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Research Article

OCCUPATIONAL HEALTH AND WORK SAFETY SYSTEMS IN COMPLIANCE WITH INDUSTRY 4.0: RESEARCH DIRECTIONS[1]

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─Abstract ─

Industry 4.0 is the contemporary approach that denotes the transformation process in the global chains of value creation. This approach has a potential to remove restrictions between physical objects, converting them into a comprehensive complex system of interoperable, interconnected and interdependent components. Given Industry 4.0 becoming the eminent concept, occupational health and safety management (OHSM) systems have been facing new challenges. On the other hand, to the best of our knowledge, we argue that current state of the art does not sufficiently take account of whether the "Fourth Industrial Revolution" will impact occupational health and safety in industry 4.0-based supply chains. The main goal of this research, therefore, is to demonstrate several new research opportunities that may advance our knowledge of Industry 4.0 based OHSM. In this regard, the contribution of this study is twofold: first, it investigates the current literature studying how Industry 4.0 may affect OHSM activities in contemporary supply chains and organizations. Secondly, given the analysis of the current state of the art, future research directions and proposals are discussed.

Key Words: *Industry 4.0, Occupational Health and Work Safety; Literature Review, Research Opportunities.*
JEL Classification: J81, M10

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1. INTRODUCTION

Industry 4.0 is not only an real movement in development of the recent overall economy but a mindset shift of its progress in future, which encourage the attainment of its strategic economic objectives (Alekseev *et al*., 2019). In other words, it is an apparatus for the development of knowledge economy, which is a milestone for prevailing value chain networks. We argue that as these disruptive technologies emerged from Industry 4.0 become widespread, it will affect how occupational health and safety (OHS) is managed in organizations. Specifically, we also argue that the three pillars of any OHS, which are standards (OHS management systems), legislation and legislative frameworks and good practices will be affected. It is vital to recognize that the role of people in manufacturing operations will never be unnecessary. Rather, Industry 4.0 considers white and blue-collar workers as essential. Interconnectedness between workers and machines along with the advanced information systems is fundamental to the successful implementations of Industry 4.0. An operational facility running under this new mindset potentially demonstrates very distinct and more complex challenges. For instance, reorganization of manufacturing fields at short notice, requiring urgent set up changes and even the physical movement of equipment can cause a range of OHS threats as these configuration to satisfy potential obligations may call for a separate risk evaluation for each. That's being said, these obligations should not be overlooked if conforming to legislation is to be managed (Minturn, 2017). Note that, at first glance, disruptive technologies emerged from Industry 4.0 bring about risks and drawbacks for working people. However, Reiner (2016) states that we must not ignore that such a technological transformation may also enable modern organizations to make work areas safer, healthier, more flexible and socially more enjoyable. There are various opportunities ranging from smart safety technology, computer-generated tools for timely hazard evaluation and safety, health improvements for analysis and care like health-monitoring wearables to digital apparatus such as e-learning instruments and smart glasses. Despite these potential affects of Industry 4.0 on OHS and challenges, we contend that current state of the art still lacks research with respect to the correlation between the "Fourth Industrial Revolution" and occupational health and safety in industry 4.0-based organizations and value chains.

The main goal of this research, therefore, is to advance our knowledge of the current studies on Industry 4.0 based OHS. To this end, the contribution of this study is twofold: first, it investigates the current literature studying how Industry 4.0 may affect OHSM activities in contemporary supply chains and organizations. Secondly, given the investigation of the current state of the art, it provides future research proposals (RPs) and discusses its implications.

2. OCCUPATIONAL HEALTH AND SAFETY: OVERVIEW

In spite of the constant and rising structured measures to avoid mishaps at work, injuries and work-related illnesses still comprise a worldwide problem in manufacturing and service industries. Thus, losses teach us a great deal of lessons, and often we learn a lot from the emerging social and economic consequences. However, those losses keep taking place although huge improvement has been accomplished in various sectors and jobs (Hakkinen, 2014). Occupational safety and health precautions have been evolving from the early years of industry revolution. The initial actions were taken to reduce the number of accidents in industrial operations by fundamental safety rules and disciplinary measures. Similarly, new safety regulations were enacted in developed countries to compel companies to develop safety and to take measures against risks (Hakkinen, 2014). As the organizational systems evolved, the development of human-machine systems and versatile disciplines such as ergonomics built new possibilities to handle the intricacies of the operations and processes with respect to technological collapses. Further, occupational health and safety and management systems (OHSMSs) were established to handle the hazards of main mishaps and health issues in many industries. The increasing interest in occupational health and safety management has also caused to additional regularization of executive applications in health and safety, e.g. OHSAS 18001 and ANSI Z10. OHSMSs are systematic instruments that enable organizations to cope with their occupational risks and assist managers to maintain health and safety issues in the workplace (Granerud, 2011).

