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EVALUATING POTENTIAL IMPACT OF INDUSTRY 4.0 TECHNOLOGIES ON SUPPLY CHAINS OF THE FUTURE

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Abstract: Digitalization and Industry 4.0 play a big role in the current world of globalized supply chains which are becoming more and more complex and require real time data based decisions to enable highly responsive measures needed to supply goods from point of origin to point of sale or use. Various concepts such as IoT, 3D printing, CPS, AR, autonomous driving etc. can be related to Industry 4.0. This paper focuses on examining and cross comparing eight technologies related to industry 4.0 that enables more responsive supply chain management activities. It also discusses the impact of industry 4.0 on future supply chains.

Keywords: digitalization, Industry 4.0, supply chain management

1. INTRODUCTION

By different definitions (Stevens, 1989; Lurenco, 2001; Siems, 2005; Ayers 2006; Verma & Kain, 2017) supply chain (SC) is a result of successive links between activities related to the planning, coordination and control of materials, semi-finished products and products from supplier to user. Globalization allows companies to cooperate with each other through the supply chain and each of the companies makes the necessary component, which eventually merges into the final product that will satisfy the customer's needs. However, in order to enable the best and fastest possible supply, with the least possible external influences, the participating companies in the supply chain must operate as uniformly as possible and without major deviations. The more interconnected the supply chain is, the cheaper the production costs, which in turn contributes to a lower product price and a greater competitive advantage for the company in the market (Adisak, 2020; Drljača , 2019). The chain can in this case be understood as chains of material and non-material streams (Klimecka-Tatar, 2018; Klimecka-Tatar and Ingaldi 2020). In order to achieve a competitive advantage, companies have begun to implement a variety of software and robotic services in their processes, which contribute to the best and most accurate work and reduce human

errors (Klimecka-Tatar and Dwornicka, 2019; Wolniak, 2020). The technologies are e.g. Iot, 3D printing, IoS (Internet of Services), autonomous vehicles and others. From all these technologies, therefore, an industry called Industry 4.0 has evolved.
Rojko (2017) and Tay et al. (2019) defined that before Industry 4.0 there were already three industrial revolutions, named industry 1.0, industry 2.0 and industry 3.0. Industry 1.0 began around 1870 with the introduction of steam, which helped improve mechanical production and greatly improve the mechanical sector. Industry 2.0 followed with the introduction of mass production. This was followed by Industry 3.0, which was based on the direct results of the tremendous development of computer and information technology in many countries. But in recent years, when the industry is mentioned, it means industry 4.0 introduced in 2011. It brings a lot of innovations to production that will simplify value chain management through digitization and reduce costs and give businesses a competitive edge (Lasi et al., 2014; Liao et al., 2017; Ray, Zhong et al., 2017).

2. METHODS

This paper is based on reviewing various professional and scientific articles. Websites which have been searched for relevant scientific literature for the subject are as fallow: ScienceDirect, ResearchGate, SSRN, and Google Scholar, which includes articles from all relevant databases.
Following key words were identified to get relevant articles: Supply chain, Industry 4.0, Digitization, IoT, 3D printing, Impact of digitization on supply chain and Impact of Industry 4.0 on supply chain and a combination of all these terms with a link "AND", "OR" and "FOR". First, about 80 articles from all results obtained, which had a title that was relevant to the topic have been selected. Based on the abstract and introduction on all selected articles, about 40 articles that relate to the selected topic have been chosen (see table 1 and table 2).

Table 1
Display the number of hits on the »Sciencedirect« database used, by search string

Database	Key word	Results
Science Direct	Supply chain	525.213
Science Direct	Industry 4.0	210.324
Science Direct	Digitisation	4.381
Science Direct	IoT	26.250
Science Direct	3D printing	35.491
Science Direct	Impact of digitization on supply chain	4.595
Science Direct	Impact of Industry 4.0 on supply chain	15.924

Table 2
Display the number of hits on the »Google Scholar« database used, by search string

Database	Key words	Results
Google Scholar	Supply chain	3.870.000
Google Scholar	Industry 4.0	3.070.000
Google Scholar	Digitisation	103.000
Google Scholar	IoT	992.000
Google Scholar	3D printing	2.390.000
Google Scholar	Impact of digitization on supply chain	42.400

This paper focuses on examining and cross comparing eight technologies related to Industry 4.0.

