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The Impact of the Industry 4.0 (as a whole) in Supply Chains

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Disclaimer

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Abstract

In the business world of today, costumers increasing demands are pushing the companies to take advantage of technology to optimise their operations, products and services. We are now watching live as the Fourth Industrial Revolution takes place built on the ongoing digital revolution. This paper studies the Industry 4.0 and its possible practical applications in the Supply Chain Management. The concepts of Industry 4.0 and Supply Chain 4.0 and its different components will be scrutinised, and potential benefits and future of this trends exhibited. Additionally, an investigation will be conducted to better understand the level of awareness of the current industrial workforce for these ongoing trends.

KEYWORDS

Industry 4.0, Smart Factory, Supply Chain Management, Supply Chain 4.0

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Word Shortcuts & Glossary

- 3D → Three dimensional
- 12-fold → Twelve times increase
- 5G → Fifth Generation of cellular mobile communications
- AI → Artificial Intelligence
- AR → Augmented Reality
- ATP → Available-to-promise (mechanism that provides a response to customer order enquires taking into consideration resource availability)
- CPPSs → Cyber-Physical Production Systems (mechanisms that combine physical and software components and are controlled and/or monitored by computer-based algorithms where there is a full integration with both the internet and the users)
- CSCMP → Council of Supply Chain Management Professionals
- EEF → Engineering Employer's Federation (UK)
- EWA → Electronics Works Amberg
- IoT → Internet of Things
- IT → Information Technology
- NB-IoT → Narrowband Internet of Things (new radio technology standard that broadens the future of IoT connectivity)
- PLC's → Programmable Logic Controllers (industrial digital computer that monitors inputs & outputs and makes logic-based decisions for automated processes or machines)
- RFID → Radio-Frequency Identification (form of wireless communication that uses electromagnetic fields to identify an object, animal or person)
- ROI → Return on Investment
- SCM → Supply Chain Management

1. Introduction

Over the last three decades, technology, especially information technology (IT) systems, has undergone significant revolutionary progress that has subsequently impacted almost every aspect of daily life. One of the most substantial and core changes is the lost battle of the computers to smart devices that take advantage of cloud computing (Tjahjono, Esplugues, Ares and Pelaez, 2017). For instance, nowadays, the smartphone has become the ultimate control panel that everyone uses to manage their everyday life. This transition marks the beginning of a new era, characterised by computer-based automation and universal computing systems where the rule is using the internet as a portal to the universal wireless network (Tjahjono, Esplugues, Ares and Pelaez, 2017). This digital revolution has made possible not only the interconnection between machines and human beings in a hybrid system but also the direct communication between machines without any human interference. In this case, the flow of information is constant what allows for up to date information in a few seconds. The application of these IT systems to industrial production and business operations is called Industry 4.0.

The introduction of this trend into businesses is going to unavoidably take a toll on the whole supply chain. Digitalisation creates disruption and will require companies to rethink and redesign their Supply Chain Management (SCM) (Alicke, Rexhausen and Seyfert, 2017). Simultaneously, customer expectations are growing and becoming more demanding. Recent trends have led to growing service expectations, much more detailed orders and further individualisation and product customisation (Alicke, Rexhausen and Seyfert, 2017). Customers no longer want to search for products. Instead, they expect companies to analyse their purchase data and send them suggestions of products they might like to buy meanwhile offering express delivery and order tracking. The digitalisation of the supply chain will lead to a Supply Chain 4.0, allowing companies to address these new requirements, the challenges on the supply side and also the remaining expectations in efficiency improvement to satisfy customers better. In this new SCM, the application of Industry 4.0 innovations – such as the Internet of Things (IoT), advanced robotics, cloud computing and big data – will kickstart performance and customer satisfaction (Alicke, Rexhausen and Seyfert, 2017).

This being, to better understand the opportunities, threats and future of the introduction of these new technologies it is necessary to analyse the impact of the Industry 4.0 as a whole in supply chains and this is precisely the primary objective of this paper. To better tackle this problem, the paper will be divided into essentially three parts. In the first one, the focus will be placed solely on the Industry 4.0, a general context and examples will be given. Next, the scope will be placed on the SCM, applications and implications of the Industry 4.0, to this management area, will be analysed. Finally, in the third part, the research questions will be brought back to the spotlight, and the results of the investigation will be presented and discussed. All the sources used throughout will appear in the Bibliography. There are no appendices attached to this paper.

2. Research Questions and Methodology

Before developing the research questions, preliminary research was conducted to better understand if the impact of Industry 4.0 in supply chains is, in fact, a real problem for the current business environment. After conducting this research, the identified problem had a solid foundation, and therefore two research questions were identified, being the first one (a) "What is the Industry 4.0 and where to apply it?" and the second (b) "What are the applications of the Industry 4.0 in supply chains and major pros and cons?".

