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Utility, Advantages and Challenges of Digital Technologies in the Manufacturing Sector

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Abstract

The technological transformations brought on by digital technologies may well make it possible for the manufacturing sector to overcome the challenges of competitiveness and a changing demographic. A literature review of the last six years identified the current uses and purposes of digital technology and its documented benefits and challenges in the manufacturing sector. The value of digital technologies is that they support or enhance human capacities and skills, as well as assist humans in their activities. This can apply to every aspect of manufacturing. The expected impact on production is the improvement of time frames (training, assembly/execution/operations/manufacturing, production idle/downtime, launch), quality, occupational health and safety. Several challenges are reported in the literature as much in terms of cost of investment, as in compatibility of the work or environment, physical and mental workload, risks (reliability, safety, behaviour of the technology) and acceptability (collection and manipulation of confidential data). Digital technologies are bearers of constructive progress. Changes must be carefully planned and humans should be at the heart of considerations. Several questions remain and will need to be addressed with the collaboration of the various work settings.

Keywords: Human Factors Engineering; Industry 4.0; Utility; Usability; Risk, Acceptability

Introduction

In several sectors, industrial players are confronted as much to the challenges of mass customization, short product life-cycle, as to productivity, competitiveness, labour shortage, job attractiveness, workforce diversity (age, gender and multiculturalism) and an aging workforce population [1-13]. In this context, many sectors are open to, among other things, hiring workers with cognitive or motor deficits, as well as retaining workers for as long as possible despite the expected changes in vision, hearing and certain physical and cognitive capacities [10,14-18]. Digital technologies (e.g. voice recognition software, touch screens, gamification, healthcare wearables and others*)* are some of the technologies that can help to overcome these challenges and prolong employment [13,19].

The internet of things and services, cyberphysical systems and smart factories are the key components of Industry 4.0, a paradigm shift in the manufacturing industry striving towards becoming smart factories managed in real time [20-24]. According to certain authors, the ultimate objective is to implement virtual and augmented reality systems (VR/AR) in which humans would only need to intervene in case of emergencies [25]. Others assert that if certain skills might become less necessary or only useful in the future in certain contexts, one should not conclude from this that human work is going to disappear [2,26]. There will be, without a doubt, a need for significant changes. Some predict that highly qualified and multi-skilled personnel will be of the highest importance [4,7]. Cyberphysical systems, smartphones, tablets, smartwatches, head-mounted displays, barcode scanner gloves, smart safety helmets, smart eyewear, smart clothing, data/assembly gloves, drones and other devices are intended to assist workers in their activities [11,27-29]. The term "digital assistants" makes sense for this purpose. The assistance systems provide the user with work-related information, for example, on the operation of devices directly on site when carrying out their work. They offer him possible solutions and decision support [4,27-30].

The possibility of using data taken from photographs, videos, sensors (geolocation, navigation, biometrics), thanks to big data and cloud computing [22], offers new opportunities in communications, visualisation, access to technical documents, organization of activities (content, coordination, localization and temporality), process inspection or surveillance (e.g. errors, execution time, quality), identification of hazardous work areas, worker alerts (presence of risks: contaminants, fatigue) and others [28,29,31-34].

Production systems must now support or enhance the capacities and competencies of humans as well as assist in training workers, especially when the actual work conditions in which the training would take place pose a challenge due to their complexity or dangerousness [35-41]. Some standards (e.g. ISO 9241-210 user-centered design process, ISO 9241-960 for the design and study of gesture interactions or the family of standards ISO 9241 as to visual display and controller interfaces, CSA Z1001-18 for occupational health and safety training) guide, to a certain extent, designers with regards to human factors engineering [37,42]. However, it remains imperative that these developments be centred on humans and the improvement of their quality of life in the workplace [38].

Based on a review of the results documented in the literature, the present article hopes to answer the following two questions:

- What are the current uses or purposes of digital technologies in manufacturing?
- What benefits and challenges do they present?

Methodology

A literature review, dealing with the use of digital technologies in manufacturing, was conducted over a six-year period. This corresponds to an "increase in the number of publications (...) on the subject (...) since 2012" [43]. Engineering Village and Scopus were the main databases consulted. The keywords used in English and in French are: usability testing, 4.0 industry, industrial internet, factory of the future, smart factory, smart production, smart manufacturing, advanced manufacturing, digital factory, cyberphysical systems, ergonomics, human factors, occupational health and safety. The list of references consulted was completed using the snowball effect.