However, despite all this legislation efforts, new standards and procedures and rising administrative interest, there appears to be some misplaced connections and failures and hazards at work have not vanished (Hakkinen, 2014). Moreover, new

technological movements, such as Industry 4.0, created additional complexities besides the existing ones. In the following section, brief introductory information will be presented with respect to Industry 4.0 to comprehend the possible correlation between the components of Industry 4.0 and OHSM at work.

3. INDUSTRY 4.0

Based on the current state of the art, we argue that Industry 4.0 is an aggregate expression for technologies, components and views of value networks. Bartodziej (2017) states that Industry 4.0 should not be considered as a closed system but instead should be approached as one fundamental element out of various key fields. Mainly, Salkin *et al*., (2018) states that Industry 4.0 constitutes the integration of operational processes and value chains to enable the foundation of sustainable networks. The successful applications of Industry 4.0 seem to include three characteristics: (1) horizontal integration through value chains, (2) vertical integration and networking of manufacturing or service systems, and (3) end to-end engineering of the overall value chain (Wang *et al*., 2016). Vertical integration entails smart connections and digital transformation of organizational entities in various hierarchal levels within a company. Nevertheless, horizontal integration yields value creation among organizations to improve product life cycle using smart technologies and smooth supply chain operations (GTAI, 2015).

3.1 The Key Components of Industry 4.0

The existing research discusses six fundamental technologies in order for any Industry 4.0 implementation to be successful:

3.1.1 Cyber-physical systems:

Cyber-physical systems usually incorporate material reality into state-of-the-art software and hardware technologies (Bagheri *et al*., 2015). They are composed of real time locating systems, sensors, actuators, controllers and network systems that data or information is being converted and exchanged among various units.
Salkin *et al*., (2018) summarize the characteristics of the cyber physical systems as follows: “flexible and reconfigurable parts and machines”, “monitoring by sensorless or with sensor switching”, “control and monitoring operating reaction loops”, “structured and continuous integration of storage and analysis of data

directly and interactively on the local control", "in private networks or in the public cloud system" and "improved safety at work over the exposure of safety-critical grade".

3.1.2 The Internet of things (IoT):

The Internet of Things consists of networked products, systems, and sensors, which uses software and hardware technologies and network interconnections to yield new functions. These "smart objects" require minimal human intervention to generate and transfer data (Rose *et al*., 2015). Giusto *et al*., (2010) points out that the term IoT allows 'things' and 'objects', such as Radio Frequency Identification, sensors, actuators, mobile phones through unique addressing schemas to cooperate with each other and collaborate with their neighboring 'smart' components to achieve mutual objectives. That's being said, Witkowski (2017) imply that three distinctive characteristics of the IoT are identified as follows: context, omnipresence and optimization. Context denotes to the likelihood of an innovative object to contact with a current ecosystems and the instantaneous reply by it to change. Omnipresence exemplifies the fact that objects today are much more than just connections to a user network of human-operators. Finally, optimization is the illustration of the functionality that each object owns.

3.1.3 Artificial intelligence:

Artificial Intelligence (AI) is interested in the formation of a software and hardware system that mimics the smart conduct of a decision maker. It owns the features such as adaptive control, better handling and reusability of stored knowledge (Kumar, 2017). Progress has been made since the advent AI system, which enhance its applications on various problems such as pattern detection, computerization, computer vision, virtual reality, identification, image processing, robotics, automated reasoning, data mining, operational optimization, multi-agents and monitoring, production etc. (Kumar, 2017).

