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Augmented Reality in Logistics 4.0: implications for the human work

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Abstract: The Industry 4.0 paradigm is spreading in logistics processes since integrating 4.0 technologies in logistics tasks guarantees several benefits compared to traditional processes. However, there are still open questions related to impacts on the workforce, including problems related to skills, competence, and several ethical and social issues. This paper focuses on one of the main technologies used in logistics: Augmented Reality (AR). Based on a deductive research approach, which considers a well-founded knowledge represented by extant literature mediated by the authors' direct experience in interacting with companies, the main applications of AR in the logistics field and its implications for human work are investigated. In particular, the three logistics activities most impacted by the AR implementation are analysed (warehouse, transportation, and training), focusing both on the benefits in terms of support and augmentation for the operators and some disadvantages, technical limitations, and human barriers observed during practice and experimentation.

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Keywords: AR, augmented technologies, workforce, human factors, industry 4.0.

1. INTRODUCTION

In recent years, the Industry 4.0 paradigm has become more and more widespread in manufacturing, in both production and logistics processes. A testament to the increasing spread of 4.0 technologies in logistics has been the birth and spread of the concept of Logistics 4.0 to indicate "the logistical system that enables the sustainable satisfaction of individualised customer demands without an increase in costs and supports this development in industry and trade using digital technologies" (Winkelhaus & Grosse, 2020). In particular, the introduction of 4.0 technologies in logistics aims to solve the different criticalities that emerged in traditional logistics. Most parts of these criticalities are related to the high presence in this sector of manual activities (e.g. picking, packing, sorting, driving of warehouse vehicles) that increase the possibility of human errors and the risk of accidents, making the governance of logistics processes more complex (Strandhagen et al., 2017). The need to increase the safety and security of logistics activities is one of the main reasons that lead to the automation of logistics tasks (Cimini et al., 2020). However, even if 4.0 technologies implemented in logistics could solve several issues coming from the presence of the so-called Human Factors (HF), "all physical, psychological, and social characteristics of the humans, which influence the action in socio-technical systems" (Stern & Becker, 2019), the implementation of new technologies should arise new issues related to the skills, competence, and capabilities required from managers and operators to exploit all the technologies' potentials. Indeed, the implementation of enabling technologies involves new types of interactions between operators and machines, influenced by the variability of human behaviour and its reliability, which can strongly affect the quality, safety, and productivity standards (Di Pasquale et al., 2021). Consequently, despite the numerous benefits that technologies can bring to the development of logistics 4.0, there are several questions still under-researched in the scientific literature that need to be addressed to overcome the disadvantages, including several ethical and social issues. These possible negative impacts on the workforce need to be deeply investigated before investing in the new technology, to avoid possible future issues and make the most of all the potential offered by the technology. This research aims to cover this gap investigating the impacts on logistics workers concerning the implementation of Augmented Reality (AR) technology, one of the most promising technology in logistics. In particular, AR, especially associated with wearable devices such as smart glasses or handhelds, should assist the operators working in different logistics areas such as picking and material handling supporting them in the access to data and information.

Two main Research Questions need to be answered in order to understand these impacts:

RQ1: Which are the main AR applications in the logistics field?

RQ2: What are the AR implementation's main impacts on the logistics workforce?

In answering this RQs, the main contribution of this research is the systematization of knowledge about the current and potential AR applications to support logistics operators. The paper will be developed as follow: Section 2 will provide a literature review regarding the main characteristics of traditional and 4.0 logistics. Moreover, the research workflow

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will be presented (Section 2.1). Then, after a brief description of AR characteristics and tools (Section 3.1) the main applications (Section 3.2) and impacts (Section 3.3) of AR in logistics will be shown, aiming to answer RQ1. Section 4 will contain a discussion related to the main benefits and impacts of the AR application in logistics and on the logistics workforce to answer RQ2. Finally, the discussions and conclusion section (Section 4 and 5) will summarise the obtained results.

2. THE EVOLUTION OF LOGISTICS TOWARDS LOGISTICS 4.0

As explained in the introduction, logistics is assuming an increasingly important role in manufacturing, and often a good logistics management strategy allows companies to reduce their operational costs and times significantly. Logistics is a sector where the human factor is still crucial: due to the complexity of some actions and movements, it is complicated to automate many of the main logistics activities fully (e.g., picking, sorting, packing). However, a strong human component also gives rise to critical issues such as worker safety and the high probability of human errors (Jäger & Ranz, 2014). In addition to this, there is the need to track all material movements within the factory (in warehouses and on production lines). This necessity requires the capability of retrieving and managing lots of data to have complete control of the production process steps, the quality of the products, and the availability of the materials (Matana et al., 2020).

