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BIM in the assessment of labor protection

BIM технологии в оценке уровня охраны труда

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Abstract. The article presents methodology of monitoring and control of safety and labor protection on the basis of modern innovative technologies and the digital model of the construction site. Monitoring based on the BIM technology enables a qualitatively new approach to monitoring safety and occupational safety on the construction site. The result of control by the offered method in the form of a security index, reflects the actual situation in the checked object and gives the chance to estimate influence of dangerous production factors. This approach to assessment will allow reacting quickly to the processes taking place in the territory of the checked object and also to prevent emergence of a dangerous situation.

Аннотация. В статье представлена методика мониторинга и контроля техники безопасности и охраны труда на основе современных инновационных технологий и цифровой модели строительной площадки. Мониторинг на основе BIM технологии позволяет качественно по-новому подойти к контролю техники безопасности и охраны труда на строительном объекте. Показано, что результат контроля предложенным методом в виде индекса безопасности отражает фактическую ситуацию на проверяемом объекте и даёт возможность оценить влияние опасных производственных факторов. Выявлено, что данный подход к оценке позволит оперативно реагировать на процессы, проходящие на территории проверяемого объекта, а также предупредить возникновение опасных ситуаций.

Introduction

Modern competitive struggle of industrial manufactures forces producers to give special influence to innovations both in the field of enhancement of the production technology, and in the field of enhancement of labor protection. Not high quality of labor conditions has negative impact on the labor market in general that is expressed in the high fluidity and labor shortage, harmful and dangerous working conditions, etc.

Even today it is possible to notice that the measures for improvement of working conditions and safety at the entities undertaken by the government bring results. Financing of the preventive measures directed to decrease in an injury rate at the entities grows, the total quantity of victims on production and the number of patients with occupational diseases decreases. So, in 2014 the Social Insurance Fund of the Russian Federation (Social Insurance Fund of the Russian Federation) fixed 47 453 insured events, linked with an injury rate at the entity that is below similar indicator of 2013 for 5.0 % (for 2486 cases) [1]. According to Federal Service for Labor and Employment (Rostrud) in 2014 as a result of occupational accidents in all organizations in all types of economic activity 2344 persons died that is for 413 people or 15 % less than in 2013 (2757 persons).

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According to the international labour organization annually, 2.3 million people die in accidents at workplace and occupational diseases. The average mortality rate is about 6,000 people daily. Registered in the world around 340 million accidents at production and about 160 million victims of occupational diseases. With regard to the construction industry, there is a disproportionately high level of accidents considered, it should be noted that unrecorded data at times overlap counted several times, which can be associated with minor injuries that have not led to deaths. Also, pay attention to the lack of proper level of control and enforcement of regulatory literature production sites.

Director for political Affairs of the International labor organization Sandra Polaski noted that "the problem of ensuring workplace safety is relevant to all countries, and a major role in improving the safety of the work belongs not only to the state but also employers and the workers themselves". In addition, Polaski noted that the state's challenge of "PREVENTIVE CULTURE" – a culture of accident prevention. Thus, for the protection of labour needs to follow all the links of the chain involved in the production of a product, whether we build a house, or manufactured item at the factory. There is a need to develop strategies to improve occupational health and safety in the workplace, which would help to monitor the current situation and signal the presence of vulnerabilities in the system of labor protection at the facility.

The Government of the Russian Federation continues work on transition of work management from compensational, costly model to the modern, oriented to the risk management, allowing realizing preventive methods to preserving life and health of workers on production, and also attempts to reduce all types of costs linked with adverse conditions of work are performed.

The presidential decree of the Russian Federation of 07.05.2012 No. 596–606 on the main activities of the Government of the Russian Federation is directed to the activization of work on creation of modern model of the organization of labor protection. Work in this direction, according to the decree, shall consist in implementation and ensuring functioning of institute of assessment of working conditions, enhancements of the legislation in the field of labor protection, updating of the specifications and technical documentation, carrying out comprehensive supervision by all concerned parties of state conditions and labor protection.

BIM technologies, including three-dimensional modeling are recognized as the most perspective way of modern modeling. So, on December 29, 2014 the Ministry of a construction and housing-and-municipal and civil engineering (Ministry of Construction of Russia) signed the order No. 926/pr "On approval of the Plan of step-by-step implementation of information modeling in the field of industrial and civil engineering" [2] which approved the plan of step-by-step implementation of BIM in the field of industrial and civil engineering.

