
Tomasz Wołczański✉

Opole University of Technology

Industry 4.0 smart technologies in workplace safety logistics

Inteligentne technologie Przemysłu 4.0 w logistyce bezpieczeństwa pracy

Abstract. Safety logistics in the age of digitization of industrial plants is complex because it embodies the technologies of Industry 4.0 by integrating people and machines and individual processes. New technologies allow them to manage machines and equipment based on communication and mutual data flow. This creates a network of connections between products, value chains and business models. The activities associated with the implementation of the Industry 4.0 concept include human interaction and occupational safety logistics in addition to technology. Digitalization creates new options for the organization of work areas and thus new opportunities for work safety logistics. Modern digitalization has an extremely positive impact on occupational safety and productivity. Intelligent work safety management requires the use of new Industry 4.0 technologies and solutions developed for the work environment area. The purpose of this paper is to present a systematic literature review covering the area of intelligent Industry 4.0 technologies in occupational safety logistics, including an indication of the importance of safety in the work environment, in the context of the continuous digital transformation of enterprises.

Key words: management, intelligent systems, logistics, work safety, Industry 4.0, digitalization, new technologies

Synopsis. Logistyka bezpieczeństwa w dobie cyfryzacji zakładów przemysłowych jest złożona, ponieważ ucieleśnia technologie Przemysłu 4.0 poprzez integrację ludzi i maszyn oraz poszczególnych procesów. Nowe technologie pozwalają im zarządzać maszynami i urządzeniami na podstawie komunikacji i wzajemnym przepływie danych. Tworzy to sieć powiązań między produktami, łańcuchami wartości i modelami biznesowymi. Działania związane z wdrożeniem koncepcji Przemysłu 4.0 obejmują interakcję międzyludzką i logistykę bezpieczeństwa pracy oprócz technologii. Cyfryzacja stwarza nowe możliwości organizacji obszarów pracy, a tym samym nowe możliwości logistyki bezpieczeństwa pracy. Nowoczesna cyfryzacja ma niezwykle pozytywny wpływ na bezpieczeństwo i wydajność pracy. Inteligentne zarządzanie bezpieczeństwem pracy wymaga zastosowania nowych technologii i rozwiązań Przemysłu 4.0 opracowanych dla obszaru środowiska pracy. Celem artykułu jest przedstawienie systematycznego przeglądu literatury obejmującego obszar inteligentnych technologii Przemysłu 4.0 w logistyce bezpieczeństwa pracy, w tym wskazanie znaczenia bezpieczeństwa w środowisku pracy, w kontekście ciągłej transformacji cyfrowej przedsiębiorstw.

Słowa kluczowe: zarządzanie, inteligentne systemy, logistyka, bezpieczeństwo pracy, Przemysł 4.0, cyfryzacja, nowe technologie

JEL codes: J01, J28, J81, L16, L26, O14, O32

✉ Tomasz Wołczański – Opole University of Technology; Faculty of Production Engineering and Logistics; Department of Safety Engineering and Technical Systems; e-mail: t.wolczanski@po.edu.pl

Introduction

Nowadays, you can see an increase in the number of solutions and smart devices that are managed using the Internet. What is important is that not only the item and the computer are connected, but also there is integration in the area of access to the network. Such solutions are used more and more often in everyday life. They can be seen in smart homes and cars, which are slowly becoming something normal and common. They are also appearing in other areas, for example in the economy – automation and digitalization is being introduced on an increasing scale. The concept of Industry 4.0 is put into practice by integrating people, machines and individual processes. Thanks to it, intelligent production systems can flourish in industrial plants, having not only their own autonomy, but also capable of self-configuration, self-control, and even self-repair. In this way, the company can improve production efficiency and save money by quickly eliminating defects and preventing production stoppages. The company will not have to spend a lot of money on repairs and will not have to think about how to compensate for the losses incurred by the interruption of production [Staleo 2018].

