

# Supply Chain Management in the Age of Digitalization

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**Abstract:** Digitalization is becoming one of the most debated technological trends radically changing how enterprises run and affect entire value chains across organizations. Factors such as globalization, increased data flow, complexity in supply chain operations, and more demanding and critical customer requirements are changing the nature of modern supply chains. The current research reveals how digitalization is reshaping supply chains and how different regions and industries are adapting to digitalization by investigating: the emerging digitalization trends in supply chain strategies, the global geographical impact of digitalization trends, and the impact on different types of business industries. This study is based on a comprehensive statistical analysis conducted on 119 scientific and management consulting studies, in order to provide conclusive insights to the development and future of digitalization. The study reveals that digitalization is becoming a revolutionary trend with an increasing pattern of interest from governments, organizations, and academic researchers in the form of nine main digitalization trends applied in various business industries and regions.

**Keywords:** *Digitalization, Supply Chain Management, Industry 4.0, Academic Trends*

## 1 Introduction

Digitalization has been defined as the use of digital technologies to improve organizations' opportunities of creating new revenue and valuable processes [56]. In the age of big data generation, digitalization is perceived as a method for analyzing data and deriving more effective and competitive business processes [6]. In a recent study, [61] the author Ribeiro surveyed 72 companies, where 85% of the companies

revealed that they apply digitalization as a strategy for optimizing resources in terms of time, personnel, and investments, while 79% of the companies saw digitalization as a method of creating better interface to end customers [61]. Furthermore, ref. [60] stated that compared to 2016, where companies had a digitalization level of 33%, it is now

expected that this number will increase to more than double (72%) by 2020. In addition, ref. [35] stated that digitalization is changing the direction and work of industries. Future businesses will have sensors, machines, devices as well as IT systems interconnected along their value chains [35], [11]. The above-described trends of businesses have so far been described as a global revolutionary change, also referred to as 'Industry 4.0' [12], [60].

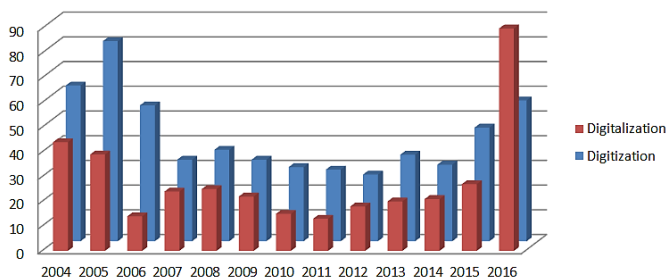
Digitalization is presented together with Industry 4.0 in numerous studies [21], [8], [45], [70], [39], [37], [72], [26]. Industry 4.0 represents the fourth industrial revolution [12], which holistically integrates traditional industrial operations with digital technologies [21]. Industry 4.0 encompasses the concept of digitalization [12] by focusing on the end-to-end digitization of products, integrating them into digital ecosystems, and generating, analyzing, and improving business by the use of data ([60]). Additionally, the initial literature review revealed that that digitalization and Industry 4.0 not only cover the same scope, but also cover the same technological concepts/trends such as Internet of Things (IoT), mobile solutions, cloud computing, cyber-physical systems, big data analytics, etc. Therefore, the preliminary conclusion of this study is that academia presents no clear distinction between the two terms; however, as indicated previously, the two terms are presented with same meaning encompassing the same technological concepts.

Digitalization represents a very complex and radical change, where the right digital actions and applications must be identified and implemented by the companies [6]. Not only does higher volume of data requires digitalization, but the digital disruptions also trigger the need for digitalization. According to [19], the threat of digital disruptions triggers companies to move from the conventional incremental approaches in modernizing IT towards a radical solution which would address an end-to-end approach.

While companies in the past decades focused on digitization (i.e., SAP), companies nowadays are shifting

their focus towards digitalization [56]. In a report from Google Analytics, it can be derived that while the search term 'digitization' has been leading throughout the past decade (marked with blue), an increasing interest in digitalization as of 2016 (marked with red) is revealed. Figure 1 shows the search trends for digitization vs. digitalization in the period from 2004 to 2016:

Figure 1: Digitization vs. digitalization



The results presented in Figure 1 are in relative terms, where a value of 100 is the most commonly searched and 50 is searched half as often [27]. For instance, in 2016, 'digitalization' has been searched 83 times relatively to 'digitization', which was searched 58 times for the same period. It is important to state that digitization should not be confused with digitalization. According to Gartner [24], digitization describes the incremental process from analog to digital, which already occurred in the 1950s with the early computers [64]. The radical process of digitalization transforms IT from a shared service to a critical part of any organization's DNA [19]. One of the reasons and consequences for the digital transformation can be described by data flows. In 2005, digital flow data was registered with 3.1 thousand gigabits per second compared to 2014, where it was registered with a level of 211 thousand gigabits per second [51]. It is furthermore highlighted that: "what gets measured, gets managed", indicating the importance of handling rich data in the best way to create more value for companies [5]. This represents a transition from data to added value, where companies generate value from their internally generated data [37].

Ref. [10] also refers that the digital transformation is becoming one of the most important business trends of our time, where organizations are no longer dependent on their own efforts, but rather on the global, digitalized network with the customers, and suppliers. Therefore, as digitalization enables more complex procurement and collaboration, it further triggers industries to shift their focus towards locations which are closer to the demand – and not only supply [51], [49] which is why digitalization is represented in supply chain management (SCM) [75], [41], [70].

Ref. [75] refers that the digital era is "redefining the world of supply chain management"; furthermore, Ref. [41] refers that the European SCM managers have communicated that the main digitalization focus in their companies is SCM IT integration. Stegkemper conducted a study based on the responses from 1000 employees from 60 companies, where it was revealed that more than 75% of the employees wanted a stronger process integration in their supply chain by means of digitalization [69]. SCM is a very complex and cross-transactional process which deals with data exchange both internally and externally in companies; an area where European businesses predict the highest increase in investments and impacts over the next three years [41]. As the next strategic step, companies are now considering transforming SCM into a competitive advantage by integrating digitalization successfully. According to Kearney [41], different companies from various industries are placing a high focus on digitalizing by investing and adopting digitalization in their SCM business models. Examples of such companies are DHL, Amazon, Alibaba, and BMW, which have invested in SCM digitalization trends such as big data for minimizing risks, robotics for automation of goods handling, and digitalization of whole factories [41]. These represent major initiatives taken by companies to move to the next level and benefit from the use of data; for example, DHL has gained a productivity increase of 25% from the global augmented reality program, where the employees have been using data glasses for picking processes [41]. According to Koch & Kuge [44], who examined 235 industrial companies, it was forecasted that digitalization would increase revenues with up to 3% per year, reaching a value of €110 billion yearly within Europe.