To tackle these research questions, the following methodology was outlined. At first, secondary research was conducted, resorting to books, journal articles and online articles, followed by primary research, based on interviews. The objective of having two stages of research was to allow the primary phase of research to validate de information gathered in the second phase. Like all the other sources, the ones used in the secondary research will appear in the Bibliography. For the primary research, two informal interviews were conducted, being one of them a group interview. All interviewees work for the same medium size industrial manufacturing company located in the Lisbon metro area, Portugal. While in the group interview the respondents were four workers, the subject interviewed alone is an engineer responsible for the management of the plant. It is vital to state the company itself did not cooperate with the investigation, so there was no access to either the facilities or any official documents. For this reason, the name of the company will not be disclosed, as well as the name of the participants. This being, the interviews were also not recorded, and the focus was placed on the individuals previous working experience rather than in the reality of their current work environment.

Regarding the structure of the interviews, they were semi-structured. The reasoning behind this decision was the following: since there was no guarantee the subjects, at least the workers in the group interview, were aware of what Industry 4.0 is and its impact in the supply chains, the interviews instead of being structured with questions they were organised by topics. The first one is as about the definition of Industry 4.0. If the individuals did not know what this trend is a brief explanation would be given before addressing the second subject which was the applications of Industry 4.0. Next, the second part of the interview addressed two other topics, the first one was the applications of Industry 4.0 in supply chains and the second covered the advantages and disadvantages of this phenomena. This kind of structure allowed the individuals to feel like they were involved in a conversation rather than in a survey-like interview.

Finalised both stages of research, the data outcomes will be compared to answer the two research questions, and in the end, the overall results of the research will be discussed.

3. Contextualisation of the Industry 4.0

3.1 Literature Review

Back in the 1780s, the introduction of water and steam-powered mechanical production sites marked the beginning of the First Industrial Revolution (Schrauf & Berttram, 2016; Datex, 2017). Approximately three decades later, electrical drives, combustion engines and breakthrough assembly line production systems initiated the Second Industrial Revolution, later consummated by the creation of the first electricity-powered assembly line in the 1870s (Pfohl, Yahsi and Kurnaz, 2015). This landmark allowed the development of mass production being responsible for bringing to life many of the products that are still considered essential nowadays (Schrauf & Berttram, 2016; Datex, 2017). Later, in the 1960s, the first programmable logistics controller was developed, enabling production automation, what started the Third Industrial Revolution (Schrauf & Berttram, 2016; Datex, 2017). Characterised by the enormous automation of the production processes, the Third Industrial Revolution set the basis for the ongoing fourth one where complex system of hardware, data and software components meet in one single product (Bauernhansi, ten Hompel and Vogel-Heuser, 2014; Brettel et al., 2014, quoted by Pfohl, Yahsi and Kurnaz, 2015). This ongoing Fourth stage of the Industrial Revolution that has changed and shaped the world by enabling greater sharing of intel in real time and collaboration is commonly referred to as Industry 4.0, the advent of digital transformation (Datex, 2017).

The term "Industry 4.0" was coined in Germany, by the government, ex-ante for an expected next stage of the industrial revolution (Glas & Kleemann, 2016; Lasi et al., 2014, quoted by Tjahjono, Esplugues, Ares and Pelaez, 2017). Although this trend is not ultimately defined, many authors see it as a global transformation of the manufacturing industry motivated by the digitalisation and the Internet (Brettel et al., 2014, quoted by Pfohl, Yahsi and Kurnaz, 2015; Tjahjono, Esplugues, Ares and Pelaez, 2017). These transformations include breakthrough improvements in the design and production processes, but also in operations and services associated with manufacturing. The Industry 4.0 is not about a single technology, is instead about the interaction of multiple innovative technologies, all coming to maturity right now, that when put together can create new ways of production (Schmidt et al., 2015, quoted by Glas & Kleemann, 2016). These technologies include: artificial intelligence (AI) and advanced robotics; high-tech sensors; cloud computing; the IoT; big data capture and analytics; digital customisable manufacturing (namely 3D printing); software-as-a-service and new marketing models; smartphones and other mobile devices; and platforms that use algorithms to direct motor vehicles (like autonomous driving and delivery & ride services) (Geissbauer, Vedsø and Schrauf, 2016). When joined together, these technologies integrate the physical and virtual worlds, enabling new powerful ways of organising the global operation. These so-called cyber-physical production systems (CPPSs) are online networks of social machines that are organised in a similar way to social networks, i.e. they link IT with both mechanical and electronic components that then communicate with each other through a network (Deloitte, 2014). Smart networks of this kind are the foundation of smart factories which themselves support Industry 4.0. Smart factories use technology to collect data that is then analysed and used to provide immediate insight (Datex, 2017). As the CPPSs, smart factories are engineered so that its operations can be monitored, coordinated, controlled and integrated via a computing, communication core. Numerous trends have accelerated the drive towards the adoption of smart factories such as the: dramatic and rapid advancement of technological capabilities; increased pressure from competitors and unexpected sources; and continual labour challenges (Datex, 2017).

According to Deloitte (2014), Industry 4.0 has four main characteristics. The first one is the vertical networking of smart production systems in the factories of the future. Using

CPPSs plants can react rapidly to changes in demand or stock levels and faults, i.e. production can then be customer-specific and fully individualised. CPPSs allow not only autonomous organisation of manufacturing management but also maintenance management, increasing, therefore, resource efficiency. The second core characteristic of Industry 4.0 is horizontal integration through a new generation of global value chain networks. These enable integrated transparency, offer a high level of flexibility to respond to problems, and facilitate better global optimisation. With the integration of both customers and business partners utterly new business models and new models of cooperation can be developed, what represents a massive challenge to all involved parties. The next characteristic is cross-disciplinary through engineering across the entire value chain and the full life cycle of both products and customers. By occurring seamlessly in all stages of a product's life cycle, new synergies can be created between product development and manufacturing systems. Finally, the fourth main characteristic is the impact of exponential technologies as an accelerant or catalyst that allows an individualised solution, flexibility and cost savings in industrial processes. Technologies like AI, advanced robotics and high-end sensors have the potential to increase autonomy, customisation and flexibility.