At the turn of XX century and XXI century the rapid growth of information technologies in a construction which qualitatively changed design approaches of architectural objects is observed, at the same time the approach to work on designing has changed too, as well as the subsequent operation of objects designed in BIM technology is affected. In other words, BIM (Building Information Modeling) is the information modeling of buildings, it is a process of collective creation and the use of project information (model) of future construction, at the same time in creation of a model all related departments of project agency take part [3].

For many years scientists and public Figures were engaged in a research of questions of operational injuries and labor protection. So at the beginning of the 20th century in Russia the big contribution to the solution of a question about social protections of wage workers and a risks assessment was made by V.V. Bervi-Flerovsky, E.M. Dementiev, G.V. Hlopin was engaged in questions of hygiene, N.A. Vigdorchik was engaged in questions of occupational diseases and social insurance.

The Russian scientists and public Figures who were engaged in studying of problems of work at the beginning of the XX century can be divided conditionally into four groups: the first should include the Figures pursuing the academic science and also public Figures to the first; to the second group is factory inspectors; the third includes the representatives of employers; and the fourth includes statesmen and officials. If we talk about the second, third and fourth groups, then their interest had something common with their job responsibilities, but the representatives of the first group made the significant contribution to studying of problems of work and they were pioneers of labor researches. These are the famous scientists: R.A. Disterlo, L.S. Tal, M.I. Tugan-Baranovsky, V.V. Svyatlovsky, V.G. Yarotsky, I.S. Voytinsky, M.G. Lunts, I.A. Trakhtenberg, V.M. Dogadov, etc.

In the research of V.D. Royk [4] the economic and legal mechanisms of workers protection against industrial hazards are considered. The work experience of the mechanism of compensation of disability

on production is considered in details. Bases of the theory and methodology of the organization of system of compulsory social insurance from occupational accidents are lit.

In the paper [5] theoretical bases and practical recommendations of insurance underwriting are stated. The underwrating role in activities of an insurance company as well as how this activity begins to play a key role in insurance is shown. Levels of underwriting and their types are considered.

We would like to notice the research [6] in which situations on labor protections and industrial safety are considered. Statistical data on an injury rate are given in production depending on a type of economic activity, as well as expenses on providing the correct working conditions.

In his research S.P. Levashov [7] provided the analytical review of system of monitoring and a risks assessment to the Russian Federation and abroad; considered a number of consecutive actions of detection of potential dangers of working conditions; provided the analysis of criteria for evaluation of the risks arising in the course of professional activity of the worker.

In the article of O.S. Gamayunova [8] the statistics of an industrial injuries in St. Petersburg is provided, education options in the sphere of safety in a construction are considered, foreign experience in the solution of questions of increase in level of safe engineering and labor protection is given.

In the articles of T.F. Morozova [9, 10] various evaluation methods of risks when implementing the investment and construction projects are considered. In particular, the example of a risks assessment by an expert method and method of statistical modeling is given.

Today the international practice in development of labor protection moves on the way of preventive measures in assessment of professional risks and creation of an effective control system. Positive experience of Great Britain in decrease in level of an industrial traumatism helped with it and it was adopted by the International Labour Organization (ILO) [11] in 1999. In the developed document OHSAS 18001:1999 "System of management of professional health and safety. The specification" new approach to a control system of labor protection is considered. Specifics of the document consist in the mechanism of continuous control of actions for improvement of working conditions.

Addressing sources of BIM technologies it should be noted that the foundation is laid by Chuck Istman professor of Technology Institute of Georgia in 1975 in the magazine of the American Institute of Architects (AIA) under the working name "Building Description System" (System of the description of the building). In 1986, for the first time Englishman Robert Ashe in his article used the term "Building Modeling" in its present understanding as information modeling of buildings. Robert Ashe showed qualitatively new approach in designing, and 3rd terminal of the London Heathrow airport became an example of successful project implementation. It was the first case of use of BIM technology in world project and construction practice.

Today in the Russian Federation quite great interest in development of BIM-of technologies is noted. More and more companies realize benefits of this technology. Many domestic authors deal with problems of implementation and development of BIM technologies. For example, V.V. Talapov [12] gives the detailed characteristic of BIM technology, he considers practical benefits of its application for all participants of the investment and construction project, he designates the main stages of creation of information model of a construction.

