

Research of the latest technologies and approaches to ensuring safety at work

Yury Polukarov*

PhD in Technical Sciences, Associate Professor
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"
03056, 37 Beresteiska Ave., Kyiv, Ukraine
<https://orcid.org/0000-0002-6261-3991>

Nataliia Prakhovnik

PhD in Technical Sciences, Associate Professor
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"
03056, 37 Beresteiska Ave., Kyiv, Ukraine
<https://orcid.org/0000-0003-0821-2166>

Oleksiy Polukarov

PhD in Technical Sciences, Associate Professor
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"
03056, 37 Beresteiska Ave., Kyiv, Ukraine
<https://orcid.org/0000-0003-4260-0330>

Hlib Demchuk

PhD in Technical Sciences, Associate Professor
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"
03056, 37 Beresteiska Ave., Kyiv, Ukraine
<https://orcid.org/0000-0003-3939-5516>

Olena Zemlyanska

Senior Lecturer
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"
03056, 37 Beresteiska Ave., Kyiv, Ukraine
<https://orcid.org/0000-0002-9608-3677>

Abstract. The implementation of appropriate measures and systems to ensure occupational safety depends not only on the economic efficiency of companies, but also on the life and health of employees, which makes this topic relevant. The purpose of the study was to assess the capabilities and effectiveness of leading technologies and new management approaches to ensuring safety at work in accordance with existing problems in the field of occupational safety. The main approaches used in the study are the statistical method, comparison, analysis, and the descriptive method. The study identified problems in the field of occupational safety in Ukraine, the main ones being a large share of undeclared labour and an inadequate system for recording accidents. Ways to ensure occupational safety are identified, which are primarily related to conducting conversations, motivating personnel, digitalisation of such safety elements as training, briefings, risk assessment, and incident management. Based on the analysis of the experience of global leading companies in ensuring

Article's History: Received: 29.11.2023; Revised: 25.04.2024; Accepted: 27.06.2024

Suggested Citation:

Polukarov, Yu., Prakhovnik, N., Polukarov, O., Demchuk, H., & Zemlyanska, O. (2024). Research of the latest technologies and approaches to ensuring safety at work. *Development Management*, 23(1), 38-48. doi: 10.57111/devt/2.2024.38.

*Corresponding author



Copyright © The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (<https://creativecommons.org/licenses/by/4.0/>)

occupational safety, effective practices for improving the effectiveness of the safety system have been identified, which include conversations with employees, special development and training programmes, the introduction of advanced technologies and unified safety systems. The conducted research allowed developing an occupational safety system that incorporates modern technologies and management approaches. The findings can be useful for company managers in selecting and implementing effective management measures and new technologies to ensure occupational safety

Keywords: occupational safety; injuries; accidents; internet of things; automation

● INTRODUCTION

The current stage of technology development and the introduction of new management approaches allow ensuring a high level of occupational safety. However, the number of workplace accidents, including those that resulted in the death of an employee, and the prevalence of occupational diseases remain significant. This problem is particularly acute in Ukraine, where occupational safety systems lag far behind those of advanced countries. Regulation of this issue can be resolved by various means, in particular, management at the state level, or at the level of an individual enterprise.

Ensuring the proper level of occupational safety in the context of Industry 4.0 significantly depends on the introduction of new, safer technologies (including digital ones) and on the effective construction of a safety management system. C. Nnaji & A.A. Karakhan (2020) and M. Akinloju *et al.* (2022) investigated the implementation of safety technologies in the construction industry. Researchers identified the main trends in the introduction of new technologies, and noted the importance of planning, management, and monitoring. W.-J. Su (2021) pointed out that an appropriate level of occupational safety is ensured through an appropriate culture. The researcher concluded that increasing management's commitment to safety is an important motivation for workers to participate in compliance with safety regulations. T. Novak (2023) noted the need for changes in the field of occupational safety at the level of international standards. The researcher noted that the right to a safe and healthy working environment should be included in the basic principles and rights at work.

The safety management concept is designed to manage the components of occupational safety. The International Labour Office (2001) defines the key components of this approach as follows: policy, organisation, planning and implementation, evaluation, measures for improvement. According to the organisation's instructions, the safety principles defined by it can be implemented both at the national and organisational levels. Many countries developed their own safety management models, which were then implemented in the activities of organisations in a wide range of industries.

In Ukraine, the protection of professional activities is also regulated by standards, considering international recommendations. O. Tveritnikova & Y. Demidova (2021), investigating this issue, noted the creation of the state standard of Ukraine (DSTU) ISO 45001:2019, which is a translation of the international standard ISO 45001:2018, IDT. Consideration of global trends, according to researchers, will help increase the competitiveness of Ukrainian enterprises, improve production safety, and ensure the implementation of certain sustainable development goals.

However, at the present stage, there are a number of problems in ensuring occupational safety in Ukraine. O. Krainiuk *et al.* (2021) pointed out the lack of a clear direction for strategic development, cyber-attacks, and legal restrictions. V. Kurepin (2022) noted the lack of qualified employees in the field of occupational safety, insufficient funding for safety measures, an inadequate system of employee motivation on safety issues, and poor quality of safety expertise. The researcher also pointed out the problems in the field of statistical reporting of industrial accidents related to the lack of a unified state system for recording such cases, which helps to conduct proper analysis and implement measures to improve the system.

These problems are mainly in the sphere of state regulation. But even at the enterprise level, researchers offer a number of measures related to improving the management system or introducing new technologies to ensure occupational safety. Y. Pushak & A. Zaverbnyj (2020) explored the possibilities of reputation management, the key element of which is to ensure the proper safety and psycho-emotional state of employees. O. Krainiuk *et al.* (2022) noted the importance of introducing the latest technologies to ensure occupational safety. Researchers argue that such technologies will contribute not only to improving safety, but also to increasing efficiency. However, there are possible negative consequences, such as negative psychosocial effects due to limited communication with employees, exposure to electromagnetic fields, diseases associated with sedentary work, etc.

