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Occupational Health and Safety Practises in The Industry 4.0 Process[1]

Endüstri 4.0 Sürecinde İş Sağlığı ve Güvenliği Uygulamaları

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Abstract

Significant advances are experienced in the area of occupational health and safety (OHS) practices as a result of technological developments and emerging new technics in the Industry 4.0 Process. Innovative production methods, and factors such as advances in software and programming, simulation and augmented reality, internet of things, smart production systems, Big Data, cyber-physical systems, which are all along the fundamental elements of the Industry 4.0 process, bring new problems in the area of occupational health and safety. Based on this foresight, the latest developments, problems, challenges, and solutions in the field of OHS are being reviewed and evaluated in this study by utilising the previous literature.

Keywords: *Occupational Health and Safety, Work Accidents, Industry 4.0, Risk Analysis, Cobots.*

JEL codes: *J 89, J 28, D 81, L 16, L 69*

INTRODUCTION

The concept of the Industry 4.0 was first introduced in Germany in the year 2011 as a suggestion for the creation of a new economic policy concept based on high-tech strategies that could combine all elements in and around the production process towards a highly integrated value chain (MacDougall, 2014). The need for a production method that is environmentally friendly, resource-saving, as well as sustainable, and the increasing global demand of diversified consumer goods has accelerated the transition to the fourth stage of industrialization, which is being coined as the Industry 4.0 phenomenon (MESI, 2016). In this context, it has been emphasized that the aim of the Industry 4.0 is to advance production and service performance as to achieve autonomous and flexible output through higher levels of automation and digitalized systems (Lasi et al., 2014).

The Industry 4.0 system provides optimisation of business processes and product qualities as to achieve real-time controls over the input and output. In addition, the system in question can reduce production costs by minimizing energy consumption and stocks by accelerating production with the use of resource assets. Thus, the expansion of smart factories, as well as, smart products, which have a significant impact on global economies, is supported through digital technology-based systems that can be adjusted according to personal preferences (Badri et al., 2018).

From this point of view, besides its economically calculable and quantifiable features, the cost-effective development of the Industry 4.0 applications, its social, economic, and environmental consequences, and its impact on the future of business making and workforce, including OHS issues, have also been needed to be taken into consideration. This new industrial roadmap inevitably leads to a new organization of work and the implementation of different methods of performing work tasks that can ensure the OHS of workers. Indeed, automation technologies can make production more adaptable, healthier, energetic, safer, and more socially inclusive through the use of new production systems, robots, and sensors to support workers in shared tasks (Frey and Osborne, 2013). The way of the Industry 4.0 to create a more sustainable industrial value is on the one hand for the economic, environmental, and social sustainability, but, on the other hand, for the improvement of the OHS situation of all parties involved in the working life. When evaluated in this context, the OHS system in the Industry 4.0 process gains utmost importance in terms of work organization, legislative framework, OHS organisation, and management of occupational risks.

1. TECHNICAL FEATURES OF THE INDUSTRY 4.0 PRODUCTION SYSTEM

Industry 4.0 can be described as a production revolution where jobs that require unskilled labour are carried out by robots and skilled labour with high added value specializes in order to be more productive. In this respect, the Industry 4.0 system deeply affects the qualifications of the job, the identity of the employee and the employee-employer relations (Kurt, 2019).

Industry 4.0 develops great adaptability and superior standards in engineering, operative and logistics production practices (Lu, 2017: 7). The main characteristics of the Industry 4.0 are its digitisation and automation of business procedures based on automatic flow of data with help of the information technologies, internet of things and services, cyber-physical systems, and cloud-formed data integration (Schmidt et al., 2015: 18). These multifaceted, active and real-time optimised networks assist enterprises in the integration of information at different hierarchical levels of a value creation modules (vertical integration), through intelligent cross-linking of data in-house (horizontal integration), as well as, by digitizing information throughout the product lifecycle (end-to-end engineering) (Stock and Seliger, 2016: 538).

In smart factories where the Industry 4.0 system is applied, products can be produced flexibly and efficiently, and less production errors occur by managing their complexity in a decentralised manner (Acatech, 2013). This autonomous system is realized thanks to production systems and production networks consisting of robots that can respond to different situations, and which are self-controlling, self-operating, data-based, sensor-equipped, spatially distributed and which have predictive modelling and execution systems (Roblek et al., 2013). As a result, personalised products with customer-specific features can be produced profitably within this model (Ferrera et al., 2017: 627). Intelligent products and devices, which are part of the Industry 4.0 system, are intended to offer instantaneous communication between machines, production resources and people, to create a basis for the implementation of new production processes and semi-autonomous control of individual stages of production (Tupa et al., 2017: 1226). The information of this system, which has a feedback loop communication, can dynamically affect the real-time design of business processes by self-optimisation (Schlechtendahl, 2015: 146).