The globalization of markets, the increased data flow, and increased complexity of processes have encouraged the introduction of a digitalization era, which aims at becoming a major player in initiating supply chain strategies. This research paper aims at understanding how digitalization is reshaping the nature of supply chains by looking into which digitalization trends are evolving into supply chain strategies, including the geographical and the industrial impact of the trends. In this regard, the research aims at examining and revealing the evolving digitalization trends by investigating underlying geographical and industrial patterns. The research paper aims at providing a generic understanding on how digitalization is reshaping modern SCM. As such, the research seeks to answer the formulated problem statement from a generic perspective by focusing on: Which digitalization trends are predominant in SCM, in which industries and regions are digitalization applied, and finally, how can different industries adapt to the trend based on the revealed information? An implementation plan will not be covered in this study.

## 2 Research design and methods

The primary source of data for this study is a proprietary literature review resulting in 119 scientific papers. The literature review was carried out in order to define the previous, present, and potential trends of digitalization for SCM operation and strategies. The literature search followed the research design from ref. [20], where targeted keywords were combined to triangulate the search for relevant materials. Using Google Scholar, we searched the keywords 'Digitalization' in combination with 'Supply Chain Management' and 'Industry 4.0' in combination with 'Supply Chain Management'. The results of the literature search are introduced in the diagram in Figure 4, revealing the amount of papers targeting various parameters of digitalization in relation to SCM. In order to analyze the results of the literature review, a meta-data analysis was performed. A meta-data analysis is a statistical analysis method developed by social scientists to interpret and draw conclusions based on conglomerated data from multiple scientific studies [4], [54], [66]. A meta-analysis can be conducted using two types of data collection: aggregated data (AD) or individual participant data (IPD) [67]. The use of AD is the most common approach in research [9], where the researchers summarize and interpret results from data published in scientific studies Smith & Marcucci (2016). A meta-analysis based on IPD entails that data is collected from individual participants in the study [67]. The results from the meta-analysis 'play a key role in summarizing the body of evidence' when answering the formulated research questions [4]. This method replaces the traditional literature reviews, as it provides more rigorous and objective results unlike the traditional reviews, which often rely on the individual interpretation of the researcher [66]. In this regard, journals recommend researchers to use this systematic approach [4], as it helps them to identify from a subjective and quantitative point of view any underlying trends and correlations from the analyzed data [66].

The meta-analysis approach chosen for this research paper is represented by an AD collection. This approach allows the researchers to summarize results based on numerous scientific studies and supports the identification of patterns of trends. The research is based on the main assumption that digitalization is becoming a revolutionary trend in supply chains. This assumption stems from the growing interest in the past few years in the concept of digitalization by both governments and academics. Governments from three continents have communicated massive investments in digitalization by 2020. In Europe, where investments with a value up to €140 billion are expected; in the US, which has established the National Network for Manufacturing

Innovation with a funding of \$1 billion for research centers; and in Asia, which is expected to invest nearly \$60 billion in the industrial IoT by 2020 [21]. Furthermore, the interest in digitalization has been demonstrated by the increase in searches on the keyword 'digitalization' as seen in the Google Analytics report [56] as well as the growing number of digitalization publications on academic journals (e.g., Elsevier Ltd., Springer, EBSCO, Emerald Group Publishing, SAGE Publications) and consulting companies (e.g., Capgemini, Accenture, Deloitte, The Boston Consulting Group, PwC).

## 3 Results and discussion

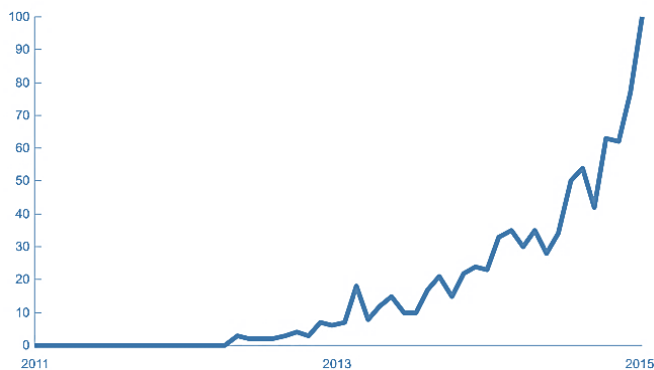
### 3.1 SCM digitalization over time

The results from the study have shown that despite the fact that digitalization is becoming a major player in supply chains, this trend has not always been a popular topic among businesses and academia. According to the author [56], companies such as SAP have been focusing on digitization in the past decades [64]. The study has shown that while digitization has been a leading trend throughout the past decade, there has been an increasing interest in digitalization since 2016 [56], where the term appeared 83 times in searches compared to digitization, which was searched 58 times for the same period of time as shown in Figure 1.

Digitalization, however, started evolving into a strategic move when factors such as globalization, increased complexity of supply chains due to higher volumes of data, and digital disruptions began to take place, triggering companies to move from the conventional incremental approaches in modernizing IT (digitization) towards a radical solution which would address an end-to-end approach called digitalization [19].