Robots, data storage technology, affordable high-performance computing and increased computing power have become widely available in recent years. The expansion of broadband coverage is particularly conducive to the use of new technologies [CIOP-PIB]. New technologies mean not only faster and more efficient work, greater effectiveness or easier estimation of productivity and better profitability, but also saving money and protecting the environment by reducing CO₂ emissions [Zadania dla rolnictwa...].

It is important to note that there are many high-risk work areas in industrial practice. Intelligent systems and a digital network that connects people, workplaces, and safety, logistics, and security logistics solutions can use real-time information, real data to protect workers from risk and improve emergency response [Inteligentne BHP...].

The purpose of this paper is to present a systematic literature review covering the area of intelligent Industry 4.0 technologies in occupational safety logistics, including an indication of the importance of safety in the work environment, in the context of the continuous digital transformation of enterprises.

Materials and methods

Based on the a systematic literature review covering the area of Industry 4.0 the subject of this paper is to present the intelligent technologies of Industry 4.0 in occupational safety logistics, including the indication of the importance of the importance of safety in the work environment, in the context of the continuous digital transformation of enterprises. Based on a systematic literature review covering the area of Industry 4.0, the topic of this article is to present the intelligent technologies of Industry 4.0 in occupational safety logistics, including an indication of the importance of the importance of safety in the work environment, in the context of the continuous digital transformation of enterprises. Based on the literature on digitalization, Industry 4.0 and digitalization, a literature analysis and evaluation of the information and results of the scientific research conducted by many authors was carried out,

which concluded that digitalization creates new opportunities for the organization of execution areas in the work environment, and thus new opportunities for work safety logistics. Modern digitalization has an extremely positive impact on safety and productivity at work. Intelligent work safety management requires the use of new Industry 4.0 technologies and solutions developed for the work environment area. The importance of the value chain in the era of digitization was also highlighted. The analysis covered the areas of Industrial Internet of Things in industrial practice, Industry 4.0 smart technologies and occupational safety, and Smart Work Environment in Industry 4.0. This paper presents a literature review and the impact of digital innovations available in the market. The aim of the presented paper is to enhance knowledge, as well as to contribute to a deeper understanding of the relevance and importance of the importance of safety logistics in the work environment, in the context of the continuous digital transformation of enterprises.

Industrial Internet of Things in industrial practice

In recent years, the fourth industrial revolution accelerated by the industrial Internet of Things (IIoT) has raised a global upsurge [Da Xu et al. 2014]. The safety logistics infrastructure of modern industrial plants is complex and highly sensitive. Legal requirements and standardized processes form the basis of modern safety concepts. At the same time, the digitization of data offers new opportunities to optimize processes and procedures, to better assess risk situations with more information, and – through data aggregation and analysis - to obtain conclusions that could not even be imagined before [Intelligentne BHP...].

In today's constantly digitally transforming manufacturing world, smart manufacturing and technologies based on the IIoT have created new opportunities for manufacturing companies to improve their business efficiency and enhance their operational process capabilities. IIoT technology in industrial practice enables machines to communicate with each other Machine to Machine (M2M) and collect and share large amounts of data. Manufacturers need to capture this data, process it into actionable information, and then, based on that information, locate the root causes of situations that occur (e.g., impending or occurring failures). Manufacturers can then use this data, collected and processed in real-time, to optimize their processes and reduce costs [Clemons 2021].

Digital transformation is a multi-threaded process. Carried out holistically and skillfully, it should be based on wide use of IT technologies in handling all, or at least most, of the processes carried out in the course of daily functioning of a company, such as production, sales, customer service, finances or distribution [Arburg].

Industry is currently investing heavily in the potential of modern, personalized safety technologies offered by the Industrial Internet of Things. It may soon be possible to use artificial intelligence to analyze collected data to predict accidents. One can also imagine the use of continuous monitoring systems that recognize serious health problems in employees [Intelligentne BHP...].