2. OCCUPATIONAL HEALTH AND SAFETY IN THE INDUSTRY 4.0 PROCESS

With the First Industrial Revolution, OHS measures and management systems have developed rapidly along with emerging and changing production methods. In its most general definition and within the scope of World Health Organisation (WHO) and International Labour Organisation (ILO) principles; OHS is to maximize the physical, mental, and social safety and welfare of all employees, regardless of their working style in the workplace, to protect continuity of this situation and to create working environments that protect workplace conditions, the environment, the goods and services produced, and the mental and physical health of employees. (Bingöl, 2014: 584). The right to OHS is expressed as the demand of employees to make their workplaces suitable for OHS conditions (Süzek, 2019: 864). In order for the OHS system to work as an effective system, it is utmost important to ensure participation of the primary social partners as workers, employers, and the state. These partners have responsibilities in forming protective (re-active) and preventive (pro-active) policies regarding OHS, ensuring the creation of an OHS culture, effective and efficient evaluation of notification, education and audit results, realization of theoretical and practical training, and enforcement of legal rules and sanctions. (Bilir and Yıldız, 2013: 8 -10). In this context, OHS, in a broad sense, can be considered as the studies aimed at revealing, eliminating, or reducing the dangers and risk factors that are affecting the wellbeing of employees, employees of subcontractors and temporary employers, visitors of the workplace, customers, and the people living in and around the production area (Kılkış, 2022: 5-6; Kabakçı, 2009: 82). Especially in the current age, working in a job has become statistically three and a half times more dangerous than wars. In addition, although many innovations have emerged with the Industry 4.0 process, new problems also arise within the framework of human-machine interaction.

The Fourth Industrial Revolution enables the digitization of production by providing full automation to enterprises by implementing self-controlled, IT-based, and sensor-equipped equipment and machines that improves production through automatic optimisation and autonomous decision-making (Rüßmann et al., 2018). Within this system, the fundamental features of business organisation are changing, and workers are starting to play a key role in the knowledge-centred production model, containing decentralised decision-making and continuous assessment of the quality of productive processes (Sanders et al., 2016: 17). This means that in this process employees have the opportunity to work more autonomously and develop themselves by qualitatively enriching their jobs by participating in higher value-added activities and reducing routine tasks (ERPS, 2015). More importantly, as greater organisational complication is inherent in the Industry 4.0 system, this process requires more flexible work environments that can offer employees greater adaptability to their job necessities in their personal lives, to establish a work-life balance and continuing their professional development processes.

In addition, the flow of information in the production contours is expected to make business management better organised and more transparent. Thus, the Industry 4.0 process can transform the work into a safer and healthier situation through hierarchical pressure on the workforce, smart security technologies and nonstop risk analysis based on virtual engineering (Lira and Borsato, 2016: 888). Wearable technologies (i.e., sensor-embedded helmets, wrist bands, digital watches) and tracking technologies are helping employees keep their safety in hazardous working environments where they might have exposed to extended OHS risk such as extreme heat, harmful objects, toxic gases, and chemical contaminants. This system enables it to continuously monitor the health condition of the employee (i.e., risk of heart attack, changes in blood pressure, sudden abnormalities such as falls or changes in stress level), as well as the state of machinery, equipment, and the enterprise (EU-OSHA, 2017). Such technologies can provide real-time alerts that preventive measures must be taken, can be designed to monitor workers, can be used to stop the work in a dangerous behaviour, can help to apply activate safety procedures, can be used to involve in preventing injuries and accidents, and can be utilised for enabling an injured worker to get help (Malinovski et al., 2015).

In addition, robots which are self-aware and self-learning, and which are equipped with an advanced analysis system, can predict dangerous circumstances during the execution of work and use different OHS management algorithms to anticipate unwanted situations. In this process these machines would be interpreting the data obtained as a result of technological monitoring and would decide on choosing the most appropriate action with the help of AI. Thus, the risk of accidents, illness, or occupational disease of workers in the production area and outside the production area are prevented more greatly with the Industry 4.0 advances (Lee et al., 2014: 5).

Industry 4.0 system's technological capabilities, together with cognitive analytics, can increase their abilities by supporting the safety and well-being of employees (Murashov et al., 2016: 66). Industry 4.0 process is benefiting from robotic power, aiming to create functional industrial robots for complex tasks such as assembly, cleaning, welding, painting, and disassembly activities that will be improved with durability and precision (ISO, 2011). In this manner, by increasing the amount and quality of the output, employees can be protected from health situations such as traumatic or fatal injuries, musculoskeletal disorders, occupational diseases, as well as product and service expenses can be lessened (Huen et al., 2015). In addition, the wellbeing of employees can be protected by using specialised machines and robots instead of humans, for example, during dangerous operations in disaster areas (NIOSH, 2014). Such robots usually interact one-way with the human operator controlling the robot, which feedbacks information about the environment and the execution (Thrun, 2004: 12). Collaborative robots (*henceforth* cobots) have been established to co-operate directly with human employees who are equipped with performance-enhancing robotic devices, as those we see in car manufacturing and automobile waterproofing enterprises. In such a interdependent human-robot association, human handiness, agility, and problem-solving skills to be extended with robotic features (Vasic and Billard, 2013: 200). In addition, robotic exoskeletons that can be dressed on the human body can perform the role of support, while performing the tasks of workers such as lifting weights, thus, potentially increasing the stamina of human workers. They have also been developed to reduce adverse health effects and the possibility of injury, while simultaneously increasing productivity and employee well-being. (Leso et al., 2018: 330). Therefore, these tools can provide a more flexible and socially inclusive work environment for employees with age, gender, and cultural differences, as well as for workers who are injured while the course of work (Reinert, 2016: 391).