Since digitalization started becoming popular in Germany (when the government encouraged the German manufacturing industry to use digital high-tech strategies to become more competitive as part of the 'High-Tech' strategy 2020), the interest in this field has grown significantly and spread throughout Europe and USA, using keywords like 'Industry 4.0', 'Internet of Things', and 'Internet of Everything' [23]. Figure 2 demonstrates the increasing interest in Industry 4.0 as retrieved from Google Analytics [71]:

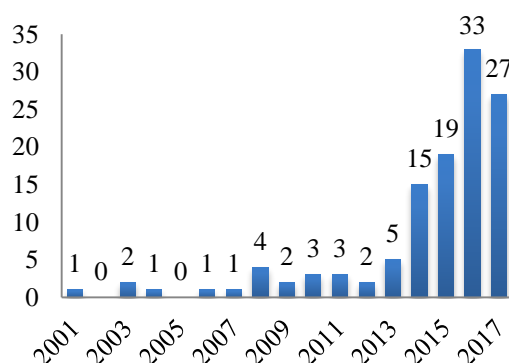
Figure 2: Google search 'Industrie 4.0' in Germany; the total keywords queries



The digital era became known to have the most impact on “redefining the supply chains” [75]. The research showed that in a study with 1000 employees from 60 companies, more than 75% companies are planning to create a stronger process integration in their supply chains through digitalization. Key players have started working on adapting their strategies and prioritizing digital opportunities [75] in order to increase supply chain performance by ensuring on-time deliveries, reduced inventories, and the ability to quickly detect and adapt to threats [68].

The increased interest of companies in SCM digitalization has triggered the attention of researchers who started analysing and publishing scientific papers with more focus on the digitalization of supply chains. For example, the results from the conducted meta-analysis on 119 studies showed a significant increase in publications over the past four years. Figure 3 illustrates the number of publications targeting SCM digitalization over time.

Figure 3: SCM digitalization studies published per year



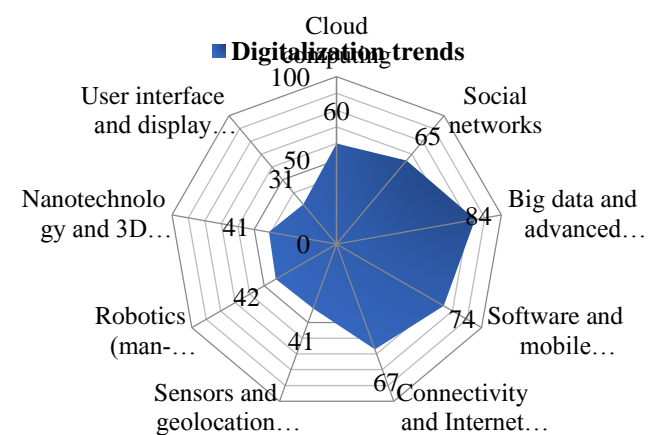
As can be seen, the number of SCM digitalization publications was relatively low from 2001 to 2013 with an average of two publications per year. Thus, starting in 2014 (i.e., when the German 'High-Tech' strategy was initiated (Figure 2), and the interest started shifting from digitization to digitalization (Figure 1)), the number of publications

targeting SCM digitalization reached 33 publications in 2016. This demonstrates the increased interest in SCM digitalization and confirms the main assumption of this research, namely that digitalization is becoming a revolutionary trend in supply chains, attracting not only the attention of businesses, but academics as well. Accordingly, the study draws a consensus based on the above findings that digitalization has evolved throughout the past decades from just a futuristic concept [11] to a revolutionary trend recognized by companies as a critical success factor for gaining a competitive advantage in supply chains [11], [36], [53] and establishing a predominant business model [53].

### 3.2 Academic SCM digitalization trends

While the previous section aimed at showing the evolution of SCM digitalization over time, this section presents the results regarding the most studied trends that have emerged in the defined age of SCM digitalization. The findings have been conveyed based on the conducted meta-analysis, revealing the top most popular SCM digitalization trends. The results from the meta-analysis revealed nine digitalization trends in SCM, which are introduced in Figure 4.

Figure 4: Top digitalization trends (statistical analysis)



The trends were debated in most of the 119 reviewed papers in the conducted statistical analysis and have been ranked as follows: 'Big data' is the top discussed trend with hits in 84 publications out of the 119, followed by 'Software and mobile applications' (74), 'Connectivity and Internet of Things' (67), 'Social networks' (65), and 'Cloud computing' (60). Furthermore, the trends 'Sensors', 'Robotics', '3D printing', and 'Augmented reality' were on average each mentioned in 30-40 publications out of the 119 reviewed. In addition, congregated data from the statistical analysis presented in Figure 5 displays which SCM digitalization trends have been published in the past 17 years, projecting a pattern on how focus has been distributed for each of the aforementioned trends over time.

Figure 5: SCM digitalization trends over time

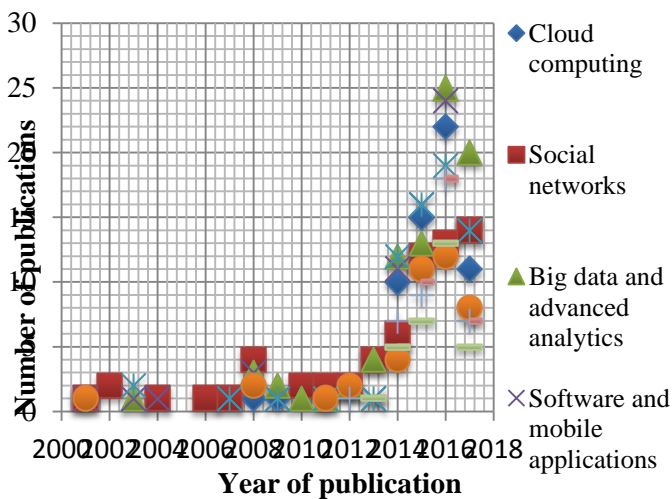


Figure 5 indicates that about two decades ago, digitalization trends were not a common topic of academic debates; few publications targeting social networks, software, and IoT were published with an average of one to two per year from 2001 to 2012. Nonetheless, the number of publications followed a sudden increase in 2014, where the numbers of publications targeting digitalization trends increased significantly, and new digitalization trends such as big data, cloud computing, exponential technologies, nanotechnology and 3D printing as well as user interface became prevalent in research overpassing earlier trends such as social networks. 2016 experienced the highest number of publications with 'Big data' being the most discussed trend in 25 publications out of the 33 papers published that year, followed by 'Software and mobile applications' (24 publications) and 'Cloud computing' (22 publications). Based on the increasing pattern of publications related to SCM digitalization, it can be expected that the 2017 number of publications will exceed the number registered in 2016 (in July 2017, 27 papers had been published already). The sudden interest in digitalization trends indicates a direct connection to 2014, when the digital data flows exploded to a level of 211,000 gigabits per second compared to 2005, where the digital data flows were registered with only 3,000 gigabits per second, leading to a 'digital globalization' [51]. The high volume of data triggered companies to find ways to measure and manage their data in order to generate value from their internally generated data [37]. As supply chains are becoming more complex and generating massive

amounts of data, strategic players in supply chains have started looking for solutions to turn their data into smart data sets for driving contextual intelligence [15] and gaining competitive advantage. PwC consulting has forecasted that digitalization will increase revenues with up to 3% per year, reaching a value of €110 billion yearly within Europe [44]. Furthermore, digitalization will help companies increase their resource efficiency by 18%, where redundancies in processes and quality losses will be minimized [44].

