Labor Safety in Construction

I Rudchenko*, A Bychkov, D Levchenko

Federal State Budgetary Educational Institution of Higher Education “Kuban State Agrarian University named after I.T. Trubilin”, 13 Kalinin street, Krasnodar, 350004, Russia

E-mail: rudchenko.iwan@yandex.ru

Abstract. The safe work state in construction has been studied. In the process of research, the causes and production conditions, as well as the circumstances of the work safety in the construction industry have been investigated. On the basis of information obtained as a result of research and in-depth analysis, the tasks to reduce the industrial injuries have been set and solved.

The problem of reducing industrial injuries in construction in the measures set study has been determined. Here, along with organizational and technological measures, an important place is occupied by the workers individual and collective protection means.

A method for choosing means of reducing industrial injuries in construction, as methods for managing the “man-to-work environment” system has been developed, which minimizes the industrial injuries’ manifestations.

The developed method of choosing the reducing industrial injuries means in construction allows real-time adoption of a technically sound and cost-effective set of measures to protect the workers from the harmful and dangerous factors’ effects.

Introduction

The main stages of selecting the reducing industrial injuries means in construction have been developed:

- The industrial injuries working conditions and factors analysis in the workplace, taking into account information on workplaces certification, construction and installation works external conditions and the legislation requirements;
- Specifying the choice goal, including clarifying the private goals list, as well as the degree of their achievement;
- The adoption of organizational and technical solutions, involving the definition of possible solutions list, selection criteria, strategies for multi-factor optimization and the best option determination;
- Implementation of the decisions made with the evaluation and adjustment of their use consequences [1]. The proposed method of making organizational and technical decisions to reduce industrial injuries in construction, which implements the developed selection method, makes it possible to substantiate a set of organizational and technical measures to improve working conditions, taking into account the exposure significance to harmful and dangerous factors, as well as technical, functional and economic consequences of their implementation in the set production conditions.
Further effective construction industry construction organizations and enterprises development is associated with their transfer to intensive technologies. One of the main reasons hindering the construction industry intensification remains a high injury level [2].

Construction under working conditions refers to potentially hazardous industries. In the construction industry, approximately 80% of workers are employed in hazardous working conditions. The low renewability of fixed assets leads to an increase in the manual labor share.

The temporary nature of workplaces, the need to perform significant amounts of work at height, in difficult climatic and technological conditions cause a large number of dangerous and harmful factors that pose a potential threat to the life and health of workers [3].

All this necessitates increased attention to the issues of improving the working conditions of construction workers.

Main Part
Solving the problem of reducing industrial injuries in construction is possible only when using a set of measures, within which, along with organizational and technological measures, an important place is occupied by the workers’ individual and collective protection means [4].

The labor protection has accumulated extensive scientific and practical experience. Questions of ensuring safety and reducing the level of industrial injuries were paid attention to by such researchers as: Belov S.V., Bulygin V.I., Vinogradov D.M., Zolotnitsky N.D., Kondratiev A.I., Koptev D.V., Kirichenko V.I., Mestyachkina N.M., Ogoltsov A.F., Orlov G.G., Pchepinaev V.A., Roytman M.Ya., Rusak O.N. and many other scientists.

At the same time, the issues of occupational injury to builders in a number of aspects are still not well understood. In particular, in all the variety of organizational and technical solutions to reduce injuries, there is no single approach to the list of criteria, assessment of their effectiveness. The simultaneous calculation of all the parameters acting as private targets is very complicated. In multi-factor optimization, it is necessary to deal with various parameters competing with each other, and also not reducible from the outset. The impossibility in most cases of achieving absolute optimism in the measures’ choice has led to the fact that in practice there are cases of one-sided assessment of decisions made without proper substantiation of their optimality for specific production conditions. Branch industry typology has become widespread. As a result, the development of a unified method for choosing the means of reducing industrial injuries in construction is an important scientific and technical problem [5].

Figure 1. Characteristic periods of operation of technical systems (devices)

The aim of the work is to develop a method for choosing the means of reducing industrial injuries, as methods of managing the “human-industrial environment” system, minimizing the construction injuries causes manifestations.

The idea of the work is to simulate the procedure of multi-criteria choice when making organizational and technical decisions to reduce industrial injuries.
The following key points are put forward:

1. The developed method of selecting the reducing industrial injuries means in construction allows real-time adoption of a technically sound and cost-effective set of measures to protect the workers from the harmful and dangerous factors’ effects [6].