3. RESULTS AND DISCUSSION

Industry 4.0 represents the future of global manufacturing. According to Tay et al. (2019) it is followed by eight different technologies that are specific to it. These are:

- Internet of Thing (IoT);
- 3D Printing;
- Cyber-Physical System (CPS);
- Internet of Services (IoS);
- Big Data;
- Augmented Reality;
- Autonomous vehicles;
- Cloud Computing (CM).

Comparative analysis of all examined technologies is presented on Table 3.

Table 3
Benefits and disadvantages of industry 4.0 related technology

Industry 4.0 related technologies	**Core benefits for SC**	**Key disadvantage for SC**
IoT	-Communication. -Cost-effective. -Automation. -Privacy & security. -Complexity. -Dependability. -More data and information -Saved time for monitoring	-Yields unemployment -Complexity -Privacy & security -Data must be encrypted
3D printing	-Enables high SC responsiveness -Fast replacement of spare parts -Personalisation of products -Independency from suppliers	-Not yet well developed for all operations, -expensive if printing material is not plastic -requires modelling/designing skills
Cyber-Physical System (CPS)	-The ability of the researcher to control the variables -The researcher is able to measure the extent of the change -The researcher is able to evaluate the cause and effect of relationship -Cost of execution is low compared to other methods -Reduced limitations on geographical reach	-It is difficult to use the method when studying people related issues -It is often done in a controlled environment without external factors -It is time consuming -Not entirely effective with complex and sensitive data -Questions can often be misinterpreted and no chance for clarification especially when mailed -Response can be subjective
Internet of Services (IoS)	-Achieve Customer-Centricity. For any business or any organization, customer satisfaction is a very critical factor that needs to be always focused. -Gathering Rich Data. -Enhanced Security Measures. -Reduction in Operational Cost. -Use of Smart Devices	-There is a risk of leakage of data -Due to its complex network, a single loophole can put entire system down, affecting everyone -With automation, the need of human labour reduces drastically
Big Data	-Using big data cuts your costs. -Using big data increases your efficiency. -Using big data improves your pricing. -You can compete with big businesses.	-Traditional storage can cost lot of money to store big data. -Lots of big data is unstructured. -Big data analysis violates principles of privacy. -It can be used for manipulation of

	-Allows you to focus on local preferences. -Using big data helps you increase sales and loyalty. Using big data ensures you hire the right employees	customer records. -It may increase social stratification. -Big data analysis is not useful in short run. It needs to be analysed for longer duration to leverage its benefits. -Big data analysis results are misleading sometimes. -Speedy updates in big data can mismatch real figures.
Augmented Reality	-Increase user knowledge and information. -AR can facilitate and accelerate the building processes at the factory. -Project managers can monitor work progress in real time through AR markers on equipment. -It can save a ton of time using digital maps and plants. -Pointing a device into location shows how the piece of a machine will fit the final construction.	-Quite expensive to use it in everyday life and it might be less accessible for small businesses -Lack of privacy is major drawback of AR. Low performance level of AR devices is a major drawback which can arise during testing phase. -Lack of security may affect the overall augmented reality principle.
Autonomous Vehicles	-Reduced Accidents. -Reduced Traffic Congestion. -Reduced CO_2 Emissions. -Increased Lane Capacity. -Lower Fuel Consumption. -Last Mile Services. -Transportation -Accessibility. -Reduced Travel Time - Transportation Costs	-Expensive. Self-driving cars are so exciting because they are stuffed to the brim with space age technology, but all this technology is currently astronomically expensive. -Potential For Technology To Go Wrong. -Potential For Greater Pollution. -Potential Loss Of Privacy.
Cloud Computing	-Limitless flexibility to different databases -Better reliability & physical security -Enhanced collaboration enabling users to work together -Accessibility of data anywhere -Simpler device Interface to the cloud -Unlimited data storage -Faster access and processing power -Reduced IT maintenance complexity & cost -Business continuity and Disaster Recovery -Automatic software upgrade in the cloud -Quicker deployment -Reduce cost -Future proofing your business -Easier and improved back up and recovery	-Security and privacy -Control of data -Data mining -Data storage location -Unavailability of certain functionality -Possibility of hacking -Compatibility of infrastructure -Integration with other systems -Lack of knowledge of CPS -Software licensing -Software pricing -Technical issues