The IIoT enables specific data processing tasks. It is also important to note that by successfully implementing IIoT in enterprises, the connectivity gap between legacy systems and industrial IoT or cloud platforms can be bridged. IIoT devices can either provide low-latency processing when connected to older heavy equipment or send data captured from these systems to the cloud, ideally both. The IIoT is a very attractive group of technologies for changing the organization of manufacturing. Transformation, however, requires classification and

ordering of processes within the plant. Thanks to these procedures we can be sure that the company will be properly organized. It will also be equipped with the infrastructure that allows it to build its way to Industry 4.0, and thus its market advantage [IIoT w przemyśle...].

The IIoT supports manufacturing with a network of sensors, advanced analytics and intelligent decision-making. The IIoT technology allows process manufacturing to collect data from equipment, sensors and devices and combine it with data and intelligence from back-end systems. The manufacturing process often depends on hundreds of variables that must be taken into account to produce a perfect, repeatable batch. The IoT sensors provide detailed visibility to optimize and adjust processes in real time. This allows process engineers to fine-tune control practices to increase repeatability. The IoT solution can also optimize overall equipment efficiency, compare and calculate production costs of equipment, systems, and production lines, monitor energy profiles of machines and systems, and trigger automatic alerts on operational parameters that will initiate system defense actions [Przemysłowy internet...].

Implementing the Internet of Things in an enterprise provides the ability to respond quickly to emergencies and operate within entirely new global markets. This is especially beneficial for companies with advanced technology and know-how, while lacking an extensive international distribution and service network. In view of the many benefits of using the IoT, it is important to remember about the necessary investments in cyber security (to protect your data, exposed to potential hacker attacks) and in staff development (to effectively implement and maintain modern installations). In summary, investments in the Internet of Things are investments in the development of the enterprise, in line with the increasingly popular trend of the Fourth Industrial Revolution. They undoubtedly contribute to increasing the flexibility and potential of the plant, allowing also to strengthen the position and increase the competitiveness and efficiency of the entire company. Therefore, it is worth investing in development of your valuable resources: time, money and people [Iwański, 2021].

To sum up, today, in the era of the fourth industrial revolution, it is enough to connect key machines to the cloud. On the basis of signals from controllers, sensors we are able to analyze data from the actual production process. With real data, we can focus on the biggest problems of production lines, which translates into increased productivity and more efficient use of employees' and machinery's time. You can't fully control a process without the right information about its progress [Zabój 2021].

Industry 4.0 smart technologies and occupational safety logistics

The enormous development and progress of new technologies in the field of IT (Information Technology) effectively support the functioning of enterprises in many areas. The application of innovative solutions of Industry 4.0 technology brings many benefits to enterprises, because after their application, companies operate more efficiently and faster, which translates into effective execution of orders, customer satisfaction and, as a result, higher revenues. Digitisation and automation of processes occurring in enterprises change the way they function at all levels and in many areas, and enterprises introducing these innovations have a great opportunity to gain a significant competitive advantage on the market [Rut and Ostafil 2020].

Today's businesses are facing the fourth industrial revolution, which offers a lot while demanding a lot. It is a challenging time for manufacturing companies. They need to integrate

where disparate systems and technologies previously operated. There is a lot of excitement about integrating technologies into a unified cyber-physical system. Companies that were accustomed to a degree of independence from digitization are now raising concerns about keeping production and organizational management running smoothly in the event of a disaster. For many, having the hardware, software, and modern data visualization systems integrated into a single panel is both a challenge and a threat. On the other hand, the Industry 4.0 era offers enormous opportunities. Companies that are able to exploit them gain an advantage in the market. New technologies allow them to manage machines and equipment based on communication and mutual data flow. This creates a network of connections between products, value chains and business models. It involves constant exchange of information, which results in increased efficiency of production plants and simultaneous reduction of production costs. Industry 4.0 contributes to the emergence of Smart Factory, or intelligent factory. This type of factory is based on cyber-physical systems, their integration using the IIoT and new methods of production organization. One of the basic success factors of a smart factory is communication between all elements of the system (Figure 1) [Przemysł 4.0...].

