant figure of each entered into the model factors with the fixed position of other factors at the average level.

Suppose that the most dangerous types of works in the forest industry are logging (X_1), transporting (X_2), low-stocking (X_3), wood-working (X_4), repairing (X5) and all other types of works (X_6), and as the resulting factor $\hat{Y}$ select the number of injuries during the corresponding year, then using the standard procedure of multifactor correlation and regression analysis, in the result of solving a system of linear algebraic equations (8) we obtain:

$$\hat{Y}=3{,}39195+1{,}38970X_1-2{,}5822X_2+7{,}3267X_3+ +0{,}4474X_4+1{,}6863X_5+0{,}0022X_6. \quad (16)$$

Confidence intervals for the coefficients of the regression equation for the reliability level of 50% in the considered case are the following:

$$-33{,}0553<a_0<39{,}8392,\ 1{,}2824<a_1<1{,}4970,$$
$$-4{,}0536<a_2<-1{,}1108,\ 3{,}8679<a_3<10{,}7855,$$
$$0{,}4181<a_4<0.4766,\ 1{,}4337<a_5<1{,}9389,\ 0{,}0017<a_6<0{,}0028.$$

Multiple correlation coefficient R=0,99835 is close to one, indicating the density of the relationship between the studied variables. Notice that the proposed model is generally adequate, as calculated statistics of Fisher F=150,8636, and the nearest value of Fisher's statistics with a level of reliability of 95% and degrees of freedom 6 and 3:

$$F_{0\,95}\,(6{,}3) = 8{,}94. \quad (17)$$

In the paper [27] a detailed statistical analysis of the proposed model has been conducted:

– the matrix of paired correlation coefficients allowing to determine the density of the link between the two studied factors (excluding their interaction with other factors) is provided;

– it is shown, that all coefficients of multiple regression equation with the reliability level of 0,5 are significant and with the reliability level of 0,95 significant are only the coefficients a_1 , a_3;

– partial elasticity coefficients ε have been calculated, and on this basis according to the model (8) the greatest number of injuries (Y) at the enterprises of forestry causes such types of works as: low-stocking (X_3), transporting (X_2) and logging (X_1);

– standardized regression coefficients β have been defined, and on this basis it was found out that the greatest amount of scope for improving the resulting rate have the following types of works: low-stocking (X_3), transporting (X_2) and logging (X_1);

– Δ – coefficients also confirm that the greatest influence on the resultant variable have the factors X_3, X_2, X_1.

If in the role of the independent variables we choose the working occupations: logger (X_{11}), driver (X_{12}) , machine(-tool) operator (X_{13}), hooker (X_{14}), master (X_{15}) and others (X_{16}), then the multiple regression equation (Y – number of injuries) assumes the form:

$$Y=-77{,}7392+2{,}0578X_{11}+2{,}9519\,X_{12}-0{,}5517\,X_{13}+ + 0{,}7870X_{14}+3{,}0449X_{15}+0{,}5112X_{16}. \quad (18)$$

CONCLUSIONS

The main results obtained in the paper:

1. Occupational injuries at the enterprises of the State Forestry Committee of Ukraine over a period of 10 years (2000-2009) have been analyzed and the main causes, consequences and factors of the injuries have been found out.

2. Using correlation and regression analysis and multifactor analysis the models for the study of functional connection between individual pairs of factors affecting the rate of occupational injuries and the influence of individual factors on injuries frequency coefficients have been developed. The level of significance of each parameter has been defined.

3. On the basis of the constructed mathematical models the state of occupational injuries in the field of forestry has been analyzed. Quantitative estimates of its main causes and factors have been obtained.

4. The developed methods will form the basis for the development of the system of administering labour protection [28, 29] in the field of forestry with the aim to reduce the occupational risks to the minimum.

All developed methods and calculation models are of general nature and can be used to determine the rate of occupational injuries not only at the enterprises of forestry.

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