Moreover, in recent times, also environmental aspects gained lots of importance, pushing companies to make their logistics processes more green and sustainable (Mörth et al., 2020). All these aspects should become critical if logistics managers do not consider them properly. 4.0 technologies play a significant role in managing these issues by automating some tasks, augmenting operators' capabilities or supporting managers and operators in their decision processes (Table 1) (Cimini et al., 2020).

Table 1. Technological aid for main logistics challenges

	Automation	Augmentation	Support
Reducing Costs	√	√	√
Reducing Time	√	√	√
Increasing Workers' Safety	√		√
Reducing Human Errors	√	√	√
Data Management			√
Inventory Control	√		
Sustainable Logistics Processes			√

According to the taxonomy provided by (Lagorio et al., 2021), depending on the type of flow (material of information) to be managed and on the logistics area considered (e.g., picking, packing, kitting, material handling), different technologies could automate a task or support/augment the worker capabilities in order to help him/her in the task execution.

Implementing 4.0 technologies helps to solve the critical issues outlined in Table 1; however, it also brings other issues, especially concerning implementation costs, the need to integrate technologies with data and information management software, and the skills required to use the implemented technology. The benefits for the workers and the critical aspects related to the implementation of AR technology, especially from the human point of view, will be highlighted in the following sections.

2.1 Research workflow

To adequately address the above-mentioned RQs, our study is built on a deductive research approach in which, starting from a well-founded knowledge represented in this paper by extant literature mediated by the authors' direct experience in interacting with companies, a generalisation is established to be tested afterwards (Hyde, 2000). Relevant literature has been retrieved by well-established databases such as Scopus, Web of Science and Google Scholar to be inclusive concerning the publications types (e.g., journal papers, conference proceedings). Moreover this scientific literature has been integrated with a secondary data (e.g., white papers, consulting companies reports) analysis in order to understand the most innovative developments related to the topic analyzed (Cowton, 1998). The first step of our research is the analysis of the literature about AR in the logistics field. Secondary data have also been used to provide more robustness to the research. We referred mainly to extant literature to leverage on a broader and diverse body of knowledge that, due to the relative innovation of the topics discussed in this paper, would have been hard to gather only from direct experience. The literature review provided the basis for the analysis of the AR implementation in the logistics field (Section 3.2) and its impact on the logistics workforce (Section 3.3).

3. AUGMENTED REALITY IN LOGISTICS 4.0

3.1 Augmented reality definition and tools

Augmented reality is classified as an "immersive technology," along with virtual reality (VR) and mixed reality (MR) (Suh & Prophet, 2018). Compared to VR, whose objects replace physical reality with a predefined environment, the purpose of AR is to intensify the interaction between humans and the environment, without replacing the real with the virtual, but instead going to "increase" the connection with what surrounds us and the perception of objects that we are dealing with. The term "Augmented Reality" has been coined in the early '90s by Tom Caudell and David Mizell, however, these technologies have existed for over fifty years and have evolved (De Pace et al., 2018).

Today, AR means a computer-mediated reality or an interactive graphics system that allows the visualisation of an enriched image by overlapping one or more information layers, whether these are virtual elements, multimedia, or simple data. Unlike VR, in which the image displayed and the related sensory inputs do not necessarily have links to the reality observed by the user, AR technologies provide a supplement of information layers in relation to the environment in which the user operates that is therefore perceived, in real-time, in both its components of observed reality and additional information (Martin et al., 2018).

Ultimately, AR allows bridging the gap between the wealth of digital data and the physical world the data relate to. While reality is three-dimensional, the information used to make decisions and perform actions is trapped on pages and twodimensional schemas. This aspect limits the human ability to exploit the data at hand thoroughly and does not allow for a 360° view of reality. AR fills this gap by bringing to light unique and untapped human capabilities (Porter & Heppelmann, 2017).

Currently, different devices can support AR technology, allowing the users to see the virtual objects and interact with them in the real world. They can be divided into three categories (Syberfeldt et al., 2016):

- Head-worn devices, such as smart glasses;
- Hand-worn devices, such as smartphones and tablets;
- Spatial devices, such as projectors.

These devices implement several types of optics to display information to the user, from simple video, in which the real and virtual worlds are merged into the same display, to retina, in which virtual objects are projected directly onto the retina using low-power laser light; to holograms and projection, in which virtual objects are displayed in the real world using a photometric emulsion that records coherent light interference patterns or using a digital projector (Alcácer & Cruz-Machado, 2019). Different types of displays and devices have strengths and weaknesses, and the choice of the most suitable technology to implement must be evaluated carefully (Elia et al., 2016).