3.1.4. Advanced robotics:

Robots are sophisticated structures that yield autonomy, flexibility and collaboration. It is argued that the robots will quickly begin cooperating with one another and work safely with human decision makers and even learn from them (Kamble *et al*., 2018). They will provide cost benefits and abilities, achieving some of the actions in the context of the smart operational ecosystems (Pei *et al*., 2017). Furthermore, to enable safety and control of the ecosystem, a safety eye is performed. If any interruption such as some workers or equipment such as an automated guided vehicle arrives the virtual space (safety eye), the system stops the robot with unique sound expecting some collusion. In that case, the worker must eliminate the barrier before the robot begins operating (Kamble *et al*., 2018).

3.1.5. Additive manufacturing:

Additive manufacturing (AM) is an evolving systems that yield three dimensional objects right from the software models through an additive process, particularly by keeping and assembling the products with the raw materials such as plastics, polymers, ceramics, or metals. Compared to "conventional" production machineries such as turning, grinding, sawing and injection molding, AM systems can provide distinctive benefits: since no object-specific tools are needed in AM, the manufacturing costs may be decreased (Mellor *et al*., 2014). However, it is argued that there are also some shortcomings of AM such as the narrow selection of materials and surface finishes compared to conventional production systems (Berman, 2012).

3.1.6. Smart Factories:

The Smart Factory has a totally new method to manufacturing (Veza *et al*., 2015). Smart factories enable transparency over the operations, which ease the efficient decision making processes (Kagermann *et al*., 2013). The essential characteristics of smart factory are as follows: (1) manufacturing customized goods, (2) a single extended product combining product itself and complementary services, (3) collaboration through distinctive operational networks (Veza *et al*., 2015).

Once brief information has been demonstrated, the basic methodology of this research will be provided in the next section.

4. METHOD

To achieve the research objectives, the structured literature review is performed with the iterative process depicted as follows:

Phase I – Selection of Database: The search was performed based on all possible pairs from 2010 to the first half of 2019 on prestigious scientific databases, i.e. Science Direct, Emerald, Springer and Taylor & Francis. This time period is selected because Industry 4.0 has become a global phenomenon since 2010.

Phase II – Selection of the keywords: In this step, keywords that can detect the current research with respect to our research topic were identified. Keywords were organized into two groups: Group one includes the words such as "Industry 4.0", "Internet of Things", "Cyber Physical Systems", "Robotics", "Artificial Intelligence", "Cloud Computing", "Smart Factory" and "Additive Manufacturing". Group two consists of the words related to Occupational Safety and Health as "Occupational Health", "Occupational Safety" and "Occupational Health and Safety Management". We also used Boolean operators AND in search terms to specify logical relationships between two groups.

Phase III – Elimination of Papers: After the initial search, duplicated results were eliminated. Then, the significance of the remaining studies was monitored by eliminating the researches that do not include both keywords with respect to Industry 4.0 and occupational health and safety in title or abstract. After this assessment procedure, the remaining studies were then filtered based on its publication platform.

Phase IV - Analysis: All selected studies were analyzed in the fourth phase.

Phase V- Research Directions: Finally, in the fifth phase, new research opportunities, directions and proposals are provided in the context of Industry 4.0 based occupational safety and management systems. Potential research plans are discussed, and possible implications are also provided.

5. RESULTS AND DISCUSSION

Once the key components of Industry 4.0 and OHS have been demonstrated, we now focus our attention on the research about OHS in the context of Industry 4.0. Note that Badri *et al*., (2018) is the only research that concentrates specifically on incorporating the idea of Industry 4.0 into OHS. Their research was grounded on four facets of OHS, namely: (1) work organizations, (2) OHS based legislative and regulatory structures, (3) OHS management systems, and (4) managing work hazards. The authors make some recommendations to improve Industry 4.0 based on OHS in the context of these four aspects. In another study, Fernández and Pérez (2015) argue that cutting-edge production systems can yield new OHS hazards but that old tools of occupation hazard evaluation seem incompetent of recognizing these evolving hazards. Beetz *et al*., (2015) suggest the problem with respect to the application of cobots and the intimate collaboration with workers to assist them perform challenging and hazardous duties. Mattasson *et al*., (2016) highlight that the IoT and Big Data put forward huge challenges where the main purpose is to scrutinize and employ information moving downstream and upstream in a workplace. They also pose inquiries about the most proper approach of incorporating innovative means to enhance performance and mishap prevention. Badri *et al.,* (2018) and Fernández and Pérez (2015) argue that the lack of a norm or an update in response to a technological advancement may have main influences in terms of OHS. Advanced manufacturing systems including a remote control process (cloud computing, Internet of things, etc.) or sensors that increase machine autonomy will no longer be subject to a standard appropriate for the conventional systems. Badri *et al*., (2018) also argue that OHSMS standards will indisputably assist entrepreneurs transform smoothly to self-governing intelligent systems. This will assist tackle barriers such as errors in ranking hazards and challenges organizing precautionary measures in new business structures.

