OHS-Related Risks in an Industry 4.0 Manufacturing Plant

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Abstract

The concept of industry 4.0 is taking more and more interest among academicians and practitioners. This concept appeared under several names and visions but for about the same purpose: improve productivity and flexibility. As part of ongoing attempts to produce goods within high quality and diversity requirements, while being the most efficient. The changeover toward the industry 4.0 era isn't risk-free. Safety, which is a big priority for manufacturers, is one of the aspects that should be seriously considered, during all the steps of the change. Technological development in manufacturing processes and the integration of new interactive elements and technologies such as collaborative robots (cobot), automated guided vehicles (AGV), sensors and others can have critical consequences. Thus, it's important to consider the different threats and risks, to be well prepared for changes. There will be many big challenges. Indeed, physical, mental and psychological safety of workers are at stake. Consequences of change are, already, a big burden. In addition to that, cyber security and information safety represent another challenge for the implementation of the industry 4.0. The insecurity-perception linked stress can cause many health issues. Therefore, to address safety concerns, it's important even vital to have a clear vision of different risks related to occupational health and safety (OHS) to which manufacturing companies must face. Moreover, because prevention is always better than cure, OHS-risk management upon industry 4.0 implementation will be a good first step to guarantee a safe workplace in the present-day and in the forthcoming.

Keywords: Industry 4.0; Risks; Occupational Health and Safety; Manufacturing Plants.

1. Introduction

The word is changing around us thanks to the rise of knowledge. An evolution accompanied by newly discovers, redesigned methods, revolutionary thinking behaviors and novel ways of exploiting resources (

Figure 1). This reality is very clear when it concerns industry. Indeed, since the eighteenth century up to present days, industry has lived various revolutions that have been prompted whether by the introduction of new energy sources (like steam

for the first industry revolution or industry 1.0), by the invention of electricity (industry 2.0), by the automation of the production process (industry 3.0) or by the actual and continuous great technological development (industry 4.0). Since the transition from craft production to the use of machines, many concepts have emerged, and the manufacturing sector has continuously seen the integration of many elements in order to improve efficiency in order to meet a growing and increasingly demanding customer need. The development of technological solutions in manufacturing is, also, a key element for transition, especially in the case of the industry 4.0 era.

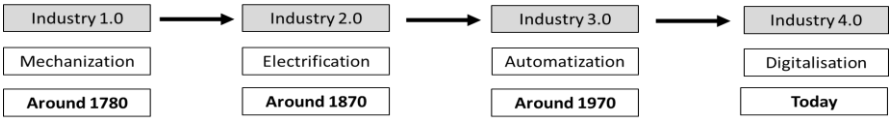

Figure 1 Industrial revolutions over the time

All over those revolutions, challenges changes and become more and more manifold. Qualified human resources, productivity, quality and safety are ones among several concerns of managers whenever change affects workplaces. To face those challenges, adaptive solutions must be established. The first step to be done is, certainly a good analysis of the situation to understand what and how to deal with the emergent situation and context. Anticipating risks, and preparing a risk management plan, is a crucial element in the management of any project. During this step, it is important to identify all possible risks, and prepare prevention measures and a contingency plan to deal with inevitable incidents (PMI 2017). This process remains of the same importance, if not more, in the case of an occupational health and safety management plan. It is, therefore, very important to take all necessary measures in order to avoid incidents which can have a huge and irreversible impact.

Occupational health and safety (OHS) principles are important for any enterprise. Not only because it has been for several years, one of the most important key performance indicators (KPI), but also because of the big negative consequences of occupational accidents and diseases on the overall performance (Tremblay and Badri 2018). Big work has been done over the last decades to improve safety and health integrity in manufacturing enterprises. And because effort must be recompensed, a marked improvement was done, particularly in prevention (Badri et al. 2018). In OHS philosophy, prevention is considered like a purpose and a goal and not only a tool to avoid occupational accidents and diseases. Indeed, because of the significant impact of a workplace accident or disease on the individual and so on the enterprise and the society levels, OHS managers and professionals emphasize the most of their effort on prevention and risk analysis and management phase.

The implementation of Industry 4.0 still facing some challenges and problems: technical issues, standardization, protection of privacy and information security,

etc. (Salgues 2018) Several education gaps and training and qualification requirements that manufacturers opting for Industry 4.0 will have to face (Benešová and Tupa 2017). Emphasis must be placed on the importance and gravity of a careless transition to the new manufacturing reality. Indeed, the sudden transformation undergone by industry with the growing use of the Internet of Things, can be costly in terms of security, if manufacturers do not strengthen enough the culture of security in the industry. The daily life of their managers, especially since cyber attackers have gigantic financial resources and very sophisticated material resources (Williams 2018). Other concerns start to be announced, especially in recent articles, about the precautions which must be taken seriously in the transition process to the industry 4.0 context. In fact, to keep the prevention level the highest possible, it's a priority to have very good overview about risks resulting from the integration of new elements and technologies in the manufacturing workplace. Many roadmaps and transition plans have been provided by governments, research institutes or consultants in order to help enterprises to have the most fluid shift to industry 4.0 (Jocelyn et al. 2017; Murashov et al. 2016; Drath and Horch 2014). Several researchers have demonstrated the impact of OSH management on process optimization and on production costs. This can be a good reason to consider the OSH aspect in the process of transition to Industry 4.0. So, do we need an OHS 4.0 management?