3.2 AR application in Logistics 4.0

Since the origins of AR introduction, the industry has been one of the main fields of application. The evolution of this technology readily responds to the Fourth Industrial Revolution's challenges, so many scholars have appointed it among the Industry 4.0 enabling technologies (Oztemel & Gursev, 2020). Indeed, the applicability of AR in the industry is greatly expanded, leading to increased productivity and an improved work experience since the high potential of AR implementation exists in enhancing human perception on the shop floor (Syberfeldt et al., 2016). Concerning industrial application, Augmented Reality Smart Glasses (ARSG) represents one of the most widely promising devices. They are becoming more and more popular since they are expected to support shop floor operators who perform various material handling, assembly, maintenance, and quality control tasks.

Moreover, smartphones and tablets are within everyone's reach and in the industrial field, in particular, tablets are starting to be widespread, offering a more sophisticated experience due to the size of the displays. In this context, logistics represents one of the most promising areas where AR can bring benefits.

Thanks to the previously described devices, workers performing inbound or outbound logistics operations are supported in the performance of their tasks and mainly benefit from immediate access and a clear view of the information of interest. In particular, analysing the scientific literature, three main logistics areas are the most impacted by the AR implementation: warehouse, transportation, and training.

3.2.1 Warehouse

The first application of AR in logistics concerns inbound logistics and more in detail warehouse management. There are many cases in which warehouse operations can be optimised thanks to the use of AR (Wang et al., 2020). For example, regarding the reception of goods, AR can be used by providing the drivers of the arriving truck with special devices that provide information about the unloading dock. In addition, through tablets or glasses, the goods received can be checked compared to the delivery note, and operators can be shown where to put the items and arrange them in the waiting area. Warehouse operations can also be managed through AR devices that inform the operators of the assigned task. The operator can see the storage location of incoming items, the image, and details of the item to be stored on the screen. The operator is also shown the route to the storage location, which can be quickly followed by simply wearing AR glasses (Fang & An, 2020). AR is also widely used in the shipping area. The devices can show operators what type of packaging to use, what is the best way to place the items, what is the right pallet to ship, but also where to place each order, for example, inside a truck, to have an optimal arrangement according to the type of orders and the destination of the good. Finally, AR is widely used and brings great advantages in the order picking activity, which is often critical. The devices with which the operators are equipped can inform them of the picking tasks assigned to them, allowing them to view the image and details of the item to be picked on the screen. Always on the virtual screen, the workers will be able to visualise the place of storage of the article to pick up and, consequently, the route to follow. Sometimes information on eventual errors or missing products is given. In many cases, AR devices can scan the bar codes of the item to mark it as picked. Examples of these AR applications are implemented in GE Healthcare warehouses (Upskill, 2017) and DHL (Porter & Heppelmann, 2017).

3.2.2 Transportation

A second application concerns outbound logistics and external transportation (Rejeb et al., 2021). In recent years, the increasing import and export of goods also boosted by e-commerce are significantly increasing the transportation flows and, despite economic benefits, logistic providers need to manage high levels of complexity. Once goods are shipped, AR can also reduce delays, support the driver by providing updated real-time traffic data and showing information on optimal routes or redirection of shipments. The benefit of this driver assistance technology is that the driver could either wear smart glasses or directly see the information projected onto the windshield. The driver, therefore, will never have to take the eyes off the road as the information is directly superimposed on the real environment (Glockner et al., 2014). This choice minimises the possibility of error and increases the driver's safety, who with traditional navigation systems (smartphones or tablets) would have to pay attention to both the road and the device. In addition, AR systems can often inform the driver about possible vehicle malfunctions or anomalies on the freight, concerning temperatures or environmental variables that can affect the goods' quality. Even at the delivery stage, AR technologies can support the operator, who can have immediate visual information about packages.

3.2.3 Training

Finally, AR can be widely used in the training phase for logistics operators, since it constitutes an intuitive way to learn how to perform logistics tasks. In the Logistics 4.0

environment, it is crucial that workers are constantly updated and able to use the new technological components and perform their tasks correctly while minimising the possibility of errors. Training, in general, is one of the most important activities that could benefit from AR (Rejeb et al., 2021) and, at the same time, contributes to value creation in logistics. Education, training and coaching are critical functions within the organisation to improve the workforce's productivity. At the same time, however, they are also costly and sometimes, however, the results are not uniform as the information is received differently from the workforce.