Analyzing works [13–15], it is possible to note that rather much attention is paid to safety issues. Authors [16, 17] emphasize the need of assessment of safety of working conditions at the level of designing of a construction object, in particular suggesting to be protected from such factor as fall from height at the level of a project portrayal. Also the possibility of an algorithm creation analyzed by a 3D model is considered and it finds threats for safety of works. The author [18] suggests to systematize and integrate all knowledge gained in course of construction in one model, beginning from designing through all stages of a construction and finishing with exploitation. Authors [19] consider construction safety issues by creation of the base guided to accurate coordination of questions of labor protection. At the same time the security system consists of the principles, both enhancement of culture of production, and general corporate safety.

In researches [20–27] the application of BIM in construction practice as the instrument of designing is considered. The author [28] made functional assessment of BIM technology in implementation in Real Estate Development Company. In researches [29–41] the authors specify that BIM is the tool which allows not only to estimate projects, but to analyze safety of future structures, as well as it gives the chance to apply alternative systems to a possibility of evacuation of people from buildings.

In Russian literature there are a large number of sources on training with the BIM tools but, unfortunately, there are not enough publications on use of these technologies for the purpose of increase in safe engineering and labor protection [3, 42].

Transition to BIM technologies in assessment of a condition of labor protection and safe engineering on the building site is the perspective and effective direction development of all construction production.

The purpose of this article is to show a possibility of digitization of the major dangerous and harmful production factors by types of installation and construction works according to MDS 12-28.2006 "A methodical management on carrying out an expert evaluation of safety of non-stationary workplaces on construction places" [43] using BIM technology for assessment of a condition of labor protection and safe engineering.

Methods

BIM is the cornerstone three-dimensional information model of future project in which the major characteristics (material) and physical parameters (the geometrical sizes) of the materials used in case of a construction and future operation of an object are laid. BIM-technology is the information platform on which additional technologies and opportunities are imposed.

BIM technologies are made on the basis of three-dimensional modeling of an object. Three-dimensional modeling of the object or the analyzed site, such as, the building site allows to divide it into separate parts and to allocate borders for assessment of the situation on safe engineering and labor protection. The valuation principle is linked with splitting of the researched object into elementary sites up to 100 m^2. At this stage it is important to research the most dangerous production factors which will be exposed to the analysis.

As the software product, the Autodesk Navisworks Simulate which supports these technologies is applied, however it isn't capable to make the analysis of labor protection and safe engineering independently therefore it is required to supplement its functionality with the program superstructure called the PLUGIN.

Developing the new program module (PLUGIN), we set in it the key parameters, namely: name of dangerous production factors and algorithm of calculation of these factors. The PLUGIN with the set algorithm helps to digitize the researched object and to receive a resulting effect.

All dangerous production factors are collected in a 3D model and tied to a certain site as it was noted above, up to 100 m^2. In turn supervisory authorities when bypassing the checked object by means of Tablet computers on which this software supporting 3D is installed will be able visually to estimate each checked elementary site and to enter data into the program module PLUGIN. In case of a bypass of the building site, the inspector gives marks opposite of each dangerous production factor in columns "Right" and "Wrong". After entering the data, the program module processes each of the checked dangerous production factors and shows the final number expressed as a percentage or in unit fractions. Conclusion of results is made in the Excel format in the form of the Table where numbers of the checked sites shall be specified, as well as the quantity of marks "right", "wrong" and the most important general security index.

It can be presented in the form of reporting Tables and schedules (Tab. 1, Fig. 1, 2)..

Table 1. The security index for each hazardous production factor

	1	3	2	9	6	8	11	5	10	4	7	Total
Actual Index, %	43	56	57	66	27	42	56	33	67	28	33	51
Current threshold, %	95	95	95	95	95	95	95	95	95	95	95	95

where Figure from 1 to 11 mean the following dangerous factors:

1 – workplace location near the height drop of 1.3 m or more;

2 – moving machines, their working parts, moved objects;

3 – high voltage electrical circuit, which short circuit can happen through a body of the person;

4 – the collapsing rocks;

5 – spontaneous collapse of building constructions, scaffolding;

6 – fall of materials and constructions;

7 – tipping machines, means of paving;

8 – sharp angles, edges;

9 – the increased content in air of dust and hazardous substances;

10 – noise and vibration;

11 – the increased temperature of the equipment, materials.