3. PROBLEMS OF OCCUPATIONAL HEALTH AND SAFETY IN THE INDUSTRY 4.0 PROCESS

On the other hand, the Industry 4.0 process can be a source of OHS risk for employees from many aspects. First of all, psychological risks caused by mental overload and workload caused by more flexible and dynamic production activities can lead to more negative phycological consequences for employees than physical risks in the workplace. In monitoring equipment working with automated systems, in dispersed decision-making, as well as in end-to-end engineering practices, employees need to be able to act more ergonomically on their own initiative and are required to have outstanding interaction abilities (Thoben et al., 2014: 2), which, as a direct result, may cause additional OHS risks.

In the Industry 4.0 process, skilled workers are more needed than unskilled workers, as workers will need to use, manage, and intervene when necessary. Older workers also face the risk of unemployment as lifelong learning becomes a prerequisite for employability due to industrial automation for semi-skilled workers as a result of the potential difficulties of working in complex tasks (Acatech, 2013). In addition, the usage of digital surveillance apparatus to uninterruptedly screen the worker's behaviour, routine, performance and productivity can create an environment of uncertainty, violation of personal privacy, as well as, psychological pressure in the workplace for the continuation of existing occupations. Moreover, advanced technology can weaken relationships between common employees and executive and managerial level employees. This situation can create the ambiguous workplace environment by increasing the work-related stress of the employees and causing the health of the employees to deteriorate in the long term (EU-OSHA, 2017). As the larger flexibility and virtual accessibility enables employees to work in distance from anywhere at any time, the individual's work-life balance can potentially be disrupted as to be against the employee's own interests (Ben-Ner and Urtasun, 2013: 230). As another point, the innovative technologies that make up the cobots possibly might lead to a novel type of accident risk due to the lack of standards on correct usage. Automatic devices can create electromagnetic, mechanical, and thermal OHS risks alongside the hazard sources of radiation, noise, vibration, and chemical exposures (ISO, 2011). Manufacturing errors caused by engineering, human errors or incorrect programming of peripheral equipment and interface errors can cause injury to those working around robots (Vasic and Billard, 2013: 200). Finally, with augmented reality technologies operating in workplaces, employees may experience increased tension when they experience a mismatch between the virtual world and the real world (Lorenz et al., 2015). Due to the gradual automation of work processes, when employees feel that their profession and expertise are insufficient, and also when they work excessively, there may be decreases in their individual creativity and productivity and this might lead to additional OHS risks.

In this context, research on the properties of the Industry 4.0 process over OHS have revealed some important results. IT innovations, internet of things, cyber-physical systems, Big Data, AI, simulation, and collaborative robotic technologies, which are defined as the elements or technological categories of the Industry 4.0 process, are increasingly being used by a wide variety of smart personal protective devices. The use of such smart devices changes the way the workers work and making production processes more complex. As a solution to emerging these new problems, a more dynamic OHS management system based on a more personalised and vigorous risk management paradigm is proposed in different research (Podgórski et al., 2017: 11).

In an environment where advanced production procedures might create new OHS risks, but systems that perform traditional risk analysis are insufficient to identify emerging risks, the application of new risk analysis models that can monitor both traditional and emerging OHS risks seems to be an effective solution (Fernández and Pérez, 2008, 2015). Meanwhile, it has been seen that enterprises can adapt to the changing environmental conditions of industrial systems by benefiting from cyber-physical systems, and thanks to the autonomous decision- making process. In industrial process automation, it is emphasized that a cyber-physical system should be defined in advanced standards such as IEC 61508 in order to better adapt to these restrictions, taking into account the security limitations that reduce the technical risks to an acceptable level (Kuschnerus et al., 2015: 431). Upon this background, emphasizing the importance of creating safety-aware robots/cobots that can detect actions that may cause injury or threaten employee's safety and to support difficult and dangerous tasks, it has been argued that for safe and effective interaction with humans, such robots should be equipped with complex codes-of-conduct, policies and software that allow human workers to understand their intentions (Beetz et al., 2015: 6530).

It has been seen that wireless communication has an important role in improving working conditions, and well-designed and properly integrated wireless sensor networks with technological support avoid accidents in self-directed and smart manufacturing systems (Palazon et al., 2013: 546). In the same vein, it is argued that information technologies and wireless communication will be able to detect workplace hazards continuously. For ensuring the consistency of such systems, common technological platforms that can monitor the operation and efficiency of all networks and remotely control and connect sensors are required to be put into practice. It has been suggested that such platforms can also reduce occupational risks by facilitating the integration of effective surveillance practices (Gisbert et al., 2014: 240). It is also rightfully being stated that it is not possible today to detect new OHS risks that may arise due to innovative production methods with traditional risk analysis techniques (Fernández and Perez, 2015).

