



ANALYSIS AND EVALUATION OF EFFECTIVENESS OF INTERVENTIONS FOR PREVENTION OF OCCUPATIONAL ACCIDENTS

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ABSTRACT. Transition to the concept of professional risk management assumes the transfer of focus from measures of response to accidents after they have happened to activities for preventive measures, *i.e.* risk management of workers' health. The strategy of "reactive" response within the framework of the traditional system of managing occupational safety of workers focused primarily on compensating for the negative consequences of accidents. However, it does not focus on eliminating the systemic causes of their occurrence and, as a result, does not lead to positive changes in reducing traumas and injuries. The results of the analysis of the socio-economic efficiency of this strategy suggest the need for a transition to a different type of occupational safety management – which is "proactive", therefore the priorities are not the management of "occupational environment", but the management of "employee work safety", based on identification and assessment of professional risks. The calculation of the economic efficiency of measures for employee protection and the prevention of industrial injuries on the example of agricultural workers in the Kurgan region was the aim of the present study.

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Introduction

One of the main directions of reforming the system of occupational safety and health in the Russian Federation is the creation of mechanisms for economic incentives for employers to ensure healthy and safe working conditions, workplace health and safety. The need to improve occupational safety and health (OSH) cannot be justified only by economic benefits and the positive results of cost-benefit analysis. The implementation of the right of workers to workplace health and safety should be ensured even if economic analysis shows that long-term investments are required, which not all business structures tend to include in the mandatory unavoidable expenses. Traditionally, it has been believed that measures to ensure the well-being of workers should be attributed to production costs, but the logic of the modern transition to the "knowledge-based economy" fundamentally changed the attitude towards "human capital", and the role of experience in production and industry acquired until then appeared in a completely new light. Under the knowledge economy is observed as a system of consumption and production that is based on intellectual capital as a value of workers' knowledge

representing a large component of all economic activity in developed countries (Kenton, 2019).

Despite improving OSH in the past Century the rate of occupational injuries show steady increase. An estimated 6.9 million worker injuries occurred in the European Union (EU) during 2006 and 8.5 million occurred in the United States during 2007 (Chau *et al.*, 2014; Leigh, Marcin, 2012). An estimated 317 million nonfatal occupational injuries and 321 000 occupational fatalities occur globally each year or 151 workers sustain a work-related accident every 15 seconds (ILO, 2013). In 2014 an estimated rates of fatal and non-fatal occupational injuries were increased compared to the statistics of global crisis year in 2008 (Hämäläinen *et al.*, 2017). In Estonia the incidence rate of work accidents in agriculture has shown continuous increase in the past decade. In the period 2008–2017 the incidence of work accidents in agriculture rose from 741–801 and in some years it was higher compared to the rate of WA in all sectors of the economy (Anni, Merisalu, 2019).

Interest in the economic aspects of occupational protection has recently increased markedly. The earlier study estimated \$249.64 billion costs in total in 2007 with \$67.09 billion attributed to medical costs and



\$182.54 attributed to indirect or productivity costs. The indirect costs: (1) lost earnings (\$110.02 billion); (2) lost fringe benefits (\$29.03 billion); and (3) lost home production (\$43.49 billion). As data given later indicates, \$37.232 billion representing medical costs and \$160.675 representing indirect costs were not paid by workers' compensation (Leigh, Marcin, 2012). The International Social Security Association (ISSA) suggest that costs associated with nonfatal workplace accidents alone equal approximately 4 percent of world gross domestic product (GDP) each year (ISSA, 2014).

In this regard, it should be noted that the results of a number of scientific studies have demonstrated the effectiveness of investments in occupational health and safety, in improving fitness for work and well-being of workers – which gives high economic returns and increases the productivity of the enterprise (Levashov, 2012; Levashov 2007a; Levashov 2007b). These results can be used to further motivate companies to expand activities to improve workplaces and improve working conditions.

The aim of the study was to calculate the economic efficiency of measures for employee protection to prevent the industrial injuries on the example of agricultural workers in the Kurgan region.