The literature was then sorted according to the internal environment of a company, namely the activities in process design, execution and management of operations. Then, the research teams studying the use of digital technologies were sorted into four geographic regions (Americas, Europe, Middle East and Africa and Asia Pacific) according to the institution of origin of the main author.

Results

What are digital technologies currently being used for in manufacturing?

Digital technologies are being deployed as much in design as in the preparation of the production launch (training and production planning), the implementation and management of the manufacturing processes (Table 1). Interactions between the different elements of the production system must be taken into consideration (Figure 1). In the literature, particular attention is paid to the processes of assembly, maintenance and order picking [44]. In occupational health and safety, human errors, compliance and monitoring of the ergonomics of work stations, use of personal protective equipment, monitoring the impact of the environment on the workers, the transmission of warnings and the proximity of hazardous work areas are concerns.

Documented uses	Americas (Canada, Mexico, USA)	Europe (Germany, England, Austria, Italy, Portugal, Spain, Poland, Finland, France, Greece, Sweden, Turkey)	Middle East and Africa (Saudi Arabia, Egypt, Israel)	Asia Pacific (Australia, China, Singapore, Korea, New Zealand, Japan)
Process design				
Simulation and optimization (e.g. human performance, assembly, plant layout)	[41,45-47]	[13, 48-63]		[43,64-72].
Preparing for production launch				
Training (e.g. assembly, manufacturing, maintenance, identifying and resolving production variabilities and accidents)	[40,41,47]	[15,27,36,51,53,55,73-84]	[85-87]	[64,70,72,88-92]
Planning production/manufacturing, maintenance and management of inventory	[6,93-97]	[24,44,63,74,80]		
Executing and managing operations				
Retrieving, sharing and viewing the documentation (e.g. procedures, work practices, technical characteristics of equipment, environment data, etc.) and dynamic improvement of it (feedback and sharing expertise)	[73,98]	[28,29,51,74,76,78,99-104]		[105]
Retrieving, sharing and viewing contextualised data about production/manufacturing (including errors in ergonomics, errors (including human errors), psycho-social risks), maintenance or inventory management (e.g. order-picking)	[73, 94-98,106-109]	[1,2,5,17,27,28,37,52,53,74-76,80,82,101,110-119]	[120]	[33,69,90-92,120-123]
Providing support to production (e.g. launch, assembly, quality, transportation, maintenance, errors in ergonomics)	[73,97,106,108,109]	[2,12,13,15,27,28,37,51,53,73,75-77,103,111,115,117,124-137]	[120]	[33,69,70,72,88,121,123,180]
a) Inspection or diagnostic of problems and fluctuations in production (including errors) or maintenance	[20,47,95]	[13, 28,29,73-76,101,103,111,116,119,124,138-141]	[120]	[33,70]
b) Providing support during process adjustments/corrections (e.g. assembly, errors, equipment, production planning)	[108]	[13,20,28,29,73,74,101,111,119,124,136,139,141]	[120]	[33]

Evaluating performances (e.g. quality, maintenance)		[28,78]		
Circulating information regarding emergency, rescue, warnings and instructions (production, occupational health and safety (e.g. wearing personal protective equipment (PPE), biometrics and functional parameters of PPE (level of protection, end-of-useful-life, activation threshold attained))	[106]	[5,29,74,142-145]		[33]
Exchanging of information, remote control and prevention for dangerous situations/risk areas (chemical risk, industrial safety, collision avoidance, evacuation)		[51,82,142,144,146,147]		[33]

Table 1: Documented use of digital technologies in production.

