Supply Chain Management

"Undergraduate / Postgraduate Course"

Undergraduate Thesis / Postgraduate Dissertation

The adoption barriers of Industry 4.0 technologies for the logistics companies in Greece

Charalampos Alexandrakis

Supervisor: Thomas Dasaklis

Patras, Greece, June 2023

The adoption barriers of Industry 4.0 technologies for the logistics companies in Greece

Charalambos Alexandrakis

Supervising Committee

Supervisor:
"Name & Surname"
"Affiliation"

Co-Supervisor:
"Name & Surname"
"Affiliation"

Patras, Greece, June 2023

“Acknowledgments and / or Dedication”

Abstract

The concept of future industrial systems has gained popularity in recent times, with terms like Industry 4.0, the Internet of Things (IoT), and Cyber Physical Systems (CPS) being widely used. These technologies offer numerous potential advantages for supply chain services, such as transportation and warehousing. However, a significant portion of these technologies is primarily developed by or for large companies. As a result, much of the current focus and efforts are disconnected from the specific requirements of small and medium-sized enterprises (SMEs), despite the fact that SMEs make up 90% of registered companies in Europe. The integration of Industry 4.0 principles into supply chain management (SCM) is a relatively new and significant area that requires further research. While a few studies have begun to examine existing literature on Industry 4.0, there is a notable gap in terms of specifically investigating its role in SCM. This research paper provides a systematic review and comprehensive analysis of the existing literature on Industry 4.0 in supply chain management (SCM). The study uncovers insightful findings that will be valuable for both academic researchers and industry professionals, particularly top-level managers. Using real data from transportation and warehousing companies related to their size, type of service, area of action etc. we are trying gather as much information as possible about the barriers that prevent then in order to adopt the Industry 4.0 technologies. The basic dependent variable of our research is the size of the company that strangle to adopt a technology. Using this variable in this paper, we are trying to analyze through qualitive and quantitive analysis, using descriptive statistics and regression analysis, how size affects different companies and which barriers are the most important for each and every one of them. The results reveal that there are some common barriers that struggle every company and most important that size of an entity matters.

Keywords

Digitalization, supply chain management, I4.0.

Τα εμπόδια υιοθέτησης των τεχνολογιών industry 4.0 για τις εταιρείες logistics στην Ελλάδα

Χαράλαμπος Αλεξανδράκης

Περίληψη

Η έννοια των μελλοντικών βιομηχανικών συστημάτων έχει αποκτήσει δημοτικότητα τα τελευταία χρόνια, με όρους όπως το Industry 4.0, το Internet of Things (IoT) και τα Cyber Physical Systems (CPS) που χρησιμοποιούνται ευρέως. Αυτές οι τεχνολογίες προσφέρουν πολλά πιθανά πλεονεκτήματα για τις υπηρεσίες της εφοδιαστικής αλυσίδας, όπως η μεταφορά και η αποθήκευση. Ωστόσο, ένα σημαντικό μέρος αυτών των τεχνολογιών αναπτύσσεται κυρίως από ή για μεγάλες εταιρείες. Ως αποτέλεσμα, μεγάλο μέρος της τρέχουσας εστίασης και των προσπαθειών αποσυνδέεται από τις ειδικές απαιτήσεις των μικρομεσαίων επιχειρήσεων (ΜΜΕ), παρά το γεγονός ότι οι ΜΜΕ αποτελούν το 90% των εγγεγραμμένων εταιρειών στην Ευρώπη. Η ενσωμάτωση των αρχών του Industry 4.0 στη διαχείριση της εφοδιαστικής αλυσίδας (SCM) είναι ένας σχετικά νέος και σημαντικός τομέας που απαιτεί περαιτέρω έρευνα. Ενώ μερικές μελέτες έχουν αρχίσει να εξετάζουν την υπάρχουσα βιβλιογραφία για το Industry 4.0, υπάρχει ένα αξιοσημείωτο κενό όσον αφορά τη συγκεκριμένη διερεύνηση του ρόλου του στο SCM. Αυτό το ερευνητικό έγγραφο παρέχει μια συστηματική ανασκόπηση και ολοκληρωμένη ανάλυση της υπάρχουσας βιβλιογραφίας για το Industry 4.0 στη διαχείριση της εφοδιαστικής αλυσίδας (SCM). Η μελέτη αποκαλύπτει διορατικά ευρήματα που θα είναι πολύτιμα τόσο για ακαδημαϊκούς ερευνητές όσο και για επαγγελματίες του κλάδου, ιδιαίτερα για στελέχη ανώτατου επιπέδου. Χρησιμοποιώντας πραγματικά δεδομένα από εταιρείες μεταφορών και αποθήκευσης που σχετίζονται με το μέγεθός τους, το είδος της υπηρεσίας, την περιοχή δράσης κ.λπ. προσπαθούμε να συγκεντρώσουμε όσο το δυνατόν περισσότερες πληροφορίες σχετικά με τα εμπόδια που εμποδίζουν στη συνέχεια, προκειμένου να υιοθετήσουμε τις τεχνολογίες Industry 4.0.

Η βασική εξαρτημένη μεταβλητή της έρευνάς μας είναι το μέγεθος της εταιρείας που στραγγαλίζεται για να υιοθετήσει μια τεχνολογία. Χρησιμοποιώντας αυτή τη μεταβλητή σε αυτή την εργασία, προσπαθούμε να αναλύσουμε μέσω ποιοτικής και ποσοτικής ανάλυσης, χρησιμοποιώντας περιγραφική στατιστική και ανάλυση παλινδρόμησης, πώς το μέγεθος επηρεάζει διαφορετικές εταιρείες και ποια εμπόδια είναι τα πιο σημαντικά για κάθε μία από αυτές. Τα αποτελέσματα αποκαλύπτουν ότι υπάρχουν μερικά κοινά εμπόδια που αντιμετωπίζουν κάθε εταιρεία και το πιο σημαντικό ότι το μέγεθος μιας οντότητας έχει σημασία.

Λέξεις – Κλειδιά

Ψηφιοποίηση, διαχείρισης της εφοδιαστικής αλυσίδας, I4.0.

Table of Contents

Abstract.. v
Περίληψη vi
Table of Contents...**Σφάλμα! Δεν έχει οριστεί σελιδοδείκτης.**
List of Figures...ix
List of Tables.. x
List of Abbreviations & Acronyms xi
1. A quick overview of this the master thesis.. 1
2. Supply chain digitalization 2
3 Literature review... 6
3.1 I4.0. Technologies 6
3.1.1 Automation.. 8
3.1.2 Big data technologies 10
3.1.3 Blockchain 13
3.1.4 Internet of Things 18
3.2 Adoption barriers..24
3.3 Background..31
3.3.1 I4.0 technologies in small and medium enterprises (SME) 32
3.3.2 *Challenges around I4.0 adoption in SMEs* 33
3.3.3 Research Gaps...34
3.3.3.1 *1st research gap*..34
3.3.3.2 2nd research gap 35
4. Research methodology..36
RQ1...37
RQ2...37
5. Results 39
6. Discussion 66
6.1 Discussion over the size of the enterprise and the different parameters...........66
6.2 Limitations...67
6.3 Ideas for future research...68
7. Conclusion 69
References...71
Appendix A: "Title of appendix" 77
Appendix B: "Title of appendix" 78

List of Figures

Figure 1 – Company size
Figure 2 – The type of services a company provide
Figure 3 – Type of services y company size
Figure 4 - % Type of services y company size
Figure 5 – Area of operation of a company
Figure 6 – Number of warehouses of a company
Figure 7 – CBM transport by a company
Figure 8 – Levels of usage of technologies
Figure 9 - Automation used by company size
Figure 10 - Total Barriers per size
Figure 11 - Total Barriers per Technology

List of Tables

Table 1 - Benefits, challenges, and critical success factors

Table 2 - Barriers to sustainability and I4.0 adoption

Table 3 - Type of services by company size

Table 4 - % Type of services by company size / Sum of company size

Table 5 - Area of action by company size

Table 6 - % Area of action by company size / Sum of company size

Table 7 - Number of warehouses by company size / Sum of company size

Table 8 - % Number of warehouses by company size / Sum of company size

Table 9 - CBM transported by company size

Table 10 - % CBM transported by company size / Sum of company size

Table 11 - Automation used by company size / Sum of company size

Table 12 – % Automation used by company size

Table 13 – Big data technologies used by company size

Table 14 – % Big data technologies used by company size / Sum of company size

Table 15 - Blockchain technologies used by company size

Table 16 – % Blockchain technologies used by company size / Sum of company size

Table 17 – Regression analysis of Number of employees according level of technology usage

Table 18 - Total Barriers per size

Table 19 – Ranking the barriers by total score

Table 20 – Ranking the barriers by each technology

Table 21 – Regression analysis of company size according different barriers throughout automation

Table 22 - Regression analysis of company size according different barriers throughout big data analytics

Table 23 - Regression analysis of company size according different barriers throughout Blockchain

Table 24 - Regression analysis of company size according different barriers throughout Internet of Things

List of Abbreviations & Acronyms

Supply chain	SC
Internet of Things	IoT
Automation	AU
Big Data Technologies	BDTs
Blockchain	BC
Small – Medium Enterprises	SME
Industry 4.0 Technologies	I4.0
Multinational enterprise	MNEs
Research Gap	RG
Research questions	RQ

1. A quick overview of this the master thesis

This research paper delves into a comprehensive analysis of the main barriers that companies encounter when attempting to adopt new technologies within a specific segment of the supply chain. The study aims to identify these obstacles and provide insights into strategies that can effectively mitigate them. By addressing these barriers head-on, organizations can unlock the full potential of technology, leading to improved operational efficiency and streamlined processes.

The first barrier explored in this research is resistance to change. Many companies face challenges in breaking free from established routines and embracing novel technologies. Overcoming this resistance requires a proactive approach to change management, emphasizing the benefits and transformative impact of the new technology on supply chain operations.

Financial constraints present another significant obstacle. Implementing and integrating new technologies often require substantial investments, which can be challenging for companies with limited budgets. Additionally, uncertainty surrounding the return on investment (ROI) and the time required to demonstrate the technology's value can further discourage adoption. To overcome these financial barriers, organizations can conduct thorough cost-benefit analyses, explore alternative financing options, or seek partnerships with technology providers.

Technical challenges also hinder technology adoption in the supply chain. Compatibility issues, interoperability concerns, and the need for system integration can pose significant obstacles. When existing systems and processes are incompatible with the new technology, implementation becomes complex. Addressing these technical barriers necessitates careful planning, collaboration with IT departments, and potential customization or modification of existing systems to ensure seamless integration.

Regulatory and compliance factors further complicate the adoption of new technologies. Industries with stringent regulations require companies to navigate a complex landscape of standards, certifications, and legal requirements. Ensuring that the new technology aligns with these regulations can be a time-consuming process. Organizations must engage with regulatory bodies, seek guidance, and invest in necessary measures to comply with industry-specific requirements.

Finally, organizational culture and employee readiness impact technology adoption. Resistance to change may manifest among employees who fear job displacement or feel overwhelmed by the learning curve associated with new technologies. To overcome this barrier, companies must foster an innovative culture, invest in training and development programs, and communicate the benefits and opportunities that new technologies bring to their workforce.

In conclusion, this research paper provides an in-depth analysis of the main barriers that hinder companies in adopting new technologies within the supply chain. By addressing resistance to change, financial constraints, technical challenges, regulatory compliance, and organizational culture, the study offers actionable recommendations to help organizations overcome these limitations and embrace innovation. By successfully navigating these barriers, companies can harness the transformative power of technology, optimizing their supply chain operations for improved efficiency and competitiveness.

2. Supply chain digitalization

The basic idea of a supply chain revolves around the seamless flow of goods or services from their initial production or procurement stage to their ultimate consumption. It encompasses a network of interconnected entities, including suppliers, manufacturers, distributors, retailers, and customers, all working together to ensure the efficient movement and delivery of products or services. The supply chain encompasses various activities such as procurement, production, inventory management, logistics, and demand planning. Effective supply chain management involves optimizing these activities to achieve cost efficiency, timely delivery, and customer satisfaction. It requires careful coordination, collaboration, and communication among all stakeholders involved. A well-managed supply chain aims to minimize disruptions, reduce lead times, manage inventory levels, and enhance overall operational performance. By streamlining processes, leveraging technology, and aligning strategies, organizations can achieve greater visibility, control, and responsiveness within their supply chains, ultimately leading to improved customer service and competitive advantage.

Furthermore, the basic idea of a supply chain extends beyond the physical flow of products to encompass the flow of information and funds. Timely and accurate information sharing among supply chain partners is crucial for effective coordination and decision-making. This includes sharing data on inventory levels, production schedules, demand forecasts, and customer preferences. By having access to real-time information, organizations can respond swiftly to changes in customer demand, market trends, or supply disruptions, enabling them to make informed decisions and adapt their operations accordingly.

Financial transactions and the flow of funds are also integral to supply chains. Suppliers need to be paid, manufacturers need funds for production, and customers need to make payments for their orders. Effective financial management within the supply chain involves ensuring appropriate payment terms, managing credit and cash flow, and fostering trust and transparency among all parties involved.

Another fundamental aspect of supply chains is the concept of value creation. Supply chains are not merely about the movement of products; they are about delivering value to customers. Value can be created through various means, such as product customization, faster delivery times, superior quality, or competitive pricing. Understanding customer needs and preferences and aligning supply chain activities to meet those expectations are vital for creating value and gaining a competitive edge in the market.

Lastly, supply chains operate within a dynamic and ever-evolving business environment. Factors such as globalization, technological advancements, changing customer demands, and regulatory requirements constantly shape and reshape supply chain strategies. Organizations need to continuously assess and improve their supply chain processes, adopt new technologies, and foster innovation to stay competitive and adapt to emerging trends and challenges.

The supply chain serves as the intricate web that connects manufacturers, suppliers, distributors, and retailers, ensuring the seamless flow of goods and services from the point of origin to the end consumer. It encompasses a vast array of processes, including procurement, production, transportation, warehousing, and distribution. A well-optimized supply chain holds the key to operational excellence, as it enables businesses to meet customer demands efficiently, reduce costs, minimize inventory levels, and enhance overall competitiveness. With the ever-evolving global landscape and increasing customer expectations, companies must continuously innovate and adapt their supply chain strategies. Embracing technological advancements, fostering collaboration with partners, implementing sustainable practices, and embracing data-driven decision-making are critical for achieving supply chain excellence in today's dynamic business environment. By recognizing the strategic importance of the supply chain and employing effective management and optimization techniques, businesses can not only enhance their operational efficiency but also gain a competitive edge in the market.

Due to the globalization and cross-border penetration of the existing industrial markets, the business world's expansion has intensified market competitiveness. Identifying developing digital technologies that may be leveraged to create a new business model is crucial for businesses if they want to survive and retain a sustainable competitive edge in this global market. The way manufacturing activities are carried out in today's competitive world has compelled firms to adopt cutting-edge technologies such 3D printing, quick prototyping, and utilization of the internet of things for information and analysis. The goal of any firm in this cutthroat and chaotic climate is to please the consumer with the correct product quality, quantity, and pricing at the best possible time. Implementing supply chain management, which includes operations administration, purchasing, production, IT, and logistics, effectively addresses these issues. In order to gain a competitive edge, it is vital to show the most recent advances in these fields and how emerging technology might be incorporated into these processes. Companies today need to change their business streams in order to respond to changing consumer needs, in addition to having a highly structured and effective supply chain. Researchers foresee the transition to digital life and anticipate a digital SCM in the upcoming years. Classical supply chains will change into networks that are responsive to demand. According to Gimpel and Roglinger et al. (2015)[1], the term "digitalization" describes "the increasing penetration of digital technologies in society with the associated changes in the connection of individuals and their behavior." Corporations and supply chain strategies will benefit greatly from digitization. Because they have seen the importance and significance of technological advancements for their own growth and businesses, numerous businesses want to evolve into more "digital," and management support for such initiatives is also rising. However, a thorough understanding of the effects and advantages of digital technologies on business is necessary before they can be implemented in the current supply chain. It has been noted that the significant supply chain concerns would be resolved by the

[1] Prakash Agrawal and Rakesh Narain, "Digital Supply Chain Management: An Overview," *IOP Conference Series: Materials Science and Engineering* 455 (December 19, 2018): 012074, https://doi.org/10.1088/1757-899X/455/1/012074.

digitization of supply chain procedures. Having an agile supply chain (SC) is every company's ultimate goal because such a modern supply chain is quick, automatic in the process (accepting orders, processing them, and distributing them to clients), flexible, and transparent. A modern SC can also operate in dynamic systems and with a large amount of data (Yin et al., 2018; Butner, 2010). One such SC is Amazon, which receives over a million orders daily from people all across the world. These orders are located and gathered by Amazon robots, who then deliver them to the staff members for timely fulfillment. DHL is a fascinating example of how Big Data technologies are being used in the field of contemporary SC. Big Data enables data analysis at a higher level than was previously possible with standard technologies. DHL is in a position to gather huge data from clients and analyze it so that it can alert clients about potential disruptions to their individual supply chains. It is possible to maintain system operations while protecting and enhancing the supply chain's efficiency. It promises to achieve client happiness consistently (Witkowski, 2017). Using a notion that makes the change from a traditional SC to a modern SC easier is required if we are to have a modern SC system that can handle dynamic conditions. The idea behind I4.0 technology is to automate, digitalize, and network business processes. When businesses are faced with dynamic systems, it aids in the development of flexible supply chain systems, especially by facilitating integration across all SC components, including suppliers, manufacturers, and customers. In 1784, the advent of steam and water power, as well as the mechanization of the production process, marked the beginning of the first industrial revolution. In the 1870s, the second industrial revolution transformed the production process into a mass production system and introduced advanced assembly lines. In 1970, the use of computers to automate production procedures began the third industrial revolution. The fourth industrial revolution, often known as I4.0, is characterized by the digitization of equipment and the integration of systems as a result (Lu, 2017). (Da Xu, Xu, & Li, 2018; Tang & Veelenturf, 2019). I4.0 is "the full adoption of information and communication technology (ICT) as well as their connection to an internet of things, services, and data, which enables a real-time manufacturing," according to Armengaud et al. I4.0 refers to a higher level of digitalization across business models, value chains, and products. According to Armengaud et al. (2017), I4.0 promotes digitalization through IT connections and solutions to increase efficiency and lower costs. Project managers are the essential leaders of projects in I4.0 that are extremely strategic for the long-term success of businesses. To implement I4.0 in their business, organizations need managers that are knowledgeable about the topic. As businesses advance, managers who are engaged in digitization will play an important role. They drive businesses toward digitization and use innovation, such as when they affix radio frequency identification (RFID) to packages being delivered and/or use cloud computing to restore data. These tools can aid in decision-making, risk reduction, and productivity growth for managers (Saucedo-Martnez et al., 2018). This study might serve as a good place for managers to start when learning about I4.0 and classifying its main supply chains. This study examines the existing literature on I4.0 and MSC, highlighting advancements, shortcomings, and future research objectives. Although there has been an increase in interest in using I4.0 in manufacturing and logistics systems in recent years, there is still a significant lack in knowledge about these concepts in industries and academic venues (Qin et al., 2016). The purpose of this study is to discover why four I4.0 technologies face acceptance hurdles in the Greek supply chain market.