3.1. Industry 4.0 representation - global manufacturing

Iot or Internet of Thing represents communication between the digital and physical worlds. Iot is used in various industries, such as automotive, manufacturing, healthcare, to make products and services smarter. In the future, IoT will have revenues more than thirty times higher than the Internet, and will connect 25 billion applications. Iot will also play an important role in supply chains, since connecting companies through network systems will lead to easier communications and better insight into the supply chain of companies. A unique concept of IoT technology is the acquisition of real-time information. »IoT offers a potential opportunity to develop powerful industrial systems

with key technologies such as RFID, sensor and wireless communication. Various industrial IoT applications have been commercialized and are beginning to expand worldwide.« (Manavalan & Jayakrishna, 2019)
3D printing is a fairly new technology and is being used as an alternative product manufacturing technique. The 3D technique is based on making the product layer by layer. 3D printing is a technology that has been gaining ground in recent years and more and more companies are choosing to introduce this technology into the concept of supply chains. Major companies that have already decided to invest in 3D printing in the past are Mercedes Benz, GE and Disney. More and more companies in the supply chain are opting for this technology, with a reason to produce products closer to end customers, in order to improve their supply chains. For businesses operating globally, this is a great advantage, especially when the printers are located closer to end users, reducing the transportation and inventory costs involved. But besides the advantages, 3D printing technology has two major disadvantages. The first downside is that 3D printers have a lower production speed than traditional manufacturing techniques. But this difference is significantly reduced in products that are more complex. Another disatvantage is the initial cost of investing in new technology which for now is not cheap. (Arbabian & Wagner, 2020)
Cyber physical system (CPS) is defined as a transformative technology used to manage interconnected systems in connecting physical things to virtual models. Due to the more frequent use of the physical systems that are in the company, it should be used to make the CPS perform stably and have certain connections between the AIs. CPS is also the foundation for IOT design that can be combined with IoS (Lee et al, 2015 ; Tay et al., 2019). As the CPS is still in the early stages of development, it is essential that the structure is clearly defined in the methodology as guidelines for the use of users in industry. To fulfill these conversations, the CPS has a unified system framework designed for general aplications. Furthermore, corresponding algorithms and technologies at each system layer are also proposed to collaborate with the unified structure and realize the desired functionalities of the overall system for enhanced equipment efficiency, reliability and product quality.
The basic idea of internet services was systematic to use the internet for new value creation in services. Different sectors have views on the approach. Eg. from the IT point of view, services are oriented architecture, services for external operation of business processes and with them trends (Schroth, 2007; Schroth & Janner, 2007). “Internet of Services” (IoS) acts as important components in the automotive industry. Activities are triggered through data transfers in the information technology to make daily mobility safer, easier and pleasant. IoS acts as “service vendors” to provide services through the internet according to the types of digitalization services. These services are available and on demand around business models, partners and any setup for services. The suppliers provide and aggregate the services into additional value services as communication among consumers can be received and accessed by them through various channels« (Tay et al., 2019).
Amanullah et al (2020) and Zhang et al. (2020) define that Big data technology has become inevitable at the moment, especially the growth of the Internet of Things (IoT), which allows communication and interaction with various devices. However, the IoT is vulnerable to breaches of security and personal data. Therefore, new technologies that are safer or combinations of existing technologies have been developed to address these security issues. In addition, the IoT generates large amounts of data and it is