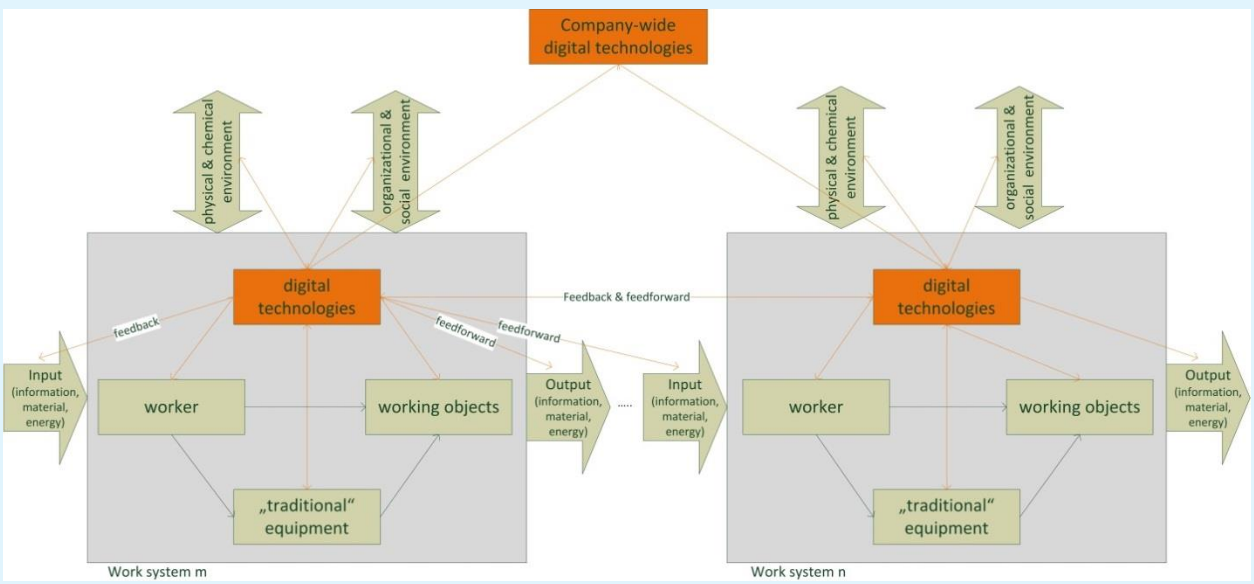

Figure 1: Digital technologies, production system interactions.

What are the benefits and challenges of the digital technologies being used in manufacturing?

These technologies open up new opportunities [19], for instance, they:

- Make it possible to concentrate on added-value and creative activities [121,131].
- Facilitate the transfer of knowledge [121] and restitution of certain types of knowledge and tacit knowledge [120,121].
- Raise risk awareness [34].
- Remove workers from certain dangerous situations [16,19,148,149].

The usefulness in terms of, for instance, shortening the length of time required for training, assembly/execution/ operations/manufacturing, production idle/downtime, length of time to launch, errors, and improving quality among other things must be ensured [2,15,17,28,36,41,44 ,45,51,52,63,69,76,77,78,85,88,90,107,119,121,125,139,1 40,150,151,]. Reliability, safety and the integration of current tools to the processes of the industrial environments of concern must be guaranteed along with their utility and usability and their energy efficiency, [2,12,29,37,40,72,82,83,88,100,104,107,120,127,132,133,138,142,152-154].

A few studies compile, quantitatively, the gains made following the implementation of such technologies. The gains in productivity could be in the order of 40 to 60% in Canada (Aéro Montréal 2018). Results from interviews about the best practices implemented in the German industry (contractors and subcontractors) compile instead gains in production efficiency (costs, quality, speed, flexibility) in the order of 35% [155]; 10 to 30% as for production costs and 10 to 20% as to quality control, [1]; gains of 30% in the electrical industry [156]. This is coherent with the results of [110], who also propose gains in the order of 50% as to the reduction of errors. Gains of 10 to 30% in supply costs have also been observed [1]. Other gains could be possible in maintenance and occupational health and safety (OHS). Some have claimed gains of 10 to 20% in Europe in OHS [24]. In the U.S., [47] noted an improvement of 33% in the lead time, an improvement of 11% in quality and a reduction in work-related injuries by using computer-aided design (CAD) and virtual reality. To the best of our knowledge, very little evaluative research has been conducted and problematics due to the generalization of results are noted [17,86].

All the same, every opportunity carries its lot of uncertainties, resistances to changes and apprehension of costs [44,72,87,137,157-159]. Research on the needs and expectations of the aging users of these technologies is emerging, notably for everything concerning the handling of said devices [160]. The widespread use of said technologies gives rise to concerns as to job satisfaction [38], as well as occupational health and safety [38,161]. Among other things, several studies emphasize the significant challenges as to:

- Mental health in the workplace [5,16,19,103,148,158,162-164];
- Ergonomics/human factors engineering (e.g. weight of these devices, speech detection performance, interfaces, compatibility with the work or work environment, complexity of the task among other things, and workload) [11,15,16,29,30,32,40,44,54,64,65,72,83,85,88,102,103,105,106,125,128,134,137,151,154,158,159,165-167].
- Collection and manipulation of confidential information including worker profiles (skills, experience, expertise, preferences, execution speed and other performance indicators (e.g. rate of errors, and quality among others), work schedule, weight, stature, functional limitations, lighting needs, biometric markers, and geolocation among others) in a context in which the scales of power between employers and employees is uneven [5,12,13,24,37,44,73,75,106,142,143,148,152,164,168,169].