To establish a real Smart Factory, the value created inside the industrial manufacturing facility as well as across the entire supply chain network would need to be maxed out. This can only be achieved by having horizontal integration through operational systems that power organisations as well as vertical integration through manufacturing processes that are linked and an end-to-end integration that permeates the entire value chain (Datex, 2017).

3.2 Case Studies and Applications

3.2.1 Ericsson

Ericsson is a Swedish company that enables communications service providers to capture value connectivity to the fullest. The company's portfolio spans networks, digital services, managed services, and emerging business and is designed to help their customers go digital, increase efficiency and find new revenue streams. (GSMA, 2018). Ericsson's investments in innovation have benefited billions of people around the globe.

To validate business value and guarantee 5G meets actual industry requirements, three Ericsson factories in Sweden, Estonia and China are fast-tracking the introduction of a new generation of smart manufacturing (Ericsson [a], 2018). According to their managers, developing and implementing the first 5G and Industry 4.0 systems in a real production plant will allow the company to take a competitive edge by reaching maturity more rapidly.

The plant in Sweden is known as "The 5G Factory" and is seen by Ericsson as the perfect inventor's playground where engineers and innovators are taking crucial steps to shape the future of the company's manufacturing processes. The site that produces test beds for 5G and ships them across the world is the perfect environment to trial new 5G and Industry 4.0 innovations in a real production environment (Ericsson [a], 2018). One of them is precise localisation technology which uses low-power tags to transmit real-time location data to the cloud. These can be placed on anything and enable the traceability of inventory, reducing the loss of assets and ultimately improving end-to-end efficiency.

Ericsson sees the site in Estonia as "The Digital Factory". The company takes advantage of the country's innovative culture to empower Ericsson's production capabilities and foster the introduction of new Industry 4.0 technologies to manufacturing. These include, as an example, the introduction of cutting-edge augmented reality (AR) troubleshooting solution, which alone has already more than doubled the team's effectiveness (Ericsson [a], 2018).

Finally, there is the crown jewel of Ericsson, "The X Factory" in Nanjing, China. This manufacturing plant uses narrowband-IoT (NB-IoT) to connect 1,000 devices within the factory which allow it only to stop production one day of the year – Chinese New Year (Ericsson [a], 2018). This connectivity is used to monitor the location of assets, stock levels, environmental factors and the performance of test fixtures and production tools. (GSMA, 2018). By having connected high-precision screwdrivers, the manufacturing operations manager can measure accurately when these tools need to be recalibrated based on their actual use rather than on a predetermined periodic basis. This solution alone, which only costs $20 per screwdriver, will save Ericsson $10,000 annually. Another example of savings is the wireless sensors, which are merely placed on existing industrial equipment and have a lifetime of up 30 years, while cables, which are prone to connector failures, can cost up to $200 per meter (GSMA, 2018). According to Ericsson [b] (2018), the first year showed a 50% return on investment (ROI), and breakeven is projected within two years. Furthermore, wireless connectivity allows flexible production lines which can be configured on-demand.

3.2.2 Siemens

Global engineering giant Siemens is widely considered as one of the best examples of a company making use of Industry 4.0 technologies. For a company that makes technology to allow other manufacturers to adopt Industry 4.0 functionalities, it was important for Siemens to practice what it preaches (RS Connected Thinking, 2018).

Siemens manufacturing plant in Amberg, Germany, has won multiple awards for its advanced product automation, optimisation and integration with the company's IT, and is known as "The Factory of the Future" (RS Connected Thinking, 2018). Since its construction in 1989, this factory has been considered as a template for other companies to follow. The Siemens Electronics Works Amberg (EWA) manufactures a range of products including type Simatic programmable logic controllers (PLCs) which are used to control anything. Around 1,000 Simatic components also control production processes in EWA itself, being 75 per cent of the value chain handled independently by machines and robots (Zoefeld, 2017). EWA also relies on software components from the Siemens Digital Enterprise Suite, such as Teamcenter, Mentor, SIMATIC IT and MindSphere, which allow simulations of a new development to be run using a digital twin (Zoefeld, 2017). This factor provides the guarantee of outstanding product quality. In an average year, it produces 16 million PLC's – that is one control unit per second – and production quality at the factory is at 99.99885%. Without increasing the square footage of the production area, which is around 10,000 square meters, and with almost no change to staffing levels, EWA has increased its manufacturing capacity by 12-fold (Zoefeld, 2017).

Reassuringly, the head of the plant, professor Karl-Heinz Büttner, states that the objective as never to create a workerless factory. Even though machines are more efficient in performing tasks, they do not come up with ideas for improving the system itself, that it up to the technicians (Barbato, 2015). For Büttner, manufacturing challenges are overcome only with a modern and flexible production environment and through cooperation and constant information exchange (Barbado, 2017). Only human intervention can close this loop.