Researchers often give priority to a specific area of improving occupational safety – the introduction of a particular technology or management approach. The problems are mostly addressed to public administration, as is the search for their solutions. In contrast to existing research, this paper offers an approach to solving problems that exist both at the state and micro levels, through improving the safety system at the enterprise level. The specific feature of such a system is that it does not give preference to a specific technology or approach, but provides for optimisation of both the technological and managerial components of ensuring occupational safety through proper planning, implementation, evaluation, and control. The purpose of the study was to analyse modern innovative technologies and management approaches to ensuring safety at work, considering existing problems in the field of occupational safety. To solve this goal, the following tasks are set: to identify the causes and key problems in the field of occupational safety in Ukraine through statistical analysis; to analyse international experience and positive examples of ways to reduce workplace injuries; to explore the latest technologies and approaches to ensuring occupational safety.

● MATERIALS AND METHODS

In the course of the study, a comprehensive system of scientific methods was applied, which allowed assessing existing problems and potential ways to solve them. The main methods used in the study were the statistical method, comparison, analysis, and descriptive method. The statistical method proved to be useful for assessing the current state of occupational safety at work on the example of Ukrainian enterprises. With its use, the following indicators were analysed (within Ukraine): work-related injuries (by the number of injured persons); work-related injuries, by types of economic activity in 2022 (by the number of injured persons); the number of injured persons for key causes of accidents in 2022; the number of informally employed persons in various sectors of the economy. The use of the statistical method identified key problems of ensuring occupational safety in Ukraine and their causes. A comparison was used to supplement the results obtained. Using this method, indicators of the state of workplace injuries in Ukraine, Poland, and Germany were compared, namely, the number of people injured at work, the number of people killed at work, and the most common causes of workplace injuries. The choice of countries for comparison is based on the fact that Poland and Germany are geographically close to Ukraine, have close economic, social, and political ties, but belong to developed countries, which makes their experience useful for Ukraine.

The study used the results of a survey conducted by the European company Quentic with the participation of 11 world-renowned experts and 500 occupational health and safety practitioners from Europe (Industry report..., 2022). Based on these data, priority areas for ensuring occupational safety were identified using the analysis. In addition, the analysis method was used to build the structure of the

industrial safety system (considering modern technologies and approaches in management). Using the descriptive method, the main latest technologies that can be used in the field of occupational safety were characterised. This helped to identify key areas in which such technologies can be implemented, and how they will ensure the safety of workers. The descriptive method was useful in the course of studying the experience of two world-renowned companies that are among the leaders in occupational safety in the list of Top 50 companies for worker health and safety (2020) according to Ethos ESG. Such companies are Range Resources (engaged in natural gas production) and Kosmos Energy (a leading deep-sea exploration and production company, its assets include oil and gas production and exploration). The use of the descriptive method allowed characterising the key ways in which companies ensure the safety of their employees, and the main security tasks that ensure their success in this area.

● RESULTS

Workplace injuries in Ukraine: statistics, causes and key issues

Improper safety at work in Ukraine is a problem that affects the health and safety of employees, and economic activity in general. This problem requires the search for new approaches to safety management, the introduction of new technologies, and the improvement of processes. The choice of optimal measures to improve occupational safety should be based on a detailed assessment of the current state of workplace injuries, identifying key problems and their causes. The current state of occupational safety can be assessed by analysing the number of employees injured by industrial accidents, according to information provided by the State Statistics Service of Ukraine (2023) (Fig. 1).

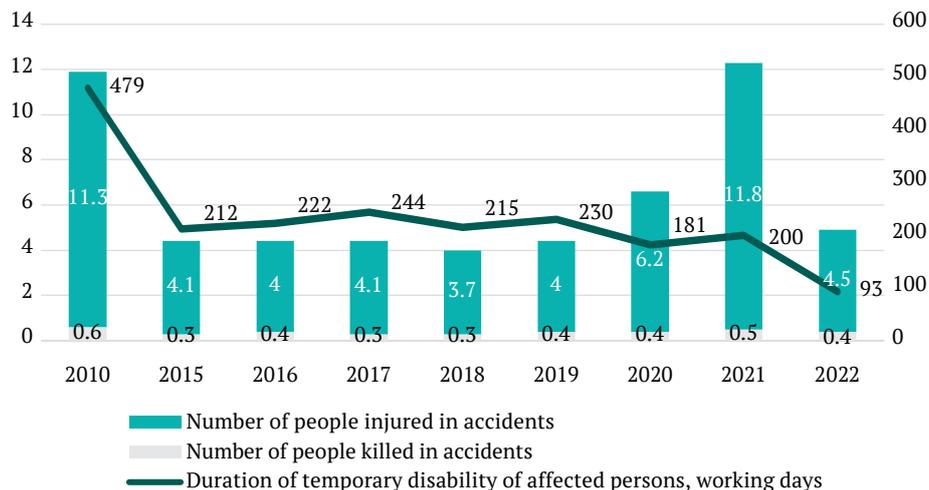


Figure 1. Work-related injuries in Ukraine

Source: compiled by the authors based on Traumatism at workplace (2023)

As can be seen from Figure 1, the number of people injured and killed in accidents during the study period was highest in 2021. In 2022, this indicator decreased significantly. The State Statistics Service of Ukraine (2023) separately provides data on workplace injuries that are not related to production. As

of 2022, the number of people who received workplace injuries that are not related to production is 17,802 people (639 – with a fatal outcome), 14,894 of whom are women (State Statistics Service of Ukraine, 2023). Figure 2 shows the number of injured persons by type of economic activity in 2022.