A well-attended survey on the OHS system reveals that businesses cannot be considered as fully prepared for the implementation of the Industry 4.0. Only 20% of the respondents evaluated themselves as equipped and ready for the full implementation of new production models. It has been observed that the level of preparedness for the uncertainty of the boundaries between industries is 17%, and the level of readiness for the integration of smart and autonomous technologies is 15%. It has been determined that only 22% of manufacturers understand how new technologies change their workforce and organizational structure, and again 22% are aware of the impact over the output based on new technologies are presented by them. Only 16% of manufacturers knew how to integrate their solutions with external infrastructure, while only 8% claimed they had concrete business foundations for the implementation of new technologies (Deloitte, 2018). In the period of insufficient preparation and transition for profiting from these new technologies, it is predicted that the deterioration in work quality, injuries, accidents, and other human errors may increase, as a side error (Kagermann et al., 2013).

Due to the content of the job (i.e., diversity, complexity, skills, uncertainty, exposure), the organization of the work (such as team planning, overtime, fast orders), the management styles (i.e., tasks, communication, roles, relationship, problem solving) and other organizational factors (i.e., promotions, wage increases, OHS, social value of work), which all important in the Industry 4.0 Production Systems, may interact as to have important consequences and these interactions may increase psychosocial risks over the workforce in particular. This situation has also revealed the fact that the prevention of psychosocial risks in terms of OHS legislation and management systems is considered quite challenging (Leso et al., 2018). It is emphasized that employees who monitor smart machines and robots or participate in decentralized decision-making and complex engineering projects are required to act more on their own, to have perfect information and digital skills, and to take utmost responsibility by organising their own way of doing the work (Kagermann et al., 2013).

Unfortunately, many research findings indicate an acute scarcity of qualified personnel and extremely short levels of digital culture accumulation, particularly among the elderly sections of the workforce, migrants and disabled workers (Lorenz et al., 2015). Therefore, employees will have to be more flexible and adopt lifelong learning in order to collaborate more effectively in this new economic model (Moniri et al., 2016: 240). This situation has the potential to lead to a decrease in the qualified workforce, and, as a result, increase in excessive fatigue, absenteeism due to illness, and number of accidents. Information and communication technologies (ICT), which is becoming increasingly important in the Industry 4.0 system, increases both the qualification gap in the general workforce and specifically the qualification gap between youth who have newly gained their qualifications and senior employees (Moniri et al., 2017: 239). Due to the decreasing share of blue-collar workers and the growing share of intellectual work in the production process, low-wage workers without additional training and abilities will be at risk of losing their jobs at an immense scale (Wrobel-Lachowska et al., 2018: 605).

As an important argument, technologies that monitor employee health is expected to increase several concerns, and this is often seen as a violation of individual's privacy and protection of personal data, which is experienced as a source of stress for employees (Kagermann et al., 2013). More widespread use of technologies that monitor employee health, if used appropriately and legally, should ensure a more accurate evaluation of employee data.

The fact that the AI lacks contextual self-awareness so far, which is preventing it from understanding reality, is seen as the most serious limitation on machine learning (Szulevski, 2018: 635). Innovative technologies reveal new hazards of mechanical, electrical, thermal and chemical origin. In addition, new accidents may occur due to disproportionate guidelines and standards regarding their proper design and implementation. However, the rapid inadequacy of technological solutions hinders the development of new standards. In this context, regulatory frameworks and standards fall short of protecting all employees from the OHS costs of implementing new technological production systems based on autonomous, intelligent, interconnected machines (Jones, 2017). In addition, the rapid increase in the number of devices with internet connection, widespread data processing over the net has the potential to increase the threat of cyber-attacks that may pose extra risks to the safety and health of employees (Pontarollo, 2016: 377).

It has been argued that in the transition phase to the Industry 4.0 system, there may be inadequacy of OHS systems, including OHS standards and other regulations, and this may also lead to the loss of the proactive approach in the OHS systems which already established in industrialized countries.

In the context of Industry 4.0, some basic suggestions have been made to maintain or improve the OHS level in production (Kagermann, 2013, Rojko, 2017: 80, Badri et al., 2018: 409-410). Accordingly, these proposed solutions existing in the literature can be summarised as follows:

1) In order to advance the incorporation of human action and intelligent solutions, the engineering and arrangements of intelligent machines should focus on human physical, social, mental, and cognitive abilities.

2) Further studies should be conducted on the psychosocial risks posed by new work organization models.

3) Research on cobots should be continued as to provide a higher safety net and increase the physiological and intellectual ability of the employee.

4) Novel global standards are required to be developed, or existing standards to be revised as to aim more precisely to guard employees against the threats originating from new technologies.

5) Collaboration with trade unions should be made on the possibility of application of technologies for continuous supervision of worker welfare and performance, such as employing robots instead of humans and using AI technologies.

6) A socio-technical approach in the implementation of Industry 4.0 solutions needs to be adopted. It should be ensured that technological innovation, business organization models and professional development are coordinated in accordance with economic and social conditions.