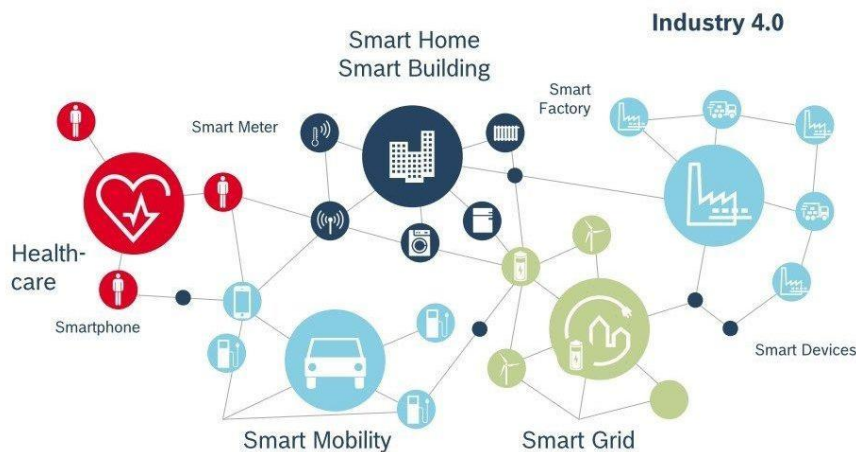


Figure 1. Industry 4.0
 Rysunek 1. Przemysł 4.0
 Source: [Piątek 2017].

Industry 4.0 is a complicated technical pattern characterized primarily by connection, integration, and industrial digitalization, highlighting the possibilities for integrating all components in a value-adding system. Digital manufacturing technology, network communication technology, computer technology, and automation technology are all included in this approach. Industry 4.0 technology breakthroughs are blurring the lines between the digital and physical worlds by merging human and machine agents, materials, products, production systems, and processes [Santos et al. 2018].

At the core of the fourth industrial revolution are nine technological pillars. These innovations blur the line between the physical and digital worlds, paving the way for intelligent and autonomous systems. Some of these technologies are already being used by companies

and supply chains, but the full potential offered by the fourth industrial revolution is only seen when they are applied together. Industry 4.0 technologies include Big Data and AI-based analytics, horizontal and vertical integration, Cloud computing, Augmented Reality (AR), Industrial Internet of Things, Space/3D printing, Autonomous robots, Simulation/digital twin, Cyber security. As a result of this transformation, sensors, machines, machined objects, and IT systems will be connected in a value chain [Kaliczyńska 2018]. The value chain represents the process of “adding” value to a product, beginning with the activities associated with a company's purchase of raw materials, supplies, semi-finished products, etc., needed for the production process. The value chain then includes design, production, logistics activities, marketing, and ends with the provision of value-added services to customers. Thus, it becomes necessary to distinguish strategically important “carriers” of added value creation within the enterprise. The value chain refers to the concept of an economic path to follow a product from its raw material source through all economic links to the end user. Each company is a link in a broader value chain, but also creates an internal chain consisting of various processes, activities and resources to be managed. Using the value chain model, an enterprise can be simplified to represent a sequence of activities, successive transformations of raw materials, materials, purchased technologies, services into final products, called core functions. These functions cannot be performed well without the existence of management and consulting activities called support functions. The integrated operation of the core and support functions and their linkage to the value chains of suppliers and buyers enables profit and business growth [Rojek 2014]. Value chain through the sequence of activities (primary and secondary) in it participates in the generation of profit. But not every action has a significant impact on the competitive advantage and efficiency of the company's operation. Selection of activities that will be implemented in the enterprise and identification of those subject to improvement is therefore of fundamental importance for the enterprise [Walas-Trębacz 2013]. Thanks to digitalization, automation and robotization of industrial processes associated with the use of the latest Industry 4.0 technologies, it is much easier to create a company that is adapted to the realities of the modern world and at the same time quickly respond to the need for changes, e.g. in technological processes, in the implementation of work safety logistics, in the functioning of the company, management and quality of services [IMI Polska].