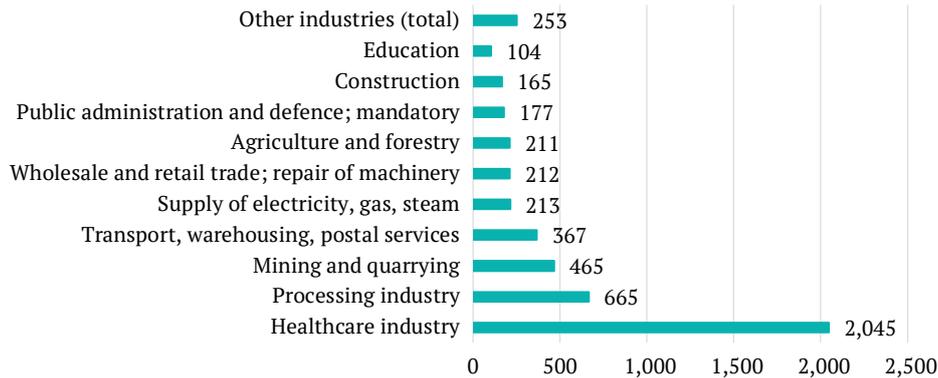


Figure 2. Number of persons injured at work, by type of economic activity in 2022

Source: compiled by the authors based on Traumatism at workplace (2023)

Figure 2 shows that the largest number of workplace accidents was recorded in healthcare and social assistance sectors. In addition, employees suffered a large number of injuries related to production in such industries as processing, mining and quarrying, transport, warehousing, postal, and courier activities. The most traumatic professions given the number of fatalities (as of 2022) are: employees of the transport industry – 99 persons, engineering and technical specialists – 75 persons, builders – 46 persons, metalworkers – 36 persons, electricians – 32 persons, employees of the socio-cultural industry – 24 persons. It is also important to note that 217 workers died as a result of injuries sustained during the hostilities (Degnera, 2023). The number of injured persons by the main causes of accidents in 2022 is shown in Figure 3.

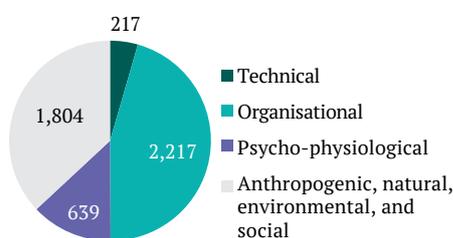


Figure 3. Number of injured persons by key causes of accidents in 2022

Source: compiled by the authors based on Traumatism at workplace (2023)

The main causes of an accident in 2022 include organisational reasons, as well as technogenic, natural, environmental, and social ones. A fairly large number of accidents were observed due to psycho-physiological reasons (including 14 people under the influence of alcohol or other types of intoxication/poisoning) and technical reasons. Accidents for organisational reasons are most often associated with violations of labour and industrial discipline (1,483 people) (Traumatism at workplace, 2023).

Comparing the level of workplace injuries in Ukraine with some countries, the following can be noted. According to the Central Statistical Office of Poland, the country recorded 45,809 work-related injuries in the first 9 months of 2023 (99 fatalities and 206 serious cases), which is 7.5% more than in the corresponding period of 2022. Most often,

accidents were caused by inappropriate behaviour of employees or improper handling of equipment, failure to comply with safety rules (Accidents at work..., 2023). According to the Deutsche Gesetzliche Unfallversicherung, in 2022, 787,412 work-related accidents (423 fatalities) occurred in the commercial and public sectors in Germany, resulting in disability for more than three days or death (Work-related accidents, 2023). These data indicate a significant increase in the number of recorded workplace accidents in Poland and Germany compared to Ukraine. The number of fatalities in the countries is lower (99 in Poland and 423 cases in Germany compared to 437 cases in Ukraine).

It can be assumed that the above indicators differ significantly due to demographic differences. The population of Germany is more than twice the population of Ukraine in 2022 (over 84 million people in Germany and over 41 million in Ukraine). However, in the case of Poland, this hypothesis is not confirmed, because the population of this country is smaller than the population of Ukraine, and amounts to over 37 million people. According to the researchers, the most likely reasons for significant differences in workplace injury rates for the countries under study are differences in approaches to the system for collecting information on industrial accidents. In Poland and Germany, such systems can be more advanced and contribute to more accurate recording of events. Statistics on fatalities are more revealing, and the lower number of fatalities in Germany and Poland compared to Ukraine indicates that the occupational safety systems in these countries are more effective. The indicators under study may also be affected by the level of undeclared labour, which is high in Ukraine (Fig. 4).

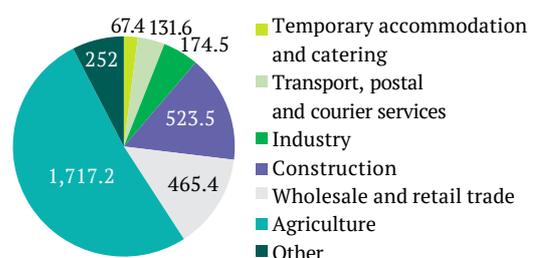


Figure 4. Number of informally employed persons in various sectors of the economy, thousand people
Source: compiled by the authors based on I. Degnera (2023)

It can be summed up that one of the problems associated with the imperfection of the occupational safety system in Ukraine may be the lack of proper recording of accidents. In addition to more accurate statistics, an effective accident recording system can provide benefits such as the ability to analyse incidents to prevent workplace injuries, grounds for paying compensation to workers, identifying key problems in the safety system and ways to improve it. Considering the causes of workplace accidents, when developing measures to counteract such cases, the largest number of them occurs due to violations of labour and industrial discipline, and due to technogenic, natural, environmental, social, and psychophysiological reasons.