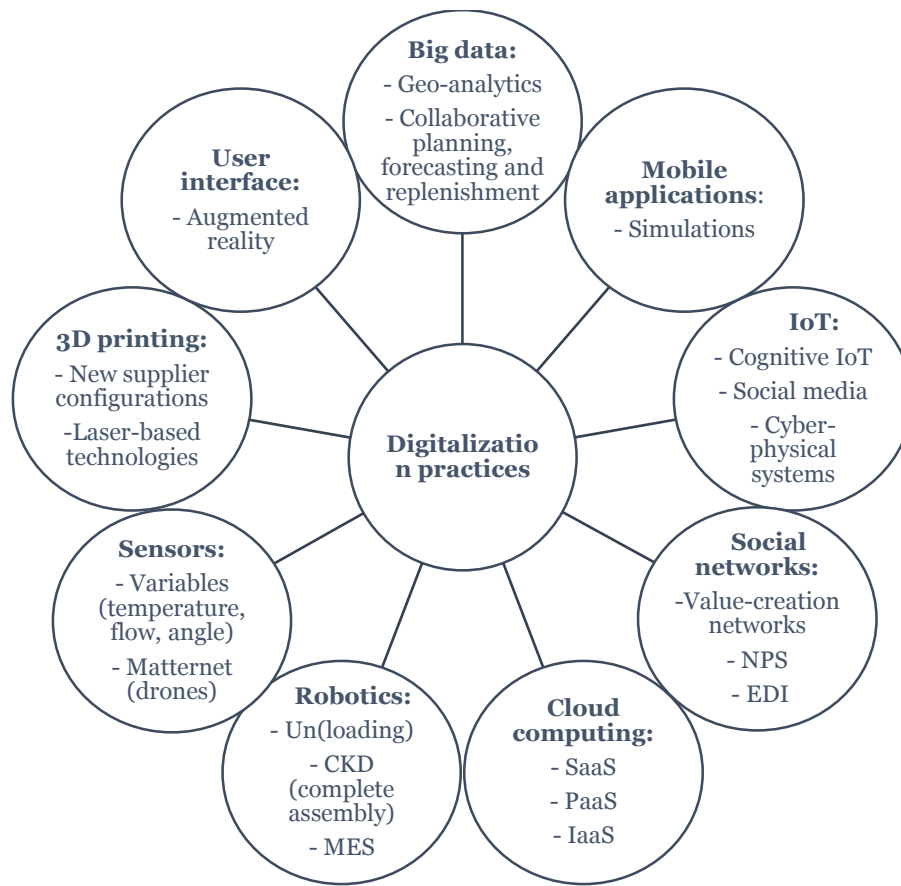
Another interesting aspect of Figure 5 is that contrary to the expectations that robotics has been a popular trend in the past decades, the results have indicated that in SCM digitalization, this trend started only five years ago, i.e., one year later from when the concept of 'Industrie 4.0' became popular in Germany. This indicates that as companies began focusing on reducing overall costs and improving their supply chain operations due to globalization [49], robotics started playing an important role in supply chains (particularly in manufacturing and warehouses), allowing manufacturers to reduce headcounts or re-assign skilled workers to focus more on higher value-added tasks [36]. Another interesting detail shown in Figure 5 is that while big data analytics is one of the most popular digitalization trends nowadays, the trend first started becoming popular back in 2008, where only three papers were published. Nonetheless, big data followed an increasing pattern in the number of publications reaching up to 25 publications in 2016, indicating an increased interest in corporate and academic world due to digitalization. The research has shown that in 2015, 43% of surveyed companies started investing in big data analytics and software for visualizing their data [55]. Furthermore, 80% of the responding companies planned to implement IT systems, where big data was listed as a significant digital lever to gain higher potential for SCM improvement [41].

### 3.3 Derived strategic actions

While the previous section presented the nine most studied trends and discussed how the trends have evolved over time, this section discusses why these specific nine trends have become popular in SCM digitalization. For this purpose, the researchers identified the strategic practices (actions) associated with the nine digitalization trends in the 119 reviewed publications, which are introduced in Figure 6 next page.



Figure 6: Focus areas in SCM digitalization



The importance of the nine digitalization trends in SCM, which have been presented in Figure 6, can be defined by understanding that digitalization trends have been defined as long-term technological influencers used by companies to prioritize and decide upon key technologies to be emerged into their business strategy [43]. Factors such as internationalization of markets [3], increased data flows from horizontal and vertical networking of value chains [60], and more demanding and critical customer requirements [32] have led companies to direct their focus towards technological trends in order to optimize their supply chain operations [53], [3].

Big data was listed as one of the top priorities in digitalization, as it helps business manage large amounts of data and discover hidden patterns [2], [63]. The research has shown two main practices associated with big data: 1) Geo-analytics and 2) CPFR (Collaborative Planning, Forecasting, and Replenishment) [31], [40]. In logistics and transportation, geo-analytics can be used to manage geographical data to reduce transportation costs for global shipments as well as optimize planning and re-routing operations. Big data – in the form of geo-analytics – represents an important digital practice in SCM, as it enables companies and their partners to build up better transportation networks and reduce transportation costs by 15-20% [52]. The second practice used in big data is CPFR

(the next generation of VMI), helping companies to better manage inventories by exchanging data with partners and working together in streamlining their mutual processes. This practice triggered an interest due to today's supply chain complexity, which requires internal and external partners to team up in finding new methods to reduce costs and redefine their channel models [34]. The research has shown that companies such as Walmart and P&G have experienced improved vendor-managed inventories [34], reduced out-of-stocks GSOM (2011), and reduced the 'bullwhip effect' (when fluctuations in the supply chain increase the costs in inventories and transportation) [34]. Other benefits associated with the implementation of CPFR techniques were listed as stronger relationships between collaborative parties, proactive management of demand chain, and integrated planning and forecasting of supply chains, where orders were updated at the same time for both parties and visualized in real time [34].