In summary, researchers conclude that if the technologies of Industry 4.0 grow in a disconnected manner and the OHS proposals of decision makers are disorganized, risks will escalate and some of the benefits made in hazard blocking so far may be missing (Badri *et al.* 2018; Mattsson *et al.,* 2016). They also argue that researchers and decision makers should cooperate on the execution of

possible actions given an all-inclusive vision of achieving transformation to guarantee an optimum and secure conversion to the ecosystem of Industry 4.0.

Given the scrutiny of the literature, we conclude that more research is necessary to achieve that transformation smoothly since there have been very few research attempts with respect to Industry 4.0 related OHS frameworks and their applications. We also conclude that the lack of sufficient scientific work, in general, indicates the importance of doing qualitative and quantitative research on developing a necessary OHS infrastructure for supporting the safe realization of Industry 4.0.

However, before proceeding to any of these attempts mentioned above, we argue that one must take into consideration the WHO's healthy work standards that depict a healthy work environment as "one in which workers and managers collaborate each other to protect and boost the health, safety and well-being of all workers and the sustainability of the work environment" by contemplating four discrete, but interconnected fields (WHO, 2011) as follows: (1) health and safety challenges of the physical workplace; (2) health, safety, and well-being concerns in the psychosocial workplace ecosystem, including work organization and workplace culture, (3) individual health supplies and the means in the work ecosystems, encouraged by employers, and (4) the means of contributing to the society to advance the health and safety of workers, their families, and members of the society.

We argue that the disruptive technologies of industry 4.0 may have a fundamental influence on the societal atmosphere and financial circumstances of work, which will, as a result, may affect the sustainability of business ecosystem and thus might have a meaning, which is more than satisfying the need for just some new safety necessities. Industry 4.0 and the possible transformation process that it needs is not only a phenomenon in manufacturing but it also influences industries from policy and strategy selection to implementation and execution. As digitalization gives rise to more mobility and flexibility with computerized instruments, it can be observed that work becomes possible anywhere and at any time. On the other hand, this might bring about psychological overload, rising job denseness or a damaged work-life-balance. In addition, note that new technologies offer discrete possibilities to monitor the performance of workers, which may

form a business ecosystem of ambiguity and stress. However, in some cases, researches suggest that Industry 4.0 provides the means to build safer work environment due to the capability to collect information in real time manner before a probable risk emerges. That's being said, we conclude that as Industry 4.0-based disruptive technologies become widespread, they may affect the way occupational health and safety is managed in value chains and organizations even if we cannot be sure in what direction these effects will take place.

Given the current state of the art, our brief discussion about the overall picture of Industry 4.0 and its possible effects on the OHS scene and the WHO's healthy workplace model, we propose five RPs as follows:

RP 1: New qualitative and quantitative studies are needed to explore how disruptive technologies of Industry 4.0 affect the way white and blue-collar workers perform their tasks: Research should be conducted how existing companies in various industries are dealing with incorporating their human capital and the way they fulfill their functions into the distinctive components of Industry 4.0 to form a safer and healthier work ecosystem in general, which is consistent with the ideas of Badri *et al*., (2018). Specifically, researchers must investigate how certain systems such as IoT, additive manufacturing, robotics, cyber physical systems, smart factories etc. may impact working conditions and labor force and how these disruptive technologies can be used to reduce certain hazards that companies have been facing. To achieve that, empirical studies based on surveys that explore the opinions of occupational health and safety experts in various industries must be planned. Accordingly, hypotheses must be constructed testing the possible negative and positive effects of Industry 4.0 technologies on the healthiness and safety of various work ecosystems in manufacturing and service industries. Moreover, case studies are also needed to reveal how companies using Industry 4.0 technologies are managing the conditions in digitized working environments to ensure the resulting challenges.