2. The main stages of choosing the reducing occupational injuries means should be considered:
   • analysis of working conditions and occupational injuries factors in the workplace, taking into account information on the certification of workplaces, external conditions for construction and installation work and the legislation requirements;
   • specification of selection goals, including clarification of the private goals list, as well as their achievement degree;
   • the adoption of organizational and technical decisions, involving the definition of a list of possible options for decisions, selection criteria, strategies for multi-factor optimization and determining the best option;
   • implementation of decisions made with the assessment and adjustment of their use consequences.

3. The proposed method of making organizational and technical decisions to reduce industrial injuries in construction, which implements the developed selection method, makes it possible to substantiate a set of organizational and technical measures to improve working conditions, taking into account the significance of exposure to harmful and dangerous factors, as well as technical, functional and economic consequences of their implementation in the specified production conditions.

The scientific novelty of the work most significant results and their significance lies in the fact that:

1. A method has been developed to select the means of reducing industrial injuries in construction, consistently implementing the stages of analyzing working conditions at workplaces; concretization and the degree of achievement of choice private goals; multifactor optimization of the parameters describing them, and organizational and technical solutions decisions use effects implementation and evaluation best variant adoption.

![Image](image.png)

**Figure 2.** The scheme of the method

2. A simulation of each of the selected stages, in which:
   • the conceptual apparatus necessary for the development of principles for managing a large socio-technical “man-production environment” system, which minimizes the manifestations of the work-related injuries causes during construction and installation work has been clarified;
   • a classification of industrial injuries causes in construction has been developed, a formalized representation of which is the system tree, which allows for a clearer decomposition of the injuries causes, their simplification, specification and refinement of targeting, necessary and sufficient for making informed decisions to reduce it;
   • a tree of goals was built in relation to the task of reducing industrial injuries, which revealed the influence one level particular goals parameters, the changes of which make it possible to most effectively achieve the main goal within the limited resources while preserving the decision-making alternativeness;
   • the concept of sanitary and hygienic reliability of measures to reduce injuries, as the degree of reliability in terms of the efficiency parameter has been introduced. The concept characterizes the
probability of a parametric gradual failure, in which the value of the measures efficiency lies in a given interval of values [1]:

- A strategy (decision tree) and a mathematical description of the multivariate optimization procedure for making organizational and technical decisions to reduce injuries have been developed, taking into account the advantage of fuzzy set theories and game theory (playing with “nature”) and allowing real-time making an objectively reasonable choice of organizational and technical solutions to reduce injuries, taking into account the totality of known information [2].

The scientific statements and conclusions reliability of the work is confirmed by:

- use of system analysis classical provisions reducing industrial injuries when developing a method of choosing means, as well as theories: decision making, fuzzy sets and games with "nature" [3];
- the industrial approbation methods use of making organizational and technical decisions to reduce the mathematical statistics industrial injuries apparatus;
- the study results consistency of the choosing method for the means of reducing industrial injuries under the existing construction organization conditions with the analysis results of its main indicators on working conditions and industrial injuries [4].

The practical significance of the work is to develop a methodology for making organizational and technical decisions to reduce industrial accidents in construction, including industrial injuries causes clarification, the private goals parameters specification and the degree of their achievement, the formation of a representative set of options for organizational and technical solutions, followed by multifactor optimization of the parameters characterizing them and choosing the best option for given production conditions, as well as subsequent analysis and adjustment of the methodology using results.

The technique can be used

- in the existing construction organizations conditions; in expert evaluation of the programs aimed at improving working conditions; in research and educational process;
- when working with different amounts of data; with their full array in analyzing the working conditions of the entire range of working specialties of a construction organization, as well as with the choice of areas given when choosing options for organizational and technical solutions to reduce injuries for a particular workplace or specialty.