Frequently, instructional videos are used, but these are not interactive and are not fully adapted to individual learning abilities. In addition, the equipment needed to learn specific tasks may not be available, and there may be a need for extra training to transfer into the real work environment what has only been learned visually. This issue sometimes leads to unexpected costs that could be avoided with improved training strategies. AR offers a good solution, providing real-time visual guidance through which workers are assured of field training. The entire supply chain operations, from the usage of logistics equipment to the picking up operation from the warehouse, are explained to new operators on-site, step-by-step, with a practical, interactive guide. AR makes it possible to overlay helpful information on the objects with which workers must interact, providing specifications on how to complete complex tasks. Multimedia content provides a rich sensory experience that enhances user-machine interaction and user-user interaction (Elia et al., 2016). This experience often leads to increased worker motivation, who is more interested and feel more protected. In fact, with AR, it is even possible to simulate dangerous tasks or destructive events without risk to new workers, who will have a greater sense of self-awareness.

3.3 AR impacts on Logistics 4.0 workforce

AR can bring about many benefits for users, but in logistics, in particular, its contribution can reach unprecedented levels. Given the crucial role of logistics and its changing nature, closely related to innovation and technological development, logistics operations, from procurement to storage and delivery, must be efficient and effective to keep pace with production and distribution. In doing this, the human factors and roles are of utmost importance. AR devices provide an exponential interaction between the operator and the working environment. AR technology has an impact and involves various company's stakeholders, both at a strategic, managerial, and operational level, given its characteristic of improving the transfer of information from the digital to the physical world. In the logistics field, operators (for example, warehouse or transport workers) are directly involved in introducing and using this technology to carry out their daily work activities. In addition, logistics managers do not personally and directly use AR but must learn to manage it and introduce it into the work environment in an appropriate way.

For operators, AR improves the way they view and access data, how they receive instructions and indications on products, and how they control processes (Fang & An, 2020). By placing the information directly in the context in which it will be applied and providing data in real-time, AR increases the ability to receive and use it, reducing the mental effort to process information and improving the operator's attention. AR also improves the decision-making process as it makes easier how the operator processes information and can increase problem-solving, decision making, and language skills with an expert in connection. Thanks to this improvement in the way the operator interacts with the outside world, AR increases several cognitive skills of the worker, such as memory, learning, perception, making decisions, problem-solving, and attention.

AR reduces human error: even the most experienced workers may suffer from information overload, have an excessive number of procedures to remember, or encounter difficulties in identifying the exact intervention points. AR can help them in the routine of their work. AR technology can offer relevant benefits (e.g. faster cycle times, reliability, reduced failure rate and traceability) to support the operator that becomes "smart" in real-time during manual operations by becoming a digital assistance system to reduce errors and at the same time reduce dependence on printed work instructions, computer screens and operator memory, which a skilled worker must first interpret. In addition, AR technology shows the smart operator real-time feedback on intelligent manufacturing processes and machines to improve decision making.

4. DISCUSSIONS

The digital transformation and the 4.0 technologies will transform the industrial workforce, affecting conceiving the role, functions, and skills of the worker (Lorenz et al., 2015). To successfully adopt the Industry 4.0 paradigm and be able to guide and implement the process of technological change underway most effectively and efficiently, companies must necessarily evaluate and consider the implications on human work.

The analysis conducted in this paper has pointed out how AR brings numerous benefits and improvements in logistics, thanks to the cognitive support provided to workers. In warehouse management, problems such as high costs, many errors, low efficiency, long times, and excessive use of paper systems can be limited thanks to the improvement in operator performance guaranteed by continuous access to accurate information. Similarly, the high costs and waiting times of vehicles and poor coordination between employees in transport management can be improved by ensuring greater safety and support for operators and reducing delays in deliveries.

Table 2. AR aid for main logistics challenges

	AUGMENTED REALITY	
	Augmentation	Support
Reducing Costs	√	√
Reducing Time	√	√
Increasing Workers' Safety		√
Reducing Human Errors	√	
Data Management		√
Sustainable Logistics Processes		√

Whereas, in the training phases, the costs and high training times and the difficulty of understanding can be easily reduced thanks to the training methods with AR, which allows direct contact between the supervisor and immediate access to information. Therefore, it is evident that AR acts positively on two of the main challenges of traditional logistics, on the one hand augmenting operators' capabilities and on the other hand supporting managers and operators in their decision processes (Table 2).