Software and apps, the second most important trend as shown by the meta-analysis research and listed by Forbes as a top digitalization trend [15], have been associated with two predominant practices called 'Simulations' and 'Mobile applications' [31], [40]. The research has shown that simulations can be used in SCM to streamline processes and work tasks leading to significant costs reductions (i.e., Siemens reduced their costs due to leaks of

water and theft with up to \$370,000 [8]. Furthermore, simulations helped with decision-making in port container terminals, showing that an adoption of AGV and IAV technologies would increase effectiveness and reduce overall costs by \$140 per day and idle time in few processes by 50%, thus the intelligent features in IAVs would further increase precision in material handling [3]. As to the second practice called 'Mobile applications', the research has shown that with the increase of digital products warehouse and manufacturing managers will be able to control industrial machines directly from their smartphones and tablets. Furthermore, using mobile applications in SCM leads to improvements in terms of managing systems and generating up to \$544,500 savings per year. Further benefits have been recognized as reduced complexity through automation and tracking of interrelated products, leading to \$222,750 savings per year and integrated products through centralized administrations, resulting in an additional amount of \$148,500 per year.

As part of the third trend referred to as 'Internet of Things', cognitive IoT has been recognized in the research as one of the most innovative IoT practices. Along with digitalization rise, computers will be able to learn, reason, and infer new knowledge listing as another key player in supply chains [22], targeting end-to-end operations from developed smart warehousing systems, machines, and production facilities to logistics and marketing [23]. The research confirmed benefits given by IoT implementation in SCM by providing evidence, where a well-known company reduced fuel consumption in transportation, leading to annual savings of €3,200 as well as cutting eight metric tons of CO<sub>2</sub> emissions [76]. Furthermore, IoT was used by Coca-Cola to connect their beverage dispensers with computed systems to measure and track their performance remotely [77]. In this way, the company reduced the need of having employees sent to collect data and saved logistics and labor costs [77].

A new trend, which will increasingly be used in SCM digitalization, is social media. In line with the research, social media use will increase in SCM, as companies will be able to predict demands and plan their inventories based on data retrieved from social media presence. In terms of social networks trend, practices such as value-creation networks and Net Promoter Score will continue to be used in creating integrated social networks between business partners as well as maintaining strong social ties with important partners that are promoting and driving forward the business. The cloud computing trend has been defined as a ubiquitous technological movement among large-scale supply chains, where the application of IoT generating data in high volumes required data to be stored and managed through cloud computing [7]. The trend has grown into a reliable information keeper used in managing and

customizing technological platforms directly by the customers [11]. Companies such as Amazon Web Services have experienced an increase in their revenues of 10% and an increase in their operating income of 89% by implementing cloud computing technology [16].

Robotics, the sixth most popular trend in SCM digitalization, has demonstrated benefits in warehouses in loading and unloading tasks as well as assembling products which are shipped to the customers in disassembled form; a practice referred to as Complete Knocked-Down assembly. Based on the research, robotics have helped companies like GreyOrange Butler reduce the need for multiple employees having to walk back and forth to pick and place needed products in warehouse [11]; consequently, decreasing costs at a tenth of the costs compared to ten years ago [36]. In addition, the literature showed an estimation, where 40% of the manufacturing tasks in companies will be performed by robots, leading to higher labour productivity reaching up to 10 to 30% higher output per worker by 2025 [36].

While the difference between how sensors are used today, as compared to few years back when the concept of digitalization first emerged, does not appear significant, it is predicted that more sensors will be used for building smart cities in the future, integrating them in roads and buildings [39], [72], [38]. Sensors have been estimated to reduce manufacturing costs for top 100 European manufacturers with €160 billion due to less defects, less scrap, and rework needed [21]. In logistics, HP and BMW reduced losses in transit with 11-14% by implementing sensors in their physical shipments.

In nanotechnology and 3D printing, the research found nanotechnology to be predominantly used in new supplier configurations and laser-based technologies, helping manufacturers save up to 60% of their costs across the supply chain by enabling simplified designs, short delivery times, and reduced logistics costs, as products will be manufactured locally [17]. The literature indicated, however, that 3D printing has not reached maturity yet in terms of quality [14], and most manufacturers prefer to wait before deploying 3D printing to mass productions until this technology will become mature enough to be used in the metal industry as well [22]. Thus, the consulting firm Deloitte has contradicted the statement by arguing that long lasting materials for 3D printing have already been progressing in terms of quality standards.

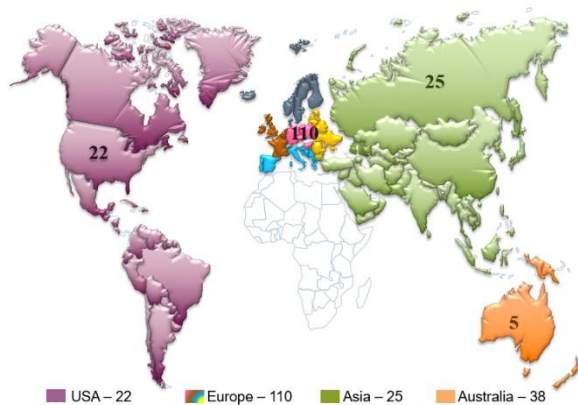
The last trend revealed by the research, i.e., user interface and display innovation, has shown that augmented reality will be widely practiced in SCM, particularly digital 'glass picking programs' in warehouses and transportation. The results have shown that augmented reality could reduce

error rates in the picking process in warehouses by 40%, and it will reduce the time for training new employees while accelerating their productivity [73]. For example, DHL and SGRE have increased their employees' productivity by 25%-33%, leading to other benefits such as paperless guides [65], [48] an automatic learning system, where the program learns from previous activities it documents, and next time, it suggests alternatives and reduced error rates.

### 3.4 Geographical impact (trends per regions)

In line with the results retrieved from the meta-analysis, SCM digitalization concept has quickly spread in the past few years to continents such as Europe, Asia, USA, and Australia. Figure 7 illustrates how active these regions are in adopting digitalization based on the reviewed 119 papers.