3 Literature review

In this section we will point out 4 of the I4.0. technologies that we will analyze and of course we will choose the most common barriers that enterprises face.

3.1 I4.0. Technologies

I4.0 has paved the way for the convergence of cyber-physical systems and internet-based communication, revolutionizing manufacturing value creation processes. Under the umbrella of I4.0, a multitude of advanced technologies such as robotics, artificial intelligence, machine learning, big data analytics, cloud computing, smart sensors, the internet of things, and augmented reality have emerged, enabling remarkable advancements. By transitioning from the prevailing centralized production model to a digital and decentralized system, remarkable enhancements in flexibility, quality, productivity, cost-efficiency, and customer satisfaction are achievable. Nevertheless, despite the potential advantages offered by I4.0, numerous firms encounter difficulties in embracing these new technologies and effectively incorporating them into their business strategies. This article sets out to identify the potential obstacles that impede the implementation of I4.0 within industrial enterprises. By conducting an extensive examination of relevant literature and consulting industry experts, the following hindrances have been identified: insufficient integration across the value chain, concerns surrounding cybersecurity, a lack of clarity regarding the economic benefits, scarcity of personnel possessing the necessary skills, substantial investment requirements, inadequate infrastructure, interruptions to job roles, challenges associated with data management and data quality, absence of secure standards and norms, and resistance to change.

I4.0 is a new field in which the Internet of Things and cyber-physical systems interact in such a manner that the combination of software, sensor, processor, and communication technology plays a significant role in enabling "things" to input information into it and, as a result, contribute value to industrial processes. I4.0's ultimate goal is to provide an open, smart manufacturing platform for industrial-networked information applications. The objective is that it would ultimately allow manufacturing enterprises of all sizes to get quick and inexpensive access to modeling and analytical tools that can be tailored to their specific needs. The idea of I4.0 is best described by the project's "smart factory," which combines the real and digital worlds through cyber-physical systems, resulting in a convergence of technological and commercial operations. The industrial production life cycle is becoming increasingly oriented toward the rising individuality of consumer requirements, and it includes: the concept and order for development and production, product distribution and recycling, and all linked Services. The interconnectedness of people, things, and systems results in dynamical, real-time optimized, and self-organized inter-company shareholder value systems that are reviewed and optimized based on criteria such as cost, availability, and resource efficiency. The concept of I4.0 stresses the constant digitalization and connectivity of all producing units in an industry. Horizontal and vertical system integration, the internet of things, cybersecurity, the cloud, big data analytics, simulation, additive manufacturing (3d printing), augmented reality, and robot are some of the technology fields that drive I4.0. The diagram below depicts the technology associated with I4.0. As intra- and inter, universal data-integration networks expand and allow totally automated value chains, horizontal and vertical system integration among firms, departments, functions, and capacities will become much more cohesive in I4.0.

The industrial web of things will, however, incorporate embedded computers into additional objects and connect them using widely accepted industry standards. This enables field devices to connect and interact with one another as well as with a greater centralized controller when needed. It also allows for real-time reactions by decentralizing data and decision making. Dependable communications, as well as sophisticated identity and access management of machines and users, are required for I4.0 to handle the issue of cybersecurity risks, which has grown substantially with greater connectivity and the usage of standard communication protocols. As technology develops, more machine information and capabilities will be sent to the cloud, allowing for more data-driven decisions services for manufacturing system. More production-related projects in Industrial revolution 4.0 will necessitate increasing data exchange across sites and business borders.

Big data and analytics allow for the collection and complete examination of data from several sources and customers to assist real-time decision making, enhance manufacturing quality, conserve energy, and improve equipment service. Real-time data will be used in simulations to create a virtual representation of the physical world, which may contain people, machines, and other objects. This reduces machine setup times and improves quality by enabling workers to test and perfect the machine configuration for the following product in line before the actual changeover. I4.0 will make extensive use of additive manufacturing techniques to create small quantities of bespoke goods with advantageous construction features like complicated, lightweight designs decentralized, high-performance additive manufacturing technologies will shorten delivery routes and cut back on inventory. Although the technologies are still in their infancy, businesses will employ them considerably more extensively as I4.0 approaches. A number of services, like choosing components from a warehouse and transmitting maintenance instructions through mobile devices, can be supported by augmented reality-based systems. Robots are developing more autonomy, adaptability, and cooperation. They will eventually communicate with one another, coexist securely alongside humans, and gain knowledge from them. Compared to the robots currently employed in production, these ones will be less expensive and have a wider variety of capabilities.

3.1.1 Automation

Automation (AU) refers to the utilization of technology to oversee and control the production and delivery of goods and services, as defined by the International Society of Automation (2022). Implementing automation in supply chain processes allows for optimization by enhancing productivity, reducing labor costs, and minimizing energy consumption (Esmaeilian, Sarkis, Lewis, & Behdad, 2020; Gustafsson, Jonsson, & Holmstrom, 2019; Moreno, Court, Wright, & Charnley, 2019). Improved autonomy and speed, associated with automation, lead to quality improvements (Hahn, 2020; Moreno et al., 2019). Moreover, automation eliminates the need for human intervention and decreases errors (Ghadimi, Wang, Lim, & Heavey, 2019; Jagtap & Rahimifard, 2019; Klumpp & Zijm, 2019), while promoting supply chain interoperability and integration (Ghadimi et al., 2019; Moreno et al., 2019). However, the adoption of automation entails significant investment requirements and coordination costs (Dolgui et al., 2019; Sanders, Boone, Ganeshan, & Wood, 2019). Additionally, it may create a disconnect between human workers and automated logistics and supply chain components, leading to inefficient human-machine cooperation (Klumpp & Zijm, 2019). Adequate preparation and alignment are crucial for successful implementation of automation (Frazzon, Dutra, & Vianna, 2015; Martn-Gomez, Aguayo-Gonzalez, & Luque, 2019; Roy & Satpathy, 2019). Stakeholders must carefully analyze and comprehend both the business and technological aspects. Businesses need to assess the alignment of their financial resources with the business landscape and ensure that their infrastructure is properly established and suitable for automation purposes.

Table 1 - Benefits, challenges, and critical success factors.1

Automation (AU)	Benefits	1)Process optimization	Buil et al. (2011); Kohli & Johnson (2011); Harrison et al. (2016); Navickas et al. (2017);Simchi-Levi & Wu (2018); Al-Saeed et al. (2019); Ghadimi et al. (2019); Gustafsson et al.(2019); Junge (2019); Sandvik and Stubbs (2019); Rejeb et al. (2019); Lüthje (2019);Klumpp & Zijm (2019); Krykavskyy et al. (2019); Jagtap et al. (2019); Moreno et al.(2019); Esmaeilian et al. (2020); Hahn (2020).
		2) Integration	Kohli & Johnson (2011); Harrison et al. (2016); Moreno et al. (2019); Ghadimi et al.(2019).

	Challenges	1) Cost	Bechtsis et al. (2018); Buil et al. (2011); Dolgui et al. (2019a); Sanders et al. (2019).
		2)Artificial divide	Klumpp et al. (2019).
	Critical success factors	Preparation and alignment	Kohli & Johnson (2011); Frazzon et al. (2015); Lin (2018); Roy and Satpathy (2019);Martín-G´omez et al. (2019).

[2]

3.1.2 Big data technologies

Big data technologies (BDTs) are characterized as data that possesses high volume, velocity, and variety, requiring specific technology and analytical methods to extract value from it (De Mauro, Greco, & Grimaldi, 2016). BDTs offer several key advantages in the context of supply chains, including improved decision making, reliability, and information integration. By leveraging real-time data collected from diverse sources, BDTs equip supply chain actors with analytical capabilities to derive valuable insights. These insights contribute to decision making in areas such as forecasting, risk management, planning, marketing, sustainability, and efficiency (Agrawal & Narain, 2021; Jabbour et al., 2020; Kache & Seuring, 2017). Furthermore, BDTs enhance the perception of reliability among supply chain actors, the overall reliability of the supply chain, and foster better collaboration (Jabbour et al., 2020; Molka-Danielsen et al., 2018). Another benefit is that BDTs promote supply chain connectivity by facilitating data sharing and improving the information environment (Brinch et al., 2018; Kache & Seuring, 2017).

However, the effective implementation of BDTs in supply chains faces significant challenges related to infrastructure and human resources. Acquiring the necessary skill sets for BDT utilization can be difficult due to the scarcity of qualified personnel (Gupta et al.,

[2] Fakhreddin F. Rad et al., "Industry 4.0 and Supply Chain Performance: A Systematic Literature Review of the Benefits, Challenges, and Critical Success Factors of 11 Core Technologies," *Industrial Marketing Management* 105 (August 2022): 268–93, https://doi.org/10.1016/j.indmarman.2022.06.009.

2020; Weersink et al., 2018; Zaki et al., 2019). Additionally, the implementation of BDTs requires well-designed and often expensive infrastructure, such as control towers and analytics algorithms (Gruzauskas et al., 2018; Raut et al., 2019; Zaki et al., 2019). The governance of large data poses another complexity, particularly when coordinating BDTs among diverse supply chain participants with varying backgrounds and perspectives (Gravili et al., 2018; Ivanov et al., 2019; Nguyen et al., 2021). Cybersecurity threats, information leaks, and concerns related to customer and individual privacy must be addressed diligently (Ivanov et al., 2019; Kache & Seuring, 2017; Nguyen et al., 2021). Furthermore, accurately measuring the economic value and financial returns of big data can disrupt supply chain connections if not managed appropriately (Kache & Seuring, 2017; Weersink et al., 2018).

To ensure successful utilization of BDTs and effective dissemination of insights throughout the supply chain, integration between internal departments (e.g., IT and business departments) and external actors is crucial (Kache & Seuring, 2017; Raut et al., 2019; Spanaki et al., 2018). Additionally, the output of BDTs' analytical processes should be understandable, relevant, and capable of identifying patterns, trends, and outliers (Kache & Seuring, 2017; Molka-Danielsen et al., 2018). Prioritization and modularization may be necessary when analyzing massive volumes of diverse data, focusing on the most significant data points (Ding, 2018; Molka-Danielsen et al., 2018). Leadership style and managerial strategies play a crucial role in maximizing the value derived from BDTs (Raut et al., 2019; Jabbour et al., 2020; Dolgui et al., 2019). Given the information-centric nature of BDTs, it is essential for all strategies and activities to comply with government-enforced information privacy regulations (Raut et al., 2019).

Table 1 - Benefits, challenges, and critical success factors.2

Big Data Technologies (BDTs)	Benefits	1)Awareness and informed decision making	Kache and Seuring (2017); Ding et al. (2018); Gravili et al. (2018); Brinch et al. (2018);Zaki et al. (2018); Vieira et al. (2019); Raut et al. (2019); Ardito et al. (2019); Ivanovet al. (2019); Hahn (2020);

			Winkelhaus and Grosse (2020); Gupta et al. (2020a); Jabbour et al. (2020); Benzidia et al. (2021); Agrawal and Narain (2021).
		2) Reliability	Kache and Seuring (2017); Molka-Danielsen et al. (2018); Jabbour et al. (2020).
		3)Information connectivity	Kache and Seuring (2017); Brinch et al. (2018).
	Challenges	1) Infrastructure and human resources	Frazzon et al. (2015); Kache and Seuring (2017); Kache and Seuring (2017); Zaki et al. (2018); Weersink et al. (2018); Zaki et al. (2018); Gruˇzauskas et al. (2018); Raut et al. (2019); Jabbour et al. (2020); Gupta et al. (2020a).
		2)Big data governance	Kache and Seuring (2017); Brinch et al. (2018); Molka-Danielsen et al. (2018); et al. (2018); Spanaki et al. (2018); Gravili et al. (2018); Ivanov et al. (2019); Jabbour Weersink et al. (2020); Nguyen et al. (2021).
		3)Cybersecurity threat, information leakage, and privacy concerns	Kache and Seuring (2017); Spanaki et al. (2018); Klumpp et al. (2019); Sanders et al. (2019); Ivanov et al. (2019); Jabbour et al. (2020); Nguyen et al. (2021).
		4)Financial value measurement	Kache and Seuring (2017); Weersink et al. (2018).

	Critical success factors	1) Integration	Kache and Seuring (2017); Molka-Danielsen et al. (2018); Spanaki et al. (2018); Raut et al. (2019).
		2)Data readability and relevance	Kache and Seuring (2017); Molka-Danielsen et al. (2018). Molka-Danielsen et al. (2018); Ding et al. (2018).
		3)Data modularization and prioritization	
		4)Managerial approach	Raut et al. (2019); Bamel & Bamel (2020); Jabbour et al. (2020); Gupta et al. (2020).
		5) Compatibility with governmental laws	Raut et al. (2019).

[3]

3.1.3 Blockchain

Blockchain technology, as described in the text, represents a significant innovation in the field of data management. Its decentralized and immutable nature ensures that transactions and data recorded on the blockchain remain secure and tamper-proof. By providing a consistent, transparent, and traceable event log, blockchain offers several benefits for supply chain management.

Data security is a critical aspect of any supply chain. The implementation of blockchain technology addresses this concern by providing authenticated and secure data storage and communication across supply chain participants. The decentralized nature of blockchain

[3] Rad et al.

eliminates the need for a central authority, reducing the risk of unauthorized access or data manipulation. This enhances the trust and reliability of the supply chain ecosystem.

In addition to data security, blockchain enables data traceability throughout the supply chain. Each transaction recorded on the blockchain forms a permanent and transparent history of materials, processes, and products. This traceability enables improved quality control, authentication, and the identification of bottlenecks or inefficiencies. Moreover, it supports sustainability initiatives and the establishment of a circular economy by facilitating the tracking of products' origin, composition, and environmental impact.

Smart contracting is another powerful aspect of blockchain technology. Through the use of self-executing smart contracts, supply chain actors can automate and streamline contractual agreements. The verification mechanisms provided by blockchain ensure the authenticity and integrity of parties involved in the contracts. This simplifies the implementation of business logic and operational processes, enhancing efficiency and reducing the potential for disputes or breaches.

The implementation of blockchain technology in supply chains can yield significant efficiency gains. By eliminating the need for intermediaries and reducing transaction costs, blockchain promotes streamlined and cost-effective operations. It enables real-time visibility and information sharing across the supply chain, facilitating faster decision-making and response to market demands. Additionally, the decentralized nature of blockchain allows for greater autonomy and agility among supply chain actors.

However, alongside its potential benefits, the text acknowledges several challenges in implementing blockchain technology in supply chains. Technical issues, such as scalability and energy consumption, need to be addressed for blockchain to handle large-scale transactions effectively. There is also a shortage of skilled professionals with expertise in blockchain technology, which poses a hurdle to its widespread adoption. Governance complexities and trust concerns further complicate the implementation process, requiring careful coordination and consensus among supply chain participants.

To ensure successful blockchain implementation, the text emphasizes the importance of preparation and alignment. This involves understanding the specific strategies, goals, and requirements of the supply chain actors, as well as integrating blockchain with complementary technologies. Infrastructure design plays a crucial role, requiring careful planning and consideration of the resources and capabilities needed to support blockchain implementation. Additionally, top management support and strategic approaches are essential to drive organizational change and maximize the benefits of blockchain technology.

In conclusion, the analysis highlights the potential transformative impact of blockchain technology in supply chain management. By addressing data security, traceability, smart contracting, efficiency, and cost reduction, blockchain offers a promising solution to optimize supply chain operations. However, careful consideration of the challenges and implementation strategies is necessary to ensure successful adoption and realization of blockchain's full potential in the supply chain ecosystem.