In the last 5 years, the number of publications focusing on health and safety challenges in industry 4.0 era keeps increasing (as shown in **Figure 2**). It confirms the pertinence and the importance of this subject study.

Database	Scopus	
Search criteria	Your query: (TITLE-ABS-KEY (industry 4.0 AND health and safety))	
Results	Number of results: 138	
Publications per year (2015-2020)	YEAR	
	2020	48
	2019	44
	2018	28
	2017	9
	2016	6
	2015	3

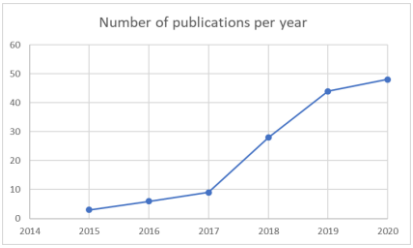

Figure 2 Number of publications in the research field per year (Scopus database 2015–2020)

2. Industry 4.0: Toward an Industrial Cognitive Revolution

The industry has gone through several revolutions from the start of the integration of the steam engine in the 18th century to the present day. Revolutions that were marked by a concern for productivity or efficiency. The development of the industrial sector has been accompanied by the integration of new means, new tech-

nologies or new sources of energy (Mohamed 2018). In search of better competitiveness, industry specialists tend to look for creative and innovative solutions in order to help to increase efficiency. The main purpose is to meet an increasingly diversified customer demand, while respecting quality and low-cost requirements. In this context, and for centuries, the industrial world has experienced several major changes. Industry 4.0, a notion born in Germany in 2011 to qualify the fourth industrial revolution, follows the trend of the today industrial world (Badri et al. 2018). A world where cyber is taking an important place in industry, and where the internet has allowed organizations to explore benefits of smartness and connectivity. In this new manufacturing era, industrial reality has changed by way of cyber-physical systems, collaborative robots, autonomous vehicles, internet of things, big data, etc. (Ghobakhloo 2018)

According to (Kusiak 2018), 6 main elements constitute the pillars of smart manufacturing: manufacturing technology and processes, hardware, information, predictive engineering, sustainability, and networking and resource sharing. He thus studied an example of a tool already used in industry, which is the intelligent vehicle. It is a connected vehicle that handles or transports matter and shares information with other vehicles or with an information center. This option allows you to closely monitor the condition of the vehicle or its location. This makes it possible to more easily predict breakdowns, failures or problems, which can, if not taken care of, cause possible accidents and/or unplanned shutdowns.

The new industrial reality will necessarily have impacts on the way in which we previously managed production, human resources, transport, etc. In terms of occupational health and safety, the change in paradigms will result in the birth of new types of risks which can affect the health and safety of workers, and which have not necessarily been taken into account in when the design or installation of new technological elements integrating traditional production systems or those newly implemented (Bragança et al. 2019; Moeuf 2018). The integration of new technologies and innovation in manufacturing have, certainly, many advantages, especially in terms of productivity and quality (Kusiak 2018). Complex and hard tasks are no longer an obstacle for human workers thanks to devices like robots, collaborative robots and exoskeleton. Logistic is also gaining easiness by way of autonomous and connected vehicles. Many control tasks are becoming simpler and can be done remotely using the internet of things. In addition to its contribution to productivity and competitiveness, the Fourth Industrial Revolution presents itself as a very effective solution to the problem of an aging workforce. Indeed, according to the European Commission and the Economic Policy Committee, the number of people able to work (by reference to working age) will be reduced by 16% by the year 2050 (Yaşar and Ulusoy 2019).

Manufacturing companies are forced to follow the trend of today's industrial world in order to survive. Indeed, it's as smart as it takes to predict the trends of consumers, stubbornly over quality and variability, and their increasingly complex needs. In addition, the benefits of adopting Industry 4.0 on efficiency and costs are very attractive, which allows companies to maintain good connectivity with their

consumer bases, while remaining competitive in the market (Davies et al. 2017). The changes in the manufacturing realty due to industry 4.0 will necessarily have an impact on old notions related to education, human, social and economic aspects. We are currently talking, for example, of the 4.0 engineer, who must acquire the adequate skills and training, and must also have a certain flexibility and adaptation to face the continual changes of the industry, which requires a modification of the educational system and especially at university level (Benešová and Tupa 2017). On the other hand, the notion of operator 4.0 or the healthy operator 4.0 refers to the operator for whom one or more components of Industry 4.0 are used. A well-known example is working clothes containing censors, GPS, or any other technology allowing the collection of information giving an idea of the operator's state of health (Romero et al. 2018).