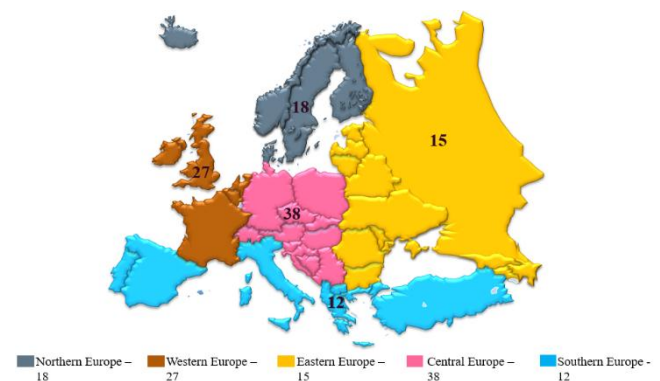
Figure 7: SCM digitalization per regions



As the map in Figure 7 shows, Europe proved to have a significant interest in SCM digitalization, where 110 out of the 119 reviewed papers have targeted the region. Asia was found to be the second most active in SCM digitalization with 25 papers targeting the region, followed by USA with 22 papers, and finally, Australia with only 5 papers.

Figure 8 takes a more detailed look into Europe. It should be noted that there are different regional segmentations, hence the geographical segmentation and clustering of countries used in this study have been based on [74].

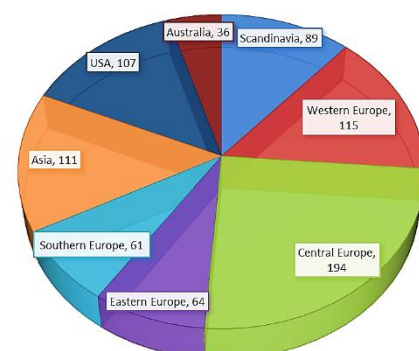
Figure 8: Close-up - SCM digitalization in European regions



This fact can be explained by the research findings which demonstrated that the entire concept of 'digitalization' first started in Europe, more specifically in Germany [23], where the German government supported digitalization as presented by the author Galindo. Since then, large companies such as Siemens situated in Germany have shown a high level of interest in digitalization [8]. Switzerland is also one of the European countries that focuses largely on digitalization, recruiting developers from all over the world to join the Institute of Robotics and Intelligent Systems and National Centre of Competence in Research and develop intelligent robotics inspired from human IQ [1]. The next European region to place a high focus on digitalization was represented by Western Europe (27 publications with most of them targeting UK), followed by Northern Europe (18 publications), where countries such as Denmark have placed a high focus on SCM digitalization as well [14]. The least focus has been registered in Eastern Europe (15 publications) and Southern Europe (12 publications).

In continuation, the research further aimed at revealing how the global regions focus on digitalization trends and how the trends have been prioritized by each region. The chart in Figure 9 shows an overview of all global regions based on the total number of hits targeting the nine SCM digitalization trends.

Figure 9: SCM digitalization per regions

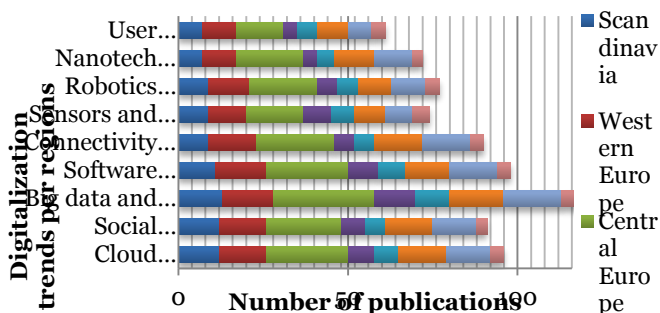




Central Europe was listed as the top region, where the number of hits from all trends has been summed up to 194 times, indicating that Central Europe has the highest level of association with the nine digitalization trends. The second top region is represented by Western Europe, associated 115 times with digitalization trends. Asia has been associated 111 times with the trends, USA 107 times, and Scandinavia 89 times. The lowest levels of association have been registered in Eastern Europe (64 times), Southern Europe (61 times), and Australia with only 36 times being associated with the nine digitalization trends. Based on the results, it could be argued that regions focusing most on digitalization are also developed regions with countries such as Germany, Switzerland, UK, Japan, etc.

To obtain a more detailed overview, the research specifically reveals the digitalization trends on which each region places its focus. The chart in Figure 10 shows the results.

Figure 10: Trends per regions over time



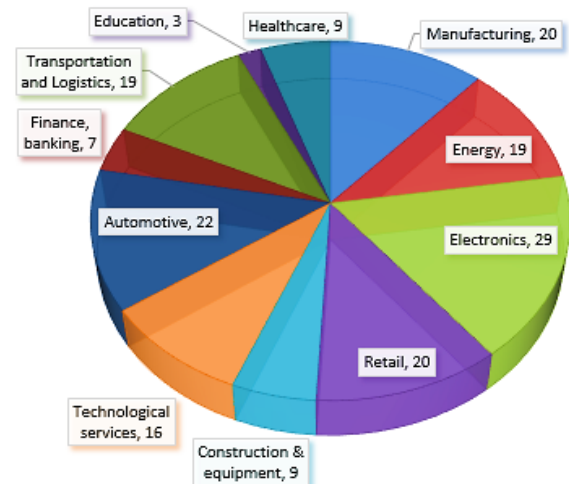
As can be seen, Central Europe, i.e., the top region focusing on SCM digitalization, pays most attention to big data analytics, software and mobile applications, and cloud computing. The trends that Central Europe focuses on the least are sensors as well as user interface and display innovation. The same pattern is seen in the second ranked region, i.e., Western Europe. In Asia, the third ranked region focuses mostly on big data analytics, while equally focusing on cloud computing, social networks, and IoT. Next, the US follows a similar pattern as Central and Western Europe, paying most attention to big data analytics, software and mobile applications, and IoT. Finally, Northern Europe has shown to focus most on big data analytics, cloud computing, and social networks.

Based on the above findings, it can thereby be concluded that SCM digitalization trends such as big data analytics, software and mobile applications, cloud computing, social networks, and IoT have most geographical impact on developed regions like Central Europe, Western Europe, Asia, USA, and Northern Europe.