3.2.3 Tesla

When people think about the youngest, most erratic U.S. automaker's assembly line, the word "automation" often comes to mind. This is all due to the infamous words Elon Musk said during a 2016 investors call: "Our internal code name for the factory, the machine that builds machines, is the alien dreadnought (…) when our factory looks like an alien dreadnought, then we know it is probably right" (DeBord, 2016).

Today, Tesla's factory in Freemont, California, which is pioneering vertically integrated manufacturing controls a good deal of the company's destiny, is one of the most advanced automotive plants in the world (Fortuna, 2018). The plant is crowded with the red arms of high-powered German robots, more than 1,000 alone work on the new Model 3 body line. Unlike in traditional auto plants, in order to save space, nearly a third of the robots hang from the ceiling (Harwell, 2018). In a visit to the factory, Bhattacharji (2017) a reporter from Wired, observed several innovative automation processes, namely: the chassis are welded together by Cold Metal Transfer welding robots designed to work on Tesla's aluminium frames; a vast number of Kuka robots work on the final assembly line, they are not restricted to stamp, paint and weld; and the stamping centre produces a week's worth of each part before retooling to make another piece, this maximises efficiency. At the end of the visit, according to Bhattacharji (2017) Tesla's facility "is like a secret Willy Wonka factory of wonders, except customers come in and out to pick up their new cars".

Elon Musk always saw the future of Tesla has to be "completely inhuman". According to the founder, the auto assembly is not the best use of human life and a fully automated factory could be operated by only a few human experts (DeBord, 2017). Although, earlier this year Musk changed his mind and used Twitter to say that "Tesla's excessive automation was a mistake" and that "humans are underrated". Later in an interview, Musk agreed that the company put too much new technology into the Model 3 production all at once and that the network of conveyor belts has so complicated it was slowing the process down (Geggel, 2018). Tesla's push to automate every finicky detail led to major delays. Nowadays, workers are stationed on nearly every part of the production line (Harwell, 2018).

Unlike the previous case study, Tesla is an example where it is concludable that technology can be beneficial to a particular scale and that the human factor cannot be removed from the manufacturing production equation.

3.3 Pros and Cons of this Trend

Instead of talking about the pros and cons of Industry 4.0 it is better to discuss these topics focusing on smart factories since they are the primary outcome of this trend.

Like it has been mentioned until this point, transforming a plant into a Smart Factory has its benefits. The principal reasons for investing in a Smart Factory include: increased asset efficiency, translated into reduced asset downtime, optimised manufacturing capacity and decreased substitution time; products with better overall quality, with lower rates of defects and recalls; more efficient processes and better quality products allow for lower overall costs (reduced warranty, maintenance and recall & return costs); improvement in workforce safety thanks to decreased incidence of industrial accidents and the reduced need for activities that require repetitive fatiguing motion; enhanced sustainability due to optimised resources and smaller environmental footprint (Datex, 2017).

Although having a Smart Factory is not all fun and games, since some problems are going to come with it. The primary concern for the companies is the IoT security, especially related to loopholes in the systems. Another major problem is the lack of training and skills that the workers currently have to be able to work with Industry 4.0 technologies. Tackling these two main problems means that the companies need to significantly increase their budget for both the staff's training & development and cyber-security. Other significant problems include: the adoption of a Smart Factory is a substantial threat for the redundant workers in corporate IT departments; general reluctance to change to a Smart Factory by company's stakeholders, especially in small to medium size enterprises; and the reliability and stability required for CPPSs which demands very short and stable latency timings in the system (Dawson, 2018).

3.4 Future of the Industry 4.0

There is a vast number of predictions about how Industry 4.0 will impact manufacturing processes around the world and how is going to change the nature of the industry. Although, there is a consensus around the fact that the companies that adopt this trend will see financial rewards for their investment. To have an idea, a report from the professional community

Wikibon estimates that by 2020 businesses will spend around $500bn on Industry 4.0, but this technology will create a value of $1.28tn (RS Connected Thinking, 2018).

According to the British Engineering Employer's Federation (EEF) Senior Policy Adviser Chris Richards, the pace of Industry 4.0 adoption will vary greatly between businesses: "While some companies who have a forward-thinking leadership will invest heavily in Industry 4.0 aiming to fully adopt the trend over the next five to ten years, others will follow a gradual learning process of increasing their use of technology". Richards also suggests that companies will try to create new business models where the manufacturer retains ownership of the product, allowing them to embed technology into the products which can feedback data in real time for future use in product development.

Even though there is an ongoing debate about the potential of this model, it is almost impossible to predict the exact outcome of this trend and its influence on the whole manufacturing sector. Just like mobility services have been disrupted by Uber and holiday accommodation by Airbnb, the manufacturing world must wait to see what sort of disruption will be caused by digital connectivity (RS Connected Thinking, 2018).

Between all the experts, though, one thing is clear: doing nothing is not an option. Businesses need to be aware of technology, invest in it at a suitable level, benchmark and prepare for future developments. Is going to come to a point where the technology becomes omnipresent, just like mobile devices and wireless internet.