The workers working conditions studying theory and practice current state analysis, reducing the industrial injuries in the construction industry allows us to say [5]:

1. To reduce the industrial injuries in construction at present, three main directions are used: the creation of the labor protection system effective organizational structure at an enterprise, the technological processes development with a minimum level of exposure to harmful and dangerous factors; selection of complex systems and means of collective and individual protection of workers;

2. The practice of reducing industrial injuries does not rely sufficiently on scientific analysis and modeling methods, there is no objective classification of industrial injuries causes suitable for the decision-making process, often only the consequences of injuries are identified with a formal mention of its causes, industry-specific decisions typology is widespread, there are cases of one-sided quotes (mainly by value) [6];

3. The problem of choosing the means of reducing production costs in construction in mathematics includes several interrelated aspects of the state of the initial data on production conditions, system ideas about the equipment technical level, tooling, means of collective and individual protection of workers, information about the criteria as basic quality indicators and procedures (optimization schemes);

4. With all the variety of organizational and technical solutions to reduce industrial injuries there is no single approach to the list of criteria for assessing the quality of their work (private purposes). The standard parameters nomenclature for assessing quality in relation to the reducing injuries means is rather limited. At the same time, a positive experience of using an extended list of quality indicators is known. Here three main groups of parameters are formed: technical, functional, and economic;
5. Reliable ways to optimize the multi-criteria tasks used in engineering practice have not yet been developed;

6. In the uniform requirements and systematized data on the selection criteria (private goals) absence, an analysis of their composition indicates the existence of several basic conditions that determine the poly-criterial optimization procedure objectivity requirements. These include: parametric multifactor, the impossibility of bringing the parameters to a one-dimensional form, their irreducibility (competition) and the impossibility in most cases to achieve an absolute optimum;

7. The existing optimization evaluation procedures diversity analysis suggests that none of them, taken separately, does not reflect all the features and cannot ensure objectivity in the actual process context of choosing the means of reducing industrial injuries in construction;

8. The method of choosing the means of reducing industrial injuries in construction should be adapted to the technical differences of construction and installation processes, take into account the current technology development level and provide a base for its further improvement: be based on a set of objective criteria and optimization procedures so that it becomes possible to formalize the decision-making process.

In accordance with the state and needs of improving occupational safety and health working in the construction industry, our goal is to develop a method of choosing the reducing occupational injuries means as fundamental methods for managing the man-roduction environment system that minimizes the manifestations of causes of construction injuries. To achieve this goal, it is necessary to solve the following tasks in stages:

1. Clarification of the basic requirements for terminology, stages, criteria and procedure for the poly-criteria selection of reducing industrial injuries in construction means;

2. The development of an industrial injuries causes classification in construction, necessary and sufficient to make informed decisions to reduce it;

3. Systematization of information and formalization of the initial data that determine the formulation of the problem of choosing the means of reducing industrial injuries in a specific production environment;

4. Systematization and formalization of information on the private goals' parameters in relation to the task of reducing industrial injuries, taking into account the alternative choice provision in real conditions of limited economic material, technical and human resources of the construction organization;

5. Expansion of the private goals list used in the selection of reducing industrial injuries in construction means, using positive experience gained in related industries to ensure manufacturability, functionality and efficiency, and organizational and technical solutions;

6. Development of a method for implementing a model for choosing the means of reducing occupational injuries, which allows making an objectively reasonable choice of organizational and technical solutions for reducing injuries in real time, taking into account the totality of known information;

7. Development of methods for making organizational and technical decisions to reduce industrial injuries in construction suitable for engineering practice.

8. Pilot-industrial approbation of the methodology of organizational and technical solutions to reduce industrial injuries under the conditions of the existing construction organization, as well as a comprehensive analysis of the results of its use;

Summary
The main results and conclusions of this work can be formulated as follows:

1. The method of choosing the means of reducing industrial injuries in construction is based on the close interdependence of the four stages:

   - analysis of working conditions and factors of industrial injuries in the workplace, taking into account information on the certification of workplaces, external conditions and the requirements of legislation;
- specification of the goal of choice, including the clarification of the list of private goals (objective functions), as well as the degree of their achievement;
- the adoption of organizational and technical decisions, involving the definition of a list of possible options for decisions, selection criteria, optimization strategy and determine the best option;
- implementation of decisions taken with the assessment and adjustment of their use consequences.

2. The intelligible apparatus, which is necessary for the development of accepted methods for managing a large social-technical “man-to-work environment” system that minimizes the manifestations of the causes of industrial injuries during construction and installation work, has been clarified.

3. The industrial injuries causes classification in construction, the formalized representation of which is the system tree, which allows for a clearer decomposition of the causes of injuries, their simplification, specification and refinement of targeting necessary and sufficient to make informed decisions on its reduction, has been improved.