Materials and methods

There is a number of theoretical models for calculating the costs and losses associated with industrial (occupational) accidents, but only a few of them are applicable in practice. As it is not possible to carry out a detailed calculation of the costs of all enterprises within the agro-industrial complex (AIC) structure at the regional level, it is appropriate for further calculations to use an adapted cost calculation method developed by the ILO Sub-Regional Bureau for Eastern Europe and Central Asia under the project 'Improving the North-West of Russia's occupational health and safety system' (ILO, 2007).

This methodology can be used to forecast the annual cost of agricultural enterprises associated with occupational accidents and incidents. As a result of the calculations, the possible minimum and maximum annual costs of these enterprises for accidents are specified. An accident in this methodology means an event at the workplace, as a result of which the person received some traumatic health damage. An incident is an event that did not lead to injuries to workers, but a malfunction in the work process, damage to equipment, materials, *etc.*

The costs associated with various incidents are divided into three groups (Labor protection and business, 2007):

1. Costs in connection with occupational accidents (with the issuance of temporary incapacity for work certificate). Because of such an accident, the employee is absent from the workplace for a number of days, *i.e.* these are accidents in the "classical" sense.

2. Costs in connection with microtraumas (without certificate of temporary incapacity for work). This group includes accidents, as a result of which the employee was unable to work for only a few hours, or no longer than up to the end of the working day (so-called microtrauma). At agricultural enterprises, such accidents, as a rule, are not investigated and are not recorded, but they occur more often than the "classical" ones and, as a whole, lead to remarkable losses. Such accidents deserve special attention.

3. Costs associated with incidents that did not result in trauma or injuries to workers, but which led to a malfunction in the work process. Foreign companies, as a rule, record such cases, since they are directly related to the safety and health of employees. The absence of serious trauma from the incident is more often just a happy accident; with a little change in circumstances, it could have had more serious consequences. Agricultural enterprises, as a rule, do not record, account for and analyse incidents that have not caused injuries to workers, but have led to disruption in the working process.

To calculate the projected annual costs of agricultural enterprises of the Kurgan region in connection with industrial (occupational) accidents, micro-injuries, and incidents that did not lead to trauma or injuries to workers, but caused a malfunction in the work process, the following initial data are required:

- the annual number of accidents at the enterprise with the registration of certificates of temporary incapacity for work (N_1);
- the annual number of microtraumas in the enterprise (without a certificate of temporary incapacity for work) (N_2);
- the annual number of incidents at the enterprise (N_3).

The dynamics of occupational traumas and injuries in the agro-industrial complex of the Kurgan region for the period 2000–2014 are presented in Table 1.

The average number of employees in the agro-industrial complex of the Kurgan region has stabilized over the past years and the basis for calculations is 23 235 people. The frequency of occupational traumas and injuries (per 1000 employees, P_1) at the agricultural enterprises over the past five years is also relatively stable and is about 25 affected persons per 10 000 employees.

The costs of the main items of expenses related to accidents and incidents are estimated according to the methodology presented by the Department of Labour Protection of the Ministry of Economic Affairs and Employment of Finland (TUTA model):

- the average cost of accidents with the issuance of certificate of temporary incapacity for work $C_1 = 215$ €.
- the average cost of accidents without the registration of the certificate of temporary incapacity for work $C_2 = 115$ €.
- the average cost of incidents that did not lead to employee injuries, but caused a malfunction in the work process $C_3 = 45$ €.

Table 1. Indicators of occupational traumas and injuries in the agricultural sector of the Kurgan region

Year	The average number of employees in the agricultural sector	Number of injured persons	Frequency of occupational traumas and injuries (No per 1000 workers, P ₁)
2000	79 263	855	10,82
2001	79 561	710	8,92
2002	83 009	581	7,02
2003	71 478	354	4,95
2004	63 457	311	4,90
2005	53 692	200	3,72
2006	35 188	149	4,26
2007	33 164	128	3,87
2008	31 479	103	3,27
2009	23 651	75	3,16
2010	24 658	85	3,44
2011	23 345	66	2,83
2012	23 119	47	2,04
2013	22 198	54	2,45
2014	23 235	59	2,56

Calculation of the average annual costs of enterprises of the agro-industrial complex of the Kurgan region, related to occupational traumas and injuries, was made according to the following procedure.