Most of the emphasis dedicated to the study of the fourth industrial revolution has mainly focused on the proposal of integration plans and roadmaps for the innovation process and on the challenges and issues facing enterprises starting this process. This was done by neglecting the occupational health and safety aspects and the great impact of a good OSH management, which has been proven through several studies previously. Indeed, the change of paradigms in Industry 4.0 will necessarily have an influence on the practices and definitions of OSH management (Badri et al. 2018).

Sensor help to protect workers by a real time monitoring of data. Personal protecting equipment (PPE) can be easily verified to validate their compliance, using new technologies. Indeed, the addition of sensors in a sensor-based technique, to a PPE lead to collect signals and analyze them. The result can help in prevention of occupational accidents caused by collisions, electrocution and injuries. In the same way, and in a vision-based technique, the use of cameras in the workplace to record and then analyze images and videos may also help in protecting workers from occupational accidents and improve their safety by making sure that their PPE are always compliant (Nath et al. 2020).

Handling heavy parts, which can be dangerous and represent a safety issue for human workers, is one of the tasks in which new technology can be very useful. Indeed, exoskeleton in human-centered workplaces (as like as the automotive industry) are more and more used to support body movement and bringing a solution to a safety issue. Even if many challenges are to be overcome, related to certifications, technical specifications, specificity of workers, sectors and workplaces, etc. (Christian and Carmen 2020)

The industry on a global scale has experienced several revolutions over the years. From the steam engine, to electrification, to automation, to globalization and arriving at digitization, every revolution has been characterized by changes, sometimes radical, in labor practices and standards. This includes occupational health and safety (OHS). Over the years, the industrial world has experienced an evolution in OSH prevention beliefs and practices. Indeed, efforts have been made to better protect workers against dangers in the workplace. This has translated into a significant

reduction in the amount of work accidents, and occupational diseases suffered by workers each year.

With the arrival of the fourth industrial revolution (industry 4.0), the working environment changes. Digitization, the internet, artificial intelligence, big data and other technologies are creating new workplaces. Companies experiencing this transition are seeing the birth of new types of risk. Suddenly, Industry 4.0 is making the mission of companies in terms of prevention more complex. Should we then keep the same current reflexes in an evolving context? practically, OHS professionals have no choice. They must adapt their ways of doing things if they want to continue to protect the life and health of workers and not see the trend towards improved working conditions reversed. It's important to define and analyze emerging risks in OHS in the context of industry 4.0 and to propose integrated approaches to decision-making tools that will come to the support of company managers involved in a process of transition to Industry 4.0. Adapting manufacturing processes to the new context has become a necessity without which workers will face dangers that can threaten their health and their lives. Therefore, the identification and analysis of new risks is a crucial step after which it will be possible to understand the challenges and act in this direction to resolve this issue. All this help to provide tools to OHS decision makers to keep workers in good health, but above all, alive!

The identification of emerging OSH risks has been the subject of several studies. A few have focused on cybersecurity as a major cause for concern since a cyber-attack can have very serious consequences on the functioning of a system, the integrity of information, and on the safety of workers in direct contact with machines on the floor which can get out of control. In addition, it is an evolutionary risk that one must review the level of its control continuously, especially as the dangers are in continuous development (Williams 2018). Other studies have identified the risks associated with the use of robots and collaborative robots in smart factories. Indeed, and even if the future of the industry foresees more autonomous and intelligent machines, the presence of humans on the industrial floor is inevitable and remains mandatory especially at the level of supervision. The sharing of space between human and robot makes health and safety management quite a complex task. Indeed, this new context of collaboration gives rise to new types of risks that may arise, and which are linked to the evolution of modern production systems (Bragança et al. 2019; Khalid et al. 2017).

In order to assess maturity in Industry 4.0 (Schumacher et al. 2016) reviewed the literature in relation to the available tools, already developed and validated. They ended up finding five models. After analyzing the gaps and shortcomings represented by each of the models, they developed a new model which serves as an extension of what exists, and which will make it possible to cover more organizational aspects related to the context of Industry 4.0. This model, presented in the form of a standardized questionnaire, is made up of 62 items grouped into 9 categories or indicators. These indicators measure the maturity of the company in Industry 4.0. The items are each represented by a question on a Likert scale.