4. Supply Chain and Practical Application of the Industry 4.0

4.1 Supply Chain Management

The SCM has been evolving throughout the years to satisfy the needs of the growing global supply chain. Due to this, the number of subjects covered by the supply chain has significantly increased causing the definition of SCM to become unclear, often being confused with Logistics Management. This was the main reason why the Council of Supply Chain Management Professionals (CSCMP) decided to create official definitions for the terms. According to the CSCMP (2013), SCM "encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all Logistics Management activities.". Moreover, it includes coordination and collaboration with channel partners. In short, SCM integrates supply and demand management within and across companies (CSCMP Glossary, 2013). On the other hand, Logistics Management is a part of SCM that is responsible for planning, implementation and control of the flow and storage of goods, services and related information between the point of origin and the point of consumption, guaranteeing the costumers needs and expectations are met (CSCMP Glossary, 2013).

Given this definition, for this paper, SCM is defined as the set of management functions that ensure both the physical flow of products (transformation, logistics and storage), and services, and the information flows around them, which allow the coordination of all the involved parties (suppliers, intermediates, outsourcing partners and customers), from the source of the raw materials until the hands of the final consumer.

4.2 Practical Application of the Industry 4.0 in SCM: Supply Chains 4.0

According to the three McKinsey & Company consultants Alicke, Rachor and Seyfert (2016), Supply Chain 4.0 is the application of the IoT, the use of advanced robotics, and the application of advanced analytics of big data in SCM. In a place where automation is key, sensors need to spread out, networks need to be created everywhere, and everything needs to be analysed to improve organisational performance and customer satisfaction. Supply Chain 4.0 will impact all areas in SCM, namely planning, physical flow, performance management, order management, collaboration and supply chain strategy (Alicke, Rachor and Seyfert, 2016).

First, when it comes to planning, this area will mostly benefit from big data, advanced analytics and the automation of knowledge work. The two biggest levers for this are: "predictive analytics in demand planning", which analyses hundreds to thousands of both internal and external demand influencing variables, with machine learning approaches, to discover and model the complex relationships and derive an extremely accurate demand plan; and "closed-loop planning", which breaks the tradition and transforms planning into a flexible and continuous process by considering the projected demand probability distribution and replenishes to fulfil a particular service level (Alicke, Rachor and Seyfert, 2016).

Then, regarding physical flow, there will be a huge step forward thanks to better connectivity, advanced analytics, additive manufacturing and advanced automation. As warehouses are being automated, autonomous vehicles will become the standard, and 3D printing will dramatically change warehousing and inventory management strategies by increasing the level of flexibility. Whereas optical head-mounted displays, such as Google Glass, will provide location-based instructions to workers, exoskeletons will have a significant impact on warehouse productivity. Meanwhile, autonomous and smart vehicles will lead to significant operating cost reduction and provide benefits regarding lead times and lower environmental impact. Apart from automation, additive manufacturing will also have its impact, as the range of applications of 3D printing has become broader (Alicke, Rachor and Seyfert, 2016).

When it comes to performance management, granular data available in real time from both internal and external sources has transformed this area into a more operational process, aimed to solve exception handling and allow continuous improvement. One approach to deal with exception handling is through automated root cause analysis where the system identifies the root causes of an exception using a comparison method or conducting big data analysis, leveraging data mining and machine learning techniques. Having identified the root cause, the system will then deal with the situation by triggering countermeasures (Alicke, Rachor and Seyfert, 2016).

Next, in order management, "no-touch order processing" and "real-time replanning" are two great examples of how Supply Chain 4.0 has improved this area. By integrating the ordering system, linking to the available-to-promise (ATP), and through upgrading with order rules, the ordering process can be fully automated using this system, meaning there is no manual intervention between order intake and order confirmation. Meanwhile, order date confirmations are possible due to instantaneous, in-memory replanning of the production schedule and the replenishment in consideration of all constraints (Alicke, Rachor and Seyfert, 2016).

Moving on to collaboration, supply chain cloud forms allows for next level collaboration between customers, the company and suppliers, providing both a shared logistics infrastructure and joint planning solutions. This way, partners can decide to tackle supply chain tasks together to save administrative costs and foment continuous learning. Another major field within this area is the end-to-end connectivity which allows for overall much lower inventories, a step change in lead time reduction, an early-warning system and gives the companies the ability to react fact to disruptions anywhere (Alicke, Rachor and Seyfert, 2016).

Finally, thanks to Supply Chain 4.0, supply chain setups adopt many more segments. This being it is crucial the mastering of micro-segmentation. The granularisation of the supply chain based on customer requirements and own capabilities developed in a dynamic, big data approach, allows to mass-customise supply chain offerings. This tailoring provides optimal value for the customers and helps minimise costs and inventory for the companies (Alicke, Rachor and Seyfert, 2016).

This digitalisation of the supply chain will bring about a Supply Chain 4.0 which is going to be: faster, with lower delivery times and faster forecasting approaches; more flexible, thanks to real-time planning and new business models; more granular, through micro-segmentation and by offering “logistics menus” to the customers; more accurate, thanks to automation and real-time, end-to-end transparency throughout the supply chain; and more efficient, boosted by the automation of both physical tasks and planning (Alicke, Rachor and Seyfert, 2016).