Activities related to the implementation of the Industry 4.0 concept include, in addition to technologies, also interactions with people and work safety logistics (Figure 2). It is an unquestionable fact that the Industry 4.0 is mostly related to automation. However, it is essential that there is a clear acceptance that humans in the production process will never be redundant. In fact, one of the main beliefs about Industry 4.0 is that people are key players in it. Connectivity between people and machines, along with the integration of information technology (IT), is fundamental to the success of the Industry 4.0 concept. In a traditional manufacturing environment, where lines or cells are often tailored to produce a single product, the safety of people working in the plant is generally simple to monitor. A risk assessment of all aspects of the operations performed, from individual components to the operator's “points of contact” with the equipment, will create a guide that, in theory, should remain valid until the use of the production line changes or changes are made to the equipment on the line. As long as proper procedures are implemented, hazards and risks to operator logistics safety can be avoided [Minturn 2021].

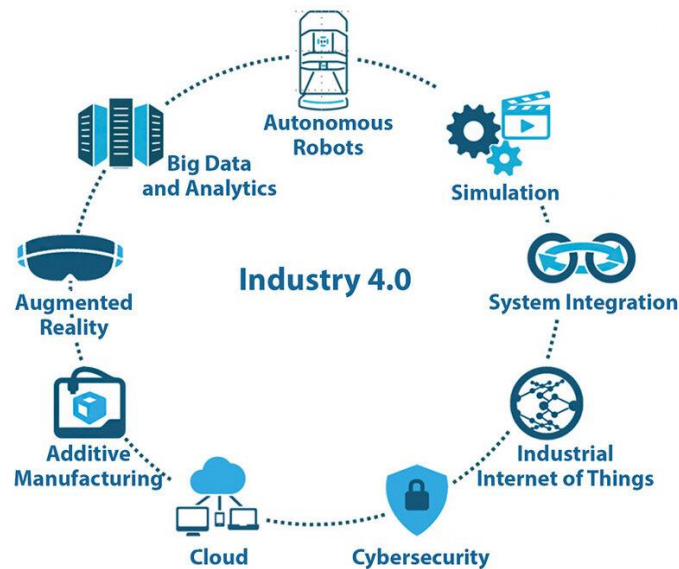


Figure 2. Industry 4.0 Key Technologies
 Rysunek 2. Kluczowe technologie Przemysłu 4.0
 Source: [Kaliczyńska 2018].

Digitalization creates new options for the organization of work performance areas and thus new opportunities for work safety logistics. Modern digitalization has an extremely positive impact on safety and productivity. Connected intelligent safety technologies speed up processes, facilitate decision-making and improve the safety level of employees and plants [Dräger]. The autonomization of processes, whether manufacturing, logistics or processing, is taking industry to the next level. Ensuring the safety and health of workers in 4.0 factories and warehouses is a relatively new and interesting challenge. Especially since we are talking about safety not only in one, but in two aspects. On the one hand, safety is of course understood as occupational health and safety, i.e. issues related to protecting health and life and ensuring employee comfort. Here, first on the list of things a company should take care of in terms of ensuring the physical safety of its employees is, of course, the verification of their skills. In the context of modern equipment working autonomously, the type of worker responsible for the actual production of the product with their own hands is de facto eliminated. What is more, this type of processes does not involve workers who take part in, for example, the transfer of products from one nest to another. Instead, we are dealing here with a large group of supervisors, i.e. people who verify whether the entire machine system works properly, is well calibrated, and does not require repair or maintenance. It is therefore a kind of hybrid of the tasks of the maintenance department, engineering and production or logistics, depending on the profile of the company. The first step towards ensuring their safety is therefore a properly designed verification of their knowledge and skills during the recruitment

process. Paradoxically, this particular process is very difficult to autonomize. Each person is different, has a different professional background and different goals. Hence, recruitment is an extremely difficult task, based on a thorough understanding of each candidate. The challenges faced by the candidate should match or even exceed those they will face on a daily basis [Hyla 2020].