(Murashov et al. 2016) have been interested to the introduction of robots and collaborative robots in the new industrial reality of today and the future. They asked themselves two very important questions concerning the ethical aspect of the use of robots: How will the robot's algorithm be structured when faced with the dilemma of probability of injury or major damage to humans versus a virtual certainty of 'better productivity and lower cost? And should this compromise be the subject of a new OHS standard? On the other hand, the authors stressed the importance of starting research in order to answer these two questions. They also proposed to consider proactive risk management approaches developed for other emerging technologies (e.g. nanotechnology) as examples to be followed by analogy. In a scientific report (Jocelyn et al. 2017), the safety functions of collaborative robotics, which represents one of the main concepts of Industry 4.0, has been studied through a theoretical analysis of the technical documentation of three examples of robots, followed by four concrete case studies in Quebec. The authors identified three advantages of collaborative robotics compared to conventional robotics: low acquisition cost, simplified programming and configuration combining robotics power, endurance and precision with human intelligence and decision-making. As part of the same research, new risks related to collaborative robotics have been identified in the literature: The risks of collisions, due to the sharing of the work area between human and robot, the risks of MSDs (Musculoskeletal Disorders) and psychosocial risks caused by mental overload linked to the need for good synchronization between the human operator and the robot. Following this, the report presents a strategy for managing emerging risks related to collaborative robotics, which consists of anticipating these risks and taking precautionary measures: Cognitive ergonomics to secure movements in the work area, development of kinetics moving parts of the robot in order to integrate intrinsic safety to the operator in the face of static collisions, analysis of OHS risks at the robot design stage, bio-mechanical calculations of the pain threshold and speeds, forces and maximum pressures during collusion prior to the design of workstations, improved presence detection sensors and greater reliability of safety-related control parts.

3. Collaborative Robots: New Contributions Lead to New Risks

Robots are one of the most significant icons of technological development. Thus, they have always been a symbol of innovation and technical l development since it was just a science fiction question. The introduction of robots in industrial environment goes back to the 1970. Since that time, several evolutions and changes have been made. Indeed, from a basic robotic manipulator arm (mostly in automotive industry) to a collaborative robot (cobot), the increasing of availability and utility and the relatively lower cost were the principal reasons of the emerging of industrial robot introduction in workplaces (Murashov et al. 2016).

In the industry 4.0 context, robots continue to manifest persuasively as one of the principal pillars of the new industrial era. Even more, robots are gaining skills, autonomy, smartness, interaction capacity and usefulness. As the artificial intelligence is evolving as much, today's robots aren't just a such passive machines, but some of them are now able to interact with humans and even to take decision based

on their own data analysis or as an interaction to some human actions. With progressive adoption of the industry 4.0, plants are using more and more collaborative robots or cobots. The strength of cobots results from the mix of human dexterity, flexibility and problem-solving skills with the strength, endurance and precision of a mechanical device like industrial robots (Murashov et al. 2016). To keep it efficient and useful, it's fundamental that the safety level of cobots functioning should be the highest possible. Cobot has the specificity of working in collaboration with human and that their surrounding environment is much bigger and less easy to identify than other industrial robots with programmed fixed tasks. That's why issues of safety are more disturbing than ever. There are two probably hazard sources: ones related to the human worker, and others related to the workplace (Murashov et al. 2016). A poor workplace design is one of the sources of uncertainty which can be a cause of injures and occupational accidents. In the other hand, human can also perform dangerous actions or neglect some security instructions if he is unaware of the dangers that he is facing.

Human-robot interaction is defined by the international standardization organization (ISO) as "*information and action exchanges between human and robot to perform a task by means of a user interface*" (International Organization for Standardization 2016). This interaction between human and cobot in industrial context can result in two types of issues. First issues related to cognitive interactions between human and cobot, while the seconds are a result of the fact of sharing the same work zone with a relatively large number of mechanical degrees of freedom, and so the capacity to move in different ways and directions without big restrictions. Cognitive interactions between human and cobot can become a source of stress and anxiety. Indeed, human will have a continuous concern about any eventual dangerous moves or reactions and a perception of being not completely safe. The prediction of all the possible moves will be almost difficult, even when some models of cobot are equipped with more sophisticated staffs which can significantly reduce the errors risk. Human worker can still have some fear of missing out. Meanwhile, safety measures are costly, especially for a small-medium enterprise (SME), and can represent restrictions when set up. In fact, limiting velocity of a robot motions, reactive motion planning or requiring a minimum worker-robot separation distance can provide a better safety level, nevertheless, this can have some side effects on work pace or productivity (Zanchettin et al. 2016). Physical harm risks as much as the psychological impact on humans are present in a collaborative human-cobot workplace. All the tow can effectively be behind work accidents and eventual mental health problems (especially stress and anxiety)(Jocelyn et al. 2017; Clarke and Cooper 2004).

4. Autonomous Guided Vehicles (AGV): new philosophy and new OHS challenges

In the industry 4.0 context, transportation and logistics have also undergone several changes. Logistic 4.0 and supply chain management 4.0 (SCM 4.0) are some notions introduced to describe the new management principles in the technological

innovation context. Increasing autonomy, connectivity, visualization and optimization are features characterizing the SCM 4.0 (Enzo Morosini et al. 2019; Strandhagen et al. 2017). Inside factories, transportation is usually guaranteed by special vehicles designed for this reason. Those vehicles are gaining autonomy and more movement freedom in the new industrial workplace. Indeed, conventional transportation vehicles are using guide tape to keep their predetermined and programmed path. However, this kind of restriction and limitation is no longer existent in the industry 4.0 manufacturing plant, and vehicles are able to select their path according to a real-time analysis and an evaluation of many parameters to reach destinations (Yilmaz and Temeltas 2019).