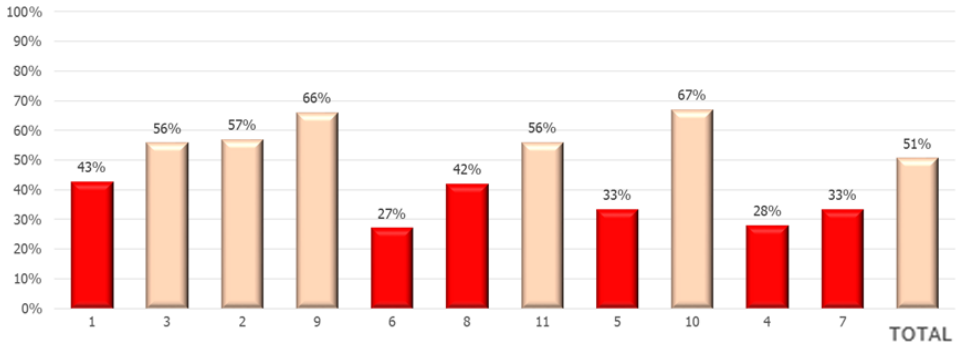

Figure 1. A security index on dangerous and harmful production factors

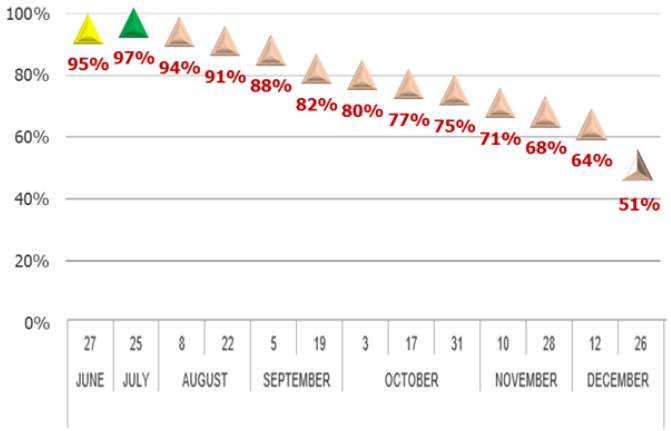

Figure 2. A security index in dynamics

The following step is determination of a stage of monitoring procedure where as the most suitable it is possible to choose a production phase of works, that is to take active part directly in forming of the standard of work and observance of safe engineering and labor protection when working.

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The system of monitoring (control) of level of labor protection and safe engineering was applied on the object, representing the site allocated under a construction of the apartment house with the built-in attached rooms and the attached car park located at the address: St. Petersburg, Obukhovskoy Oborony Avenue, house 110, Lit. B, in borders of the territorial zone TD1-2.

When implementing this monitoring the software products of the Autodesk company are used. The implementation of a technique on a specific example is shown in the Figure 3.

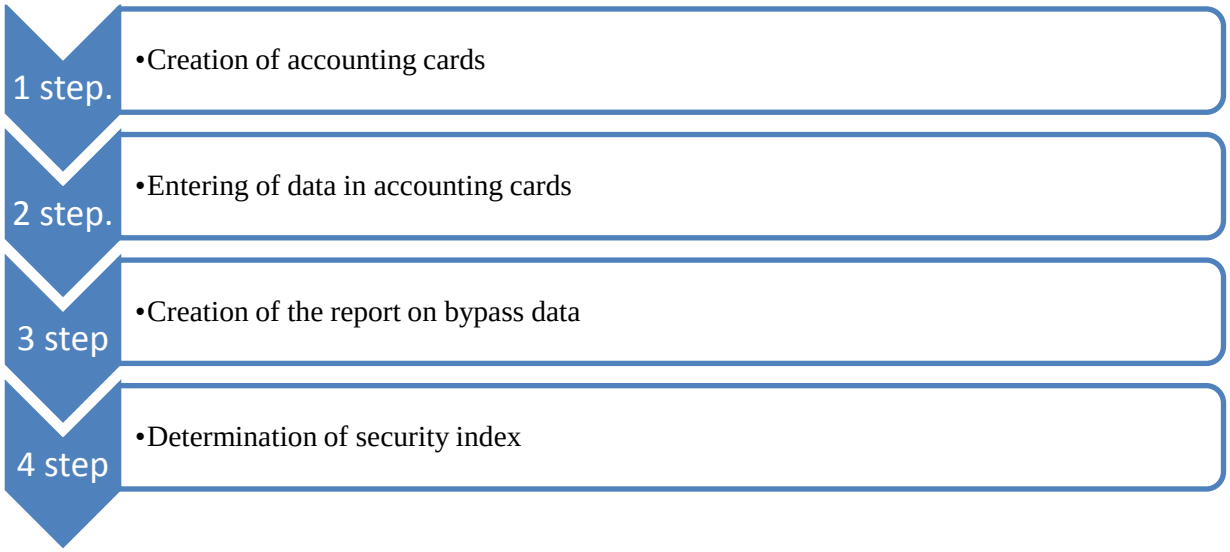

Figure 3. The integrated scheme of implementation of a technique

Results and Discussion

First step. The PLUGIN built in program complexes of the Autodesk Company is developed for implementation of control. At the same time the accounting cards for entering of bypass data are created. This program allows to calculate the security index of the object. The model of a general view of a bypass on occupational health and safety is provided in the Figure 4.