4.1AR practical challenges and implications for human work

However, AR and other enabling technologies also have disadvantages, technical limitations, and human barriers, as observed during practice and experimentation (Bräuer & Mazarakis, 2018; Reif et al., 2010; Stoltz et al., 2017).
Some of these limitations are device-specific, both hardware and software. The tools' battery may not be designed to last for long hours to cover a full working day, and the use of extra batteries carried by operators can be cumbersome. Furthermore, processors overheating and slowing down after long periods of use or when complex computing is required can affect the physical process, or screens might not automatically adapt to a light change (e.g., from moving in and out a building). Programming environment/languages are not standardised, thus making it hard for practitioners to experiment with devices, develop their own applications, and link devices with existing systems. Further technical limitations also impact device users. Many AR devices are not designed for an extended period of continuous use, which can cause comfort problems:

- screen latency can cause headaches,
- non-central view, as the information appears in the upper right or left, creates eye tiredness due to the effort to focus their gaze only on the point of the screen,
- heavy devices are hard to wear.

On the other hand, there are two main human barriers linked to integrating these technologies in the logistics field that should not be overlooked: privacy and skills.
While AR is a technology appreciated by most workers, sometimes users are unwilling to wear these devices or use AR apps for smartphones or tablets due to the perceived privacy issues that could arise from built-in cameras and microphones or permissions allowing access to Face Recognition, Contacts, Location, Microphone, Storage and Speech Recognition (Harborth & Frik, 2021). Considering the possibility for data collection and non-consensual recording, AR involves questions of what data is transmitted and stored, how data is used, how transparent those processes are, who can access the data. This can also have important impacts in terms of workers' acceptance of the AR technology (Bhutta et al., 2015).
Instead, the second main barrier is linked to the workforce's ability to manage change and innovation processes and the hard and soft skills of the employees involved in the use and management of AR (Demir, 2019). On the one hand, the operators do not need high training and technical skills, because unlike in the past, they can see the correct methods to perform a task while they are performing it, be guided by a procedure of visual instructions superimposed on what they see or by voice commands during logistics operations. On the other hand, transversal and digital skills are required to exploit the advantages of AR technology: the use of the new digital interfaces and the ways of iterating with holograms, screens, and touchscreens; the ability to read and interpret the data that is provided in real-time; the ability to quickly make the right decision and solve complex problems because the correct information is available; cognitive flexibility, critical thinking, communication skills, and teamwork.
Indeed, the operators who use the smart glasses, AR apps or spatial projectors in logistic tasks do not need skills and programming specifications of the used hardware/software but skills regarding their usability. For example, the operators must know that there are sensors integrated into the glasses, which allow them to use their gaze to move the cursor, to be able to select the holograms, and that by approaching or moving away from objects, the whole context is correctly scaled accordingly. Alternatively, the operators must know that with simple gestures (e.g., pinch, slide your finger down), they can open apps, select and resize elements and drag and drop holograms into the real world. They must know that it is possible to interact through voice commands, with which it is possible to navigate, select, open, command, and control apps. Furthermore, the operators must be able to be multitasking. AR technology provides devices that allow the operators to have their hands free to view the instructions and information they need to operate, and at the same time be able to continue to carry out the activity without any interruption. The hands-free use of the devices, as happens for other technologies applied in the logistics field (e.g. finger scanner for barcodes or voice picking systems), requires the operators to be able to perform more than one action at the same time, differently from what happened with the use of non-hands-free systems, with which the operators often found themselves managing both the reading devices and the items picked up in their own hands, slowing them down and misleading them.
Therefore, several human barriers must be taken into consideration and cannot be neglected in the introduction of AR technologies in logistics processes. The retraining of workers, especially older ones, will be essential to teach them to use the new digital interfaces correctly and effectively. The transition to a new work logic and digital technologies such as AR is very complex, especially for workers used to working only in physical environments. For this reason, the best form of retraining seems to be that of very specific training on the use of tools, without this involving the deepening of knowledge of specific technologies.

5.CONCLUSIONS

This research offers some useful insights about the main advantages and challenges in implementing AR in logistics. However, this study is based only on a preliminary analysis of the extant literature, which could be further systematized in future research. Moreover, laying mainly on a theoretical background the research does not take in consideration properly the industrial perspective. For this reason, further research will be devoted to gain more knowledge about the impacts of AR on logistics workforce by analyzing some industrial cases, in which AR tools have been already applied or evaluated. The final aim will be to provide companies with guidelines that can drive correct AR implementation strategies taking into account the human factors.

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