The average number of accidents with the issuance of a certificate of temporary incapacity for work per year:

$$N_1 = P_1 / 1000 * A = (2.5 / 1000) * 23\,235 * 1.5 = 87$$

The minimum estimated number of accidents without a certificate of temporary incapacity for work per year:

$$N_{2min} = P_1 / 1000 * A * P_2 = (2.5 / 1000) * 23\,235 * 1.5 * 10 = 870$$

The maximum estimated number of accidents without a certificate of temporary incapacity for work per year:

$$N_{2max} = P_1 / 1000 * A * P_2 = (2.5 / 1000) * 23\,235 * 1.5 * 17 = 1479$$

The minimum estimated number of incidents without a certificate of temporary incapacity for work per year:

$$N_{3min} = P_3 / 1000 * A * P_3 = (2.5 / 1000) * 23\,235 * 1.5 * 27 = 2349$$

The maximum estimated number of incidents without a certificate of temporary incapacity for work per year:

$$N_{3max} = P_3 / 1000 * A * P_3 = (2.5 / 1000) * 23\,235 * 1.5 * 30 = 2610$$

The minimum annual costs for the region due to accidents and incidents:

$$Q_{min} = N_1 * C_1 + N_{2min} * C_2 + N_{3min} * C_3 = 87 * 215 + 870 * 115 + 1479 * 43 = 18\,700 + 100\,050 + 63\,600 = 182\,350 \text{ €}$$

The maximum annual costs for the region due to accidents and incidents:

$$Q_{max} = N_1 * C_1 + N_{2max} * C_2 + N_{3max} * C_3 = 87 * 215 + 115 * 1479 + 45 * 2349 = 1\,305\,000 + 11\,832\,000 + 7\,830\,000 = 294\,495 \text{ €}$$

The calculations of the cost-effectiveness of trauma and injury prevention in the agricultural industrial complex were calculated from roubles to euros (by currency rate 1 € = 70.62 RUB).

Results and discussion

The results of the calculations, as well as an assessment of the cost-effectiveness of trauma and injury prevention in the agricultural industrial complex are presented in Table 2.

From the calculations in the table 2 above we can see, that the expected annual cost savings from the implementation of the prevention of the incidents range 10–30% from expected annual costs. These results quite similar to the results of ratio analyses of construction industry where the benefits of accident prevention far outweigh the costs of accident prevention by a ratio of approximately 3:1 and the results demonstrated that for every £1 spent on accident prevention, contractors gained £3 as benefits (Ikbe *et al.*, 2012).

Table 2. Results of calculations (€) according to statistics in the agro-industrial complex of the Kurgan region annually occur

Statistics in the agro-industrial complex of the Kurgan region annually occur (€):	Min.	Max.
– accidents with the registration of sick leave;	58	90
– accidents without the registration of sick leave;	580	986
– incidents.	1566	1740
The expected annual costs of agricultural enterprises due to the occurrence of these incidents (€).	182 350	294 495
The expected annual cost savings from the implementation of the methods worked out for the prevention of these incidents (%).	10	30
Expected annual cost savings for agricultural enterprises from the implementation of the methods worked out for prevention of these incidents (€).	18 120	89 860

Traditionally, the economic aspects of occupational health are considered through the prism of reducing production costs (reducing the loss of working time due to illness, reducing the severity of work-related injuries and the associated costs of compensating for the consequences, preventing early retirement, *etc.*). The initial

parameters for the calculation are the price of one day of sick leave, calculated as the sum of the minimum wage of an affected employee and the corresponding expenses of the employer. Obviously, this estimate does not reflect the full amount of losses. Nevertheless, even such a simplified assessment of the cost of one lost

day allows us to visually show the scale of the problem and therefore arise the interest of the companies' management in a more accurate estimate of losses. It is noted in (Dorman, 2000): Accidents at work lead to consequences that go beyond the immediate and obvious damages". Potential indirect losses due to occupational accidents at the company level:

- disruption of the production process immediately after an accident;
- moral impact on co-workers;
- involvement of personnel in accident investigation and reporting;
- hiring and training costs for new employees;
- damage to equipment and materials (if it is not indicated as part of normal accounting procedure);
- declining product quality after an accident;
- reducing the productivity of injured workers who are transferred to an easier job;
- the cost of maintaining reserve capacities to cover losses associated with accidents.