Although, the Supply Chain 4.0 also brings a major concern with it in the form of digital waste. Digital waste is a factor that can prevent the supply chains from leveraging the potential of Supply Chain 4.0. It is crucial that managers can identify the sources and develop solutions to either reduced it or avoid it. According to Alicke, Rachor and Seyfert (2016) there are three types of digital waste sources: (1) data capturing and management, for instance when the available data is analysed manually, not updated regularly and then remains unchanged for years; (2) integrated process optimisation, many companies, even though they have an integrated planning process, this process is still done in silos and not all information is leveraged to achieve the best result possible; and (3) physical process execution of humans and machines, since nowadays many of the supply chain processes are done based on gut feeling, but not leveraging available data.

4.3 Case Studies and Achievements

4.3.1 Adidas

Thanks to a Supply Chain 4.0 initiative, in Russia, Adidas was able to increase sales in the city of Moscow by double digits in only 24 hours (Cordon, 2017). The leading sports shoe brand in Russia, with well over 1,200 stores, as part of its strategy to satisfy the costumer's needs, decided to implement an omnichannel strategy. This would allow customers to buy, both online or in a physical store, any product that is available anywhere in the country, and for it to be delivered to them at home, at the store or even at a pick-up point. This was achieved by combining radio-frequency identification (RFID) chips, "ship from store" tools, a digital "click and collect" solution and "endless aisle" technology (Cordon, 2017).

It all started with the implementation of a pilot "click and collect" – buy online and collect the product at a store – in Moscow. Adidas expected only a few customers to utilise this option, projecting 10 to 20 orders per week, although this idea was very well received, and orders reached 1,000 per week (Cordon, 2017). This being, Adidas was forced to stop the pilot and develop the necessary SCM infrastructure to support the demand levels, and nowadays 70% of the online sales are through this service. Another successful example is "ship from store". In the largest country in the world, fast shipping can take up to 15 days, but thanks to this service Adidas drastically reduced delivery times and increased sales (Cordon, 2017). Thanks to these initiatives, Adidas Russia redefined what supply chain is, moving on from costs reduction and focusing now on increasing sales. Without Supply Chain 4.0 this would not be possible.

4.3.2 Amazon

Back in 2016, the tech giant and the biggest retailer online introduced a conceptual drone-based delivery system named Amazon Prime Air (Amazon, 2018). This service will work just like any other Amazon shipment allowing small orders with less than 2.25 kg to be delivered in 30 minutes or less to a location within a 10-mile radius of an Amazon order fulfilment centre. From the moment the order is in the air, the buyer will be able to track the entire delivery process, knowing exactly when it will land. These autonomous drones will be equipped with a technology Amazon calls "sense-and-avoid" which will ensure they do not hit any obstacles during flight, such as trees, birds or lampposts (Amazon, 2018).

Even though many supply chain executives see this idea as "outrageous", it also makes much sense. According to Cordon (2017), the obsession with lowering costs has been around for decades and for companies that are looking at savings regarding cents and not euros, of course delivering by drones looks crazy to them. Although in Amazon's case less than 30 minutes deliveries means lowering the rate of return of products, fewer returns mean higher sales, higher profit and lower logistics costs. This means, the comparison is not about costs, is instead about sales (Cordon, 2017). There are many tools to understand supply chain costs but none about increasing sales, however, Supply Chain 4.0 requires the focus to be placed increasing sales through a better understanding of how customers behave (Cordon, 2017).

Although the official announcement was almost three years ago, this service did not take off yet. At an internal level, Amazon says the level of security of the drones needs to be tested thoroughly. Externally, the company is dependent on the Federal Aviation Administration (FAA) regulations which restrict drones flying out of the "line of sight" of their operators. Until the drones can be operated safely and the FAA changes its restrictive aerial vehicle regulations, Amazon prime customers have to rely on two-day shipping (Amazon, 2018).

4.3.3 Alibaba and STO Express

In China, the world's largest retailer, Alibaba, and one of the biggest national courier services providers, STO Express, are both in the front line when it comes to smart warehousing. In the last couple of years, both these companies have made tremendous investments to automate their respective logistic centres to the fullest.

Back in 2017, T-mall, subsidiary of Alibaba, opened the largest smart warehouse in China. Situated in Huiyang, this warehouse has a footprint of 3,000 square meters and is manned by 60 cutting-edge Wi-Fi-equipped and self-charging robots (You [a], 2017). These machines role is to move goods in the warehouse and deliver them to human workers who then sort the products into the packages and posts them to clients around the world. The robots receive instructions via Wi-Fi, and they are fitted with laser detection what keeps them safe from each other (You [a], 2017). When fully charged they can work a full eight hours shift non-stop. According to Quicktron, the manufacturer, these automated delivery boys have increased the warehouse output by threefold in only a month. With the help of these robots, a worker can sort 3,000 products in a shift with only 2,563 steps (You [a], 2017).