7) Applicable augmented reality techniques should be used in the prototype validation phase through simulation technics in order to disseminate a proactive approach to safety risk assessment which is already in the design phase or in the early stages of implementing Industry 4.0 innovation.

8) More research should be done to make personal protective equipment devices more effective, using smart technologies and to create innovative devices for continuous monitoring of employees' well-being.

9) OHS safety experts and occupational physicians are to be ensured of reaching to opportunities for continuing professional development and training as to adapt emerging new technics to their profession.

10) Lifelong learning and continuing professional development should be encouraged for all employees, especially towards emerging the new abilities.

11) Employees should be provided with the use of virtual reality and augmented reality tools during their OHS training.

12) Good practice platforms should be established that showcase examples of integrating OHS into production within the context of Industry 4.0.

13) Protection against illegal access to corporate secrets, business data and cyber threats should be offered principally via systems (data encryption) and corporate security architecture.

4. POLICIES ON OCCUPATIONAL HEALTH AND SAFETY PRACTICES IN THE INDUSTRY 4.0 PROCESS

Policies that are being offered to be implemented within the scope of OHS in the Industry 4.0 process are outlined below:

4.1. Making Plans for the New Business Organization

The complexity of the Industry 4.0 production systems is continuously increasing (Waschneck et al., 2017, Block et al., 2015: 658). This complexity causes problems especially in terms of the content of the job, the possibility of employees being exposed to risks, the organisational structure of the workplace, the working hours, the management and production systems and the personnel transactions (Leka and Jain, 2010: 136). Engineers and designers of advanced manufacturing systems frequently oversee such risks, which can become a significant risk to manage in this process. In particular, the definition and monitoring of psycho-social risks has already become a main test in terms of OHS management systems (Sanders et al., 2016: 817).

Another important issue facing businesses that implement Industry 4.0 processes is to recruit new employees who are better prepared to train and learn from existing employees (Lorenz et al., 2015, EU Commission, 2013: 117). To be able to work efficiently in the Industry 4.0 system through employees with newer skills, employees need to obtain a variety of specific skills and combine their expertise in traditional tasks with computing skills (Lorenz et al., 2015, EU Commission, 2013: 117). Effectively adapted planning and organizational models offer new solutions for the management of this increasing complexity (Waschneck et al., 2017; Kress et al., 2016: 21; Toro et al., 2015: 365).

The basis of Industry 4.0 is to reveal the most appropriate forms of sharing tasks within the framework of increased interfacing and cooperation between humans and machines (Christiernin and Augustsson, 2016: 311). Thus, to evade generating unanticipated hazards in the production environment, tasks need to be planned more carefully, and each employee's job descriptions and work-related limitations need to be precisely clarified and defined.

4.2. Failure of Existing Regulations to Guide New Practices

All regulations regarding OHS are aiming to support the successful implementation of safety and health management in the workplace (MacEachen et al., 2016: 6). Several of the measures implemented are aiming to force businesses to assess risks, apply standardised business procedures, and deliver guidance that reduces the frequency of work accidents and occupational diseases (Badri et al., 2018: 406).

From a legal point of view, an audit system based on various judicial or administrative penalties or court processes comes into play if the employer does not comply with its OHS obligations. However, the legislation does not regulate mechanisms to eliminate the source of threats to OHS practices and management systems originating from the Industry 4.0 systems. In addition, standard procedures are insufficient in terms of reducing new risks. The current regulations do not contain any framework or guidance on how the OHS system will be integrated into operations for above mentioned new risks (Jones, 2017). Despite the swift progress of the technologies used in smart production, it is seen that the current old-school OHS legislation will be implemented as it is regulated in the coming years and classical problems will continue.

4.3. Necessity of Redesigning Occupational Health and Safety Management Systems

A number of OHS management systems such as OHSAS 18001, CSAZ 1000-06, Z1002-12 have been developed to guide practices in working life. The main source of these systems is primarily related to the concept of management of total quality. This model established a general guideline for the management of accident and disease prevention, education, emergencies, and regulatory requirements regarding the work. By definition, these systems founded on the continuous upgrading model should be arranged more flexibly and be more suitable to catch up with the deviations brought by the Industry 4.0 system (Badri et al., 2018: 408).

Experience shows that OHS integration can increase productivity and reduce costs (Van Holland et al., 2015: 399). It has also been proven that there is a positive correlation between productivity and the better implementation of OHS measures. Increasing the efficiency of the industrial system, which is the goal of the Industry 4.0, does not seem to be in any essential contradiction with the implementation or maintenance of OHS management systems. OHS management systems, which will be developed in accordance with the Industry 4.0 processes, will help manufacturers to seamlessly implement autonomous and smart systems in their workplaces. This will help remove faults in prioritising risks and barriers to regulating preventive action in new management and production systems. In addition, it is claimed that the agile nature of these systems comes to the fore in order to make OHS management systems adjustable to progressively multifaceted, flexible, and autonomous industrial processes (Mızrak, 2020: 237-238).