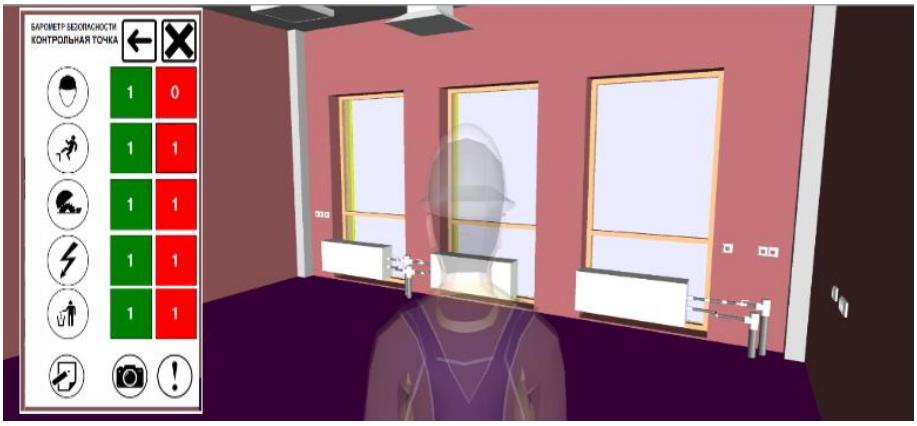

Figure 4.The bypass model of occupational health and safety

Second step. Bypass Information is entered in accounting cards. At the same time the program complex determines itself the inspector's arrangement in space by GPS navigation. In the accounting card necessary parameters of control are programmed. These parameters will be controlled throughout all construction. Each sphere has its identification number or ID-code. The following parameters of control were considered:

1. the engineering processes of construction and installation works;
2. the unprotected sites influencing injury risk on the object;
3. the processing equipment used in work;
4. electrical engineering;
5. garbage.

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All parameters of control are checked according to the regulating documentation.

In the PLUGIN there is also an opportunity to take pictures of the revealed violation and to attach them to the accounting card on which filming (Fig. 5) was made. At the same time the photo receives the same ID code, as the accounting card.

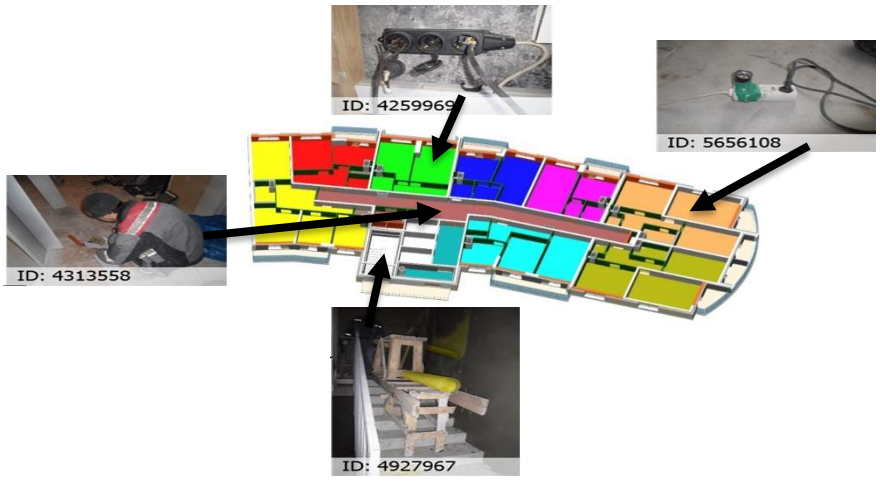

Figure 5. The accounting card with the photo attached to it

The number of accounting cards is appointed from accounting of at most 100 m^2 of the checked area (the elementary site), however in the reviewed example one card was appointed to one room. Each accounting card creates control data on all criteria according to which the assessment of actual state of the checked elementary site is carried out. The assessment of actual state of the checked site is noted as "right" and "wrong". To assess an objective situation on the checked site, it is necessary to expose both marks. Each of the checked parameters shall conform to requirements of the regulating documentation, Construction Rules and Regulations, Design and Construction Specifications, otherwise the mark "Wrong" is given.