One of the challenges of AGV is localization. That includes the determination of initial position, position tracking, kidnapping, position in the idling periods, etc. (Yilmaz and Temeltas 2019; Fanti et al. 2018). From an OHS point of view, some sub-problems of localization may represent risks to the physical and mental integrity of human employees. Kidnapped problem, which refers to a situation when the autonomous vehicle is carried to an arbitrary location, can easily result from incidents like a power cuts off or an unexpected collision or uncontrolled skid. Recovering itself from a catastrophic localization failure or deadlock situation, knowing initial position and tracking real-time position is necessary to keep an acceptable safety level and avoid accidents. And because AGV are smart, autonomous and have the capacity to use all the free space in a factory in carrying out loads from one point to another, the collision risk is higher than for fixed robots or for vehicles having preprogrammed path and tasks. Humans and machines are sharing the same working environment and can enter in collision or go beyond safe limits by accident, especially when AGV management system face complex tasks and multiple vehicles. The result can be an occupational accident with more or less significant damages on human on the physical side as like as in mental and psychological sides.

AGV are smart and connected machines with a relatively high freedom level which let them to take some decision and choices when operating, in order to optimize tasks or to avoid collision. These advantages can, however, have some dark sides. In fact, security of algorithms and cyber security can be a major challenge. Not only because of the possible damages which can result from a security attack, but also and above all because that kind of incident can put the live and the physical integrity of employees in a real and big danger (Clark et al. 2017). This is in addition to psychological issues and mental concerns my result from the insecurity perception of employees who can suffer from anxiety when facing stressful conditions.

5. Big data and Cloud Computing: how safe is it?

Data is one of the most important weapons for any decision maker. Indeed, there is no advantage more useful for managers and employees than to have the relevant data, knowledge and information before starting a decision-making process of any strategic or even simple decision (Li et al. 2019). However, this fact is a double-edged knife. In fact, there is a limit for a human being assimilation before saturation. Information overload and infobesity are some of the possible consequences, among others, of the continuous grow up of information and data quantity and complexity.

Information overload has several negative effects on emotional, mental and physical health and it was proven that this consequence deteriorates work behavior (Roetzel 2019). The ubiquity of information and its availability mostly through smart devices has social and psychological effects on people as it can jeopardize their privacy and expose their personal lives. This can be a big source of stress for them. Many pathologies are associated with the integration of new technologies in manufacturing environment like burnout and exhaustion or impaired judgment and sub-optimal decisions (Knippenberg et al. 2015).

Decision maker attention is more and more demanded and struggles to achieve the goal of keeping only the most important and prior information and data to be the most efficient and effective (Knippenberg et al. 2015). Bad decisions can lead, more or less consciously, to many safety risks as they can cause work accidents. The limited human capacity to procure, analyze and process information as well as their restricted capabilities to bear attention are among constraints that are still relevant in the new era of industrial revolution, even if they were always being present before technological revolution (Knippenberg et al. 2015). Attention is very important when associated to safety. In fact, an inadvertence action can have irretrievable consequences on employees live or physical integrity.

Meanwhile, cloud computing continues to attract SME and large businesses due to many advantages like efficiency, agility, cost effectiveness and boosted storage resources (Jang-Jaccard and Nepal 2014). This, even though from OHS point of view, both public and private cloud computing deployment environments present significant risk (Carstensen et al. 2012). Hybrid computing models are also presenting some security concerns (Catlett 2013). In fact, the changes affecting the computing environments are impacting security. The move from static (from owned computing environment, proper and centralized security components and complex and even only manual configuration and physical infrastructure change possibility by the same organization) to dynamic (outsourcing and hosting environment by third parties) gave birth to new issues. This makes sense, of the fact that when delegating something, the possibility of losing control may increase. There is no more one server (one location) and one user (which can be a whole company) but instead a cloud provider and a cloud user, thing that can justify the existence of a shared security responsibility (Carstensen et al. 2012). A security attack can have the possibility to access to unlimited resources and compromise data and systems integrity (Catlett 2013). This kind of circumstances cannot be, by far, a good thing for mental health and safety of employees since it can be a source of stress and anxiety as like as occupational accidents. Especially when new workplaces, in the industry 4.0 context, are characterized by the importance of data and Cyber security which apparent like a technological issue for computer specialists and users is also and above all, a safety glitch with eventual mental health problems. Mental health pathologies such as anxiety, stress, and information overload and more other pathologies can result from the change that affect the workplace in the industry 4.0 context. New technologies and innovation may result in an irritation of employees since it will disturb

their comfort zone. Occupational accidents and health issues can be the consequences of a non-protected evolution through innovation in manufacturing plants.