therefore necessary to introduce big data technology to facilitate data handling. The development of industrial big data in smart manufacturing is faster and more accurate. The possibilities for development in this area are almost limitless. In terms of policies, many countries have issued appropriate conditions that allow the opportunity to increase industrial value to be seized. In marketing, the use of industrial big data is still in the development phase, and its potential use value needs to be exploited constantly. Lopik et al. (2020) and Nee et al. (2012) found out that production has been a key contribution to the country's economic growth over the past few hundred years. Due to increasing competitiveness and dynamism in the business environment, the industry is facing new challenges. These challenges are cost, time, quality and flexibility. In order to ensure that companies face these challenges as well as possible and that there are as few errors as possible in the production process itself, they have developed a augmented reality (AR). This allows companies to place the real process in a virtual environment, where they can use various simulations to detect process errors and test new processes that would contain fewer errors. So the term AR is defined as a system that connects the real world with the virtual. Although this system is not the latest, it has come to life due to advances in computing and the consequent increased capacity of computers.

Many authors (Bezai et al., 2020; Mordue et al., 2020) believe that the most important uses of digital and physical world integration are automated driving and autonomous vehicles. Autonomous driving will radically change the transport infrastructure and will bring many advantages, especially in freight transport and the vehicle will be able to drive smoothly without a break, which is currently not possible. Autonomous driving technology will also reduce human mistakes and thus prevent many accidents. But in addition to all the good features that autonomous driving brings, there is still a lot to be done about regulations and reliability. The biggest problem with autonomous driving is decision-making in ethically controversial situations. So far, the driver has played a role in deciding in case of unforeseen situations. While in the future, the predominance of responsibilities will be taken over by various actors, namely: car companies, autonomous vehicle programmers and policy makers.

Next is Cloud computing. Today, cloud computing is a payment-based model that provides convenient access to the network. Cloud computing is used to store data in a so-called "cloud" and allows access to this data via the Internet, without any hardware devices, such as a USB stick. The biggest problem posed by cloud computing technology is that anyone who has access to or somehow enters the database can change the data entered into the so-called "cloud". He can do this without notifying the administrator. Therefore, various protocols have been developed for this technology to help better protect data. These protocols are ciphertext policy attribute-based encryption (CP-ABE); key policy attribute-based encryption (KP-ABE); the fine-grain, multi-authority, revocation mechanism; the trace mechanism; proxy re-encryption (PRE); hierarchical encryption; searchable encryption (SE); and multi-tenant, trust, and a combination of multiple technologies (Mingzhe & Zhang, 202; Sun, 2020).

3.2. Impact of digitisation and Industry 4.0 on supply chains

The development of Industry 4.0 is currently revolving into production or production-related logistics processes. Nevertheless, a positive implementation of Industry 4.0 requires integration across the supply chain. The forerunners of Industry 4.0 were powered by three major technologies: mechanization, electricity and IT. With their implementation, strong technical improvements and higher productivity have been achieved. Industry 4.0, however, is powered by so-called cyber-physical systems (CPS) that rely on the Internet of Things. Cyber-physical systems include the interconnection between the physical and virtual worlds, and the collection and analysis of data. They offer mechanisms for interaction between humans, between humans and objects, and between objects. The benefits of Industry 4.0 are reflected, for example, in real-time monitoring, forecasting, remote diagnosis and remote monitoring, self-organization, greater predictability of errors, and continuous optimization that goes beyond the boundaries of businesses to their customers and suppliers, and across all functions. Real-time interconnection is intended for the entire product life cycle, interconnection, value creation, consumption and recycling (Müller & Voigt, 2018).

CPS, as a basic technology, does not change the task of machines in the equipment used in production, development is reflected in the management of control - from a hierarchically organized system to a decentralized semi-autonomous collective. The interaction between the machine and its operator is also changing. In the production area are included new ways of communicating in the form of mobile devices such as smartphones and smart desks. With innovative applications, employees can have more real-time information available. Data from security vendors and intelligent facilities in other manufacturers say the data requires infrastructure to be aggregated for analysis. That is the only way a business can create raw data in the real amount of production and use it for its decision (Schröder et al., 2014).