In most cases, the prospects for reducing costs are very limited, so you need to consider the problem more broadly even in cases where the total cost of paid sick leaves, compensation payments due to injuries or early retirement are themselves significant enough. Often, in addition to these payments, additional costs are required for hiring temporary workers to replace the ones unable to work, as a result of which a specific factor of staff turnover must also be included in the calculation of total losses.

The economic efficiency of implementing occupational health and safety measures is expressed in reducing the cost of a production unit and is manifested, ultimately, in improving production efficiency. The main sources of economic benefits from measures to improve working conditions and occupational health and safety are the following:

- growth in labour productivity;
- an increase in the efficiency of working time as a result of a reduction in time losses due to temporary incapacity for work caused by occupational traumas and injuries;
- improving the efficiency of equipment;
- reduction of losses from damage caused by labour turnover due to unsatisfactory working conditions;
- reduction of insurance payments and compensations to employees.

Currently, funds allocated by the Social Insurance Fund (SIF) of Russia for the financial provision of preventive measures to reduce occupational traumas and injuries are targeted financing. According to the current Regulations (2012), "financial support for preventive measures to reduce occupational traumas, injuries and occupational diseases of workers, carried out at the expense of the Social Insurance Fund of the Russian Federation for compulsory social insurance against occupational accidents and occupational diseases, provides:

1. Conducting a special assessment of working conditions;

2. Implementation of measures to bring exposure levels of harmful and (or) hazardous occupational factors at workplaces in accordance with the state regulatory requirements for labor protection;
3. Occupational safety training for the following specific categories of workers;
4. Acquisition of special clothing, special footwear and other personal protective equipment for employees;
5. Sanatorium-resort treatment for workers;
6. Mandatory periodic medical examinations;
7. Providing medical and preventive nutrition for employees;
8. Acquisition of instruments to detect the presence and level of alcohol;
9. Acquisition of devices for monitoring the work and rest arrangement of drivers;
10. Acquisition of first-aid kits;
11. Acquisition of individual instruments, devices, equipment and systems directly designed to ensure the safety of workers and (or) control the safe conduct of work within the framework of technological processes;
12. Acquisition of individual instruments, devices, equipment and complexes that directly provide training on workplace safety".

The results of the analysis indicate that the economic efficiency of preventive measures to reduce occupational traumas, injuries and occupational diseases, formed on the basis of indicators of the current system for monitoring safety and working conditions, is extremely low (Levashov, 2012; Levashov 2007a; Levashov 2007b).

Analysis of statistical data indicates that, for the period of 1999–2012 the total costs of occupational health and safety in the agro-industrial complex of the Kurgan region in current prices increased 9,5 times (1,20–10,9 million €); occupational health and safety costs per worker increased 18 times (5,15–93,65 €); Kurgan region expenses for providing preventive measures to reduce occupational traumas, injuries and occupational diseases, even for the period of 2007–2013 only, increased 2,3 times (192,90–445,43 thousand €). At the same time, the number of days per person of incapacity for work for one working day or more per one victim, which amounted to 21–23 in 1999–2006, increased to 30–35 by 2011–2012; the total amount of temporary incapacity benefits for compulsory social insurance against occupational accidents and occupational diseases for the period of 2007–2012 increased 1,8 times (101,6–181,8 thousand €).

An analysis of the items of expenses shows that the policy of financial support for occupational health and safety, based on the principle of compensation, does not provide for active measures to prevent trauma and injuries. Table 3 presents the items of expenditure on occupational safety and health protection (OSH) recommended in the EU countries (Dorman, 2000).

Table 3. Trauma and injury prevention costs

Measures	Percent of total expenditure on OSH, %
Prevention, including:	56
personal protective equipment	28
health checks	15
equipment for collective protection	13
Training, instruction, information, including:	37
training	27
instruction	9
information	1
Predictive risk assessment, including:	4
identification of risks, monitoring	3
planning and documentation	1
Formation of the OSH system	3
Registration and investigation of occupational trauma, injuries and occupational diseases	1

Numerous studies of costs and results show that investments in occupational safety and health give positive results when individual measures have combined into a comprehensive program. Enterprises benefit from measures to improve occupational hygiene, safety and health, since the costs of preventing occupational traumas, injuries and diseases are incomparably lower than the costs of treatment and compensation for the consequences. Often, indirect costs associated with occupational incidents are ten times higher than direct costs (Grachev, 2015). Often the safety practitioners have used the ratio of indirect to direct costs of work accidents and the most commonly it's 4:1, but they must follow good research protocols to provide valid cost ratio data (Manuele, 2011).