Table 1 - Benefits, challenges, and critical success factors.3

Blockchain (BC)	Benefits	1) Data security	Gromovs and Lammi (2017); Sharma et al. (2018); Yanovich et al. (2018); Radanovi´c and Liki´c (2018); Mandolla et al. (2019); Rejeb et al. (2019); Choi et al. (2019); Dolgui et al. (2019a); Mondal et al. (2019); Cole et al. (2019); Saberi et al. (2019); Rouhani & Deters (2019); Min (2019); Sarkis et al. (2020); Wang et al. (2020); Kamble et al. (2021).
		2)Data traceability, transparency, and management	Gromovs and Lammi (2017); Sharma et al. (2018); Yanovich et al. (2018); Perboli et al. (2018); Mandolla et al. (2019); Rejeb et al. (2019); Choi et al. (2019); Dolgui et al. (2019a); Mondal et al. (2019); Cole et al. (2019); Saberi et al. (2019); Rouhani & Deters (2019); Min (2019); Sarkis et al. (2020);

			Wamba et al. (2020); Wang et al. (2020); Batwa and Norrman (2020); Kamble et al. (2021); Mubarik et al. (2021); Esmaeilian et al. (2020); Agrawal and Narain (2021).
		3)Smart contracting	Sharma et al. (2018); Rejeb et al. (2019); Choi et al. (2019); Cole et al. (2019); Dolgui et al. (2019a); Rouhani & Deters (2019); Saberi et al. (2019); Batwa and Norrman (2020); Sarkis et al. (2020); Wang et al. (2020); Kamble et al. (2021).
		4) Efficiency	Gromovs and Lammi (2017); Radanovi´c and Liki´c (2018); Perboli et al. (2018); Gausdal et al. (2018); Sharma et al. (2018); Dolgui et al. (2019a); Krykavskyy et al. (2019); Cole et al. (2019); Choi et al. (2019); Min (2019); Rouhani & Deters (2019); Saberi et al. (2019); Batwa and Norrman (2020); Sarkis et al. (2020); Wang et al. (2020); Kamble et al. (2021).
		5)Decentralization	Sharma et al. (2018); Yanovich et al. (2018); Choi et al. (2019); Junge (2019); Saberi et al. (2019); Wang et al. (2020); Kamble et al. (2021).

		1)Technical issues	Radanovi´c and Liki´c (2018); Cole et al. (2019); Min (2019); Mondal et al. (2019); Rejeb et al. (2019); Rouhani & Deters (2019); Saberi et al. (2019); Du et al. (2020); Sahebi et al. (2020); Shoaib et al. (2020); Batwa and Norrman (2020); Kumar et al. (2020); Omar et al. (2020); Kayikci et al. (2020); Kohler & Pizzol (2020); Esmaeilian et al. (2020); Etemadi et al. (2021); Jabbar et al. (2021); Sundarakani et al. (2021).
	Challenges	2)Human resources	Cole et al. (2019); Min (2019); Saberi et al. (2019); Sahebi et al. (2020); Omar et al. (2020); Wang et al. (2020); Jabbar et al. (2021); Mathivathanan et al. (2021).
		3) Governance	Cole et al. (2019); Min (2019); Saberi et al. (2019); Alkhader et al. (2020); Chod et al. (2020); Esmaeilian et al. (2020); Sahebi et al. (2020); Batwa and Norrman (2020); Du et al. (2020); Lambourdiere & Corbin (2020); Rogerso & Parry (2020); Omar et al. (2020); Kayikci et al. (2020); Kohler & Pizzol (2020); Sobb et al. (2020); Wang et al. (2020); Jabbar et al. (2021); Etemadi et al. (2021); Sundarakani et al. (2021).

		4) Altering smart contracts	Dolgui et al. (2019b); Saberi et al. (2019); Kumar et al. (2020); Omar et al. (2020); Sobb et al. (2020); Etemadi et al. (2021).
	Critical success factors	1) Preparation and alignment	Gausdal et al. (2018); Radanovi´c and Liki´c (2018); Perboli et al. (2018); Cole et al. (2019); Rouhani & Deters (2019); Min (2019); Batwa and Norrman (2020); Kayikci et al. (2020); Kohler & Pizzol (2020); Wang et al. (2020); Jabbar et al. (2021); Tezel et al. (2021).
		2)Strategic approach and the support of top management	Saberi et al. (2019); Min (2019); Wamba et al. (2020).

[4]

3.1.4 Internet of Things

The term "Internet of Things" (IoT) refers to a vast network comprising smart and connected devices that have become possible due to significant advancements in computing power, device miniaturization, and ubiquitous wireless connectivity (Porter & Heppelmann, 2014). This interconnected system of objects has garnered significant attention in the literature, primarily due to its numerous potential advantages within supply chain management.

One of the key benefits of implementing the IoT in supply chains is performance optimization. By leveraging a network of interconnected devices at the supply chain level, resources can be unified and synergies can be created, leading to enhanced performance in various aspects of the supply chain, including transportation, goods management, and asset

[4] Rad et al.

utilization (Huang et al., 2020; Li et al., 2018; Rebelo et al., 2021). The IoT enables real-time monitoring and tracking of physical objects, commonly referred to as "things," throughout the supply chain, facilitating efficient and streamlined processes. This level of visibility and control allows for improved transportation planning, asset allocation, and overall supply chain efficiency (Huang et al., 2020; Li et al., 2018; Rebelo et al., 2021).

Another advantage of the IoT in supply chains is its ability to generate continuous data and provide access to valuable insights. The IoT facilitates the collection of granular data at various touchpoints within the supply chain, enabling detailed tracing of products, understanding consumption patterns, monitoring asset status, and gaining insights into various processes and activities (Mastos et al., 2020; Rebelo et al., 2021; Teucke et al., 2018; Yang et al., 2021). This wealth of information contributes to supply chain sustainability efforts, as it allows for improved decision-making regarding environmental impact, resource allocation, and the establishment of circular economy practices (Mastos et al., 2020; Rebelo et al., 2021; Teucke et al., 2018; Yang et al., 2021).

Furthermore, the IoT enables integration and connectivity across the supply chain, fostering collaboration and informed decision-making. By connecting physical objects, supply chain players, and stakeholders, the IoT creates a networked environment that facilitates seamless information exchange and enables collaborative decision-making processes (Bienhaus & Haddud, 2018; De Vass et al., 2021b; Rebelo et al., 2021). This connectivity empowers supply chains with expanded insight and expertise, thanks to real-time access to comprehensive and granular data. Consequently, supply chain actors can make more informed decisions, adapt quickly to changing conditions, and respond effectively to market demands (Agrifoglio et al., 2017; Hahn, 2020; Rebelo et al., 2021).

However, despite its potential benefits, the implementation of the IoT in supply chains is not without challenges. One significant obstacle is the availability of the necessary technology infrastructure and the required skill sets. Many organizations struggle to acquire and deploy the requisite technologies and expertise to effectively utilize the IoT throughout their supply chains (De Vass et al., 2021a; Kamble et al., 2019). Additionally, the adoption of IoT solutions can be costly and demanding, requiring substantial investments in infrastructure, hardware, software, and employee training (Buil et al., 2011; De Vass et al., 2021a; Sandvik & Stubbs, 2019). Furthermore, the sheer volume of data generated by the IoT poses challenges in terms of coordination and control mechanisms. Managing and analyzing large amounts of data in real-time can be complex and resource-intensive (Exposito et al., 2013; Sobb et al., 2020).

Data security and privacy concerns are also critical issues that need to be addressed when implementing the IoT in supply chains. With centralized data storage and management, decentralized actors within the supply chain may be apprehensive about the potential leakage of sensitive information or the existence of information asymmetry (De Vass et al., 2021a; Rejeb et al., 2019; Sobb et al., 2020). There is a need for robust data security measures and privacy safeguards to protect sensitive information and ensure the trust and confidence of all supply chain participants.

To ensure successful implementation of the IoT in supply chains, several critical success factors have been identified in the literature. First and foremost, establishing a solid foundation requires connecting the physical objects, such as products, equipment, and infrastructure, to the IoT network (Bienhaus & Haddud, 2018; Dunke et al., 2018; Huang et al., 2020; Kamble et al., 2019). Top management engagement and commitment are crucial for the successful adoption and integration of IoT technologies throughout the supply chain, as they have far-reaching implications for the organization (Ardito et al., 2019; Wang et al., 2010). Continuous monitoring and assessment of technologies enabling the communication and interaction of physical objects are essential to ensure optimal performance and functionality (Huang et al., 2020; Leite et al., 2019). Proactive responsiveness of connected devices, facilitated by features such as actuators, is necessary to enable autonomous decision-making and enhance operational efficiency (Molka-Danielsen et al., 2018).

While the literature highlights the potential benefits of IoT technology in manufacturing and supply chain management, it also indicates that most studies conducted so far are descriptive and focused on understanding the technology. Real-life case studies that demonstrate the financial and practical advantages of IoT technology in manufacturing and supply chain management are relatively scarce (Zhong & Ge, 2018). Furthermore, research has primarily been conducted in industrialized countries, and obstacles to IoT adoption in other contexts need further exploration (Tu et al., 2018; Arnold et al., 2016).

In conclusion, the Internet of Things holds immense potential for revolutionizing supply chain management by enabling performance optimization, enhancing traceability and sustainability, and fostering integration and flexibility. However, the successful implementation of the IoT in supply chains requires addressing challenges related to technology infrastructure, cost, data management, and security. By overcoming these obstacles and leveraging the identified success factors, organizations can unlock the transformative power of the IoT to drive efficiency, innovation, and competitiveness in their supply chain operations.

Table 1 - Benefits, challenges, and critical success factors.4

Internet of Things (IoT)	Benefits	1)Performance optimization	Tserng et al. (2005); Gessner et al. (2007); Roussos (2008); Wang et al. (2010); Exposito et al. (2013); Maier et al. (2015); Bogataj et al. (2017); Agrifoglio et al. (2017); Gromovs and Lammi (2017); Li et al. (2018); De Vass et al. (2018); Anke et al. (2018); Molka-Danielsen et al. (2018); Ding et al. (2018); Teucke et al. (2018); Al-Saeed et al. (2019); Sandvik and Stubbs (2019); Rejeb et al. (2019); Daú et al. (2019); Krykavskyy et al. (2019); Mondal et al. (2019); Jagtap et al. (2019); Jagtap and Rahimifard (2019); Huang et al. (2020); Hahn (2020); De Vass et al. (2021a); De Vass et al. (2021b); Rebelo et al. (2021).

		2)Transparency and traceability	Tserng et al. (2005); Gessner et al. (2007); Roussos (2008); Wang et al. (2010); Buil et al. (2011); Exposito et al. (2013); Suresh et al. (2015); Maier et al. (2015); Moneimne et al. (2016); Bogataj et al. (2017); Szozda (2017); Agrifoglio et al. (2017); Gromovs and Lammi (2017); Li et al. (2018); De Vass et al. (2018); Molka-Danielsen et al. (2018); Ding et al. (2018); Teucke et al. (2018); Bienhaus and Haddud (2018); Al-Saeed et al. (2019); Sandvik and Stubbs (2019); Rejeb et al. (2019); Daú et al. (2019); Mondal et al. (2019); Jagtap et al. (2019); Jagtap and Rahimifard (2019); Ardito et al. (2019); Hahn (2020); Huang et al. (2020); Mastos et al. (2020); Sarkis et al. (2020); De Vass et al. (2021a); De Vass et al. (2021b); Rebelo et al. (2021); Yang et al. (2021).
		3)Connectivity and integration	Maier et al. (2015); Nishioka et al. (2016); Harrison et al. (2016); Bogataj et al. (2017); Kache and Seuring (2017); Szozda (2017); Agrifoglio et al. (2017); Gromovs and Lammi (2017); Li et al. (2018); Bechtsis et al. (2018); De Vass et al. (2018); Ding et al. (2018); Teucke et al. (2018); Bienhaus and Haddud

			(2018); Al-Saeed et al. (2019); Rejeb et al. (2019); Ardito et al. (2019); Hahn (2020); Huang et al. (2020); Shahzad et al. (2020); De Vass et al. (2021b); Rebelo et al. (2021).
		4) Awareness and flexibility	Maier et al. (2015); Bogataj et al. (2017); Agrifoglio et al. (2017); Gromovs and Lammi (2017); Li et al. (2018); De Vass et al. (2018); Molka-Danielsen et al. (2018); Ding et al. (2018); Teucke et al. (2018); Dunke et al. (2018); Al-Saeed et al. (2019); Rejeb et al. (2019); Mondal et al. (2019); Jagtap et al. (2019); Jagtap and Rahimifard (2019); Hahn (2020); Huang et al. (2020); De Vass et al. (2021a); De Vass et al. (2021b); Rebelo et al. (2021).
	Challenges	1)Technological infrastructure and human resources	Gessner et al. (2007); Roussos (2008); Buil et al. (2011); Exposito et al. (2013); Kamble et al. (2019); Sandvik and Stubbs (2019); Shahzad et al. (2020); de Vass et al. (2021a).
		2)Control and coordination	Roussos (2008); Exposito et al. (2013); Junge (2019); Ben-Daya et al. (2019); Yang et al. (2019); de Vass et al. (2020); Sobb et al. (2020).
		3)Data security and privacy concern	Suresh et al. (2015); Szozda (2017); Ding et al. (2018); Rejeb et al. (2019); Ben-Daya et al. (2019); Mondal et al. (2019); Shahzad et al.

			(2020); Sobb et al. (2020); de Vass et al. (2021a).
	Critical success factors	1) IoT alignment	Dunke et al. (2018); Bienhaus and Haddud (2018); Kamble et al. (2019); Yang et al. (2019); Huang et al. (2020).
		2)Top management support	Wang et al. (2010); Ardito et al. (2019).
		3)Performance monitoring	Leite et al. (2019); Huang et al. (2020).
		4) Proactive IoT	Molka-Danielsen et al. (2018).

5

3.2 Adoption barriers

Table 2 in this section lists the adoption hurdles for sustainability and I4.0 that have been found in the literature. Table 2 lists the 43 obstacles to resilience and I4.0 that were discovered using 24 distinct sources. Nine of these 43 barriers, such as "lack of relevant technology," "lack of customer pressure," "lack of data," "lack of suitable business process models," "absence of a green disposal system," "lack of effective implementation policies," "lack of environmentally focused capabilities," "lack of intention to become sustainable," and "perception of no environmental impact," were relevant to sustainability. Short-term strategy, workers' aversion to change, lack of digital engineering deployment, requirement for software as well as hardware upgrades, and inability to integrate seamlessly were five that applied to I4.0, while 29 applied to both. Experts in the industry were consulted on the classification, expansion, and modification of these 29 obstacles from an industrial standpoint.

Table 2 - Barriers to sustainability and I4.0 adoption .

[5] Rad et al.

Barriers	**Sustainability**	**I4.0**	**References**
"Lack of suitable tools"	Yes	Yes	Leng et al. (2020)
	Yes	—	Kalmykova et al. (2018)
"Semantic interoperability"	Yes	Yes	Rajput and Singh (2021)
"Lack of relevant technology"	Yes	—	Kirchherr et al. (2018)
"Outdated and less flexible laws and regulations"	Yes	Yes	Leng et al. (2020)
	Yes	Yes	Pham et al. (2019)
	Yes	—	Salimzadeh and Courvisanos (2015)
"Process digitalization"	Yes	Yes	Rajput and Singh (2019)
"Short-term strategy"	—	Yes	Müller, Buliga, and Ingo Voigt (2018)
"Lack of customer pressure"	Yes	—	Salimzadeh and Courvisanos (2015)
"Technology standards and specifications"	Yes	Yes	Rajput and Singh (2019)
"Limited awareness and interest"	Yes	Yes	Leng et al. (2020)
	Yes	Yes	Pham et al. (2019)
	Yes	—	Salimzadeh and Courvisanos (2015)
"Lack of clarity about implementation"	Yes	—	Salimzadeh and Courvisanos (2015)
	Yes	Yes	Bai et al. (2020)
"Lack of cultural feasibility"	Yes	Yes	Pham et al. (2019)

Barriers	Sustainability	I4.0	References
"Lack of data transparency"	Yes	Yes	Leng et al. (2020)
	Yes	Yes	Pham et al. (2019)
"Lack of data"	Yes	—	Kirchherr et al. (2018)
"Lack of government support"	—	Yes	Gu et al. (2019)
	Yes	Yes	Ingaldi and Ulewicz (2020)
	Yes	Yes	Pham et al. (2019)
"Lack of quality infrastructure"	Yes	Yes	Pham et al. (2019)
	Yes	Yes	Rajput and Singh (2019)
"Lack of skilled specialists"	Yes	Yes	Ahmad et al. (2020)
	Yes	Yes	Ingaldi and Ulewicz (2020)
	—	Yes	Ivascu (2020)
	Yes	—	Munsamy, Telukdarie, and Fresner (2019)
"Perception of job insecurity"	Yes	Yes	Birkel et al. (2019)
	—	Yes	Leong et al. (2020)
"Lack of training"	Yes	Yes	Tiwari and Khan (2020)
	Yes	Yes	Ingaldi and Ulewicz (2020)
	Yes	—	Munsamy, Telukdarie, and Fresner (2019)
	Yes	Yes	Birkel et al. (2019)
"Lack of suitable business process models"	Yes	—	Munsamy, Telukdarie, and Fresner (2019)