STO Express is another Chinese firm that is known for its investments in automation. In their warehouse, located in Linyi, 300 robots work together to sort 20,000 parcels an hour, 200,000 a day. According to Hikvision, the manufacturer, these machines not only save the company 70% of work power in their 21,000 square-foot warehouse but also improve the overall quality of the sorting process (You [b], 2017). A spokesman of the manufacturer also stated that it would take a worker five hours to sort the number of parcels a robot sort in three. Like the robots in Alibaba's warehouse, they take one and a half hour to charge and once it is fully charged they can work an eight-hour shift non-stop (You [b], 2017). Besides this robots, STO Express also relies on warehousing, transferring and parking robots.

4.4 Future of the Supply Chains 4.0

Combining the implementation of the Industry 4.0 technologies with the eradication of surrounding digital waste will increase the operational effectiveness of the supply chains, creating a Supply Chain 4.0. According to Alicke, Rachor and Seyfert (2016), the forecasted impact of Supply Chain 4.0 in the years to come is massive – around 30% lower operational costs, a reduction of 75% in lost sales, decreasing inventories by up to 75%, all of this while increasing the flexibility of the supply chains significantly.

Thanks to increasing the level of interaction with the customers, leveraging all available data, improving drastically the forecast accuracy, and combining demand shaping with demand sensing, the service level will increase dramatically, therefore decreasing the lost sales. The adoption of advanced methods to calculate costs and the optimisation of the network combined with the leverage of dynamic routing, "Uberisation" of transport and the utilisation of autonomous vehicles and 3D printing will lead to a massive cost reduction. Meanwhile, advanced system support will allow the automation of almost 90% of all planning tasks, ensuring better overall quality. Regarding inventory, thanks to these new planning algorithms, and 3D printing, the level of uncertainty will be reduced, making safety stock unnecessary (Alicke, Rachor and Seyfert, 2016).

Some authors believe that over the next years, the terms Industry 4.0 and Supply Chain 4.0 will be replaced by Value Chain 4.0 (Cordon, 2017). This is because companies may need to recombine and rethink how they work and how they are organised in order to generate and capture value in the whole chain. In other words, companies need to leverage Industry 4.0 technologies to the fullest by using them everywhere, not just in the factory. This being, IT functions need to be combined with all the business areas.

5. Results of the Investigation

5.1 Group Interview with the Workers

Topics	Major Takeaways
1st – Definition of Industry 4.0	Before the explanation most of the workers had no idea what Industry 4.0 was, only one of them tried to grasp on to the main ideas behind this trend by using expressions such as: "technological evolution"; "everything is in the cloud"; and "digitalisation". Curiously, the worker that came closer to the real definition was the one with the highest academic qualifications – 12th grade vs 6th and 9th grade. Although, after the explanation, all the workers stayed on the same page and the ones that did not know what the trend is were familiar with some of its mainstream components such as robotics and cloud computing.
2nd – Applications of the Industry 4.0	After being fully contextualised, the workers were very quick to identify aspects of their lives were components of Industry 4.0 are present.

	One worker mentioned the fact that his mobile phone does an automatic safety backup to the cloud. Another worker corroborated this idea by saying that thanks to this technology he can access files saved in his home computer from his laptop ("everything is connected"). One other worker talked about online ads, such as Facebook and YouTube, and the fact that "they are always right" (even though he did not mention big data analytics, he was referring to it). The most literate worker placed his focus on AI and robotics by talking about virtual assistants. He said that "they can do almost everything we want" and also mentioned the fact "we are surrounded by robots in our house, from hoovers to washing machines". This last worker also started a debate around self-driving cars ("they are becoming a reality").
3rd – Applications of the Industry 4.0 in supply chains	To foment the discussion around this topic, a prior definition of supply chains was given to the group. The conversation around this topic was pretty much lead by the most literate worker. He started by talking about the news he had seen a couple of years ago where the entire storage unit of a pharmacy was fully automated (in his words "you just press a few buttons and the drugs drop into a bag"). Then he moved on to talking about Amazon's idea to use drones to deliver goods to customers ("it sounds crazy, but it is happening" he said). The discussion went around these two topics other examples were brought up, but they did not fit into the supply chains core area (like McDonalds and Brisa automatic machines).
4th – Advantages and Disadvantages of this trend	There was no need to introduce this topic to the group since the discussion around the third topic quickly moved on to this last one. One of the workers quickly said that "it must be workers losing their jobs over this". All the other followed up and fomented the discussion around this topic. Then, the most literate worker decided to point out that the "machines do not work alone" and that there is still room for workers in the factories of the future ("someone needs to flip the switch and tell them what to do" he said).

	Following a lengthy discussion, the focus was brought to the pharmacy and Amazon's examples by the interviewer. All the workers agreed that an entirely automated storage and drone delivery were beneficial to both the employees and the customers ("easier job and faster service" one of them said) but one of them pointed out the high level of financial investment necessary as a threat. Regarding this threat, all the workers agreed that this could change soon.