4.4. The Necessity of Reorganizing Occupational Risk Management

OHS risk management, which includes identification, analysis, and evaluation stages, is used as a decision-making tool to improve the determinatio of risks that may have an impact on currently implemented workplace objectives and controls (Badri et al., 2012: 193). Process errors appear to be eliminated as new controllers, online data analysis, and the Internet of Things continue to make machines and industrial systems increasingly autonomous (Yaqiong and Danping, 2017: 750). With the comprehensive and full automated factories, it becomes possible to reduce both OHS risks and deficiencies in the value chain (ABB, 2014; Lira and Borsato, 2016: 888). Costs and errors can be reduced as a result of evaluating the processes more accurately with the simulation method before the production system is established. In case the production can be adjusted to meet the actual demand rather than the anticipated demand; work-related stress, occupational injuries, work accidents and occupational diseases are expected to be reduced (Shibin et al., 2016: 2876).

In the Industry 4.0 process, overcoming the difficulties in the correct definition of risk factors and maintaining the presence and participation of OHS safety specialists and workplace physicians, who will take part in production less and less, becomes one of the most controversial issues. However, with the concept of real-time risk management, identifying many potential risks and reducing risks will become very effective in dynamic industrial environments (Podgórski et al., 2017: 11).

5. RISK ASSESSMENT IN THE INDUSTRY 4.0 PROCESS

In the Industry 4.0 process, risk assessment focuses on recognising operative risks related to all stages of the production, from management of data to maintenance of information flow, from operation methods to tools used, quality and suitability of materials, human errors, machinery, and technologies of production (Tupa et al., 2017: 1225). This will result in a system in which OHS risk assessment and management procedures will change, and risk information becomes more important as to be continually evaluated and improved. Therefore, it is recommended to adopt a preventive risk management approach to ensure the supportable development of innovations of the Industry 4.0 system (Badri et al., 2018: 406).

In this perspective, one of the most appropriate ways to prevent and control occupational risks, injuries, diseases, and fatalities in emerging technologies is to design or minimize hazards and risks at the design or implementation stages (NIOSH, 2014). In these development stages, it is necessary for employers, employees, stakeholders and relevant occupational safety experts, occupational physicians, and other health personnel to focus on the characteristics of beneficial applications of Industry 4.0 and their possible effects on employment and occupational safety within the scope of a common action plan. This method will enable the active participation of employees in the risk assessment process and the effective adoption of practical protective systems (Niesen et al., 2016).

From an organisational point of view, considering that this new approach takes into account the diverse characteristics of workers (skilled or unskilled, technical, or academic qualifications, age differences, education levels, life experience or cultural background), the employees are more likely to be assigned tasks appropriate to their skills and capacity. Employees with managerial and supervisory duties need to be supported with broad-based training and work organization models that support lifelong learning and continual professional development (Zhou et al., 2015).

The Industry 4.0 process has both positive and negative effects on employees in terms of OHS. Thanks to the elements of the Industry 4.0, occupational diseases caused by physical labour use and repetitive actions can be reduced. With wearable devices and AI supported workplace applications, the mental and physical condition of the employee can be monitored and the easier adaptation of the employee to the workplace environment can be achieved. Digital systems can call back operators by voice or other data to establish a code of conduct and terminate their operations when employees engage in non-standard and insecure activities. This reduces physical workload factors, among others, such as manual lifting and carrying, repetitive work, working with screen equipment, and difficult or static working positions, but more skilled workers are needed to produce these designs. Studies evaluating the effects of Industry 4.0 on the production or in office environments have revealed that advanced technology complements the skilled workforce (Pavon et al., 2018: 448).

It is emphasized that technological changes based on skills cause structural changes in employment and new threats in terms of OHS as the demand for these skills increases. The use of digital tools to monitor the behaviour, productivity and performance of employees can create an environment of psychological pressure, with the emergence of issues related to employee privacy and the feeling that employees are constantly being watched (Ben-Ner et al., 2013: 240). This situation can also increase conflicts among employees by increasing work-related stress and causing negative health effects in the long run (EU-OSHA, 2017).

The most positive effects of the Industry 4.0 process on production are the reduction of quality problems and repetitive actions of employees. On the other hand, the most negative aspect of the Industry 4.0 system is that it causes new OHS problems. Some of these problems are eye-related disorders, mental fatigue, disorders caused by static working position, exposure to unknown dangerous particles as a result of cooperation with robots, and psychological pressure arising from problems of adaptation to tasks that require creativity (Adem et al., 2020).

Another challenge faced by enterprises implementing the Industry 4.0 system is that more careful planning of activities has become necessary to prevent the development of undesirable hazards in the production process. In this case, in extremely complex production environments, the idea of real-time risk management often becomes valid (Podgorski et al., 2017: 11). The use of AI-based applications in the workplace can play an important role by encouraging effective decision-making processes and reducing the risks that will arise due to the complexity of the new work environment (Percy, 2017).

While Industry 4.0 production transformations, which are rapidly and globally spreading, can provide the labour with a wide range of advanced digital tools and practical solutions to support their tasks, they can also lead to new OHS risks that can affect almost all economic sectors. This requires a proactive approach to risk assessment in the design or early stage of investment and the adoption of appropriate management strategies for employee protection (Schulte et al., 2010: 7).