Uncertainty, ambiguity and over-information characterize the actual organizational world (St-Pierre and Labelle 2017). Uncertainty caused by the multiplication of communication channels, but also by the continued complexity of the human mind which benefits from technological progress, but which suffers all the more (Karoui et al. 2013).

6. Cyber-physical system and Internet of Things: cybersecurity issues lead to health and safety problems

Since 1988, when Robert Morris (now, MIT professor) developed the first computer worm (called Morris worm), security of networks has always been a big challenge for enterprises and computer scientists. Over the past decades, cyber-attacks have grown in number and have an increasingly severe impact (Jang-Jaccard and Nepal 2014) (cybercrime magazine predicts in their official annual cyber-crime report that damages linked to cyber-attacks in the world will reach the astronomical level of $6 trillion annually by 2021 (Morgan 2019)). Data breach, identity stole, and other cyber criminality may imperil persons, information and physical system's integrity.

In the other hand, embedded systems are also a main part of the new manufacturing environment. Characterized by a high level of autonomy and smartness and being interconnected and connected to internet, embedded systems are very vulnerable to cyber-attacks. Cybersecurity is a major cause for concern since a cyber-attack can have numerous serious consequences on a system operation, on the integrity of information, and on the safety of workers in direct contact with the machines that can get out of hand. In addition, it is an evolving risk that we must review the level of its control continuously, especially as the dangers are constantly developing (Williams 2018).

In a world characterized by technological advancement at all levels, security is becoming a major challenge. Indeed, the security of information systems requires a grandiose effort to ensure an acceptable level of security and to protect against possible data theft attempts (Bahl and Wali 2014). Enterprises are, therefore, in a dilemma: how much to invest in security, knowing that there is absolutely no silver bullet to total flawless security (Chen et al. 2012). There are many things within the organization that can be sources of important and confidential data infiltration. One of the things that can be, if not supported, a weak point in an organization's security level are its own employees (Spears and Barki 2010). Indeed, serious consequences can flow from a fair lack of attention by an employee, and there are many examples of this. A fairly simple act, like forgetting an unlocked computer, can cost the organization or its third-party astronomical losses.

7. Learned lessons and recommendations

The fourth industrial revolution is marking the actual manufacturing context by many paradigms shift. Several notions and methods are still up to date and should be kept. However, the transition to a smart manufactory in the industry 4.0 environ-

ments comes with emergent elements which should be considered linked to innovation and integration of new technologies and embedded systems. In the OHS field, it's even more important to be very attentive during the innovation process because any bad step can have dangerous consequences on the health and safety of human workers and managers. That's why a special care should be taken in the analysis and comprehension of emergent OHS risks before it will be late. It's preferable to have this thought, in the meantime, of the first steps and later during the innovation process progression.

The transition to the manufacture of the future is a long and demanding process. Training and recruitment need to be adapted with the creation of more cyber jobs than traditional jobs. Understanding these needs will greatly facilitate the transition and operation of smart manufacturing (Kusiak 2018). In terms of occupational health and safety, the change of paradigms will result in the emergence of new categories of risks which can affect the health and safety of workers, and which have not necessarily been taken into consideration at the time of design or installation of new technological elements integrating traditional production systems or those newly implemented (Khalid et al. 2017; Bragança et al. 2019; Kohler and Weisz 2016; Badri et al. 2018).

The resistance to change can greatly harm the fluidity and proper functioning of any enterprise involved in an innovation process through industry 4.0. Accidents and mental health issues can also result for a bad management of change. To successfully negotiate this change, it is important to put in place practices that will help employees to accept it and even commit to it (Iverson 2010). Among these practices, good listening to fears related to change. This allows effort to be put where it is needed to address these concerns. It is also important to support the implementation of changes related to the integration of new technologies and emergent manufacturing techniques throughout the process. Good support will facilitate acceptance at the employee level and ensure that a good percentage of change is successful (Davidson 2009).

The concept of learning factory is a new concept used since a little over a decade in many countries in the world, in academic as in manufacturing environment. It consists of a revolutionary training and qualification programs indented to employees or students in special facilities prepared for this purpose. These facilities may be used as a trial environment to test new technologies or processes integration and simulate many scenarios before the official implementation or integration (Schallock et al. 2018). Adapted for industry 4.0, this concept can be used as a platform to test prevention measures, occupational accidents risk scenarios and response plans in case of any OHS event. In addition to the main role of learning skills and knowledge concerning the manufacturing digitalization (Zarte et al. 2019). A dedicated platform has to be set up, taking into consideration all the priorities and needed skills to guarantee a safe transition through industry 4.0 (Sackey et al. 2020).