Barriers	Sustainability	I4.0	References
"Lack of protocols and standards"	Yes	Yes	Rajput and Singh (2019)
"High investment cost"	—	Yes	Ghobakhloo and Fathi (2020)
	Yes	Yes	Ingaldi and Ulewicz (2020)
	—	Yes	Ivascu (2020)
	Yes	Yes	Rajput and Singh (2019)
	—	Yes	Gu et al. (2019)
"Lack of privacy, integrity, confidentiality, and trust"	Yes	Yes	Leng et al. (2020)
	Yes	—	Tiwari et al. (2019)
"Lack of knowledge"	Yes	Yes	Bai et al. (2020)
"Top management support"	Yes	Yes	Ahmad et al. (2020)
"Lack of resources"	Yes	Yes	Birkel et al. (2019)
	—	Yes	Cerezo-Narv et al. (2019)
"Employees' resistance to change"	—	Yes	Ivascu (2020)
"Lack of Integration and adoption in the system"	Yes	Yes	Ahmad et al. (2020)
	Yes	Yes	Bai et al. (2020)
	—	Yes	Jabbour et al. (2020)
		Yes	Gu et al. (2019)

Barriers	**Sustainability**	**I4.0**	**References**
"Lack of energy balance system"	Yes	Yes	Birkel et al. (2019)
"Lack of specialized support"	Yes	Yes	Ingaldi and Ulewicz (2020)
"Lack of adequate environmental sustainability"	Yes	Yes	Ingaldi and Ulewicz (2020)
"Lack of technological infrastructure"	Yes	Yes	Ingaldi and Ulewicz (2020)
"Employees' competence and skills in the market"	Yes	Yes	Ingaldi and Ulewicz (2020)
"Lack of understanding of the organizational goals"	Yes	Yes	Ingaldi and Ulewicz (2020)
"Absence of a green disposal system"	Yes	—	Karuppiah et al. (2020)
"Lack of effective implementation policies"	Yes	—	Chofreh et al. (2020)
"No deployment of digital engineering"	—	Yes	Belinski et al. (2020)
"The need for hardware and	—	Yes	Leng et al. (2020)

Barriers	**Sustainability**	**I4.0**	**References**
software upgrading"			
"Lack of environmentally focused capabilities"	Yes	—	Lawrence et al. (2006)
"Lack of intention to become sustainable"	Yes	—	Leng et al. (2020)
"Cost and complexity"	Yes	Yes	Ahmad et al. (2020)
"Less vendor services"	Yes	Yes	Ahmad et al. (2020)
"Perception of no environmental impact"	Yes	—	Lawrence et al. (2006)
"Lack of seamless integration capability"	—	Yes	Ghobakhloo and Fathi (2020)

[6]

Despite the fact that numerous research studies have explored sustainability and I4.0 adoption, Müller, Buliga, and Ingo Voigt (2018) contend that the transfer of traditional business operations towards automated processes remains difficult for SMEs. The majority of current frameworks/models/roadmaps are unrelated to real-world concerns and lack implementation methods, making them difficult for SMEs to embrace.[7]

[6] S. Kumar et al., "Barriers to Adoption of Industry 4.0 and Sustainability: A Case Study with SMEs," *International Journal of Computer Integrated Manufacturing*, 2022, https://doi.org/10.1080/0951192X.2022.2128217.
[7] Shivika Mittal, Erik O. Ahlgren, and P.R. Shukla, "Barriers to Biogas Dissemination in India: A Review," *Energy Policy* 112 (January 2018): 361–70, https://doi.org/10.1016/j.enpol.2017.10.027.

In order to boost production and efficiency, I4.0 (I4.0) connects the digital and physical worlds via cyber-physical entities and human-machine interfaces. Real-time synchronization of production processes is provided by the new manufacturing methodology to satisfy customer demands for standardized or customized goods.[8] Through the use of intelligent machines, intelligent sensors, and other computer-based technologies, I4.0 ensures customized, effective, and efficient production at a fair cost. Despite the obvious advantages of I4.0, there remain obstacles to the adoption of these new technologies and their impact on traditional production techniques. To overcome these obstacles, it is necessary to identify and characterize the impediments to I4.0 deployment.

Manufacturing industries are in the transitional period of I4.0, thus they should be aware of the hurdles in implementing this new paradigm and be prepared and able to handle them. I4.0 implementation barriers have been highlighted, including high implementation costs, a lack of IT system knowledge, cyber security, data privacy concerns, an inexperienced workforce, organizational and process changes, and job disruptions. Numerous academics have looked at the challenges associated with implementing I4.0 technologies in the manufacturing sector from an international comparative viewpoint. DEMATEL was used to analyze the challenges found through a thorough study of the literature and expert comments. For the analysis of I4.0 and other application areas' enablers and constraints, various methodologies are published in the literature. From the literature, it can be inferred that researchers regularly use ISM and Fuzzy MICMAC [2, 5-8] to analyze obstacles and facilitators in various application domains. In the literature, additional methods such as Grey-DEMATEL [5], DEMATEL-MMDE-ISM, AHP-factor analysis, Best-Worst Method [23], and structural modeling are also shown to be useful in determining the influencing variables of the barriers, enablers, drivers, and challenges that are part of the I4.0 application area. Additional information regarding obstacles relating to technological, financial, operational, and human resource factors is still needed in the literature that is currently accessible on I4.0-related obstacles. In order to identify the obstacles to I4.0, this study fills the gap by thoroughly analyzing the literature and consulting with industry professionals.

a) Poor Value-chain integration

In an I4.0 context, it is challenging to achieve interoperability and IoT integration between various technologies and systems in order to build a cyber-physical infrastructure.

---

[8] Tariq Masood, "I4.0: Challenges and Success Factors for Adopting Digital Technologies in Airports," 2021.

b) Cyber-security challenges

I4.0 environments are at risk for cyber-security since the entire value chain is interconnected.

c) Uncertainty about economics benefit

No clear assessment of economic benefits of capital investment in implementing I4.0 technologies

d) Lack of adequate skills in workforce

Lack of digital skills is a major challenge in realizing the proper implementation of I4.0

e) High investment requirements

Difficulties in implementing new technologies in their manufacturing environment due to lack of funds

f) Lack of infrastructure

Lack of internet coverage and IT infrastructure may act as potential blockage in implementation of I4.0 strategies

g) Job disruptions

Automation brought on by new technical advancements will change the nature of existing jobs, which will further complicate labor markets.

h) Challenges in data management and data quality

Automation brought on by new technical advancements will change the nature of existing jobs, which will further complicate labor markets. These difficulties relate to the ability to manage massive amounts of data produced by various devices, processes, sensors, and goods, as well as the ability to extract useful information from the large volumes of data.

i) Lack of secure standards and norms

There are difficulties connecting value-creation networks with various standards because there are no secure and universal standards.

j) Resistance to change

Employees show unwillingness to adopt newer technologies

3.3 Background

This section involves a review of current literature, concluding with a synthesis, gap identification, and progression into a developed research question.

3.3.1 I4.0 technologies in small and medium enterprises (SME)

Interdisciplinary research, which involves the integration of two distinct domains, namely Industry 4.0 (I4.0) and media, has gained momentum in recent years. While the concept of this intersection has been under discussion for some time, it is only in recent times that it has garnered significant attention and recognition. In 2012, Würtz and Kölmel published the pioneering article that drew attention to the potential challenges associated with implementing smart factories in smaller companies. However, it wasn't until 2016 that the issues raised by these authors were further explored and investigated in subsequent articles.

A series of studies published after 2016 have shed light on the discrepancies between the ongoing I4.0 research and the specific needs and realities faced by small and medium-sized enterprises (SMEs). Researchers such as Rauch et al., Sevinç et al., Moeuf et al., Mittal, Khan et al., Bär et al., Orzes et al., and Türkeş et al. 2018 have all contributed to this growing body of work by identifying and addressing the gaps between current research and the requirements of SMEs. These scholars have proposed various frameworks, models, toolkits, and strategies with different focal points to bridge this divide and offer valuable insights into aligning I4.0 with SME contexts.

Furthermore, there is a rising interest in raising awareness about I4.0 technologies through practical workshops and media initiatives. Scholars like Wank et al., Scheidel et al., and McFarlane have emphasized the importance of disseminating knowledge and practical skills related to I4.0 through hands-on workshops and media platforms. They recognize that SMEs, with limited exposure to academia and larger corporations, may struggle to keep pace with the rapid advancements in technology. Therefore, efforts to bridge this knowledge gap and facilitate the adoption of I4.0 practices are of paramount importance.

To objectively evaluate the most recent implementation hurdles faced by SMEs, Orzes et al. conducted a comprehensive focus group study involving 37 SMEs from Italy, Thailand, Austria, and the USA. Their findings revealed six key obstacles to the adoption of I4.0 in SMEs: economic and financial factors, cultural considerations, expertise and resource constraints, legal complexities, technical challenges, and the implementation process itself. This study serves as a valuable reference point for understanding the current state of research in this area, which is projected to experience significant growth and development in the coming years.

While multinational enterprises (MNEs) have already embraced and harnessed the potential of I4.0 technologies, SMEs are still in the early stages of widespread adoption. Studies by Mittal et al. and Horvath and Szabo underscore the fact that while the advantages of I4.0, including cost savings, improved quality, enhanced efficiency, flexibility, productivity gains, and a competitive edge, have been well-documented in the literature, SMEs face unique challenges in fully capitalizing on these benefits. Overcoming these obstacles and enabling SMEs to leverage I4.0 technologies effectively is a crucial area of focus for future research and industry initiatives.

3.3.2 *Challenges around I4.0 adoption in SMEs*

The literature highlights three main challenges faced by SMEs when adopting I4.0 (I4.0): limited financial resources, limited knowledge resources, and limited technology awareness. These challenges hinder SMEs from fully embracing the benefits of advanced technologies and digitalization. Another set of challenges includes the abundance of technologies that SMEs need to be aware of and the difficulty in assessing the varying nature of SMEs.

Financial resource limitation: SMEs often encounter budget constraints when implementing I4.0 due to their limited financial resources. Investing in new hardware, software, and infrastructure required for I4.0 can be challenging for SMEs with competing priorities.

Knowledge resource limitation: SMEs may lack the necessary expertise and knowledge for implementing I4.0 technologies. Acquiring the skills and training needed for technologies like IoT, data analytics, and automation can be difficult and costly for SMEs.

Technology awareness limitation: SMEs may struggle to keep up with the rapidly evolving I4.0 landscape. The wide range of available technologies and their specific applications can be overwhelming for SMEs, making it challenging to select the most suitable options.

Moreover, the fragmented nature of research in this field is due to the abundance of technologies available for SMEs, and the unique characteristics and contexts of each SME, making it challenging to develop a comprehensive model that fits all. This heterogeneity adds complexity to understanding the impact of I4.0 on SMEs.
To address these challenges, tailored support for SMEs is essential. This includes initiatives such as financial assistance, training programs, and awareness campaigns, facilitated through collaboration between academia, industry associations, and government bodies. Such efforts can help SMEs successfully adopt I4.0 and reap its benefits.

3.3.3 Research Gaps

Benefits of I4.0 are well acknowledged, with several frameworks and tools already in existence, based on the systematic review and synthesis. Yet, there is only a tiny amount of work focusing on the adoption of I4.0 within SMEs. The obstacles are clearly defined in 2019, but the industry is still growing. This leads to the identification of the first research gap (RG):

3.3.3.1 *1st research gap*

One area that requires further research is the ongoing struggle of SMEs to navigate the dynamic and ever-changing landscape of Industry 4.0 (I4.0) technologies. SMEs often find it challenging to stay updated and informed about the plethora of emerging technologies within the I4.0 realm. While workshops and training sessions can provide some insights into the benefits of these technologies, their effectiveness is often limited in terms of scope and depth.

Furthermore, seeking external expertise from specialists or consultants is another avenue pursued by SMEs. However, the costs associated with such consultations can be prohibitive for many SMEs, making it difficult for them to access the necessary guidance and support.

Addressing this research gap requires exploring alternative approaches to help SMEs overcome the challenges of keeping pace with I4.0 technologies. This could involve the development of more accessible and cost-effective knowledge-sharing platforms, tailored training programs, or collaborative initiatives that facilitate knowledge exchange among SMEs. Additionally, investigating the effectiveness of government policies or industry-specific support programs aimed at assisting SMEs in their I4.0 technology adoption could also provide valuable insights.

This second research gap below highlights the difficulty for SMEs in maintaining awareness and acquiring the necessary knowledge to effectively adopt and implement I4.0 technologies. SMEs need access to affordable and targeted resources that can assist them in understanding the benefits, selecting appropriate technologies, and overcoming the challenges they face in adopting I4.0.

Addressing this research gap below requires the development of accessible and cost-effective knowledge-sharing platforms, targeted training programs, and support networks that cater specifically to the needs of SMEs. These initiatives can help bridge the information and expertise gap, enabling SMEs to make informed decisions and successfully integrate I4.0 technologies into their operations.

3.3.3.2 2nd research gap

Evaluating the needs and requirements of SME organizations regarding Industry 4.0 (I4.0) technologies is a complex undertaking. Existing tools, frameworks, and models designed for SMEs typically assess an organization's current level of "I4.0 readiness." However, these tools may not sufficiently capture the distinctive nuances and specific requirements of individual SMEs.

Moreover, the vast array of implementation technologies and possibilities within the I4.0 landscape has led to a knowledge gap for SMEs. They may lack a comprehensive understanding of available technologies, their potential applications, and the specific benefits they can offer their organization.

These challenges underscore the necessity for more comprehensive assessment approaches and customized guidance tailored to SMEs' adoption of I4.0 technologies. It is crucial to develop tools and methodologies that go beyond readiness assessment and provide deeper insights into the specific needs and priorities of SMEs. Additionally, efforts should be directed towards bridging the knowledge gap by providing accessible information resources, platforms for knowledge sharing, and targeted training programs that cater to the unique requirements of SMEs.

4. Research methodology

A questionnaire is a widely used methodological approach in research and data collection. It involves a structured set of questions designed to gather information and insights from respondents. Questionnaires can be administered in various formats, including paper-based, online, or through interviews, depending on the research objectives and target population. The use of a questionnaire offers several advantages. Firstly, it allows for standardized data collection, ensuring consistency in the information obtained from different respondents. This uniformity facilitates data analysis and comparison across participants. Additionally, questionnaires can reach a large number of respondents efficiently, making them suitable for studies with large sample sizes. The ability to collect data from a diverse range of individuals enhances the representativeness and generalizability of the findings. Questionnaires also enable researchers to explore a wide range of topics and collect both quantitative and qualitative data. Closed-ended questions with pre-determined response options facilitate quantitative analysis, enabling statistical comparisons and data summarization. On the other hand, open-ended questions provide qualitative insights, allowing respondents to express their thoughts and opinions in their own words. Furthermore, questionnaires offer a level of anonymity and confidentiality, which can encourage respondents to provide honest and accurate responses, particularly on sensitive topics. This can be beneficial when studying sensitive issues or gathering personal information. However, questionnaires also have certain limitations. They rely on self-reported data, which may be subject to biases or inaccuracies due to memory limitations, social desirability bias, or misunderstanding of questions. Ensuring the clarity of questions and providing clear instructions can help minimize these issues. In conclusion, questionnaires serve as a valuable methodological approach for gathering data in research. They provide a structured and standardized means of data collection, allowing for efficient administration and analysis. By considering the strengths and limitations of questionnaires, researchers can effectively utilize this method to gain valuable insights and address research objectives. In my essay, I extensively relied on Excel's diverse and powerful data analysis tools, using all the collected date from the relative questionnaire,[9] to conduct comprehensive and in-depth data analysis. These tools provided me with a broader perspective and enabled me to extract valuable insights from the data.

Based on the two identified gaps, the following research questions (RQ) are proposed:

RQ1

Which of the following technologies of I4.0. is used in your company and to what extent?

I4.0. Technologies	None	In pilot stages	Interdepartmental	Intracompany	Globally with collaborators
Automation					
Big data Technologies / analytics					
Blockchain					
Internet of Things					

RQ2

Focusing on the previous technologies, what are the barriers that limit you from using the technology one step further?

I4.0. Technologies	Automation	Big data Technologies / analytics	Blockchain	Internet of Things
Cost				
Data security and privacy concern				
Lack of skilled workforce				

[9] https://forms.gle/6PwdHgH2YzzrRfTU6

Technological infrastructure-prerequisites technologies and equipment				
Control and coordination issues-specialized department				
Information leakage				
No usage of the similar tech from suppliers or customers				
No further benefit margin				
Employees resistance to change				
Lack of management support				
Lack of awareness of I4.0				

Lack of knowledge and expertise.				

The aim of this research is to find out, from a range of different companies of a business segment, the reasons why companies strangle to adopt or evolve those I4.0 technologies in their business.

We are going to analyses the results of the survey with distinctive statistics and check how important there are though a regression analysis. Although, in order to make the regression analysis we make a new column into our collecting data, next to the size of company, where we randomly choose a number with the excel function RANDBETWEEN, below or even to 50 and above 20 for small companies, below or even to 250 and above 50 for medium companies, above 250 and below 500.

The research questions of this paper are:

1) Which barriers are the most common throughout every company based on their size for each technology.
2) Does the size of a company matters most or there are other variables that affects the outcome ?