### 3.5 Impact of digitalization on different industries

In line with the statistical analysis, the results have revealed the industries focusing most on digitalization. The chart in Figure 11 comprises an overview of the industries associated with digitalization. The ranking has been based on the number of digitalization publications found to be associated with specific industries and introduced in Figure 11.

Figure 11: SCM digitalization trends per industries



The industry with the highest interest in digitalization is that of 'Electronics', where 29 scientific papers out of the 119 reviewed presented a correlation between the industry and the revolutionary trend. The second industry placing a high focus on digitalization is 'Automotive' (22 publications). Next, 'Manufacturing' and 'Retail' are ranked as the third most interested industries in SCM digitalization with 20 publications, and 'Transportation' and 'Energy' ranked fourth with 19 publications. The industries focusing the least on digitalization are represented by 'Education' (3 publications) and 'Finance' (7 publications). Figure 12 further shows a pattern over time in terms of how industries shift their focus on SCM digitalization.

Figure 12: Interest in SCM digitalization per industry over time

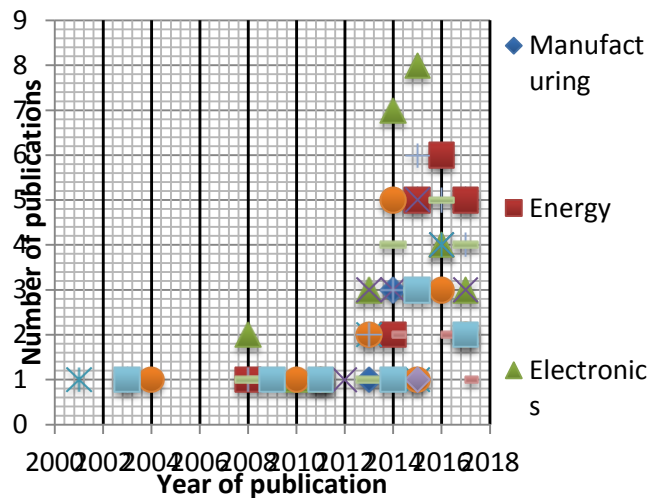


Figure 12 reveals that in the early 2000s, only a few industries focused on digitalization; the industries of 'Construction', 'Healthcare', and 'Technological services' have been associated with an average of one publication per year suggesting that at the time, SCM digitalization was perceived only as a prospective trend, thus not yet ready to be attained. Nonetheless, starting with 2014 (the same year as the number of research publications suddenly increased), it can be seen that industries such as 'Electronics', 'Automotive', and 'Energy' have highly increased their focus on SCM digitalization. In 2016, eight publications associating SCM digitalization with 'Electronics' were released, followed by 'Automotive' (3) and 'Energy' (6).

The electronics industry first looked into digital trends in 2008, focusing on social networks and big data, while in the following four years, the industry experienced a decrease in digitalization. Starting with 2014, however, the chart shows a sudden increase, registering in 2015 the highest activity level, where the industry appeared to be looking into supply chain trends like cloud computing and IoT. It is interesting to see that in the following year (2016), it placed an equal interest in trends such as nanotechnology and robotics, along with cloud computing and IoT. Dell mastered IT-based SCM systems [47], [13] such as cutting its inventory costs and reducing the risks for obsolescence through big data analytics [50], [33], [46]. The company created a zero-time organization, which resulted in a significant growth (a 58% revenue increase and an 82% profit increase) [57]. The automotive industry started its digitalization trends earlier than the electronics industry, seeing publications from 2003 associated with the trends big data, IoT, and social networks. As with the electronics industry, a high increase in publication starting in 2014 has been registered, focusing on software and mobile applications as well as big data, robotics, and IoT. The highest activity level was seen in 2016; again, focus was on big data and IoT, but this time,

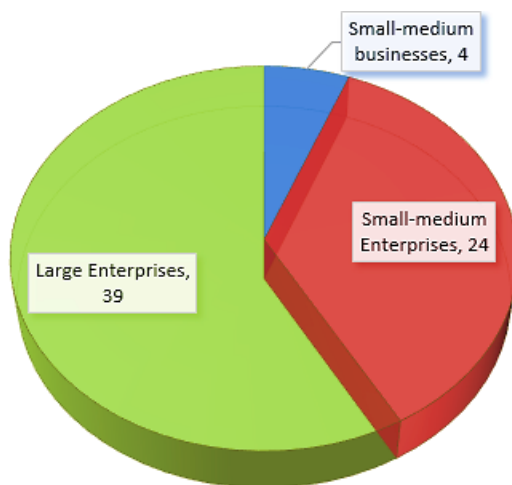
nanotechnology was also included. Companies such as Ford have become very popular thanks to their digitalization strategies for the automation of manufacturing [59] and their new directions in logistics, targeting fewer suppliers: From 4,000 suppliers, Ford moved to only 350 [13]. The manufacturing industry, surprisingly, first showed activity in digitalization in 2013, where it targeted nanotechnology. Thus, like the electronics and automotive industries, it dramatically showed an increase in SCM digitalization activity in 2014, focusing on big data, software and mobile applications, and robotics. The highest activity was registered in 2016, focusing on the trends cloud computing, nanotechnology, robotics, and IoT, which shows a logical pattern considering that manufacturing can benefit significantly from 3D printing and robotics, while using IoT and cloud computing to manage the programs behind. Kubota Manufacturing of America planned to increase their manufacturing capacity by 60% over a five-year period by level-loading their facilities (a production planning method used when demand is high and production capacity risks to be limited) [29]. Similar system is used by Coca-Cola called 'Black Book', which helps plan manufacturing up to 15 months in advance [33]. The retailing industry first registered activities in SCM digitalization in 2011, targeting social networks, big data, and sensors. Later on, in 2013, a significant increase (double) was seen, compared to 2012, where the industry appeared to have placed a high focus on social networks and big data. The highest activity was registered in 2016, where the industry appeared to focus heavily on cloud computing, software and mobile applications, and IoT. One of the most well-known retail brands that has excelled in digitalization is Walmart, also listed in Gartner's top 25 supply chain companies [42], [68]. The company introduced real-time dynamic pricing according to customer group, real-time demand pattern, and supply capability [48]. Furthermore, Walmart uses RFID (for product tracking), vehicle management systems, and voice-directed picking devices, proving that the company is 'a best in class example' when it comes to its supply chain improvements [58]. The transportation industry registered the highest rate of interest in digitalization in 2008, compared to the previous industries. The industry followed a similar pattern of decreasing activity in digitalization in the following years until 2014, where it registered a significant increase placing a high focus on cloud computing, software and mobile applications, and IoT. Later, in 2016, the highest activity in SCM digitalization in the areas of cloud computing, software, and robotics was registered. It is surprising, however, that the industry placed a higher focus on robotics rather than sensors and geolocation. Companies like DHL have invested in SCM digitalization trends such as big data for minimizing risks, robotics for automation of goods handling, and