New industrial ways may be unhealthy for workers and managers. They can be a source of supplementary stress and a fear of missing out perception. This can be even a cause of occupational accidents. A special care must be taken when dealing

with new technologies and advancements during the adoption of the industry 4.0 turns. Indeed, emergent threats are moving the situation almost under control, even if big work is still needed, to a situation which risks being out of control. Many achievements in prevention may be endangered with the rise of new types of OHS risks linked to the growing integration of up-and-coming technological advancement in the workplace of SME and big enterprises. A multi-level risk management plan is one of the options that have managers to enable a real-time reaction as the risks change. Another important point is to include risk management in the planning strategy and even in small-level planning (Jong-Wan et al. 2017). Managers can also opt for more flexible solutions that can ensure a response, at least in part, in unforeseen situations (Zuscovitch 1983).

To improve cyber security in enterprises, one of the most effective practices will be training. Indeed, it is very important to properly train employees on the various errors and spontaneous actions that can be done without paying attention and which can put the safety of the organization or their own safety at stake. It is also important to train them on the seriousness of the consequences that may result. This training must be ongoing to keep employees up to date as this is an area subject to constant change. It is important to be creative and strategic to be able to convey the message clearly enough to employees (Kebbel-Wyen 2016). An informational display system for monitoring can be set up through posters or other visual display tools indicating safety instructions (Kwon and Johnson 2014). Reminders and indications can be strategically installed wherever the risk arises and through fairly clear messages (with photos and clear and attractive writing), in order to maximize viewing and vigilance of the employees.

Commitment has been shown to play a very important role in the success of an organization in general (Hon and Grunig 1999). Likewise, it can facilitate the mission of strengthening the security of information systems within the enterprise. Thus, engaged employees are employees who take information system security seriously and work hard to ensure success, at all levels, in their organization (Spears and Barki 2010). Steps can be taken to increase employees' sense of belonging and engagement. Among these measures, internal communication. Indeed, internal communication is one of the ways used to build a bond of trust, which is an important element in engagement. Communication that must be done on the basis of honesty and transparency, where face-to-face contact is privileged (Togna 2014). On the other hand, leadership practices like inspiring a shared vision, leading by example or encouraging, are practices that have been shown to be effective when used by leaders to increase the engagement of their subordinates (Metscher et al. 2011).

The management of the collaborative human-machine environment in the case of using cobots or AGV must be considered very seriously even before the integration of equipment. Thus, the high complexity level and the uncertainty can make the work of OHS managers hard. Choosing the right metrics to measure security distance and movement zones for human and robot, modulating velocity and a good

control strategy are some proposed solutions to improve safety in this kind of working environment (Zanchettin et al. 2016). On the other hand, cyber-attack scenarios and the impact that can result from every scenario, especially on human safety, have to be prepared, discussed and analyzed (Clark et al. 2017). Prevention is the best way to improve safety and that's why preparing a good risk management plan is crucial to prepare countermeasures for any unforeseen event affecting safety of human employees.

Roadmaps as well as game plans that will be followed by companies wishing to switch to Industry 4.0 must consider much more than purely technical and technological aspects. Human, psychosocial and economic aspects must be taken into consideration to avoid unintended consequences on workers and managers. A multidisciplinary study of the best techniques and efficient means for a progressive adaptation of the human workforce to the new reality and to the existence of intelligent and autonomous equipment in the workplace (Badri et al. 2018).

(Jocelyn et al. 2017) presented a strategy for managing emerging risks related to collaborative robotics, which consists of anticipating these risks and taking these precautionary measures: • Cognitive ergonomics to secure movements in the work area. • Development of the kinetics of the moving parts of the robot in order to integrate intrinsic safety to the operator against static collisions. • Analysis of OSH risks at the robot design stage. • Bio-mechanical calculations of the pain threshold and of the maximum speeds, forces and pressures during collusions before the design of the workstations. • Improved presence detection sensors. • More reliability of the safety-related control parts.

The transition to Industry 4.0 must be put in its economic, social and cultural context. Society 5.0, a concept that was born in Japan in 2016, designates the current and especially future intelligence society in which physical and cyber spaces intersect. In this society, several sectors are changing with the integration of artificial intelligence and innovation (Salgues 2018).

A passage without precautions towards the manufacture of the future can have harmful consequences. Indeed, the sudden transformation of industry with the growing use of the Internet of Things, can be costly in terms of security, if manufacturers do not sufficiently strengthen the culture of security in the daily life of their employees, especially since cyber-attackers have gigantic financial resources and very sophisticated material resources. Manufacturing enterprises must end the culture of "if it's not broken, don't fix it". It is important to revolutionize the culture of safety, by offering more training, better adherence to best practices and industry standards and more openness, transparency and a high level of collaboration (Mohamed 2018).

8. Limitations of This Work

The analysis and the results presented and discussed in this work are done with a specific background. Advantages and challenges of OHS in the industry 4.0 era are examined from an occupational risk management system and a human perspective only. OHS regulatory, legislative and economic perspectives will be examined in future contributions.

Technologies and computer science advancements were not considered from technical and technological side, but as a cause of other health and safety issues.