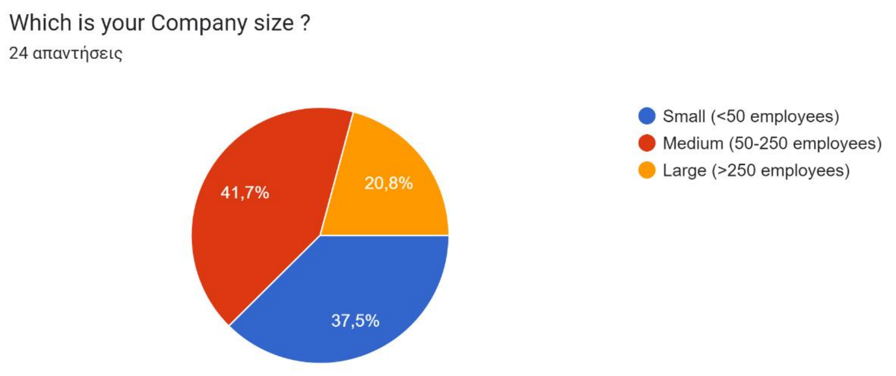
5. Results

The analysis within the study is based upon the expert opinions of employees within companies located alongside Greek cities, which are specialized on logistics.

1) Those companies split into 3 categories based on their size: Small, Medium and Large, according the number of employees.

Small companies are those who have less than 50 employees, while medium companies have more than 50, but less employees than 250. At last, large companies are those with more than 250 employees. This classification is based on how European Commission distinguish an enterprise by its size (SME definition) [10]. In order to simplify the SME definition, we only took into account the number of employees.

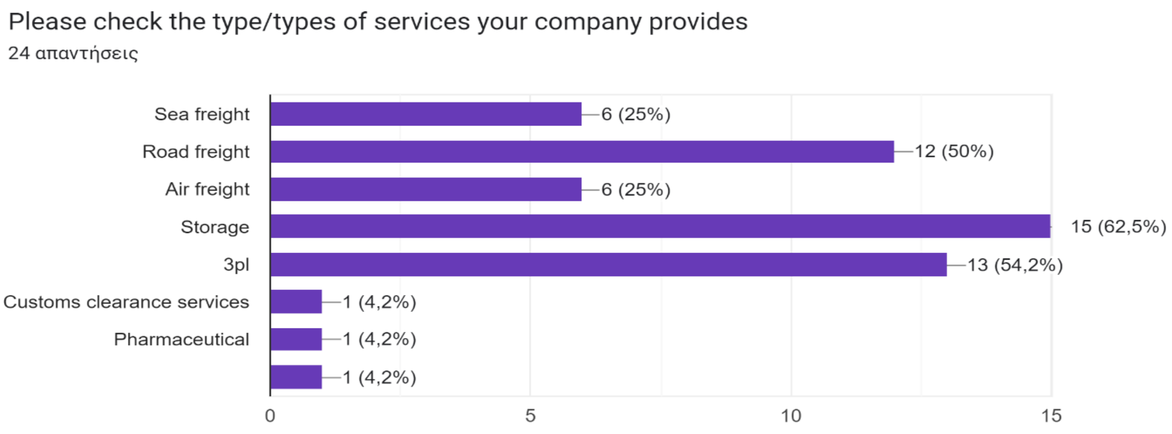
Figure 1 – Company size



From our questionnaire we manage to obtain answers from 24 companies, from which 37,5 % were small, 41,7 % were medium and 20,8% were large companies[11].

2) We also gather the different types of services those companies provide. The major services are Sea freight shipping, road freight shipping, air freight shipping, storage services,3pl services, etc.

Figure 2 – The type of services a company provide



The figure 2 above depicts the total number of companies that provide each service, while the table 3 and 4 below analyze Figure 2.

[10] "CELEX_32003H0361_EN_TXT.Pdf," n.d.
[11] Figure 1

According the answers given by those 24 enterprises, the total amount of services we obtain was 55. So, each enterprise provides 2,29 services on average.

The most common services are Storage services, with an impressive 62,5 % of the companies provide that service, 3pl service with a 54,2 % and road freight transport service with a 50 %. Next, we have sea freight and air freight transport with one out of four companies provide that type of service.[12] Beyond that we have handful of companies that provide some extra services like customs clearance services, which are very important for importing goods from countries that do not belong into a common trading system like EU.

Table 3 - Type of services by company size

Type of services by company size	Sea freight	Road freight	Air freight	Storage	3pl	Customs clearance services	Pharmaceutical
Small (<50 employees)	0	4	0	2	4	1	0
Medium (50-250 employees)	3	5	4	8	5	0	1
Large (>250 employees)	3	3	2	5	4	0	0
Total	**6**	**12**	**6**	**15**	**13**	**1**	**1**

From the 15 enterprises that provide storage services to their clients only 2 are small businesses. That means that 22,2 % of small businesses provide a storage service, while 100% of large enterprises provide this particular service. The medium companies are second in the list with 8 out of 10 providing this type of service. The second most common service among logistics is 3pl, according the questionnaire, where equal number of businesses of each size provide this service. As we can see on Figure 3 and 4, nearly 44 % provide that type of service. On the other hand, half of medium companies provide that service and 4 out of 5 large companies do the same. In the same way as before, all small, medium and large companies use to operate. Small businesses are focused on one or two services in order to be competitive. Medium companies are trying to gather more customer by expand their type of services and finally the large enterprises not only have mastered the services that small companies act but try to be competitive in other services in which even medium companies try to add into their operation.[13]

[12] Figure 2
[13] Table 4

Table 4 - % Type of services by company size / Sum of company size

% Type of services by company size / Sum of company size	Sea freight	Road freight	Air freight	Storage	3pl	Customs clearance services	Pharmaceutical
Small (<50 employees)	0,0%	44,4%	0,0%	22,2%	44,4%	11,1%	0,0%
Medium (50-250 employees)	30,0%	50,0%	40,0%	80,0%	50,0%	0,0%	10,0%
Large (>250 employees)	60,0%	60,0%	40,0%	100,0%	80,0%	0,0%	0,0%

Figure 3 – Type of services y company size

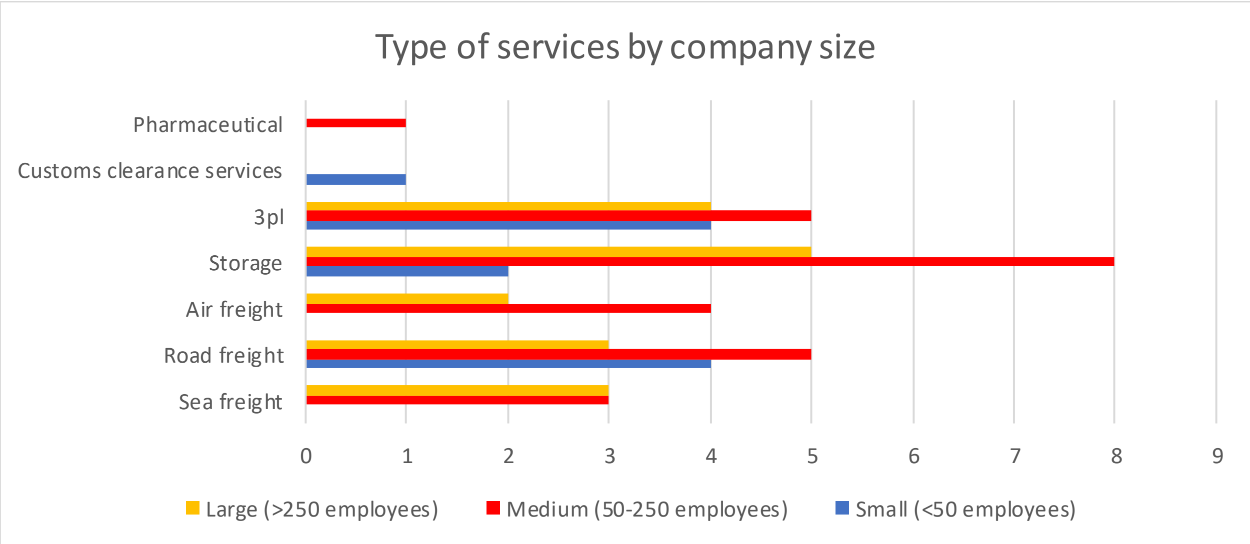
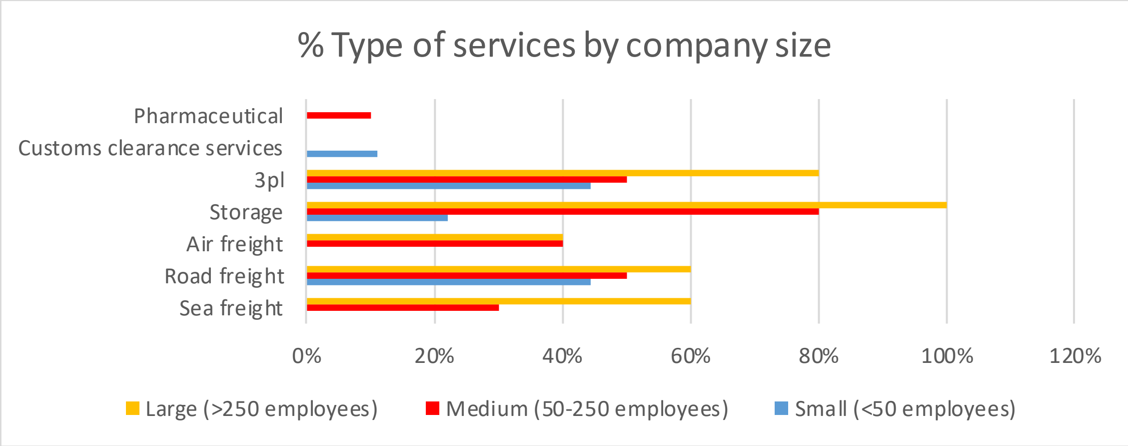


Figure 4 - % Type of services y company size



3) The next information we gather was the area of operations of the companies, throughout a big list of designative areas like: Domestic, Balkans, Western Europe, Eastern Europe, Middle East, Scandinavia, British Isles, North Africa and International. Some of these areas are part of some other. For instance, Domestic is including in Balkans or every other area is including to international area of operation.

Figure 5 – Area of operation of a company

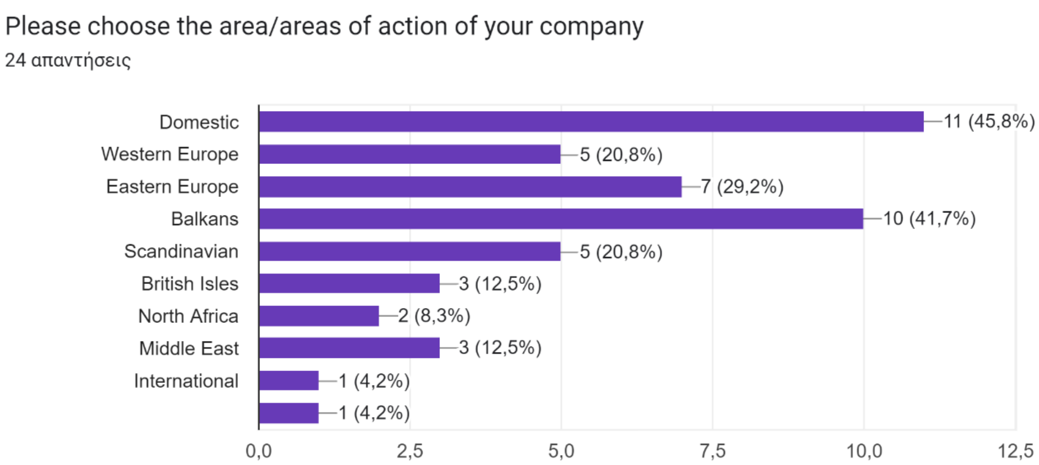


Figure 5 above shows us the number of companies who can operate on the aforementioned areas by our companies. As we can see 11 out if 24, nearly the 46 % operate in domestic areas. Although from those 11 companies, only 6 out of 11 operates only in domestic areas. The rest 5 operates at least at one more area. The next most operative area is the Balkans with 10 out of 24, nearly 42 %. In this area only 3 out of 10 companies operate only in

Balkans. The rest have at least one more area of operation. The third most operative area by our sample is Eastern Europe with 7 out of 24, nearly 30 % of our companies. From those 7 only 1 company operates only in Eastern Europe. The rest 6 operates at least at one more area. The total number of areas, in which the enterprises operate, is 47. This means that one company, by means, operate nearly in 2 different areas. (47/24 = 1,96).

Table 5 - Area of action by company size

Area of action by company size	Domestic	Western Europe	Eastern Europe	Balkans	Middle East	Scandinavian	British Isles	North Africa	International	Total
Small (<50 employees)	6	1	2	2	0	0	0	0	0	11
Medium (50-250 employees)	3	1	2	6	2	1	1	2	0	18
Large (>250 employees)	2	3	3	2	1	4	2	0	1	18
Total	**11**	**5**	**7**	**10**	**3**	**5**	**3**	**2**	**1**	**47**

In table 5 we can see the area of action based on the company size. As we previously observed from Figure 5, the total number of the companies that operates in each area are depicted at the last row of table 5. So, as we can observe, 6 out of 11 companies that operate in domestic regions are small. This metric shows us that nearly 67 %[14] (6/9) of the small companies operate in domestic regions, since the number of total small companies are 9. In addition, 3 out of 11 are medium and 2 out of 11 are large companies. So, 30% and 40% of the enterprises accordingly operate in Domestic region. The second most active region is the Balkans with 10 of the companies operate in that region. Small enterprises in this region are 2 out of 10, medium are 6 out of 10 and large are 2 out of 10. The last column of Table 5 shows us to sum of areas for each company size. For instance, the small companies that operates in domestic regions are 6 out of 11. Eleven are the sum of all areas that operated from small companies. So, as we can see, only 1,22 areas correspond to 1 small company (11/9=1,22)[15].

[14] Table 6

[15] Table 6

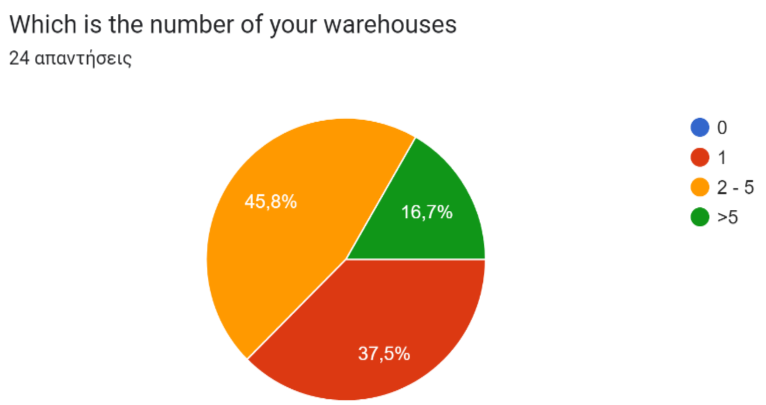
From table 5 and 6 we also can see a pattern for all three types of companies bases on their size. For small and medium size companies we can see that the closer the region, the more businesses will operate. As we go further from the base of the company less enterprises will operate on those regions. The number of small companies decreases when the distance from the base is becoming further, while medium businesses have a further range of operation. Last, we have the large companies where operate nearly everywhere.

Table 6 - % Area of action by company size / Sum of company size

% Area of action by company size / Sum of company size	Domestic	Western Europe	Eastern Europe	Balkans	Middle East	Scandinavian	British Isles	North Africa	International	Total
Small (<50 employees)	66,7%	11,1%	22,2%	22,2%	0,0%	0,0%	0,0%	0,0%	0,0%	1,22
Medium (50-250 employees)	30,0%	10,0%	20,0%	60,0%	20,0%	10,0%	10,0%	20,0%	0,0%	1,80
Large (>250 employees)	40,0%	60,0%	60,0%	40,0%	20,0%	80,0%	40,0%	0,0%	20,0%	3,60

4) We have also gathered the information about which is the number of the warehouses they use or they own. The answers are distinguished in four categories: 0, 1, 2 – 5, >5.

Figure 6 – Number of warehouses of a company



From figure 6 we can observe that everybody has at least on warehouse. The 37,5% have at least 1 warehouse, while 16,7 % has over 5. The rest 45,8 % uses or obtain at least 2 warehouses to 5 warehouses.

Table 7 - Number of warehouses by company size / Sum of company size

Number of warehouses by company size / Sum of company size	1	2 - 5	>5	Total
Small (<50 employees)	6	3	0	9
Medium (50-250 employees)	3	7	0	10
Large (>250 employees)	0	1	4	5
Total	**9**	**11**	**4**	**24**

The above table indicates us that the bigger the enterprise the more warehouse uses. From the sample of 24 companies only 4 operate over 5 warehouses. Those 4 companies are 4 of the 5 large companies of our sample. That shows us that the 80 % of large companies have a lot of warehouses.

Table 8 - % Number of warehouses by company size / Sum of company size

% Number of warehouses by company size / Sum of company size	1	2 - 5	>5
Small (<50 employees)	66,7%	33,3%	0,0%
Medium (50-250 employees)	30,0%	70,0%	0,0%
Large (>250 employees)	0,0%	20,0%	80,0%

5) Last but not least we also gathered the how many cubic meters each enterprise transport per week. The below figure 7 and Tables 8,9 provide us this information that is related with how busy those companies are. With the first glance somebody would tell that there is a highly competition due to the fact that 45,8 % transport 200 to 500 CBM per week.