digitalization of whole factories [41]. Finally, the energy industry first focused on SCM digitalization in 2008, addressing the trends cloud computing, social networks, big data, etc. Like the rest of the industries, an increase of interest was seen in 2014 and in 2016, showing the highest level of interest by targeting trends like IoT, robotics, and social networks. Companies such as Siemens have developed their own IoT platforms and made their solutions ready for customer use. For example, Siemens has created the first cloud infrastructure called 'Mindsphere' based on SAP HANA, which compresses and exchanges massive amounts of data linked to products [37].

### 3.6 Defining the specifications of companies investing in digitalization

This research has already revealed the types of industries embracing SCM digitalization and, more specifically, the trends targeted by the industries. Another interesting aspect in terms of SCM digitalization has been to determine which types of companies embrace the revolutionary trend. The chart in Figure 13 breaks down the results.

Figure 13: Types of companies investing in SCM digitalization



In line with the presented results, large enterprises (1000+ employees) have shown to have the highest activity in SCM digitalization. As can be seen, 39 of the reviewed papers have associated large enterprises with SCM digitalization. Furthermore, small and medium-sized enterprises (SMEs) (101-500 employees) appear to have the second highest rate of interest in SCM digitalization with 24 of the reviewed papers associating SMEs with digitalization. Small and medium-sized businesses (SMBs) (0-100 employees), on the other hand, have the lowest rate of activity in SCM digitalization, where only 4 publications out of the 119 reviewed have associated SMBs with digitalization.

The results have shown a large degree of consensus on the research as stated by the European Parliamentary Research Service in their report that large investments are required

for enterprises to transition their supply chains into digitalization: "Investments with a value up to €140 billion are expected in Europe which can be daunting for small enterprises" [21]. In addition, Geopointe stated that small companies that are dealing with short distribution routes do not need to invest in geo-analytics; this, however, is recommended for large companies serving various customers globally [25]. Nevertheless, the research has also shown that European countries and the European Structural and Investment Funds are encouraging SMEs to invest in digitalization. For this reason, France offered small and medium-sized companies €1 billion in loans for investing in robotics, and the European Structural and Investment Funds have made available a €77 million budget to help small companies implement digitalization [21].

The results provided in this study therefore confirm our second assumption stating that: Digitalization is predominantly used by large corporations, rather than small companies. Thus, as the research has shown, small companies are encouraged by funds to invest in digitalization with the scope of gaining comparative advantages through smart specializations into specific fields of digitalization, e.g., robotics [21]. Strategies such as smart logistics using IoT, drones, autonomous vehicles, and predictive transportation (delays, rescheduling) will help companies improve their inventories and ordering policies, and thereby increase customer satisfaction Sáenz (2017).

## 4 Conclusion

This research has provided an understanding of how digitalization is reshaping the nature of modern supply chains by targeting the most studied trends in SCM digitalization, the impact of digitalization on industries and regions, and how different types of industries can adapt to the trend based on the revealed information. Given the generic nature of this research, the findings are considered applicable for any parties interested in learning more about the concept of digitalization, its impact on SCM, and potentially use the learning as a starting point towards embarking on a digitalization journey.

The extensive literature review presented the evolution of SCM digitalization over time. While digitalization followed a slow progression throughout the years, the research has shown that since 2014, the concept of digitalization has quickly spread throughout Europe, first becoming popular in Germany under the name 'Industrie 4.0' and being promoted as part of the 'High-Tech strategy 2020', targeting the development of German industries. The research furthermore revealed the nine most studied SCM digitalization parameters which have been ranked

based on their recurrence in the 119 studied scientific papers aggregated in the statistical analysis.

It is possible to conclude that digitalization primarily has an active impact in Europe, Asia, and the US. While digitalization was first seen in Central Europe, it has quickly spread to other continents as well created an increasingly competitive digital environment. Policy mechanisms in Germany, France, Switzerland, Denmark, Asia, and the US are encouraging businesses to adopt digitalization as means of developing small and medium-sized companies towards specific fields of specialization. This means that companies can benefit by either loaning money for investments in specialized fields of digitalization or specialized professionals driven by innovation can join the Institute of Robotics and Intelligent Systems and National Centers of Competence in Research in Switzerland with the scope of developing brain-inspired intelligent robotics. Overall, it is expected according to the European Parliamentary Research Service that digitalization will bring globally a value-added of \$1.3 trillion by 2020, whereas investments of more than \$500 billion by 2020 will be made [21]. The threat of digital disruptions is triggering companies to move from conventional incremental approaches to radical solutions like digitalization.

While digitalization is evolving into a revolutionary trend, affecting the way businesses run their supply chains, the results have shown that different types of industries at the same time are taking action by adopting relevant technological practices. The research has shown that the most active industries investing in digitalizing their supply chains are electronics, automotive, manufacturing, retail, transportations, and energy. The research has further shown that SMEs are adapting to the digitalization era by primarily investing in big data analytics, software and mobile applications, cloud computing, and IoT in order to reduce costs and optimize their supply chain operations. Through several examples, it has been demonstrated that investments in these technological trends have helped companies significantly reduce costs and increase revenues. Generally, the results have indicated that digitalization in SCM is highly complex and it affects the entire organization through an end-to-end approach. Furthermore, it is important to note that digitalization trends are interrelated, indicating that companies should be committed to making large investments. In other words, companies would not be capable of capturing and analysing data (big data analytics) without having implemented sensors in their machines and devices; therefore, they will not be able to control their machines/robots without having IoT-connected devices or storing their data in a common infrastructure without cloud computing.

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