9. Special Pandemic mention

The world is going through a historical event right now. We have to go back to the year 1918 to relive a similar event, when the Spanish flu claimed the lives of millions of people (between 50 and 100 million according to estimates) (Taubenberger and Morens 2006). Several repercussions on the economy are often expected during and after such events. The industrial sector is one of the sectors that will be affected by the COVID-19 pandemic (the disease caused by the Corona virus discovered in China at the end of 2019). Indeed, currently, several methods and techniques of manufacturing and manufacturing management are starting to be called into question. Methods that have proven good performance and several advantages in productivity and quality, such as just-in-time production, global supply chains and overseas subcontracting. In general, several questions arise regarding the capacity of the modern world to cope with a pandemic of this magnitude.

In the industrial sector, health and safety aspects represent a grandiose challenge in this type of situation. Several sectors considered necessary (such as the food industry, the pharmaceutical industry or that of medical equipment), must continue to operate at the same rate, if not at a higher rate, to ensure the supply of people, companies, hospitals. On the other hand, the workers of the companies concerned must remain healthy and not be contaminated. This is the only way to keep the business running. Contamination of a single worker can have serious consequences for the entire business, including closure. The most worrying subject in these kinds of circumstances is, without a doubt, that of prevention.

Since the first characteristic of a pandemic is rapid contagion, the first concern will therefore be to limit the contagion and to ensure the safety of people. This by following several recommendations made by the World Health Organization (WHO), such as respecting the rules of hygiene or social distancing. In industry, prevention, being a basic pillar of the management of occupational health and safety (OHS), continues to remain important. It is even more urgent than ever to consider the aspect of workplace health in all industrial activities.

With the changes affecting industries with the advent of Industry 4.0, the management of OSH was about to change. The integration of new technologies has several advantages, even if precautions must be taken and changes in regulations and risk management are required (Badri et al. 2018). These technologies allow, among other things, to minimize dependence on humans in several tasks and to have the possibility of remote control (Mohamed 2018). Benefits that promote, a priori, confinement and social distancing.

In this circumstances, one question arises: can Industry 4.0 present solutions to the problems of OSH in the era of the pandemic?

10. Conclusion

The rise of the new information and communication technologies (NTIC) in the several last decades has made a revolution in many activities and sectors from the everyday routine to the highest technological sector. The main reason for that is that

technologies are making things faster, simpler, and effortful. Some other tasks are simply being possible thanks to the usefulness of new technological advancements. Internet, cloud computing, robots and cobots, artificial intelligence, and many other technologies are changing our lives every day.

Industrial world, like other many sectors, is also seeing the impact of this tendency by the continuous integration of new technologies is manufacturing. By the year 2011, this change affecting manufacturing reality was started to be considered as the beginning of a new industrial era which was named industry 4.0 to refer to a fourth industrial revolution. A new era distinguished by connectivity, autonomy and smartness. Many tasks were delegated to robots instead of humans. Machines are connected to each other and to the computer and we are now speaking about the Internet of Everything. Data is bigger and more available and there is no need to worry about storage thanks to big data and cloud computing. Controlling many activities are now possible from the comfort of the divan using Internet. Additive manufacturing and 3D printing is changing efficiency notion and making things easier and costless.

An analysis of the new physical risks associated with the integration of new technologies in the manufacturing environment as part of the Fourth Industrial Revolution has become imminent. Risks due, above all, to sharing the workspace with intelligent machines that interact and have the possibility of being autonomous and of moving around. This can increase the danger of collision and confusion. An analysis which will lead to a better appreciation of emerging risks, which will help managers and OHS specialists to prepare well for the new industrial reality and not lose the knowledge gained in prevention. In addition, a fairly complete understanding of the changes affecting the manufacturing environment is more than necessary to maintain a high level of prevention. Indeed, the integration of new technologies also has a psychosocial and mental effect on workers, which must be taken into consideration in a process of transition towards what can be called the factory of the future. A readjustment of training activities is very important for a smooth transition without damages.

In the other hand, there are challenges and concerns about the too fast change of industrial context in the last few years. Technical implementation challenges, financial challenges, regimentation challenges and cyber security challenges are some of the principal inquires which were identified by recent research studying a perfect and safe transition to industry 4.0. Several recommendations were given to ensure this transition. Occupational health and safety management are undergoing some effects of the change of the workplaces in the new manufacturing era. To keep a good control on prevention, as the main pillar of a successful OHS management, it was important to understand the whole picture and the state of the art of the industry 4.0 transitions on different aspects of OHS management in manufacturing plants. And that was the main goal of this study. One of the most important conclusions is that OHS can't be dismissed from any industry 4.0 roadmaps. Thus, OHS 4.0 should be considered as one of the most important components of any

transition plan; otherwise it will be too late to think about it when changes take place.

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Important field-related web sites:

https://osha.europa.eu/
https://ww1.issa.int/fr
https://www.ilo.org/global/lang--en/index.htm
https://www.inshpo.org/
https://www.irsst.qc.ca/
https://www.iso.org/
https://www.ohscanada.com/
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