Figure 7 – CBM transport by a company

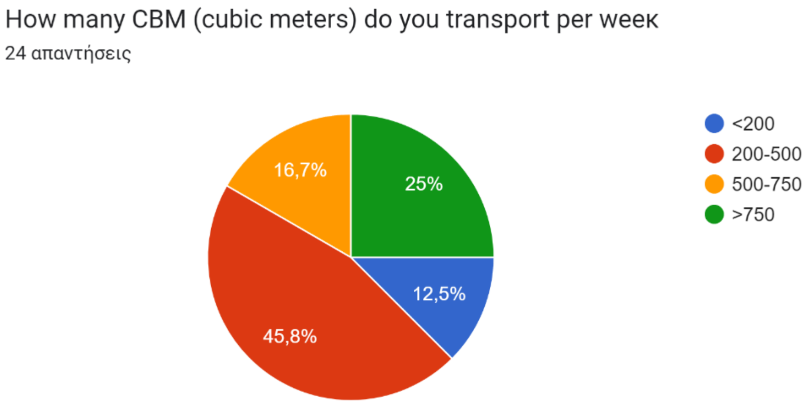


Table 9 - CBM transported by company size

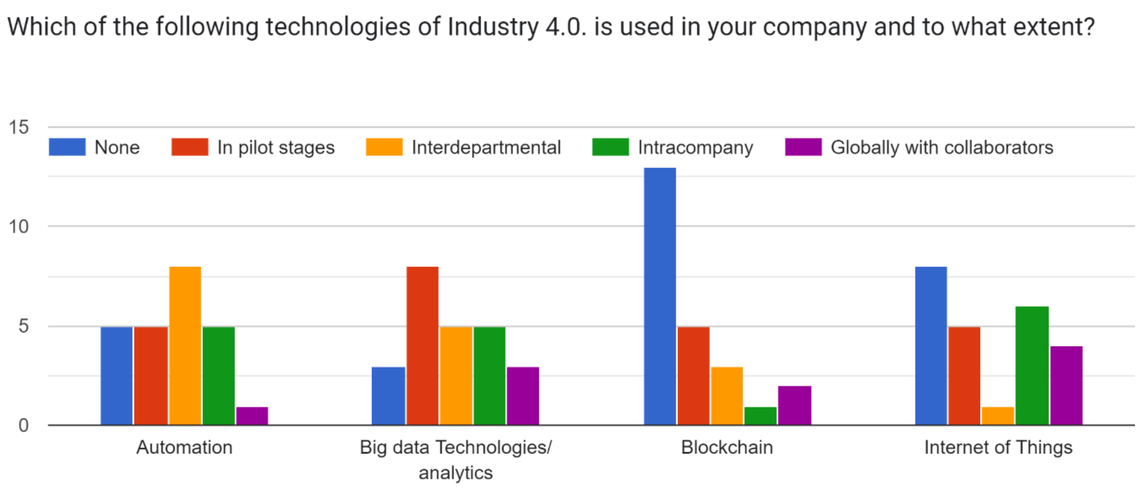
CBM transported by company size	<200	200-500	500-750	>750	Total
Small (<50 employees)	3	4	2	0	9
Medium (50-250 employees)	0	5	1	4	10
Large (>250 employees)	0	2	1	2	5
	3	**11**	**4**	**6**	**24**

Table 10 - % CBM transported by company size / Sum of company size

% CBM transported by company size / Sum of company size	<200	200-500	500-750	>750
Small (<50 employees)	33,3%	44,4%	22,2%	0,0%
Medium (50-250 employees)	0,0%	50,0%	10,0%	40,0%
Large (>250 employees)	0,0%	40,0%	20,0%	40,0%

The first question we made to our sample group RQ1 was about which of our target I4.0 technologies are used and to what extent. With that question we gathered information about how many companies use those technologies and we make some assumptions about the possible barriers they have in order to use those technologies in a larger extend.

Figure 8 – Levels of usage of technologies



From figure 8 we can understand that, Blockchain technologies cannot be adopted from a lot of companies, because 13 out of 24 enterprises do not use at any extent this technology. For the rest 3 technologies we can say that the answers, about how much they are used and at which extend, are evenly distributed among the different levels of usage.

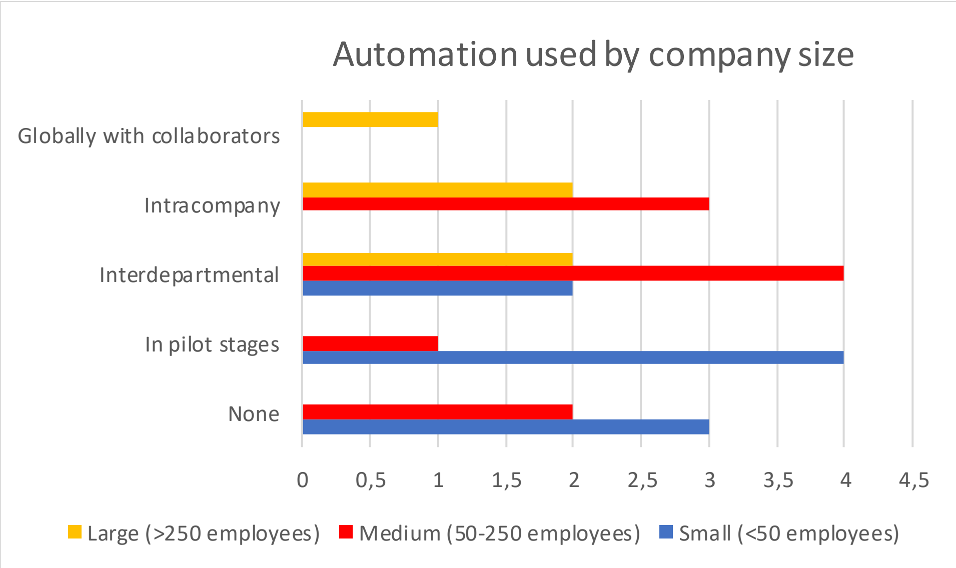
Table 11 - Automation used by company size / Sum of company size

Automation used by company size / Sum of company size	None	In pilot stages	Interdepartmental	Intracompany	Globally with collaborators	Total
Small (<50 employees)	3	4	2	0	0	9
Medium (50-250 employees)	2	1	4	3	0	10
Large (>250 employees)	0	0	2	2	1	5
Total	**5**	**5**	**8**	**5**	**1**	**24**

Table 12 – % Automation used by company size

% Automation used by company size	None	In pilot stages	Interdepartmental	Intracompany	Globally with collaborators
Small (<50 employees)	33,3%	44,4%	22,2%	0,0%	0,0%
Medium (50-250 employees)	20,0%	10,0%	40,0%	30,0%	0,0%
Large (>250 employees)	0,0%	0,0%	40,0%	40,0%	20,0%

Figure 9 - Automation used by company size



From both Table 11, 12 and Figure 9 we can observe that the answers of small companies use the automation technology are concentrated around the level : In pilot stages, None of the small companies use this technology into the whole company, only some of them 22% use it among departments, 44% have started to use it in pilot stages in order to found the benefits of using it and 33 % do not use any kind of automation technologies. For the medium businesses stats are different. We can see that the center of gravity has drifted upwards, only 20 % do not use this technology, while 40 % and 30 % are using the technology among departments and through the whole company accordingly. There is only a 10 % that use the technology in pilot stages. At last, we have large enterprises from which the 80 % are using automaton technologies all around the company and among departments and we have a 20% who use the technology with their collaborators, sharing with this way information and working for efficient between them.

Table 13 – Big data technologies used by company size

Big data technologies used by company size	None	In pilot stages	Interdepartmental	Intracompany	Globally with collaborators	Total
Small (<50 employees)	2	6	1	0	0	9
Medium (50-250 employees)	1	2	3	3	1	10
Large (>250 employees)	0	0	1	2	2	5
Total	**3**	**8**	**5**	**5**	**3**	**24**

Table 14 – % Big data technologies used by company size / Sum of company size

% Big data technologies used by company size / Sum of company size	None	In pilot stages	Interdepartmental	Intracompany	Globally with collaborators
Small (<50 employees)	22,2%	66,7%	11,1%	0,0%	0,0%
Medium (50-250 employees)	10,0%	20,0%	30,0%	30,0%	10,0%
Large (>250 employees)	0,0%	0,0%	20,0%	40,0%	40,0%

The big data analytics usage of figure 8 is analyzed by tables 13 and 14, where most of the companies using the particular technology in pilot stages. Most of them are small sized companies, nearly 67 % of them are willing to obtain the benefits of big data analysis. It is worth to mention that big data is used a lot by medium and large companies, as we can see from the forementioned tables, both among departments or by the hole business. While the 40 % of large enterprises is using this technology globally with their collaborators. Worth mentioning that a 10 % of medium companies is using the technology globally with collaborators as well.

Table 15 - Blockchain technologies used by company size

Blockchain technologies used by company size	None	In pilot stages	Interdepartmental	Intracompany	Globally with collaborators	Total
Small (<50 employees)	8	1	0	0	0	9
Medium (50-250 employees)	5	3	2	0	0	10
Large (>250 employees)	0	1	1	1	2	5
Total	**13**	**5**	**3**	**1**	**2**	**24**

Table 16 – % Blockchain technologies used by company size / Sum of company size

% Blockchain technologies used by company size / Sum of company size	None	In pilot stages	Interdepartmental	Intracompany	Globally with collaborators
Small (<50 employees)	88,9%	11,1%	0,0%	0,0%	0,0%
Medium (50-250 employees)	50,0%	30,0%	20,0%	0,0%	0,0%
Large (>250 employees)	0,0%	20,0%	20,0%	20,0%	40,0%
Total	54,2%	20,8%	12,5%	4,2%	8,3%

For Blockchain technologies as we already have seen in figure 8 and as we already made a comment that this technology is hardly can be adopted by the companies, we can analyze further with the tables 15 and 16. As we can see, nearly 54% of all companies do not use this technology. From those 13 companies 88,9 % of the small companies do not use it, while the rest of is the half of the medium companies. For the rest medium sized companies, 30% is trying to use in in pilot stages and the rest 20% use it in some departments. For large sized companies we can tell a different story. First of all, all of them using the technology in different levels. At all stages we have a 20% except from the last stage where a 40% is using it globally with collaborators. Those companies have mastered the use of it and have tried to acquire all the benefits from it.

Using data analytics from excel, we made a regression analysis for the particular topic. Our independent variables are the total number of employees of each company and the dependent variables is the usage of blockchain technology in the 5 different stages. So, we have 5 dummy variables.

Our linear regression model is Number of employees =B0 + B1 x None + B2 x In pilot stages + B3 x Interdepartmental + B4 x intracompany + B5 x Globally with collaborators.

Table 17 – Regression analysis of Number of employees according level of technology usage

Regression statistics	
Multiple R	0,741618787
R Square	0,549998426
Adjusted R Square	0,402629673
Typical error	99,72894641
Sample size	24

ANALYSING VARIANCE

	Degrees of freedom	*SS*	*MS*	*F*	*Significance F*
Regression	5	230963,566	46192,71321	5,80551863	0,002310645
Residuals	19	188971,3923	9945,862753		
Total	24	419934,9583			

	Coefficients	*Standard error*	*t*	*p-value*	*lower 95%*	*upper 95%*
B0	342,5	70,51901429	4,856846107	0,00010954	194,9020068	490,0979932
None (B1)	-264,3461538	75,74957255	-3,489737895	0,002451775	-422,8918313	-105,8004764
In pilot stages (B2)	-157,9	83,43922295	-1,89239538	0,073776708	-332,5403007	16,74030072
Interdepartmental (B3)	-136,5	91,03965598	-1,499346615	0,150216622	-327,0481899	54,04818987
Intracompany (B4)	80,5	122,1425157	0,65906617	0,517761929	-175,1472233	336,1472233
Globally with collaborators (B5)	0	0	65535	#ΑΡΙΘ!	0	0

From our regression analysis we can tell that there is a fairly strong linear regression between the different usage levels and the responsible variable, which is the number of employees. This statement comes from the Multiple R which is 74,16%.

Also, the 54,99% of the variances of the dependent variables can be explained by the number of employees.

From F-statistic, which in our case is slightly over 5%, we can say that our linear regression analysis is useful.

Although the p-value of the coefficients can depict us that almost all coefficients are not significant, except from the level “in pilot stages”.

The second question of the questionnaire that we made (RQ2) was, which are the barriers that limit the businesses from using the technologies one step further?

For this question we set 11 different barriers on a table alongside with the 4 technologies of our research. From each technology, a company was able to select all of the barriers all none of them.

Table 18 - Total Barriers per size

Total Barriers per size	Automation	Big data Technologies/analytics	Blockchain	Internet of Things	Total
Small (<50 employees)	80	87	87	67	321
Medium (50-250 employees)	54	71	75	35	235
Large (>250 employees)	9	16	24	7	56
All sizes	**143**	**174**	**186**	**109**	**612**

Figure 10 - Total Barriers per size

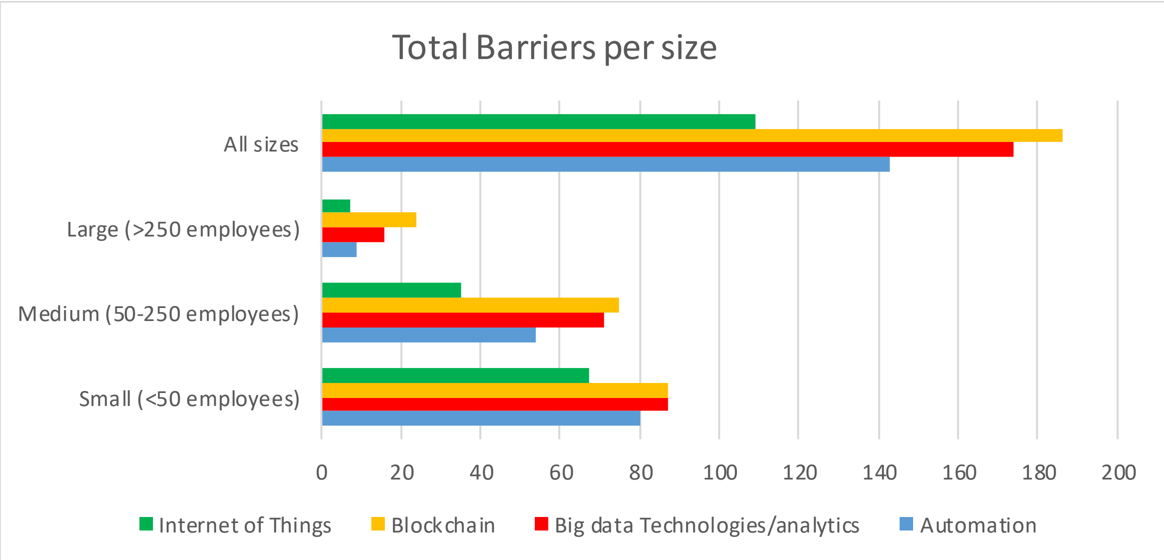


Table 18 was created by the summarizing each problem of every company for the 4 different technologies. As we can see from this table, small companies have the most problems from the other two sizes, while medium sized companies are slightly behind.

From analyzing more, we observe that at small sized companies, big data Technologies and blockchain are the technologies with the more serious adoption problem. In both of them, 9 small companies summarize 87 barriers, while the maximum score they could get is (11 barriers multiplied by 9 companies) 99 barriers. The next technology in line with enough barriers is automation with 80 barriers while at last we have the Internet of things, which as it seems contain lower barriers than the rest of the technologies. The score it gets was only 67. As we can see from Figure 10 the small sized score for this technology is lower than the medium sized of blockchain technology, which is 75. Sightly behind we have big data with 71 and 54 for automation. Again, IoT have the lowers score out of the rest 3 technologies,35 nearly half of the score of blockchain technology. It is worth mentioned that he maximum score that medium sizes companies could get was 110 because the number of mid-sized companies into our sample are 10 in comparison with small sized, which are 9. Last, we have the 5 large sized companies, which can get maximum a score of 55. The row of technologies with more barriers remains the same but with nearly the 1/5 from small sized companies. Blockchain gather 24, big date 16, automation 9, while IoT gather only.