An important component of the national policy in Ukraine regarding occupational safety and countering workplace accidents is preventive work. Such work consists in improving the level of safety culture through promoting safety and ways to reduce safety risks, forming a responsible attitude to one's own safety, the safety of others, the industrial and natural environment. This can be implemented through consultations, lectures, seminars, information campaigns, etc. One of the most effective methods of prevention is to conduct scheduled inspections at enterprises by qualified inspectors.

In the field of occupational safety, digital tools are increasingly used, which is especially relevant during quarantine

restrictions, and in the context of the legal regime of martial law. In particular, according to I. Degenera (2023) the State Labour Service of Ukraine implemented the following measures in the field of digitalisation: introduced the possibility to issue permits for the performance of work and the use of equipment that pose an increased danger in digital format; provided expert opinions in digital format; provided an opportunity to translate document flow in the occupational health and safety management system into electronic form; created an information platform for quick information about wage arrears; created an online consultation service "Interactive inspector". To further optimise and improve the efficiency of work in the field of occupational safety, it is worth referring to international experience in this area, in particular, considering the successful examples of individual companies.

International experience: ways to reduce workplace injuries and positive examples

Ensuring safe and decent working conditions is a priority for the world's leading countries, including the developed countries of Europe. Given this, the results of a study by the European company Quentic (Industry report..., 2022) are worthy of attention. The study analyses which areas, according to experts and practitioners, are a priority in the field of ensuring occupational safety and health (Fig. 5).



Figure 5. Priority areas for ensuring occupational safety and health according to European experts and practitioners

Note: EHSQ – environment, health, safety, and quality system

Source: compiled by the authors based on Industry report: An in-depth look at safety management in 2022 (2022)

As can be seen from Figure 5, most experts and practitioners prefer to increase employee motivation and talk to them about ensuring occupational safety. Such measures are justified, because, as it was established above, most often the causes of workplace accidents are associated with inappropriate behaviour of employees, improper use of equipment, and failure to comply with

safety rules. Experts and practitioners also pay great attention to problems related to psychosocial stress, and consider it effective to conduct conversations with management. Figure 6 shows the ratio of experts' and practitioners' responses to the question about which safety management elements their companies have digitised or plan to digitise.

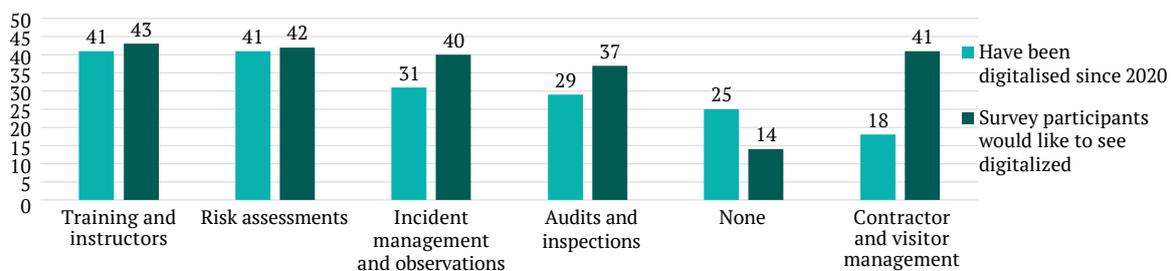


Figure 6. Safety management elements that have been digitalised since the beginning of 2020/planned to be digitalised (according to experts and practitioners)

Source: compiled by the authors based on Industry report: An in-depth look at safety management in 2022 (2022)

The most popular elements that have been digitalised or are expected to be digitalised in the future are: training and instruction, risk assessment, incident management and surveillance, audit and inspection, contractor and visitor management. In particular, training and instruction, and risk assessment, were digitalised in companies by more than 40% of respondents – approximately the same share of respondents plans to digitalise these areas in the future.

Examples of world-renowned companies that pay great attention to employee safety and health are Range Resources and Kosmos Energy. Companies occupy a leading position in the list of Top 50 companies for worker health and safety (2020) according to Ethos ESG. To ensure a high level of security, Range Resources uses both management approaches and proper technological support. Employees are regularly interviewed on occupational safety issues. The safety process involves both the safety department and senior management, as well as all employees, operational groups and contractors. There is a well-developed system of accountability, and appropriate employee development and training programmes are being implemented. The extraction and development of natural gas resources takes place using advanced technologies in this area that ensure the safety of not only employees, but also the environment and society (Our industry-leading innovation, 2023).

Kosmos Energy, in addition to information and preventive work with employees, has implemented a comprehensive management system that connects employees and contractors and conveys expectations regarding safety, risk management, emergency preparedness, and environmental protection. There is a system for evaluating each component of this system, which allows adjusting the effectiveness. The company adheres to a number of standards, including international ones, and practices corporate social responsibility. Occupational safety is ensured by implementing the following tasks: risk assessment in order to prevent incidents; reduction of emissions and waste; efficient use of energy; effective response and emergency preparedness, etc. On its official website, the company shows safety statistics: for the period from 2020 to 2022, one person died at work. The mortality rate for the corresponding year (2021) reached 0.18 (Kosmos Energy health and safety, 2023).

The data from the survey of experts and practitioners, and the study of the experience of leading companies, reveal opportunities to ensure occupational safety at work. From the above, it can be summed up that most often this applies to certain management approaches. However, it is also important to investigate what opportunities exist to ensure safety through technological measures.

The latest technologies and approaches to ensuring occupational safety

In today's digitalised environment, the introduction of the latest technologies is no less important in ensuring an appropriate level of safety at work than appropriate safety management. This applies not only to advanced equipment that can ensure the safety of employees, reduce harmful effects on the environment, etc., but also to digital technologies. Digital technologies can increase the level of safety both directly (for example, when using smart robots that can perform dangerous work instead of

humans, or exoskeletons), and indirectly – by improving the capabilities for analysis to identify risks, minimise them, and other tasks.