6. OPPORTUNITIES AND BENEFITS FOR OCCUPATIONAL HEALTH AND SAFETY IN THE INDUSTRY 4.0 PROCESS

Due to the production style in dark factories, employees increasingly have to monitor digital systems and equipment, integrate into the decentralized decision-making process, and also participate in engineering activities as a part of end-to-end engineering (Stock and Seliger, 2016: 538). This integration enables employees to participate in more value-added activities and to have opportunities to improve themselves by leaving routine tasks (Kagermann et al., 2013).

The blurring of workplace boundaries, the increasing flexibility of working hours, and the rapid spread of distant/ remote work, especially with the COVID-19 Pandemic Period, have been evaluated differently in the literature. Many researchers underline that increased working time flexibility is expected to tolerate the worker to establish a greater work-life balance. (Mas-Machuca et al., 2016; Aybas, 2021: 246). The transformed and diversified work environment allows employees to organize their own working hours. The fact that the Industry 4.0 system includes elements such as smart security technologies, virtual engineering, Big Data, and the internet of things can make employees safer and healthier through continuous risk analysis and management policies in the workplaces (ABB Group, 2014). Accidents and occupational diseases can be prevented in autonomous and smart industrial environments with wireless sensor networks and via properly designed and integrated technical support (Palazon et al., 2013: 545). Machines equipped with technical tools to monitor all parameters that have any impact on the process are better suited to respond appropriately as soon as any dysfunction occurs (Mattson et al., 2016: 232).

Newer systems might be also capable of sending information to companies' headquarters, which will increasingly monitor themselves and their environment and determine whether further intervention is needed. In order to ensure the reliability of these systems, it is necessary to establish common technological platforms that can monitor the operation and performance of all networks and connect sensors to remote control centres (Gisbert et al., 2014: 240). These platforms might be able to reduce occupational risks by facilitating the integration of general surveillance practices, which will be complemented by appropriate risk management.

In addition, a new risk management system called a smart work environment in terms of OHS can be implemented by using new technologies and solutions developed for the needs of safety-related workspaces (Graetz et al., 2015). This approach, which is based on the spread of smart workplace management, is based on new technologies and solutions where some tasks related to OHS are determined. These tasks can be summarised as monitoring the health of the employee, oversight of the machinery and technologies, scrutinising personal protective equipment in the working environment, warning the employees, and facilitating a timely information flow regarding the OHS implementation.

In addition, decision-making systems and virtual 3D simulations have an important place in the risk management hierarchy in terms of fulfilling these enlisted tasks. This approach, based on organizational risk management, enables real-time solutions to changes in work environment factors and final analysis of risk assessment for individual employee profiles, including psychosocial risk factors, work environment factors in the workplace, and their position in relation to machines (including robots and cobots) (Graets and Michaels, 2015).

It has been revealed that the production of a wide variety of personal protective devices using smart technologies can help employees stay safe in extremely dangerous workplace environments where they may be exposed to excessive noise, heat, toxic gases, chemicals, and harmful elements (Wang et al., 2016: 10). Similarly, technologies that monitor the health of workers (i.e., heart rate, emotions, activity, temperature) may satisfy the need for preventive measures designed to stop dangerous behaviours, update safety procedures, prevent accidents and injuries, and to enable an injured worker to get help as soon as possible (Mattson et al., 2016: 524).

Over top of all these, machines that are self-learning and configuring, capable of programming with advanced analysis capabilities, compatible with sensors and cameras will be able to predict potential workplace hazards and manage unexpected conditions that will facilitate the prevention of accidents that employees are exposed to (Kagerman et al., 2013: 23). In this proactive approach, the main aim is to prevent undesired events before they occur. With the emergence of Industry 4.0 systems, more and more industrial robots are used in digital factories, which replace humans, especially in performing tasks that are dangerous, that have high musculoskeletal load and that are requiring excessive physical strength (Beetz et al., 2015:6530). With the development of machines with AI, thanks to special sensors and control methods, cobots autonomously and actively increase awareness of their environment and analyse activities to eliminate atypical situations. This way of working becomes indispensable especially for the safe interaction of cobots with humans. In this way, productivity and product quality can be increased, while occupational health complaints and diseases, injuries and accidents can be prevented (Chiabert et al., 2018: 22).

According to the German Federal Institute for OHS, musculoskeletal injuries are the cause of 23% of sick leave days in Germany, causing an estimated 17 Billion Euros in production loss per year. The situation is almost the same for any other European country. These problems mainly occur in work that requires lifting and carrying and cause muscle, ligament, bone, and cartilage damage. In some cases, common static aids such as forklifts and lifting devices may not be available or not flexible enough. In the event of such OHS risks, it is beneficial to design mechanical exoskeletons that can be worn on the human body to reduce the stress/compression force on the back, shoulders, elbows, and wrists, to protect against injuries in the musculoskeletal system of the human employees (Bogue, 2015: 7). The design of exoskeletons is based on micromechanical elements and an ultra-light ergonomic system. In the future, this exoskeleton models are expected to be strengthened with a sensory data transmission system. This will enable machine learning and AI to be introduced to the exoskeleton controller (Szulevski, 2108: 633). Therefore, these devices will be able to provide safer and more ergonomic working conditions for an increasingly diverse workforce in terms of age, gender, cultural background, and level of fitness. (Reinert, 2016: 390 29).