To form the security index the borders of danger areas are determined:

- 70 – 100% – safe level of occupational health and safety;
- 50 – 70% – satisfactory level;
- - 0 – 50% – unsatisfactory level.

In the reviewed example 2711 accounting cards are processed, at the same time 3206 measurements are performed (in one bypass of the engineer). The accounting cards which aren't participating for any reasons in measurements and entering of data weren't taken into consideration respectively. From 3206 measurements: 1359 yielded positive result, 1847 were negative - that shows the availability of dangerous actions when implementing installation and construction works which can lead to an injury rate.

Third step. For handling and calculation of the security index the PLUGIN can unload the bypass data in a text format. In the reviewed example results of a bypass were unloaded in the MicrosoftExcel program as it is shown in the Table 2.

Table 2. A report form after unloading of the entered data on a bypass

Date		**Report**				
Project:	Project name					
Security index:	90%					
ID of the accounting card	**Evaluation criteria**					
	criterion 1	**criterion 2**	**criterion 3**	**criterion 4**	**criterion 5**	
3659807	0	0	0	0	0	
3659957	0	0	0	0	0	
3660423	0	0	1	0	0	
3660539	0	1	0	2	1	
3661000	0	0	0	0	0	
3591626	0	0	1	0	0	
3591958	0	0	1	0	0	
3654682	0	0	0	5	0	

Numbers of each accounting card and indicators are reflected in the unloaded Table 6. The quantity of marks is determined proceeding from that how many compliance or discrepancies according to the regulating documentation were revealed.

Fourth step. As a result of unloading of the data PLUGIN calculates the security index expressed as a percentage. The report on the level of the security index is created automatically by the program and directly goes to the server to a management of the company. It should be noted that by results of a bypass and depending on what positions there is weakening, the program gives particular recommendations for rising of general level of the security index. Calculation of the security index is made only according to accounting cards according to which the measurements were made, i.e. data were entered.

The security index represents the generalized indicator characterizing a general condition on the building site, being the effective tool capable to determine the level of safe engineering and labor protection on a construction object. It is at the same time possible to track each of controlled parameters and all situation in dynamics. Table 3 shows dynamics (Dynamics of the security index) of change of a situation on the building site for five months.

Table 3. Dynamics of the security index

Year/month	**July**	**August**		**September**		**October**			**November**	
Date	25	8	22	5	19	3	17	31	10	28
Index	68%	68%	70%	71%	69%	73%	75%	76%	79%	79%

Dynamics of change of level of the security index can be synchronized with the works schedule, analyzing which, it is possible to reveal in case of what work types there is a decrease in the security index, and thus the occupational health and safety.

Dynamics of the key indicators creating a general security index is shown in Table 4.

Table 4. Dynamics of the key indicators creating a general security index

	Engineering procedures of construction and installation work implementation	The unprotected sites influencing injury risk on an object the	Processing equipment used in work	Electrical engineering	Garbage	Total
Actual Index, %	71	64	50	67	75	79
Current threshold, %	70	70	70	70	70	70

Table 4 shows the ways in which there is a weakening of the positions. Using this approach it is possible to work for the prevention.

Conclusion

As the monitoring of safe engineering and labor protection was carried out before commissioning of the object, the substantial increase of discipline of workers, and also increase in culture of production became result of its implementation. Thus, the result of control by the offered method reflects the actual situation in the checked object, gives the chance to receive specific Figures on each of dangerous production factors, and allows carrying out the analysis of the dangerous production factors weakening positions. This approach to the assessment will allow reacting quickly to the processes which are taking place in the territory of the checked object, preventing emergence of a dangerous situation. In view of dynamics of change of the security it is possible to consider seasonality of the organization of works as the practice shows, seasonality of works is also a key indicator on the organization of such works as excavations, concrete, stone, roofing, etc.

Monitoring on the basis of BIM technology allows to approach qualitatively in a new way to control of safe engineering and labor protection on the object.

Thus, it is possible to measure the level of labor protection at the enterprise.

The presented method allows not only to estimate the level of labor protection in the enterprise, but also to analyze its weaknesses. This approach to the analysis of labor protection has a wide application range, can meet the needs and interests of any customer, when you select and enter criteria that meet the requirements of the state or particular enterprise. When considering the future application of the final numbers, it should be noted that it is possible to set a target (lower) limit (level) for which it is impossible to escape, and to associate it with the bonus the bonus system of remuneration as a motivational component.

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