In the context of the study, it is worth analysing the most common technologies used in the field of occupational safety, and ways to apply them. Z. Liu *et al.* (2020) note that the concept of Safety 3.0 meets the conditions of Industry 4.0. Within the framework of this concept, the main means of ensuring safety are information and automated technologies, and an established safety system. Safety 2.0 (1930s-early 21st century) corresponded to such basic tools as safety management theory and safety management system, Safety 1.0 (1760s-1930s) – safety and inspection legislation. Previous safety concepts were implemented through compliance with relevant safety laws, conducting inspections, implementing safety management systems, etc. The key “symbols” of Safety 3.0 are: the use of smart personal protective equipment, smartphones, smart cameras, special clothing for employees, drones and robots, radio frequency identification, the Internet of Things (IoT), cloud technologies, etc. Occupational safety services are provided by a number of world-renown companies, in particular, SafetyCulture, German Bionic, Physical Sciences Inc., etc. (Top workplace safety companies, n.d.).

One of the new technologies that have successfully proven themselves in the field of occupational safety is collaborative robots – special machines that can work in a common workspace with employees and help them perform work tasks more efficiently and safely. Their work is made possible by special sensors that perceive the environment and allow robots to respond to a dynamic environment. Similar functions are performed by exoskeletons – devices worn by workers to ensure safety and efficiency during difficult or dangerous tasks. Knowledge-based smart machines are quite widespread – special machines equipped with cameras and sensors that, like robots, can perform individual tasks more efficiently than employees. Such machines can independently transmit information about potential failures in their operation to service centres. Among smart technologies, it is also worth highlighting smart mobile technologies – these include smart bracelets, smart glasses, etc. They are designed to monitor the activities of employees, working conditions, and health status.

Technologies that combine the physical and digital worlds in a certain way are becoming important. Augmented reality allows accompanying real events with computer data through the addition of digital elements to the physical world. This can be used to project computer-generated images onto real objects for various purposes (for example, for training, modelling, providing instructions, etc.). The IoT involves combining physical objects through different sensors using the Internet. The technology allows collecting and combining data about different objects into a single system. Big data technology allows analysing a large amount of information that cannot be analysed using conventional methods. Remote cloud technologies allow storing, sharing, and processing information for analysis, monitoring, and more. Virtual reality allows simulating certain work situations digitally, and also allows interacting with the virtual environment. Artificial intelligence simulates the processes inherent in human intelligence. It may be used, for example, in autonomous vehicles (Savković *et al.*, 2021).

Thus, there is a wide range of technologies that can be implemented to improve occupational safety. The choice of the technology that a particular company needs should be based on sound management decisions. The effectiveness of technologies directly depends on safety management and proper training of employees to interact with and handle such technologies. Figure 7 suggests a system for ensuring safety at work, which contains both technologies that ensure occupational safety and the main components of the management system for making effective decisions.

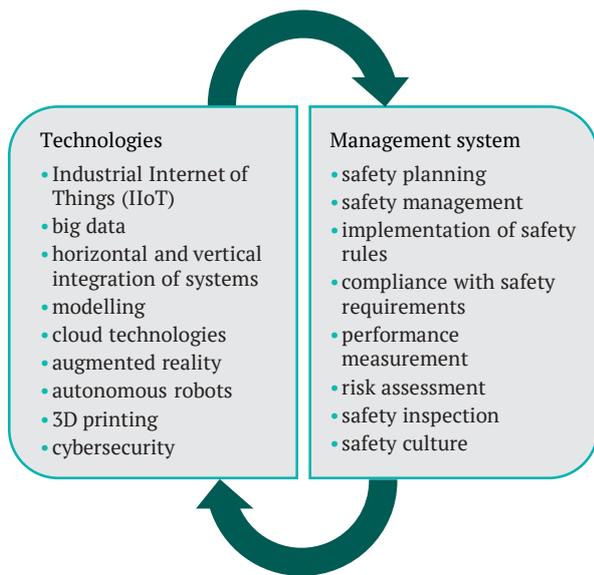


Figure 7. Components

of the industrial safety system considering modern technologies and approaches in management

Source: compiled by the authors based on U. Khalid *et al.* (2021) and A. Forcina & D. Falcone (2021)

Thus, the system of ensuring occupational safety involves the use of the latest safety technologies and effective management approaches that operate in an indissoluble relationship. The choice of technologies suitable for a particular enterprise is not possible without making balanced management decisions, detailed analysis and planning. In addition, the use of even the most advanced technologies will not bring the expected result without proper personnel management, the introduction of training programmes and motivation to participate in ensuring personal safety and the safety of others. First of all, ensuring a high level of occupational safety is based on corporate social responsibility and a safety culture, which should be considered by both management and each employee.

● DISCUSSION

Thus, the study analysed the current state of occupational safety at Ukrainian enterprises, examined the main approaches and successful experience in the field of occupational safety by international companies, and outlined the main management measures and digital technologies used in this area. It was noted that the introduction of the latest technologies should be inextricably linked with the development of a proper safety management system.

Z. Liu *et al.* (2020), investigating the concept of safety management, point out its close connection with such areas of activity of enterprises as organisation, planning, decision-making, control. This approach involves the application of safety principles and methods, and the implementation of appropriate technological, organisational and managerial measures. B. Wang (2021) considers safety management as the process of implementing certain safety features and examines this approach both from an organisational standpoint (promoting safety in the company and protecting employees and property from certain risks), and from the introduction of intelligent systems and technologies for safety management. The researcher considers the concept of safety intelligence as one that aims to transform raw data into meaningful information that can be used to improve safety management. In another study by B. Wang & C. Wu (2020), the phenomenon of safety information stands out as a separate discipline – safety informatics, whose task is to solve the problem of lack of safety information. These studies reinforce the authors’ position that ensuring occupational safety occurs primarily through a combination of the latest technologies with effective management approaches, which proves the feasibility of the proposed system for ensuring occupational safety.