The future of Industry 4.0 therefore lies in the connection between machines and humans in cyber-physical systems (CPS). The new systems focus their resources on introducing intelligent products and industrial processes that will enable the industry to make rapid changes in shopping habits. Industry 4.0 also promotes Internet of Thing (IoT), 3D printing, Cyber-Physical System (CPS), Internet of Services (IoS), Big Data, Augmented Reality, Autonomous vehicles and Cloud Computing. The aforementioned revolution envisages an environment where smart machines will be able to communicate with each other so that, in addition to the automated production line, analysis and understanding of a certain level of production and issues that can be solved with minimal human impact will be carried out. Although Industry 4.0 is based largely on the manufacturing industry, its innovations and ingredients will also impact retailers, operating companies and service providers (Tjahjonoa et al., 2017).

To create an innovative business environment, industry managers adopt modern technology such as 3D printing, the Internet of Things, Data Analytics, Industry 4.0. These technologies, including Industry 4.0, significantly alter the behaviour of supply chains. Also important is the concept of Sustainable Development based on Industry 4.0 as it helps industry managers not only integrate environmental protection and control initiatives, but also integrate process security such as resource efficiency, employee and community wellbeing, and smarter and more flexible processes into their care chains (Luthra & Mangla, 2018). Today, globalization is acting as an important economic reason for improving businesses. The key to this is an optimized supply chain aimed at meeting customer needs. Low labour costs in developing countries are forcing developed countries' companies to constantly advance to meet competitiveness. The result of the written wishes are Industry 4.0 and Supply Chain 4.0. Businesses need to incorporate new technology concepts and digitization into their supply chain in order to reduce costs and maximize the quality of their products or services. In addition to technological and digital parameters, social and environmental dimensions are included in this vision and sustainability as such is justified for the success of the supply chain (Dossou, 2018).

Table 4.
Research focus and motivation for industry 4.0 define by different authors

Research	Research focus	Motivator for Industry 4.0
Müller & Voigt, 2018	-Real-time monitoring; self-organization. -Greater predictability of errors.	-Interaction between humans, humans and objects and between objects.
Schröder, Indorf & Kersten 2014	-New ways of communicating in the form of mobile devices such as smatphones and smart desks in production area. -Inovative applications.	-Employes can have more real time information avalible.
Tjahjonoa, Espluguesb, Aresc & Pelaez, 2017	-Industry 4.0 promotes Internet of Thing (IoT), 3D printing, Cyber-Physical System (CPS), Internet of Services (IoS), Big Data, Augmented Reality, Autonomous vehicles and Cloud Computing. - Communication between smart machines will enable the automation of the production line, which will be able to create a product with minimal human impact	-Connection between machines and humans in cyber-physical systems (CPS). -Focused on introducing intelligent products and industrial processes that will enable the industry to make rapid changes in shopping habits
Luthra & Mangla, 2018	-The important is the concept of Sustainable Development based on industry 4.0, witch helps industry managers not only integrate environmental protection and control initiatives, but also integrate process security such as resource efficiency, employee and community wellbeing, and smarter and more flexible processes into their care chains.	-The concept of sustainable development, environmental protection, process safety, smarter and more flexible supply chain processes
Dossou, 2018	Optimizing and personalizing SC performance	Globalization and meetind customer demand

4. CONCLUSION

Industry 4.0 plays a big role in the current world of globalization and due to various concepts such as IoT, 3D printing, CPS, AR and others, it makes it much easier to manage supply chains that are increasingly complex. All of these concepts also allow better insight into real-time data that play an important role for all companies cooperating in the supply chain. It makes it easier to monitor material flow and the decrease possibility of mistakes. Industry 4.0 has made a big revolution based on production and data acquisition itself, and reduced the chances of production itself failing in unpredictable situations. It must be pointed out that much remains to be done with regard to regulation, and this applies in particular to the acquisition and exchange of data without violating human rights.

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