4. Introduced the concept of sanitary-hygienic reliability of measures to reduce injuries as a degree of safety on the efficiency parameter, characterizing the probability of parametric failure, in which the value of the effectiveness of measures is in a given range of values from E_min to E_max;

5. A strategy (decision tree) and a mathematical description of the multivariate optimization procedure when making organizational and technical decisions to reduce injuries, taking into account the advantages of the theories of fuzzy sets and game theory (playing with “nature” and allowing decision makers to realistically make an objective choice - technical solutions to reduce injuries, taking into account the totality of the information known to him ), have been developed.

6. A methodology for adopting organizational and technical decisions to reduce industrial injuries, clarifying the causes of industrial injuries in construction, including: including the specification of the parameters of private goals and the degree of their achievement; the formation of a representative set of options for organizational and technical solutions with the subsequent multifactor optimization of parameters characterizing them, and the choice of the best option for measures to ensure industrial safety in specified production conditions, has been developed.

7. As a result of the practical use of organizational and technical decision-making to reduce industrial injuries, an objective choice of the best (reflecting the weighted average position between optimism and pessimism) measures to ensure industrial safety in specific conditions of construction, has been made.

**Table 1. Mathematical description of the basic laws of the distribution of uptime**

| View of failure | Law distribution - Lenina state value | Probability uptime, | Intensity arises veni bounc e 1/h | The expectation of uptime, h | RMS the deviation of uptime, h |
|----------------|-------------------------------------|---------------------|-------------------------------|--------------------------|-----------------------------|
| Sudden         | Exponential                         | \( P(t) = \frac{1}{\lambda} - \frac{1}{\lambda} \) stable operation \( \exp(-\lambda t) \) - cycle operation \( \exp(-k t) \) | \( \lambda = \frac{T}{\frac{1}{K_o}} \) | \( T = \frac{1}{n} \sum t_i \) | - |
| \( \gamma \)   | distribution                        | \( P(t) = \frac{1}{\lambda} \left( \frac{T}{\sigma^2} \right)^n \exp(-\lambda t) \) | \( \lambda = \frac{T}{\sigma^2} \) | \( T = \frac{1}{n} \sum t_i \) | \( \sigma = \left( \frac{1}{n-1} \sum (t_i - T)^2 \right)^{1/2} \) |
Gradual, (wear) Normal $P(t) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{t} \exp\left(\frac{u^2}{2}\right) du$ - $\frac{1}{n} \sum_{i=1}^{n} t_i \phi$ $\sigma = \frac{1}{\sqrt{n}} \sum_{i=1}^{n} \left( t_i - \bar{t} \right)$

Logarithm-mystically normal $P(t) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{t} \exp\left(\frac{u^2}{2}\right) du$ - $\frac{1}{n} \sum_{i=1}^{n} t_i \phi$ $\sigma = \frac{1}{\sqrt{n}} \sum_{i=1}^{n} \left( t_i - \bar{t} \right)$

**Note:** $k$, $k_0$ - respectively, the number of current and “fail-safe” inclusions (cycles) of the object, pcs; $t$ - the considered period of time of the object, h; $n$ - the object measurements (tests) number, pcs.

**References**

[1] Rudchenko I I, Zagnitko V N 2015 *The behavior of building materials in a fire*, Emergencies (Industrial and Environmental Safety) 4 (24) 36 - 48

[2] Rudchenko I I, Strakhova N A, Bepalov V I 2005 *The choice of means of reducing industrial injuries in construction*, Ministry of Education and Science of the Russian Federation (Federal Agency for Education, State Educational Institution of Higher Professional Education "Rostov State University of Civil Engineering", Rostov-on-Don).

[3] Grinev A P, Rudchenko I I, Nikogda V O 2016 *Fine concrete for monolithic construction* (Works of the Kuban State Agrarian University) 58 203 - 214.

[4] Rudchenko I I, Musatov A A 2016 *Optimization, safety, quality, risk*, In the collection: Actual questions of economy and technological development of branches of a national economy (Materials of the regional scientific-practical conference of students, graduate students, undergraduates and teachers) 123 - 129.

[5] Rudchenko I I, Never V O 2015 *Safety of operation of buildings and structures in the agro-industrial complex* (Works of the Kuban State Agrarian University) 56 239 - 248.