Table 19 – Ranking the barriers by total score

Total Barriers per Technology	Automation	Big data Technologies	Blockchain	IoT	Total	RANK
A [Cost] B1	16	23	20	12	**71**	1
B [Data security and privacy concern] B2	10	7	12	14	**43**	11
C [Technological infrastructure-prerequisites technologies and equipment] B3	14	17	18	11	**60**	4
D [Control and coordination issues- specialized department] B4	13	15	22	9	**59**	5
E [Information leakage] B5	9	15	12	13	**49**	9
F [No usage of the similar tech from suppliers or customers] B6	13	11	21	7	**52**	7
G [No further benefit margin] B7	14	19	13	8	**54**	6
H [Employees resistance to change] B8	17	21	16	10	**64**	3
I [Lack of management support] B9	14	15	15	7	**51**	8
J [Lack of awareness of I4.0] B10	9	12	16	7	**44**	10
K [Lack of knowledge and expertise] B11	14	19	21	11	**65**	2

Figure 11 - Total Barriers per Technology

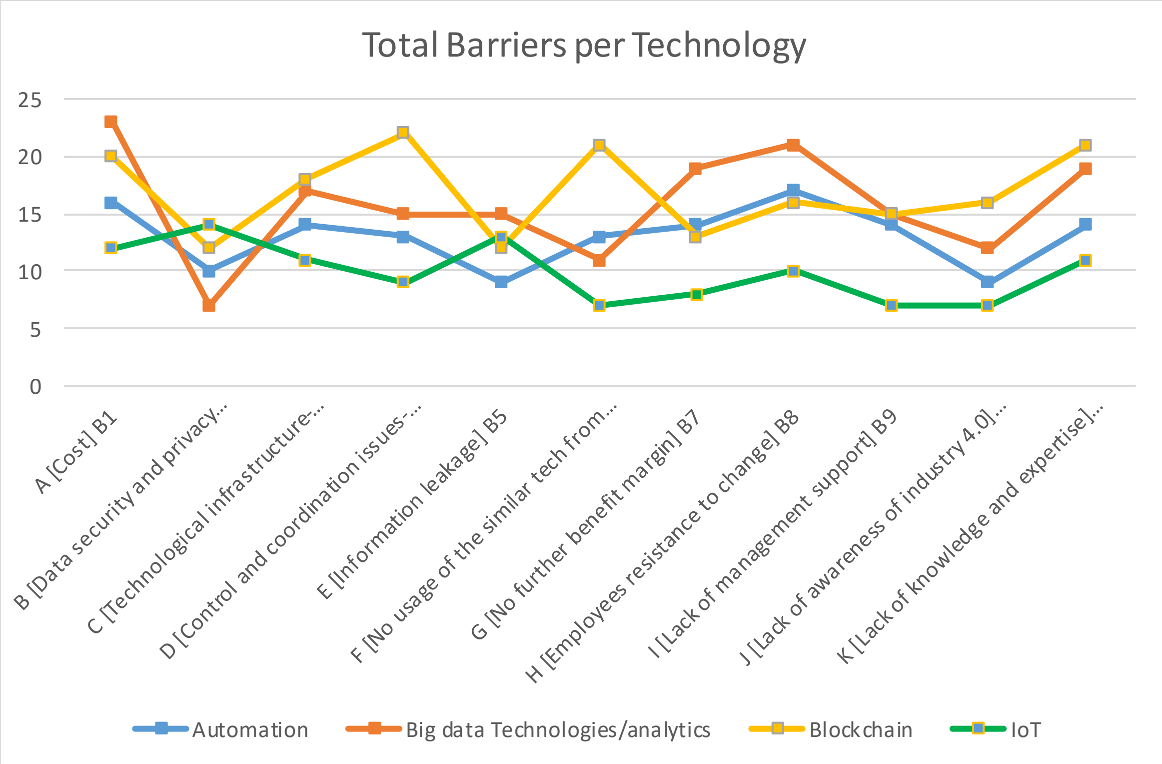


Table 19 is a whole different view of the case, where we have all the scores gathered by the 3 company sizes split for each technology into our 11 barriers. The last column indicates us the ranking, based on the total score of each barrier. With this way we can understand which barrier is more popular than others. Our ranking is constructed based on the summarize of all scores from every company for every technology by barriers. That means that each technology has their own rankings among the barriers. In the number 1 of our total list, cost is the most common barrier for most of the cases, while second comes the lack of knowledge and expertise. Employees resistance to change is following in the 3rd place. It is worth mentioned that the range between the first barrier with the last is 28 and the standard error is 2,69.

On table 20 below is depicted the rank throughout every technology. This table was created by ranking table 19 from the highest score to the lowest according each technology and throughout the total score of each barrier.

Table 20 – Ranking the barriers by each technology

Rank	Automation	Big data Technologies /analytics	Blockchain	IoT	TOTAL
1	B8	B1	B4	B2	B1
2	B1	B8	B11	B5	B11

3	B3	B7	B6	B1	B8
4	B7	B11	B1	B11	B3
5	B9	B3	B3	B3	B4
6	B11	B9	B8	B8	B7
7	B4	B4	B10	B4	B6
8	B6	B5	B9	B7	B9
9	B2	B10	B7	B6	B5
10	B5	B6	B5	B10	B10
11	B10	B2	B2	B9	B2

In order to check our sample, we made 4 different regression analysis tests for our 4 different technologies.

The first regression analysis is for the first technology, which is AU.

Table 21 – Regression analysis of company size according different barriers throughout automation

Regression statistics	
Multiple R	0,909282646
R Square	0,82679493
Adjusted R Square	0,668023616
Standard error	77,85395723
Sample size	24

ANALYSING VARIANCE

	Degrees of freedom	*SS*	*MS*	*F*	*Significance F*
Regression	11	347200,0945	31563,64495	5,207457872	0,004157573
Residual	12	72734,86387	6061,238656		
Total	23	419934,9583			

	Coefficients	*Standard error*	*t*	*P-value*	*lower 95%*	*higher than 95%*
Arranged on principle	363,013236	41,80681137	8,683112252	1,60948E-06	271,924019	454,102453
B1	-43,36874518	43,47299847	-0,997601884	0,338164224	-138,088272	51,35078163
B2	-24,0425285	39,93867584	-0,60198612	0,558386278	-111,0614278	62,97637083
B3	74,73809934	49,77205573	1,501607644	0,15904683	-33,70589424	183,1820929
B4	-85,05567821	44,98007424	-1,890963491	0,083011253	-183,0588411	12,94748464
B5	10,6540487	49,13015042	0,216853574	0,831965464	-96,39135335	117,6994508
B6	38,51262036	59,64538429	0,645693222	0,530631494	-91,44350817	168,4687489
B7	68,43701474	48,01506652	1,425323751	0,179552302	-36,17882822	173,0528577
B8	-194,4355782	67,48818915	-2,881031194	0,01380414	-341,4797106	-47,39144583
B9	-38,73912281	48,93243556	-0,791685972	0,443911927	-145,3537412	67,87549558
B10	-102,4506291	54,05602709	-1,895267459	0,082395994	-220,2285945	15,32733624
B11	-59,89018069	53,24956626	-1,12470739	0,282707176	-175,9110188	56,13065746

Based on the provided statistics, we can make the following observations about the sample:

1. Multiple R: The multiple correlation coefficient (R) of 0.909282646 indicates a strong positive linear relationship between the independent variables and the dependent variable. This suggests that the independent variables collectively explain a significant portion of the variation in the dependent variable.
2. R-squared: The R-squared value of 0.82679493 indicates that approximately 82.67% of the variance in the dependent variable is explained by the independent variables in the regression model. This implies that the model provides a good fit to the data.
3. Adjusted R-squared: The adjusted R-squared value of 0.668023616 takes into account the number of predictors and sample size. It provides a more conservative estimate of the model's explanatory power, considering the complexity and potential overfitting. In this case, it suggests that about 66.80% of the variance is explained by the independent variables, accounting for model complexity.
4. Standard Error: The standard error of 77.85395723 represents the average deviation of the observed values from the regression line. It provides a measure of the accuracy of the predictions made by the model. Smaller values indicate a better fit.
5. ANOVA: The ANOVA table shows the analysis of variance, indicating the significance of the regression model. The F-statistic of 5.207457872 and its associated p-value of 0.004157573 suggest that the regression model as a whole is statistically significant, meaning that at least one of the independent variables has a significant effect on the dependent variable.
6. Coefficients: The coefficients table displays the estimated coefficients for each independent variable in the regression model. The coefficients represent the magnitude and direction of the relationship between each independent variable and the dependent variable. The t-values and p-values associated with each coefficient indicate the statistical significance of the individual predictors. The lower and upper 95% confidence intervals provide a range within which the true population value of the coefficient is likely to fall.

Overall, the analysis suggests that the regression model has a strong overall fit, with significant predictors explaining a considerable portion of the variance in the dependent variable. However, the interpretation of the specific coefficients and their significance would require further context and domain knowledge.

To determine the relative significance of the independent variables, we can examine the t-values and associated p-values in the coefficients table. A lower p-value indicates a higher level of significance.

Based on the provided p-values, I can rank the independent variables in ascending order of significance:

1. B8 (p = 0.01380414)
2. B4 (p = 0.083011253)
3. B10 (p = 0.082395994)
4. B3 (p = 0.15904683)
5. B7 (p = 0.179552302)
6. B11 (p = 0.282707176)
7. B1 (p = 0.338164224)
8. B9 (p = 0.443911927)
9. B6 (p = 0.530631494)
10. B2 (p = 0.558386278)
11. B5 (p = 0.831965464)

Based on the p-values, we can observe that B8 (the coefficient for the independent variable associated with B8) has the lowest p-value of 0.01380414. This indicates that B8 is the most significant independent variable in the model at a conventional significance level (e.g., 0.05). Its low p-value suggests that it has a statistically significant impact on the dependent variable.

This ranking is based solely on the p-values and represents the relative significance of the independent variables in the regression model. However, it's important to consider other factors such as the magnitude and direction of the coefficients, as well as the theoretical relevance of the variables to the problem at hand, when determining their actual importance.

The second regression analysis is for the second technology, which is Big Data analytics.

Table 22 - Regression analysis of company size according different barriers throughout big data analytics

Regression statistics	
Multiple R	0,978519392
R Square	0,9575002
Adjusted R Square	0,918542049
Standard error	38,5650445
Sample size	24

ANALYSING VARIANCE

	Degrees of freedom	*SS*	*MS*	*F*	*Significance F*
Regression	11	402087,8064	36553,43695	24,57766069	1,57485E-06
Residual	12	17847,15189	1487,262657		
Total	23	419934,9583			

	Coefficients	*Standard error*	*t*	*P-value*	*lower 95%*	*higher than 95%*
Arranged on principle	498,9517334	45,80771975	10,89230672	1,41165E-07	399,1452859	598,7581809
B1	-142,6772058	62,68753461	-2,276006014	0,041980136	-279,2616104	-6,092801087
B2	-3,224733093	23,76802993	-0,135675237	0,894327403	-55,01082163	48,56135544
B3	-106,0464184	21,55436005	-4,919952071	0,000353833	-153,0093346	-59,08350216
B4	-22,78125186	26,00221994	-0,876127189	0,398159928	-79,43522226	33,87271854
B5	-1,905315043	20,5126674	-0,092884802	0,927527817	-46,59857794	42,78794785
B6	17,79183492	21,47017363	0,828676807	0,423463762	-28,98765483	64,57132467
B7	7,458531633	25,95222168	0,287394726	0,778712754	-49,08650193	64,00356519
B8	95,99137254	40,47635612	2,371541852	0,035302236	7,800968534	184,1817766
B9	-51,11126831	21,91128373	-2,332645999	0,037888064	-98,85185442	-3,37068221
B10	-74,19330453	19,44991859	-3,814581752	0,002463621	-116,5710367	-31,81557237
B11	-185,7293448	31,38999356	-5,916832842	7,06633E-05	-254,1222655	-117,3364241

Based on the provided regression statistics, the following conclusions can be drawn:

1. The regression model as a whole is highly significant (p = 1.57485E-06). This indicates that the independent variables collectively have a significant impact on the dependent variable.
2. The model has a strong overall fit, as indicated by the high multiple correlation coefficient (R = 0.978519392) and R-squared value (0.9575002). Approximately

95.75% of the variance in the dependent variable can be explained by the independent variables in the model.

3. The adjusted R-squared value (0.918542049) takes into account the number of independent variables and penalizes the inclusion of irrelevant variables. This adjusted value suggests that the model accounts for a significant portion of the variance while avoiding overfitting.
4. The standard error (38.5650445) represents the average deviation of the dependent variable from the regression line. A lower standard error indicates a better fit of the model.
5. The coefficients table provides information about the estimated coefficients for each independent variable. It also includes their standard errors, t-values, and corresponding p-values.
6. The "Arranged on principle" variable has a significant coefficient (p = 1.41165E-07), indicating a strong positive impact on the dependent variable.
7. Among the other independent variables (B1 to B11), B3, B8, B9, B10, and B11 have statistically significant coefficients with p-values below 0.05. This suggests that these variables have a significant impact on the dependent variable.
8. Variables B2, B4, B5, B6, and B7 do not have statistically significant coefficients, as their p-values are above 0.05. This suggests that these variables may not have a significant impact on the dependent variable in the current model.
9. The confidence intervals (lower 95% and higher than 95%) provide a range within which the true population coefficients are likely to fall.

Overall, the regression analysis indicates that the model has a strong overall fit and the majority of the independent variables have significant impacts on the dependent variable. However, further analysis and interpretation may be required to understand the practical significance and implications of the variables in the specific context of the analysis.

Based on the provided regression statistics and their associated p-values, the independent variables can be ranked in descending order of significance:

1. B11 (p = 7.06633E-05)

2. B3 (p = 0.000353833)
3. B10 (p = 0.002463621)
4. B9 (p = 0.037888064)
5. B8 (p = 0.035302236)
6. B1 (p = 0.041980136)
7. B4 (p = 0.398159928)
8. B6 (p = 0.423463762)
9. B7 (p = 0.778712754)
10. B2 (p = 0.894327403)
11. B5 (p = 0.927527817)

This ranking indicates the relative importance of each independent variable in explaining the variation in the dependent variable, with B11 being the most significant and B5 being the least significant in the given analysis.

The third regression analysis is for the third technology, which is Blockchain.

Table 23 - Regression analysis of company size according different barriers throughout Blockchain

Regression statistics	
Multiple R	0,917785083
R Square	0,842329458
Adjusted R Square	0,697798129
Standard error	74,28064594
Sample size	24

ANALYSING VARIANCE

	Degrees of freedom	*SS*	*MS*	*F*	*Significance F*
Regression	11	353723,586	32156,68964	5,828006006	0,002534321
Residual	12	66211,37234	5517,614361		
Total	23	419934,9583			

	Coefficients	*Standard error*	*t*	*P-value*	*lower 95%*	*higher than 95%*
Arranged on principle	536,4745639	87,91745575	6,10202558	5,31969E-05	344,9188834	728,0302444

B1	54,12738807	54,6783405	0,989923754	0,341752669	-65,00648171	173,2612579
B2	-5,576692858	34,94136521	-0,159601459	0,875849915	-81,70738765	70,55400194
B3	4,090186081	66,22571661	0,061761296	0,95176969	-140,2032549	148,3836271
B4	-83,69452051	62,41175595	-1,341005701	0,204750211	-219,6780551	52,28901407
B5	-66,05873377	53,2818952	-1,239796999	0,238748242	-182,1500106	50,03254308
B6	-139,4789809	82,06177703	-1,699682678	0,114940871	-318,2762335	39,31827169
B7	-9,030463514	44,26782532	-0,203996095	0,841775224	-105,4817693	87,42084224
B8	-92,56483746	45,63192382	-2,028510519	0,065299485	-191,9882585	6,858583605
B9	-18,13484271	42,4871777	-0,426830957	0,677060125	-110,7064506	74,43676515
B10	-121,8368626	45,07363175	-2,703062919	0,019200263	-220,0438698	-23,62985548
B11	-43,65483839	63,46387458	-0,687869102	0,504614698	-181,9307426	94,62106577

Based on the regression analysis conducted, the following conclusions can be drawn:

1. The regression model shows a reasonably good fit to the data, as indicated by the high multiple R-squared value of 0.917785083. This suggests that approximately 91.78% of the variation in the dependent variable can be explained by the independent variables included in the model.

2. The overall regression model is statistically significant, as supported by the low p-value associated with the F-statistic (0.002534321). This implies that the model is useful in explaining the dependent variable.

3. Among the independent variables, B10 (with a p-value of 0.019200263), the arranged-on principle (with a p-value of 5.31969E-05), and B8 (with a p-value of 0.065299485) are found to be statistically significant. This suggests that these variables have a significant impact on the dependent variable.

4. The coefficient values associated with the significant independent variables provide insights into the direction and strength of their relationship with the dependent variable. It is recommended to examine the magnitude of these coefficients to understand the relative influence of each significant independent variable.

Based on the provided regression statistics and their associated p-values, the independent variables can be ranked in descending order of significance:

1. B10 (p = 0.019200263)
2. B8 (p = 0.065299485)
3. B11 (p = 0.504614698)
4. B4 (p = 0.204750211)
5. B5 (p = 0.238748242)
6. B6 (p = 0.114940871)
7. B1 (p = 0.341752669)
8. B9 (p = 0.677060125)
9. B7 (p = 0.841775224)
10. B3 (p = 0.95176969)
11. B2 (p = 0.875849915)

This ranking indicates the relative importance of each independent variable in explaining the variation in the dependent variable, with B10 being the most significant and B2 being the least significant in the given analysis.

The last regression analysis is for the fourth technology, which is IoT.

<u>Table 24 - Regression analysis of company size according different barriers throughout Internet of Things</u>

Regression statistics	
Multiple R	0,884545273
R Square	0,78242034
Adjusted R Square	0,582972318
Standard error	87,25886083
Sample size	24

ANALYSING VARIANCE

	Degrees of freedom	*SS*	*MS*	*F*	*Significance F*
Regression	11	328565,6528	29869,6048	3,922928554	0,013351464
Residual	12	91369,30552	7614,108793		
Total	23	419934,9583			

	Coefficients	*Standard error*	*t*	*P-value*	*lower 95%*	*higher than 95%*
Arranged on principle	313,3297283	36,92581327	8,485384627	2,0469E-06	232,8752926	393,784164
B1	-129,6911605	63,28461682	-2,049331528	0,062945947	-267,5764956	8,194174531
B2	-24,78034254	78,68243232	-0,314941237	0,758215327	-196,2146355	146,6539505
B3	-19,16878604	48,15295583	-0,398081192	0,697561634	-124,085064	85,7474919
B4	-2,279744753	44,89504865	-0,050779425	0,960336752	-100,0976527	95,53816324
B5	-41,00912049	71,92483764	-0,570166327	0,579083932	-197,7198795	115,7016385

B6	25,1264383	70,52767609	0,356263522	0,727828395	-128,5401672	178,7930438
B7	-53,06903645	57,79688583	-0,918198891	0,376601188	-178,9976328	72,85955991
B8	-31,25056894	51,94333939	-0,60162803	0,55861693	-144,4253832	81,92424534
B9	-91,77669233	55,97821255	-1,639507375	0,127040701	-213,74274	30,18935535
B10	28,10641019	69,41842702	0,404883997	0,692687202	-123,1433492	179,3561696
B11	-16,39426846	40,31561523	-0,406648103	0,691425494	-104,2344482	71,44591123

Based on the regression analysis results provided, the following conclusions can be drawn:

1. The regression model exhibits a moderate fit to the data, as indicated by the multiple R-squared value of 0.884545273. This implies that approximately 88.45% of the variance in the dependent variable can be explained by the independent variables included in the model.