Decisive is the acceptance of the digital technologies by the users [11]. Employees need to understand the benefits of digital technologies and even consider enriching them. It is important to involve employees early in the development and deployment of digital technologies.The possibility that said technologies present an unexpected behaviour (e.g. untimely start up) or that they could be vulnerable to cyber-attacks is of concern and must be taken into consideration from the very beginning of the system's design [12,19,141,147]. The results of industrial applications of digital technologies are ambiguous: work safety and health protection can be improved, but digital technologies can also pose new threats [30].

To the best of our knowledge, few authors discuss the possibility that a worker rely solely on a technology or give up his status as decision-maker or come up with a creative way of bypassing the said technology [8,16,31,148,162,170-172]. Yet, the factors that would lead a worker to trust or distrust automated systems are known and documented, as well as the impacts of stressful situations on the decision-making process [170,173,174]. Introducing technologies that operate in real-time in complex environments also brings its lot of uncertainties and difficulties [175] in the mental representation of the process and its operating rules. Also, the said technologies might not function as expected by the workers and thus, cause accidents or various types of malfunctions [142,170]. The design, management, work organization and human-machine-tasks interactions will thus be significantly transformed [5,12,16,38,105,131,148,164].

Discussion

The original results presented herein make it possible to answer, in the limits of the methodology used, to the two fundamental questions any manufacturing company wishing to invest and implement digital technologies could have.

Automation made its appearance in the manufacturing sector decades ago now and the new digital technologies are making it possible to take manufacturing a significant step further. They provide and will continue to provide access to a considerable amount of data regarding every aspect of a manufacturing system. This being said, "data is not useful unless it is processed in a way that provides context and meaning that can be understood by the right personnel. Just connecting sensors to a machine or connecting a machine to another machine will not give users the insights needed to make better decisions" [108]. In a context of limited resources and emerging technologies, this raises the delicate question of added value in the improvement of various industrial processes, whether the organization is an SME or a multinational operation [157]. Should all the manufacturing system processes be digitized? Or only partially? Which process has the most potential? What is to be done to achieve the greatest competitive advantage? These questions of utility, among others, can only be answered in collaboration with the various work settings.

Developments are occurring at an unprecedented rate "(...) usage (...) remains difficult to predict for the upcoming years given the immense potential of possibilities and their budding development" [108]. Testing the usability, risks and acceptability of said digital technologies will be, more than ever, necessary to ensure its adequate deployment in the industry wherefrom the relevance of initiatives such as living labs [36,60,115,120,153,157,171,176-181]. In the workplace, there will always be risk scenarios that are difficult to detect or manage [157]. Indeed, the undesirable effects of risks have several ways of coming into effect (some of which are ways that are not so well known or cascading effects [107] in which the related systems are complex to such a degree that their behaviour is difficult to anticipate. The currently proposed technologies have their share of challenges. Research and development will admittedly make it possible to traverse these new frontiers. Human judgment will always be necessary.

Conclusion

Digital technologies are a promising solution to market globalization, mass customization and changes arising in the world of work. In the manufacturing sector, these technologies are meant to complement tasks and humans or focus on assisting humans in their activities. Every manufacturing environment is targeted; primary activities, assistive activities and supply chain. The distribution of tasks between human and technology will certainly have to change. In many contexts, the human worker will not only be able to concentrate on what makes him or her superior to the technology, in return, the technology will support human workers in whatever they may need. This is expected to lead to the improvement of several industrial performance indicators. Nevertheless, all these changes require thorough planning. Several challenges still need to be overcome. Several questions are still unanswered due to a lack of documented experience and evaluative research. Industrial partners and initiatives such as living labs will certainly make it possible to clarify the utility, usability, risks and acceptability of the various digital technologies while keeping humans at the heart of all considerations.

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