U. Khalid *et al.* (2021) develop the structure of an effective safety management system consisting of the following interrelated elements: implementation of safety regulations, safety management, planning, compliance, performance measurement, risk assessment, safety verification, and safety culture. Despite the close relationship between these factors, the researchers emphasise that the effectiveness of the entire system depends primarily on the proper prioritisation of these factors. The researchers note that in the field of healthcare and safety, there are more than 60 factors that were grouped into 6 groups in the study: organisational, managerial, legislative, social, environmental, and personnel. As follows from the above, the study identifies not only internal factors that depend on technology and management, but also external ones (legislative, social, and environmental). In contrast to this study, the researchers analysed purely internal safety areas related to management and digitalisation. Despite the narrow scope, this allowed for a more in-depth analysis of key problems in this area and measures to address them.

Many papers are also devoted to the study of the technological side of the problem, in particular, A. Forcina & D. Falcone (2021) define the “nine pillars of technology” through which innovation occurs in production, and an ordinary factory turns into a “smart” factory. These “pillars” include: the IIoT, big data, system integration, modelling, cloud technologies, augmented reality, autonomous robots, 3D printing, and cybersecurity. According to the researchers, in the context of production, the most representative technologies are IIoT and cyber-physical systems. These technologies allow efficient processing of digital information and high-quality monitoring. Specific ways of applying these technologies are also noted, for example, to increase the level of safety in warehouses and logistics, the safety of products, their storage and transportation places, etc.

Some studies include an in-depth analysis of one technology, in particular, many papers are devoted to the investigation of the effectiveness of the IoT in the field of

occupational safety. M.G. Gnoni *et al.* (2020) find that the IoT, which is widely used in many industries, is becoming increasingly popular in the field of occupational health and safety. Most often, solutions using IoT technologies are used for dynamic safety management in workplaces with increased complexity. The researchers devote their work to describing a prototype system using IoT technologies, the scope of which can be both analysing equipment deterioration and tracking dangerous working conditions on a remote basis. S. Misra *et al.* (2022) also focus on the benefits of the IoT and the possibilities of its implementation in the occupational safety system. The research focuses on occupational safety and various solutions based on the IoT that can increase the level of such safety in a number of areas.

A.L. Perales Gómez *et al.* (2021) investigate the use of cyberphysical systems in production, that is, those that combine the physical and cybernetic worlds. Unlike previous studies, the researchers cite not only the benefits of applying technological innovations, but also express concern about possible cyber-attacks. Such attacks can target a cyber and physical system and, given that employees interact closely with machines in a single workspace, can affect the security of the entire workflow. In this regard, researchers offer their own approach to improving the security of cyber-physical systems using a single management structure to detect and prevent cyber-attacks, and security threats in the workflow.

In contrast to these studies, the authors of this paper did not conduct an in-depth assessment of specific technologies, but provided a wide range of the most commonly used innovations. This can be explained by the desire to cover the research issues more comprehensively – from existing problems in the field (on the example of Ukraine) to a wide range of areas for their solution (considering the views of experts, practitioners, positive examples, management decisions and technologies).

While this paper reveals the areas of implementing a safety management system in production, some studies have also identified advantages and obstacles in this process. In particular, N.S.N. Yiu *et al.* (2019) find that the main benefits of implementing safety management systems include safer working conditions, minimising injuries and harm to workers, including safety management in the project management system, and improved project management in general. At the same time, researchers note barriers to the implementation of safety management systems: cultural differences in companies, significant staff turnover, short project deadlines, and obstacles caused by contractors and insufficient team interest in implementing a safety management system.

F. Simone *et al.* (2023) note that despite the reduction in the number of workplace accidents, adverse or tragic situations still occur, and incident-based training can prevent the recurrence of such situations. Researchers propose a special methodology designed to extract information from accident reports for further analysis, modelling and monitoring of safety and provide instructions on how to comply with it. However, the effectiveness of such a system depends on the accuracy of information in reports, which may not be sufficient in the case of a high share of undeclared labour, which, as revealed in the study, is typical for Ukraine.

Comparing the conclusions of researchers with the results of this study, the authors fully agree with the identified advantages and obstacles. It is worth noting that the main obstacle both in this paper and in the analysed studies is the disinterest of management and/or employees in implementing safety measures and systems. In addition, the study revealed such a problem (on the example of Ukraine) as a significant share of undeclared labour. This leads to inaccurate recording of accidents and makes it difficult to develop measures to minimise them. Imperfect recording of accidents makes it virtually impossible to implement such an important area of occupational safety as incident-based training. Ensuring occupational safety is an issue that affects the vital interests of employees and affects economic efficiency. It is possible to increase the effectiveness of occupational safety management through government measures, but given the duration of such measures, it is an important issue to ensure safety in ways available at the enterprise level. It is necessary to consider the need to improve the safety management system, and the introduction of the latest technologies that can significantly optimise the safety system.

● CONCLUSIONS

In the course of the study, an analysis of the current state of occupational safety at Ukrainian enterprises was carried out. Compared to countries such as Poland and Germany, Ukraine has significantly lower indicators in terms of the number of workplace accidents. The number of fatalities in the country is higher than in the EU countries under study. It is revealed that such differences in indicators may be conditioned by an imperfect system for recording accidents in Ukraine, and a high proportion of undeclared labour, which is confirmed by statistical data.