CONCLUSION

This research analyses the emerging OHS risks within the Industry 4.0 Process. In the context of the Industry 4.0, as new OHS risks and opportunities has emerged, it has become necessary to take various measures to improve OHS policies. Extensive further research should be conducted specifically on the psychosocial risks associated with the consequences on the work organization, focusing on occupational risks and work accidents at all levels of production, designing the enterprises and workplace, and utilising from information technologies. There is a need to develop new standards or update existing standards to adapt OHS systems to the Industry 4.0 Process and improve the use of new technologies. All relevant tunable physical and cognitive factors must be taken into account when allocating tasks between human workers and automation systems and smart devices such as cobots. Employee expertise and motivation is required to be strengthened to foster secure collaboration between the human workforce and cobots and to make new technologies safer for the humans in the working environment. Future OHS integration systems should be combined with virtual task analysis, dynamic assessment of occupational risks, cognitive analysis of workload, and skills management tools. Adaptive interfaces and emotion sensors should be developed to monitor employees and ensure their safety continuously. It is a necessity to analyse extensively overlapping and emerging risks of the Industry 4.0 over the OHS systems in terms of modelling human behaviour, intentions, reactions to stress, difficulty, and uncertainty. It has become imperative to constantly renew the OHS systems against unauthorized access to the recorded data and information in a production system, as well as against cyber-attacks. Since these technologies that drive the Industry 4.0 are developed in laboratories and smart factories, human-machine harmony should be at the forefront in this challenging mission.

While the trend of continuous and globally pervasive transformations of the Industry 4.0 can provide solutions to support to the workforce in terms of advanced digital infrastructure, it can also lead to new and additional occupational health and safety risks. This requires a proactive approach to risk assessment in the design or development of innovative practices and necessitates adoption of appropriate management strategies to protect employees in this new process. The impact of Industry 4.0 on the occupational health and safety management system, especially the risk assessment that is carried out by occupational physicians, should focus on identifying new risks occurring at all stages of the production process such as data management, maintenance, operation methods, tools used, materials, human errors, machines, and production technologies. This policy also means that risk assessment processes and management procedures will change, and risk information will become more important in terms of occupational health and safety. In addition, this has to be noted that it is very challenging task to implement these policies in an evolving flexible factory system.

At this stage, a precautionary risk management approach should be adopted to ensure the sustainable development of Industry 4.0 innovations. In this perspective, one of the most appropriate ways to prevent and control occupational risks, injuries, diseases, and deaths in emerging technologies is to "design" or minimize hazards and risks at the design process or during the implementation stages. In these development stages, employers, employees, stakeholders and all relevant occupational health and safety professionals should focus on identifying the characteristics of their applications developed within the scope of Industry 4.0 and their probable effects over work practices, employment, and occupational safety.

From an organizational perspective, job design should take into account the different characteristics of employees (unskilled and skilled, technical qualifications, age differences, education, life experience or cultural background). Employees who have the authority to make policy and oversee the system need to be supported by broad-based training and work organization models are to be based upon lifelong learning and continuous professional development. In the context of rapid technological changes, an employee-centred approach can be implemented in smart factories by applying appropriate training strategies.

In this context, more research is required to evaluate the comparative effectiveness of distance education and vocational education within the context of Industry 4.0. As an example, virtual reality applications can help to identify potential work accidents virtually, and workers can be trained using this technology. Targeted seminars aiming for such innovative applications make it possible to share existing knowledge and experience so that Industry 4.0 can be applied correctly. In addition, special training should be given rather than general training on occupational health and safety, especially before starting work or after a change in the workplace, work task, work equipment or equipment devices, and when new technologies are adopted. It will also be a challenge to encourage the implementation of preventive policies to protect the safety and health of workers, as automation technologies will support new forms of employment such as on-demand work.

In this regard, occupational health and safety professionals should be encouraged to take a proactive approach when creating risk profiles that may arise during the industry 4.0 process and developing international standards designed to protect workers from all potential risks. Workplace safety standards should be defined in relation to machine maintenance, operation and interaction between humans and robots. In addition, companies, stakeholders, and employees should evaluate the global applicability of these preventive and protective measures.

Last of all, policies for designing Industry 4.0 processes and operational working environments should come to the agenda. Regarding the ethical impact of Industry 4.0, a socio-technical approach should be adopted so that technological innovations, work organization models and continuous professional development can offer solutions in close connection with economic and social conditions. It should be ensured that these new developments achieve a realistic work-life balance in the whole production process, where a more flexible production, labour-oriented and unemployment-reducing organizational design, worker rights and educational opportunities are taken into account simultaneously.

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