RP 2: Research is also needed to demonstrate how Industry 4.0 will impact the performance of the current OHSMSs: Empirical studies should be performed to expose the performances of the existing OHSMSs based on a comprehensive indicator framework in terms of various OHSMS activities, such as planning, policy, procedure, implementation and monitoring. The followings are some

examples of the criteria that may be used to achieve that assessment: "top management commitment", "workers' participation level", "allocation of financial resources to OHSMS activities", "training workers", "sharing precautionary actions", "numbers of investigative meetings held" etc. Given such a scrutiny, in accordance with Badri *et al.* 2018; Mattsson *et al.,* 2016, we argue that it is possible (1) to reveal how strategic the existing OHSMSs role is in terms of maintaining efficient health and safety practices in the workplaces, (2) to adapt the existing systems to the new requirements of Industry 4.0 based on the findings.

RP 3: New standards should be studied and developed in order for the current OHSMSs to adapt to the necessities of Industry 4.0: Note that the existing OHSMSs have been designed to satisfy the requirements of the conventional business ecosystems. However, digital transformations of the business systems necessitate defining and contemplating new types of hazards, risks, health issues, risk assessment methodologies, streamlined occupational health and safety models, new implementation methods, societal issues etc. That's being said, we maintain that it is not probable to meet those new needs using the current OHSMSs. As Fernández and Pérez (2015) also maintained, they should be redesigned based on the possible effects of contemporary technologies that organizations employ. To this end, surveys should be conducted to investigate what new strategies, plans, rules, guidelines, policies, tactics and procedures should be added to the current programs to achieve today's Industry 4.0-based occupational health and safety challenges.

RP 4: Current legislative framework should be reviewed, necessities should be discussed, and a new legislative framework should be developed to achieve its adaptation to Industry 4.0: Consistent with Badri *et al*., (2018), researches should be performed to demonstrate how the decision makers of companies and governmental institutions should streamline the existing legislative framework to satisfy the current needs of new working environment. Note that this is an ecosystem that entails human, machine and information systems interoperability. Therefore, one should investigate if new laws are to be enacted, or only the modifications to existing laws are sufficient. Moreover, we argue that identifying stakeholders are invaluable to achieve optimum legislation framework. Therefore, we also argue that relevant stakeholders should be identified possibly through a comprehensive social network analysis. To this end, an empirical study that

surveys the interactions of all possible stakeholders with one another should be launched.

RP 5: Studies should be done on how educational programs associated with occupational and safety science should be designed and streamlined: Social sustainability is one of the pillars of sustainability phenomenon in today's challenging business world. Note that to achieve social sustainability, employees' health and safety requirements must also be maintained besides the requirements of the rest of the stakeholders (Hakkinen, 2014). Note also that maintaining health and safety necessities entail skilled human capital that has higher education on occupational health and safety. Moreover, it is also crucial to comprehend that training for contemporary OHMSs is essential for building an occupational health and safety-based culture in organizations. We argue that comprehensive training programs assists them to gather the information and dexterities needed for them to perform their duties and introduce them to the probable hazards. Since building undergraduate, graduate, training and certificate programs and forming their underlying curriculums are so crucial, comprehensive surveys, case analyses and possibly the Delphi studies that investigate the stakeholders' view on how to develop such educational programs should be conducted.

6. CONCLUSION

It is argued that Industry 4.0 and its underlying technologies have been impacting the business models of today's value chains. It is also argued that this impact on the performances of organizations has been both positive and negative depending on key performance indicators considered. Then, the question that should be raised is if the current business models have been affected by the components of Industry 4.0, what may be suggested with respect to the health and safety performances of the same organizations? Given the review of the state of the art, we argue that the three pillars of any OHS, OHS management systems, legislative frameworks and benchmarks, may mainly be affected. Therefore, in order for organizations to deal with this transformation process smoothly, new scientific studies that will possibly propose effective frameworks are needed. To this end, we propose five research questions with respect to exploring (1) the way white and blue collar workers perform their tasks in the context of Industry 4.0 based systems, (2) the performance of the current OHSMSs (3) the adaptation of the

current OHSMSs to the necessities of Industry 4.0, (4) the prospective legislative framework in the context of Industry 4.0, and (5) the future occupational and safety science programs in higher educational institutions.

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