An analysis of the views of experts and leading practitioners in the field of occupational safety in Europe revealed that effective measures to improve safety are most often associated with conducting conversations and motivating staff. Experts and practitioners consider it appropriate to digitalise certain elements of the safety system, in particular, training and instruction, risk assessment, incident management and surveillance, audit and inspection, management of contractors and visitors. The description of the successful experience of leading companies that are leaders in ensuring employee safety helped to determine which areas of security they pay the most attention to. First of all, it is informational and preventive work with employees, which consists in conducting conversations, special development programmes, and training. At the same time, both the management and the security department, and all employees, and other interested parties (contractors, operational groups, etc.) take part in ensuring occupational safety in companies. Companies also apply advanced security technologies, and implement unified safety systems that connect all employees and ensure a proper assessment of safety elements. Important areas in the field of occupational safety are risk assessment to prevent incidents, reduce emissions and waste, energy efficiency, constant readiness and effective response to problems and emergencies.

The paper revealed the components of the occupational safety system (considering modern technologies and approaches in management), and modern technologies

that can be used to improve occupational safety, and described exactly how they can be implemented. These technologies include: collaborative robots, exoskeletons, knowledge-based smart machines, intelligent mobile technologies, augmented reality, IoT, big data, cloud technologies, virtual reality, artificial intelligence. Further research should be devoted to the development of a model for assessing the needs of an enterprise to introduce the latest

technologies, considering their potential effectiveness in specific areas of production.

● ACKNOWLEDGEMENTS

None.

● CONFLICT OF INTEREST

None.

● REFERENCES

- [1] Accidents at work in January-September 2023 – preliminary data. (2023). Retrieved from <https://stat.gov.pl/en/topics/labour-market/working-conditions-accidents-at-work/accidents-at-work-in-january-september-2023-preliminary-data,4,55.html>.
- [2] Akinlolu, M., Haupt, T.C., Edwards, D.J., & Simpeh, F. (2022). A bibliometric review of the status and emerging research trends in construction safety management technologies. *International Journal of Construction Management*, 22(14), 2699-2711. doi: 10.1080/15623599.2020.1819584.
- [3] Degnera, I. (2023). *Public report of the head of State Labour Service of Ukraine on the results of 2022*. Kyiv: State Labour Service of Ukraine.
- [4] Forcina, A., & Falcone, D. (2021). The role of Industry 4.0 enabling technologies for safety management: A systematic literature review. *Procedia Computer Science*, 180, 436-445. doi: 10.1016/j.procs.2021.01.260.
- [5] Gnoni, M.G., Bragatto, P.A., Milazzo, M.F., & Setola, R. (2020). Integrating IoT technologies for an “intelligent” safety management in the process industry. *Procedia Manufacturing*, 42, 511-515. doi: 10.1016/j.promfg.2020.02.040.
- [6] International Labour Office. (2001). *Guidelines on occupational safety and health management systems, ILO-OSH 2001 (2nd ed.)*. Geneva: International Labour Office.
- [7] Industry report: An in-depth look at safety management in 2022. (2022). Retrieved from <https://www.quentic.com/press/dv/80003239-safety-management-2022-trend-report-an-in-depth-look-at-safety-in-industry/>.
- [8] Khalid, U., Sagoo, A., & Benachir, M. (2021). Safety management system (SMS) framework development – mitigating the critical safety factors affecting health and safety performance in construction projects. *Safety Science*, 143, article number 105402. doi: 10.1016/j.ssci.2021.105402.
- [9] Kosmos Energy health and safety. (2023). Retrieved from <https://www.kosmosenergy.com/health-safety/>.
- [10] Krainiuk, O., Buts, Y., & Barbachyn, V. (2021). SWOT analysis of the implementation of digital technologies to ensure occupational safety. *Municipal Economy of Cities, Series: Engineering Science and Architecture*, 3(163), 234-238. doi: 10.33042/2522-1809-2021-3-163-234-238.
- [11] Krainiuk, O., Buts, Y., & Bogatov, O.I. (2022). *Digitalization of labor protection: Problems, prospects, opportunities*. In *Modern science: Innovations and prospects. Abstracts of XIII international scientific and practical conference* (pp. 74-77). Stockholm: SSPG Publish.
- [12] Kurepin, V. (2022). *The system of occupational safety and hygiene organization in Ukraine*. In *Modern approaches to occupational health and safety in vocational education institutions: Proceedings of the all-Ukrainian scientific and practical online conference* (pp. 74-78). Bila Tserkva: Bila Tserkva Institute of Continuous Education of State Higher Educational Institution “University of Educational Management”.
- [13] Liu, Z., Xie, K., Li, L., & Chen, Y. (2020). A paradigm of safety management in Industry 4.0. *Systems Research and Behavioral Science*, 37(4), 632-645. doi: 10.1002/sres.2706.
- [14] Misra, S., Roy, C., Sauter, T., Mukherjee, A., & Maiti, J. (2022). Industrial Internet of Things for safety management applications: A survey. *IEEE Access*, 10, 83415-83439. doi: 10.1109/ACCESS.2022.3194166.
- [15] Nnaji, C., & Karakhan, A.A. (2020). Technologies for safety and health management in construction: Current use, implementation benefits and limitations, and adoption barriers. *Journal of Building Engineering*, 29, article number 101212. doi: 10.1016/j.jobbe.2020.101212.
- [16] Novak, T. (2023). The role of collective-contractual regulation in ensuring the right of agricultural workers to a safe and healthy working environment. *Law. Human. Environment*, 14(3), 60-78. doi: 10.31548/law/3.2023.60.
- [17] Our industry-leading innovation. (2023). Retrieved from <https://www.rangeresources.com/about-us/innovation/>.
- [18] Perales Gómez, Á.L., Fernández Maimó, L., Huertas Celdrán, A., García Clemente, F.J., Gil Pérez, M., & Martínez Pérez, G. (2021). SafeMan: A unified framework to manage cybersecurity and safety in manufacturing industry. *Software: Practice and Experience*, 51(3), 607-627. doi: 10.1002/spe.2879.
- [19] Pushak, Y., & Zaverbnyj, A. (2020). Corporate reputation as a key vector for improving the economic security level. *Social and Legal Studies*, 3(2), 130-136. doi: 10.32518/2617-4162-2020-2-130-136.
- [20] Savković, M., Dašić, M., Đapan, M., Vukićević, A., Mačuzić, I., & Stefanović, M. (2021). *Improving workplace safety using advanced Industry 4.0 technologies*. In *XI international conference industrial engineering and environmental protection* (pp. 545-552). Zrenjanin: University of Novi Sad.
- [21] Simone, F., Ansaldi, S.M., Agnello, P., & Patriarca, R. (2023). Industrial safety management in the digital era: Constructing a knowledge graph from near misses. *Computers in Industry*, 146, article number 103849. doi: 10.1016/j.compind.2022.103849.