Intelligent Work Environment in Industry 4.0

Another technological leap is taking place in the world's industry, exploiting the potential of Internet-connected machines and equipment. Giving this idea the name Industry 4.0, many countries are talking about the so-called fourth industrial revolution. A new approach to intelligent occupational safety management requires the use of new Industry 4.0 technologies and solutions developed for the work environment area. Changes in the markets, both local and global, caused by short product life cycles, new technologies, innovations and the increase of individualized customer requirements in terms of product functions, increase the level of competitiveness of companies. This state of affairs forces manufacturers to seek advanced technologies and solutions – guaranteeing shorter production times and unconventional possibilities of reducing costs, while improving the quality of products. Changes in the markets, both local and global, caused by short product life cycles, new technologies, innovations and the increase of individualized customer requirements in terms of product functions, increase the level of competitiveness of companies. This state of affairs forces manufacturers to seek advanced technologies and solutions - guaranteeing shorter production times and unconventional possibilities of reducing costs, while improving the quality of products [Gralewicz 2021]. This new approach will allow the improvement of productivity and efficiency, carrying enormous potential effects, and it will support a set of economic and social opportunities among the companies that are adopting this new manufacturing paradigm [Pereira and Romero 2017]. Industry 4.0 has a huge potential impact in many areas and its application will transform the working environment. Industry 4.0 leads to potential in three dimensions of sustainability for example smart factories, M-2-M, smart robots etc. [Abdelmajied 2022].

Companies operating under Industry 4.0 principles potentially present a very different and more intricate set of challenges. Re-configuring and abruptly reconfiguring production areas, involving very rapid changes in tooling and even physical movement of equipment, can present a range of occupational safety challenges, while the very large number of configurations possible to meet potential customer requirements may entail performing a risk assessment separately for each. But when it comes to another key feature of Industry 4.0, the security of personnel and data in a secure value creation network, these considerations cannot be ignored if compliance with regulations – local, state and international – is to be maintained. Fortunately, with the help of various technologies, these issues can be countered, and it is no exaggeration to say that Industry 4.0 offers an opportunity to further enhance workplace safety and the ability to collect data in real time and then use it before potential danger becomes a reality. For example, a set of devices can be installed on equipment in a factory that can detect and report on such operator behaviors that may pose a threat to workplace safety. This equipment can take a number of forms, the most common being smart digital cameras that take pictures or video, which they then send to a central control point, which automatically signals any abnormal behavior, such as a worker entering a no-go area. Many

system designers also advocate equipping machines with safety sensors that can immediately detect when an operator enters a hazardous area or gets too close to a specific machine or piece of equipment in the factory. In such cases, the default response is usually to shut down the machine, or in the case of a collaborative robot, to slow the machine down to a safe speed, giving the worker time to move away from the source of danger [Minturn 2021].