The largest costs per year are associated with the purchase of personal and collective protective equipment, with training workers in occupational health and safety requirements, and also with checking the health checks of hired personnel. These activities require up to 90% of the funds allocated annually to the Health and Safety Organization. All other activities (registration and investigation of occupational accidents and diseases, providing specialists and representatives of workers on occupational safety and health, as well as conducting predictive risk assessments) during the year comprise a small fraction of the costs of employers.

Most large enterprises and multinational companies are capable of organizing services and provide working conditions conducive to maintaining the health of staff. Often, they allocate sufficient resources to ensure occupational safety and health. The introduction of a safety and health management unit into the existing management system makes it possible to really include occupational safety and health issues in the daily program of company administrative personnel. Studying the action mechanisms of various management systems opens the way for strengthening the positions of specialists in occupational health and safety at all levels of management – from strategic planning to operational control of the production process.

Optimal planning of preventive measures ("interventions") at the company level should be carried out, so

that they are not reduced to purely medical, technical or organizational activities. An integrated approach to the development of methods of prevention and risk management of occupational traumas and injuries provides for the implementation of measures to prevent, control and minimize risks in two strategies – reactive, using safety barriers, and proactive, based on the use of key risk indicators (Levashov, 2018).

The reactive risk management strategy is based on the fact that accidents are "defects" in the functioning of the occupational health and safety management system. Effective implementation of these measures is ensured by the formation of security barriers representing physical systems (objects), technical or hardware measures, procedural or organizational actions that are aimed at preventing negative consequences in the human-equipment-technology-environment system.

A reactive management strategy is formed on the basis of information on the effectiveness and consequences of implemented risk reduction initiatives. The necessary safety functions are implemented using protection barriers aimed at preventing, controlling or minimizing hazards. In accordance with the specified functions, the barrier can act on the source of danger, reducing the level of its impacts, existing between the source and the employee, increasing the security of the employee or reducing the effect of exposure by mitigating the negative health effects.

An effective professional risk management process involves the implementation of preventive measures aimed at ensuring safe working conditions. Management of professional risks should be carried out to enable the adoption of proactive decisions that provide the ability to systematically identify existing risks and develop measures to reduce them. Actions must address the hazards associated with the work environment and human behaviour before an accident occurs. Their goal is to minimize risk where it is not possible to eliminate it and to guarantee control of risks that cannot be eliminated.

Conclusions

The calculation of the economic efficiency of measures for employees' protection and the prevention of industrial injuries on the example of agricultural workers in the Kurgan region was carried out in the present study. The main goal of risk management in the field of occupational safety is to provide measures for controlling and reducing risks. This can be achieved by implementing risk management strategies that prevent the occurrence of negative events and/or reduce the severity of possible consequences.

A proactive management strategy is based on active monitoring methods. Proactive monitoring assumes the existence of an effective incident and accident reporting system that records not only the immediate causes of deviations but also any serious failures that could potentially lead to incidents. It includes research, analysis and subsequent implementation of measures to ensure that lessons learned are applicable to future processes.

Based on the analysis of the ways and methods of injury prevention worked out in the project "Improving the North-West of Russia's occupational health and safety system", the reduction of accidents up to 30% for agricultural enterprises of the Kurgan region provides annual cost savings ranging from 18 120 to 89 860 €. So, due to the fact that the economic effect of the implementation of a number of measures is apparent after a certain period of time, and also depends on the scale of their implementation, the real economic efficiency seems to be significantly higher.

Particular attention should be paid to the economic aspects of wellness programs and measures to improve working conditions. This is important both for top managers who operate in the field of health care management and for companies, as it affects their profitability and market image. In many companies, analyses on investment efficiency are a mandatory component of management activities that provides the basis for planning and implementing wellness programs.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author contributions

VSh, SL, RS, VSe, EM, TK contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript.

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