-
- [22] Su, W.-J. (2021). The effects of safety management systems, attitude and commitment on safety behaviors and performance. *International Journal for Applied Information Management*, 1(4), 187-200. doi: 10.47738/ijaim.v1i4.20.
- [23] Top 50 companies for worker health and safety. (2020). Retrieved from <https://www.ethosesg.com/blog/top-50-worker-safety>.
- [24] Top workplace safety companies. (n.d.). Retrieved from <https://www.ventureradar.com/keyword/Workplace%20safety>.
- [25] Traumatism at workplace. (2023). Retrieved from <https://stat.gov.ua/en/datasets/traumatism-workplace>.
- [26] Tveritnikova, O., & Demidova, Y. (2021). [Integration of the safety management system of professional activities of Ukrainian enterprises based on the requirements of international standards](#). In *Information technologies: Science, engineering, technology, education, health* (p. 330). Kharkiv: Planet-Print.
- [27] Wang, B. (2021). Safety intelligence as an essential perspective for safety management in the era of Safety 4.0: From a theoretical to a practical framework. *Process Safety and Environmental Protection*, 148, 189-199. doi: 10.1016/j.psep.2020.10.008.
- [28] Wang, B., & Wu, C. (2020). Safety informatics as a new, promising and sustainable area of safety science in the information age. *Journal of Cleaner Production*, 252, article number 119852. doi: 10.1016/j.jclepro.2019.119852.
- [29] Work-related accidents. (2023). Retrieved from <https://www.dguv.de/en/facts-figures/work-related/index.jsp>.
- [30] Yiu, N.S.N., Chan, D.W.M., Shan, M., & Sze, N.N. (2019). Implementation of safety management system in managing construction projects: Benefits and obstacles. *Safety Science*, 117, 23-32. doi: 10.1016/j.ssci.2019.03.027.

Дослідження новітніх технологій та підходів до забезпечення безпеки на виробництві

Юрій Полукаров

Кандидат технічних наук, доцент

Національний технічний університет України «Київський політехнічний інститут імені Ігоря Сікорського»
03056, просп. Берестейський, 37, м. Київ, Україна
<https://orcid.org/0000-0002-6261-3991>

Наталія Праховнік

Кандидат технічних наук, доцент

Національний технічний університет України «Київський політехнічний інститут імені Ігоря Сікорського»
03056, просп. Берестейський, 37, м. Київ, Україна
<https://orcid.org/0000-0003-0821-2166>

Олексій Полукаров

Кандидат технічних наук, доцент

Національний технічний університет України «Київський політехнічний інститут імені Ігоря Сікорського»
03056, просп. Берестейський, 37, м. Київ, Україна
<https://orcid.org/0000-0003-4260-0330>

Гліб Демчук

Кандидат технічних наук, доцент

Національний технічний університет України «Київський політехнічний інститут імені Ігоря Сікорського»
03056, просп. Берестейський, 37, м. Київ, Україна
<https://orcid.org/0000-0003-3939-5516>

Олена Землянська

Старший викладач

Національний технічний університет України «Київський політехнічний інститут імені Ігоря Сікорського»
03056, просп. Берестейський, 37, м. Київ, Україна
<https://orcid.org/0000-0002-9608-3677>

Анотація. Від впровадження належних заходів та систем забезпечення безпеки на виробництві залежить не лише економічна ефективність компаній, а й життя та здоров'я працівників, що робить дослідження цієї теми актуальним. Мета дослідження полягала в оцінці можливостей та ефективності провідних технологій та нових управлінських підходів щодо забезпечення безпеки на виробництві відповідно до існуючих у сфері забезпечення безпеки праці проблем. Основними методами, використаними в дослідженні, є статистичний метод, метод порівняння, аналіз та описовий метод. У результаті проведеного дослідження було виявлено проблеми, що існують у галузі забезпечення безпеки праці в Україні, основними з яких є велика частка незадекларованої праці та неналежна система фіксації нещасних випадків. Виявлено шляхи забезпечення безпеки на виробництві, що пов'язані насамперед із проведенням бесід, мотивацією персоналу, зокрема цифровізацією таких елементів безпеки, як тренування, інструктажі, оцінка ризиків, управління інцидентами. На основі аналізу досвіду всесвітньо відомих компаній-лідерів із забезпечення безпеки праці визначено ефективні практики з підвищення ефективності системи безпеки, до яких належать бесіди з працівниками, спеціальні програми розвитку та навчання, запровадження передових технологій та уніфікованих систем безпеки. Проведене дослідження дозволило сформулювати систему забезпечення безпеки на виробництві, що містить сучасні технології та підходи в менеджменті. Отримані висновки можуть бути корисними для керівників компаній у цілях вибору та впровадження на практиці ефективних управлінських заходів та нових технологій із забезпечення безпеки на виробництві

Ключові слова: охорона праці; травматизм; нещасні випадки; Інтернет речей; автоматизація