Table 1: Group interview results

5.2 Individual Interview with the Engineer

Topics	Major Takeaways
1st – Definition of Industry 4.0	As expected, unlike the workers, the interviewee was fully aware of what the Industry 4.0 is and how it is changing the way companies do business ("everything is becoming digital, and the old way of doing things is no longer the best way…companies must adapt to this new reality" he stated). Questioned about what level of knowledge does the current industrial workforce has about this topic the interviewee said that even though they might not know all the stages of the industrial revolution, what lead to this current stage and finally what Industry 4.0 is, but they do know technology is changing the way they do their work (in his word "the lack of technical knowledge is clear, but they are well aware of the ongoing transformations").
2nd – Applications of the Industry 4.0	By being contextualised with the Industry 4.0, it was effortless for the interviewee to talk about some applications of some this trend's technologies. He started talking about how technology is present around us on our every day and how we got so used to it that we no longer acknowledge its presence ("our house is no longer home, it is a smart home, nowadays technology acquired a God-like characteristic by being omnipresent" he stated). Then he went on talking about numerous examples, from the capabilities of our smartphones to the rise of smart appliances and he even talked about AI impact in both

	the software world and in the physical world with the help of robotics ("a university lab built a robot and thought him how to parkour…if that is not a sign of the direction we are heading in I do not know what is"). Is vital to point out that when talking about this topic the interviewee used very technical language what shows his high level of knowledge in this matter.
3rd – Applications of the Industry 4.0 in supply chains	The interviewee started by talking about the concept of Smart Factory and how this is the translation of Industry 4.0 into reality. In his opinion, the Smart Factory is the first step in order to achieve a Supply Chain 4.0. The application of the Industry 4.0 technologies to manufacturing, such as automation and cloud computing, will allow a constant and up to date flow of data into supply chain management (in his opinion "generating and leverage data is now key"). Apart from the creation of this networking system, the interviewee also pointed out that some technologies can be directed implement into different stages of the supply chain. For instance, he talked about using AI to help companies designing their logistic distribution itineraries ("Nowadays you just need to feed data into the system, and it will tell you the best way to do your work"). When questioned about automation in supply chain management the interviewee said that for now only the more powerful could put that into practice.
4th – Advantages and Disadvantages of this trend	First, the interviewee tackled the idea that in this current stage of the industrial revolution people will lose their jobs due to technology. According to him, rather than a massive loss of jobs, we will assist to a transformation of the workforce ("the workforce will become more specialised, workers like the ones you interviewed will keep their positions as long as they receive the right training, is up to the companies to do this"). Then, he stated that the Supply Chain 4.0 would dramatically increase the level of operational efficiency and flexibility that will, therefore, reflect in a substantial reduction regarding costs ("if you know until where you can push, you will not push it more than that" he said). We also moved on

	to say that the levels of inventory will decrease due to these improvements. In the final part of the discussion, he focused on the online threats that come with digitalisation, pointing out that cybersecurity needs to become a major concern ("if you have an online network you are vulnerable to attacks").

Table 2: Individual interview results

6. Critical Appraisal of the Investigation and Discussion

Regarding the interviews alone many conclusions can be taken from them. First, it is clear to state that, when it comes to the current Portuguese industrial workforce, there is an overall lack of knowledge of what the Industry 4.0 is as a trend and how it impacts the supply chains. While in the group interview the workers showed this lack of knowledge, in the individual interview the engineer confirmed this hypothesis. This limitation is due to both the low level of academic qualification and specific training that the current Portuguese industrial workers have and to generational factors since most of them are part of Generation X and therefore had a low level of contact with technology growing up. Second, even though they are not familiar with the Industry 4.0, they show a relatively high-level of technological awareness, this means, workers know that technology is evolving at a fast pace and that is changing the way they live their life's and how they do their work – different applications of the technologies. This being, they can quickly identify some advantages, namely the simplification of the tasks and improved level of service, and disadvantages of this trend such as the probable loss of jobs and the high level of investment necessary. Finally, this ongoing trend aligned with the lack of knowledge of the current workers will force a transformation of the workforce. The new needs risen by this trend will force the specialisation of the workforce and is up to the companies to give the right training to their workers in order to prevent a massive job loss.

Moreover, the insights gathered from the primary research did its purpose and validated the information collected from the secondary research. This latest stage on the industrial revolution, named Industry 4.0, will dramatically change the way companies do their work and interact with all the involved parties, namely customers and suppliers. Fostering the birth of the Smart Factories, new manufacturing processes will be introduced, and the old way of doing things will no longer be the best way. Technologies such as cloud computing, robotics and AI will revolutionise production sites making them more efficient, effective and reliable. Even though investing in these technologies is much more than worth it, the level of adoption will vary dramatically between businesses. While some organisations will push harder and take the lead others will just follow along at their own pace. The application of these Industry 4.0 technologies to SCM will create what is called Supply Chain 4.0 by the specialists. This will have an impact in all SCM areas, from operational planning to the overall strategy, and will give place to a faster and more flexible, granular, accurate and efficient supply chains. Although Industry 4.0 and Supply Chain 4.0 does not bring only benefits, it also brings some drawbacks namely in the form of digital waste and cybersecurity issues. Given the high level of impact that technology will have on the way companies conduct their businesses it is necessary to start using the term Value Chain 4.0 since the Industry 4.0 needs to be fully leveraged in every management area to generate and capture value in the whole chain.

It is important to point out that this investigation had a few limitations, especially in the primary stage of research. It would have been extremally helpful if the company had fully cooperated, giving access to their facilities, documents and especially all the staff. This would have allowed the development of a case study around this organisation. This is definitely something to explore in the future. Even the access to any other organisations would provide more data to support the claims made through this paper. However, these are just limitations and the investigation results are solid given the accessed data.

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