The idea of Industry 4.0 is not only based on the use of modern technologies. It is realized through knowledge, tools, optimization and monitoring of all production systems. Also important is the interaction of people with machines, therefore it is so important to provide them with appropriate working and safety conditions. With help come technological innovations that are able to protect workers from accidents and thus loss of health or life, and also increase the comfort of work. The concept of Industry 4.0 is put into practice by integrating people, machines and individual processes. Thanks to it, industrial plants can prosper from intelligent production systems that not only have their own autonomy, but are also capable of self-configuration, self-control, and even self-repair. In this way, companies can improve production efficiency and save money by quickly eliminating defects and preventing production downtime. The company will not have to spend a lot of money on repairs and will not have to think about how to compensate for the losses incurred by the interruption of production. Introduction of new technologies often goes hand in hand with a discussion about the importance and necessity of human labour. However, the currently developed concept of Industry 4.0 assumes (it is in its assumptions, by the way) that people are an indispensable link in the production process. This can, of course, cause complications and difficulties in industrial plants. Indeed, in advanced manufacturing areas, it is a challenge to ensure the safety of workers performing their duties. However, new technologies and intelligent systems are also conducive to solving this problem. Developed technologies based on Industry 4.0 basically support like never before in providing adequate safety to employees. Our machines are equipped with the right hardware and software to prevent danger, e.g. laser machines have special cabins to protect the operator from being hit during material processing and also to prevent the laser beam from escaping. Automatic loading and unloading systems, on the other hand, are equipped with intelligent light barriers and barrier nets. To avoid accidents and breakdowns it is very important to collect data in real time. Therefore, special sensors are installed in the machines to detect and analyze any disturbing and life-threatening behavior of the worker. As soon as a dangerous situation arises, the machine suspends or slows down operation until the risk is eliminated. In addition to this method, smart cameras are also used that can take pictures or videos while the operator of the machine is doing the work. The footage collected in this way is sent in real time to the control room that manages the machine and if the situation becomes dangerous, they are immediately notified of the incident. Another very commonly used solution are safety protocols. This tool, which is used in the field of Industry 4.0, was created as an extension of older wired systems. It allows the machine to be switched off and enables a greater flow of information. This ensures maximum uptime - the machine is only shut down as a last resort. IoT devices and hybrid solutions also allow for monitoring and sending security information along with employee biometrics. As a result, companies can reduce insurance costs and improve workplace safety in an efficient and intelligent way. The development and collaboration of IoT technologies is important for businesses because safety in the workplace is paramount [Staleo 2018].

Conclusion

The purpose of the study was to present a systematic literature review covering the area of intelligent Industry 4.0 technologies in occupational safety logistics, including an indication of the importance of safety in the work environment, in the context of the continuous digital transformation of enterprises.

Industry 4.0 has enormous potential effect in many areas, and its application will have an impact across the entire value chain, improving production and engineering processes, improving product and service quality, optimizing customer-organization relationships, bringing new business opportunities and economic benefits, changing educational requirements, and transforming the current work environment [Abdelmajied 2022].

Digitalization offers enormous development opportunities and offers solutions to many problems, as well as new options for the organization of work areas and thus new possibilities for work safety logistics. Digitalization has an extremely positive impact on work safety and productivity. However, the intelligent management of occupational safety in a logistical work environment requires the use of new Industry 4.0 technologies and solutions individually tailored to the needs of companies, including the work environment. It is important to remember that digital transformation is a multi-faceted topic with a major impact on safety logistics, the work performance area, and the work environment as a whole.

Availability of new technologies and ubiquitous digitalization requires from enterprises the ability to adapt and readiness for changes. The concept of Industry 4.0 is realized on the basis of knowledge, tools, optimization and monitoring of all production systems. It is based not only on technology, but also on direct interaction of people with machines, which in turn is associated with ensuring adequate safety in the plant. Modern solutions not only significantly increase the comfort of work, but, what is important, they can often protect an employee from losing their health or even life. Nowadays, there are more and more smart devices and solutions that are managed via the Internet. This is done not only by connecting the item and the computer, but also by integrating them in the area of network access. We deal with such solutions almost every day – examples are smart homes or cars. They can also be seen in other sectors, e.g. economy, where automation and digitalization are introduced on an increasingly wider scale. They fit into the idea of Industry 4.0. by integrating people, machines and individual processes. Implementation of this concept into the industrial plant allows for the prosperity of intelligent production systems, which in addition to their own autonomy will have the ability to self-configure, self-control or even self-repair. This brings many benefits to the enterprise such as increased production efficiency or significant savings due to the elimination of defects and downtime in production. With many opinions on the introduction of new technologies into manufacturing, a debatable issue is human labor. With the evolving concept of Industry 4.0, one of its main tenets is that people in the process will never be redundant [Główny Mechanik 2019].

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