2. The overall regression model is statistically significant, supported by the low p-value associated with the F-statistic (0.013351464). This suggests that the model as a whole is useful in explaining the dependent variable.

3. Among the independent variables, "Arranged on principle" stands out as statistically significant, with a very low p-value (2.0469E-06). This suggests that this variable has a substantial impact on the dependent variable.

4. The coefficients associated with the significant independent variables provide insights into their relationships with the dependent variable. In this case, the coefficient for "Arranged on principle" is 313.3297283, indicating a positive relationship. However, it's important to note that the coefficients for the remaining independent variables are not statistically significant (as indicated by their higher p-values).

5. The adjusted R-squared value of 0.582972318 suggests that only 58.30% of the variability in the dependent variable can be attributed to the independent variables after accounting for the degrees of freedom in the model. This indicates that there may be other factors not accounted for in the regression analysis that influence the dependent variable.

It is important to interpret these findings with caution and consider additional factors, such as the context of the study, potential limitations of the model or data, and the practical significance of the results, when drawing conclusions from the regression analysis.

Based on the provided regression analysis, the independent variables can be ranked based on their t-values and corresponding p-values:

1. B1 (p-value: 0.062945947)
2. B3 (p-value: 0.697561634)
3. B4 (p-value: 0.960336752)
4. B5 (p-value: 0.579083932)
5. B6 (p-value: 0.727828395)
6. B7 (p-value: 0.376601188)
7. B8 (p-value: 0.55861693)
8. B9 (p-value: 0.127040701)
9. B10 (p-value: 0.692687202)
10. B11 (p-value: 0.691425494)
11. B2 (p-value of 0.758215327)

Please note that this ranking is based on the significance levels determined by the p-values. Variables with lower p-values are considered more statistically significant.

We also compare all 4-regression analysis. From these comparisons, we can observe that the multiple R values are relatively high in all analyses, indicating a good overall fit of the regression models. The R Square values indicate the proportion of the dependent variable's variance explained by the independent variables, with Analysis 2 having the highest R Square value of 0.957.

In terms of the significance of the F-tests, Analysis 2 has the lowest p-value (0.000001), followed by Analysis 3 (0.002), Analysis 4 (0.013), and Analysis 1 (0.004). This suggests that the regression models in Analysis 2 and Analysis 3 have a stronger overall statistical significance compared to Analysis 4 and Analysis 1.

Regarding the most significant independent variable, in all four analyses, the variable "Arranged on principle" consistently emerges as the most significant variable, as it has the highest coefficient estimate and the lowest p-value among all the independent variables.

Overall, it appears that Analysis 2 has the highest overall fit and statistical significance among the four analyses, followed by Analysis 3, Analysis 4, and Analysis 1. However, it's important to note that the specific context and purpose of the regression analyses should also be considered when interpreting the results.

Based on the available information, it seems that the independent variables in the four regression analyses do not have consistent coefficients and statistical significance across the analyses. The significance and direction of the coefficients vary between different analyses. Therefore, it is difficult to identify clear similarities among the independent variables in terms of their impact on the dependent variable across the four analyses.

6. Discussion

6.1 Discussion over the size of the enterprise and the different parameters.

In conclusion, the regression analysis of the four technology domains - Automation, Big Data analytics, Blockchain and Internet of Things - provides valuable insights into the relationship between independent variables and their impact on the dependent variable. The results demonstrate strong overall fits for each model, with high multiple correlation coefficients and R-squared values indicating significant explanatory power. The adjusted R-squared values highlight the models' ability to account for the variance while considering model complexity. Furthermore, the significance of the regression models is supported by the ANOVA analysis, revealing statistically significant F-statistics and low p-values. When examining the individual coefficients, certain independent variables stand out as being statistically significant across the models, suggesting their importance in explaining the dependent variable. However, it's essential to consider other factors such as effect sizes, theoretical relevance, and practical implications when assessing the true significance and applicability of these variables in specific contexts. Overall, these regression analyses provide valuable insights into the impact of independent variables on various technology domains, informing decision-making processes and further research in these fields.

The dependent variable plays a crucial role in the regression analysis. It represents the outcome or response variable that the regression models aim to explain or predict based on the independent variables. In this analysis, the dependent variable could be related to a specific aspect of technology domains, such as market adoption, performance metrics, or user satisfaction.

The paragraph emphasizes the strength of the regression models in explaining the dependent variable. The high multiple correlation coefficients and R-squared values indicate that a significant portion of the variation in the dependent variable can be accounted for by the independent variables. This suggests that the chosen independent variables, such as AU, Big Data analytics, Blockchain, and IoT have a meaningful impact on the dependent variable within the technology domains under investigation.

However, it's important to note that the significance of the dependent variable is not solely determined by statistical measures. Other factors, such as effect sizes, theoretical relevance, and practical implications, should also be considered. These factors help evaluate the substantive importance of the dependent variable in the context of the specific technology domains and the goals of the analysis.

Furthermore, the analysis acknowledges that while certain independent variables may be statistically significant in explaining the dependent variable, their true significance and applicability can vary depending on the specific context. The paragraph highlights the need to consider additional factors and conduct further research to assess the practical implications of these variables accurately.

In summary, the dependent variable in the regression analysis represents the outcome or response variable within the technology domains under investigation. The paragraph recognizes the strengths of the regression models in explaining the dependent variable but also emphasizes the importance of considering other factors and conducting further research to fully understand its significance and applicability.

6.2 Limitations

The analysis of the dependent variable presented in the paragraph has several potential limitations that should be acknowledged. Firstly, the sample size used in the analysis may be limited, which could affect the generalizability of the findings. A larger and more diverse sample would enhance the reliability and robustness of the results. Additionally, the quality of the data used to measure the dependent variable may have limitations, including potential biases and measurement errors. Ensuring the accuracy and reliability of the data is crucial for drawing valid conclusions. Moreover, while the paragraph mentions independent variables such as AI, Big Data analytics, and Blockchain, it is important to consider other potentially influential factors that might have been overlooked. Including a comprehensive set of relevant variables is essential for a comprehensive analysis. Furthermore, the analysis should be mindful of establishing causal relationships, as regression analysis alone does not determine causality. Exploring other research designs and methodologies can help strengthen causal claims. Moreover, the scope and context of the analysis should be clarified, as the findings may be specific to certain technology domains and may not be readily applicable to other contexts. External factors such as economic conditions, regulatory environments, and cultural differences should also be considered to enhance the external validity of the findings. Lastly, the timeframe of the analysis is not specified, and changes in technology over time could impact the relationships between the variables. Being aware of these potential limitations is crucial for interpreting the results accurately and ensuring a comprehensive analysis of the dependent variable.

6.3 Ideas for future research

Moving forward, several avenues for future research can be explored to address the limitations and expand the understanding of the dependent variable. Firstly, conducting a longitudinal study over an extended period can provide insights into the temporal dynamics and changes in the relationships between the dependent variable and its predictors. This would help capture the evolving nature of technology and its impact. Additionally, further investigation into the mediating and moderating mechanisms between the independent variables and the dependent variable would enhance our understanding of the underlying processes. Exploring the potential role of contextual factors, such as organizational culture, leadership styles, and industry-specific characteristics, can provide a more comprehensive understanding of the factors influencing the dependent variable. Moreover, considering alternative research designs, such as experimental or mixed-method approaches, would strengthen the causal claims and provide a richer understanding of the phenomenon. Furthermore, expanding the scope of the analysis to different industries, regions, or cultural contexts would enable researchers to identify any variations or similarities in the relationships. Lastly, exploring the long-term implications and potential unintended consequences of the dependent variable, such as ethical considerations and societal impact, would contribute to a more holistic understanding. By pursuing these avenues, future research can build upon the existing knowledge and provide valuable insights into the complexities surrounding the dependent variable.

7. Conclusion

In conclusion, the analysis of the dependent variable within the regression models sheds light on its importance and impact within the technology domains under investigation. The regression models exhibit strong statistical significance, indicating that the chosen independent variables have a meaningful relationship with the dependent variable. However, it is essential to consider additional factors, such as effect sizes and theoretical relevance, to fully comprehend the significance of the dependent variable beyond statistical measures.

Despite the strengths of the analysis, it is important to acknowledge its limitations. The sample size used in the analysis may limit the generalizability of the findings, and expanding the sample to include a more diverse range of participants would bolster the reliability and validity of the results. Furthermore, the quality of the data used to measure the dependent variable may introduce biases and measurement errors, which should be addressed to ensure the accuracy of the conclusions drawn from the analysis.

Another limitation to consider is the potential exclusion of other influential variables that were not included in the analysis. Future research should aim to incorporate a comprehensive set of relevant variables to provide a more holistic understanding of the factors influencing the dependent variable.

Moreover, while regression analysis provides valuable insights, it does not establish causality. Therefore, it would be beneficial for future research to explore other research designs and methodologies to strengthen causal claims and further validate the relationships between the independent and dependent variables.

Additionally, the analysis should clarify the specific scope and context of the study, as the findings may be specific to the technology domains and may not readily apply to other contexts. Considering external factors such as economic conditions, regulatory environments, and cultural differences would enhance the external validity of the findings.

Furthermore, future research can explore several avenues to address the limitations and expand our understanding of the dependent variable. Conducting longitudinal studies over extended periods would provide insights into the temporal dynamics and changes in the relationships between variables, capturing the evolving nature of technology and its impact. Investigating the mediating and moderating mechanisms between independent and dependent variables would help uncover the underlying processes and provide a deeper understanding of the relationships.

Furthermore, considering alternative research designs, such as experimental or mixed-method approaches, would strengthen the causal claims and provide a more comprehensive understanding of the phenomenon. Expanding the scope of the analysis to different industries, regions, or cultural contexts would allow for identifying variations or similarities in the relationships, contributing to a more robust and nuanced understanding.

Lastly, future research can explore the long-term implications and potential unintended consequences of the dependent variable, such as ethical considerations and societal impact. By delving into these aspects, researchers can provide a more holistic understanding of the complexities surrounding the dependent variable.

In conclusion, while the analysis of the dependent variable within the regression models provides valuable insights, it is crucial to acknowledge the limitations and pursue future research avenues to further enhance our understanding of the dependent variable and its implications within the technology domains. By addressing these limitations and exploring new directions, researchers can contribute to the advancement of knowledge and inform decision-making processes in the field.

References

Abdirad, M., and K. Krishnan. "Industry 4.0 in Logistics and Supply Chain Management: A Systematic Literature Review." *EMJ - Engineering Management Journal*, 2020, 1–15. https://doi.org/10.1080/10429247.2020.1783935.

Agarwal, S., M. Tyagi, and R.K. Garg. "Framework Development and Evaluation of Industry 4.0 Technological Aspects towards Improving the Circular Economy-Based Supply Chain." *Industrial Robot* 49, no. 3 (2022): 555–81. https://doi.org/10.1108/IR-10-2021-0246.

Agnusdei, G.P., M.G. Gnoni, F. Sgarbossa, and K. Govindann. "Challenges and Perspectives of the Industry 4.0 Technologies within the Last-Mile and First-Mile Reverse Logistics: A Systematic Literature Review." *Research in Transportation Business and Management*, 2022. https://doi.org/10.1016/j.rtbm.2022.100896.

Agrawal, Prakash, and Rakesh Narain. "Digital Supply Chain Management: An Overview." *IOP Conference Series: Materials Science and Engineering* 455 (December 19, 2018): 012074. https://doi.org/10.1088/1757-899X/455/1/012074.

Agrawal, R., V.A. Wankhede, A. Kumar, S. Luthra, and D. Huisingh. "Progress and Trends in Integrating Industry 4.0 within Circular Economy: A Comprehensive Literature Review and Future Research Propositions." *Business Strategy and the Environment* 31, no. 1 (2022): 559–79. https://doi.org/10.1002/bse.2910.

Amal Krishnan, U.C., A.T. Sasidharan, T. Prakash, and C.P. Vivek. "Challenges in Adoption of Industry 4.0 in Apparel Supply Chain: A Cross Case Study." *Lecture Notes in Electrical Engineering* 355 (2021): 267–75. https://doi.org/10.1007/978-981-16-1244-2_23.

Armengaud, Eric, Christoph Sams, Georg von Falck, Georg List, Christian Kreiner, and Andreas Riel. "Industry 4.0 as Digitalization over the Entire Product Lifecycle: Opportunities in the Automotive Domain." In *Systems, Software and Services Process Improvement*, edited by Jakub Stolfa, Svatopluk Stolfa, Rory V. O'Connor, and Richard Messnarz, 748:334–51. Communications in Computer and Information Science. Cham: Springer International Publishing, 2017. https://doi.org/10.1007/978-3-319-64218-5_28.

Avilés-Sacoto, S.V., J.F. Avilés-González, H. García-Reyes, M.C. Bermeo-Samaniego, A.K. Cañizares-Jaramillo, and S.N. Izquierdo-Flores. "A Glance of Industry 4.0 at Supply Chain and Inventory Management." *International Journal of Industrial Engineering : Theory Applications and Practice* 26, no. 4 (2019): 486–506.

Bag, S., and J.H.C. Pretorius. "Relationships between Industry 4.0, Sustainable Manufacturing and Circular Economy: Proposal of a Research Framework." *International Journal of Organizational Analysis* 30, no. 4 (2022): 864–98. https://doi.org/10.1108/IJOA-04-2020-2120.

Begum, H., K. Abbas, A.S.A.F. Alam, H. Song, M.T. Chowdhury, and A.B. Abdul Ghani. "Impact of the COVID-19 Pandemic on the Environment and Socioeconomic Viability: A Sustainable Production Chain Alternative." *Foresight* 24, no. 3–4 (2022): 456–75. https://doi.org/10.1108/FS-02-2021-0053.

"CELEX_32003H0361_EN_TXT.Pdf," n.d.

Chiarini, Andrea, Valeria Belvedere, and Alberto Grando. "Industry 4.0 Strategies and Technological Developments. An Exploratory Research from Italian Manufacturing Companies." *Production Planning & Control* 31, no. 16 (December 9, 2020): 1385–98. https://doi.org/10.1080/09537287.2019.1710304.

Dalmarco, G., and A.C. Barros. "Adoption of Industry 4.0 Technologies in Supply Chains." *Contributions to Management Science*, 2018, 303–19. https://doi.org/10.1007/978-3-319-74304-2_14.

Dasaklis, T.K., T.G. Voutsinas, and A. Mihiotis. "Integrating Blockchain with Enterprise Resource Planning Systems: Benefits and Challenges." In *ACM International Conference Proceeding Series*, 265–70, 2021. https://doi.org/10.1145/3503823.3503873.

De Vass, T., H. Shee, and S.J. Miah. "IoT in Supply Chain Management: Opportunities and Challenges for Businesses in Early Industry 4.0 Context." *Operations and Supply Chain Management* 14, no. 2 (2021): 148–61. https://doi.org/10.31387/oscm0450293.

Elhazmiri, B., N. Naveed, M.N. Anwar, and M.I.U. Haq. "The Role of Additive Manufacturing in Industry 4.0: An Exploration of Different Business Models." *Sustainable Operations and Computers* 3 (2022): 317–29. https://doi.org/10.1016/j.susoc.2022.07.001.

Etemadi, N., P. Van Gelder, and F. Strozzi. "An Ism Modeling of Barriers for Blockchain/Distributed Ledger Technology Adoption in Supply Chains towards Cybersecurity." *Sustainability (Switzerland)* 13, no. 9 (2021). https://doi.org/10.3390/su13094672.

Feng, Y., K.-H. Lai, and Q. Zhu. "Green Supply Chain Innovation: Emergence, Adoption, and Challenges." *International Journal of Production Economics* 248 (2022). https://doi.org/10.1016/j.ijpe.2022.108497.

Garrido-Hidalgo, C., T. Olivares, F.J. Ramirez, and L. Roda-Sanchez. "An End-to-End Internet of Things Solution for Reverse Supply Chain Management in Industry 4.0." *Computers in Industry* 112 (2019). https://doi.org/10.1016/j.compind.2019.103127.

Ghadge, A., M. Er Kara, H. Moradlou, and M. Goswami. "The Impact of Industry 4.0 Implementation on Supply Chains." *Journal of Manufacturing Technology Management* 31, no. 4 (2020): 669–86. https://doi.org/10.1108/JMTM-10-2019-0368.

Habib, M.K., and C. Chimsom I. "CPS: Role, Characteristics, Architectures and Future Potentials." In *Procedia Computer Science*, 200:1347–58, 2022. https://doi.org/10.1016/j.procs.2022.01.336.

Hassoun, A., F. Boukid, A. Pasqualone, C.J. Bryant, G.G. García, C. Parra-López, S. Jagtap, H. Trollman, J. Cropotova, and F.J. Barba. "Emerging Trends in the Agri-Food Sector: Digitalisation and Shift to Plant-Based Diets." *Current Research in Food Science* 5 (2022): 2261–69. https://doi.org/10.1016/j.crfs.2022.11.010.

Jamwal, A., R. Agrawal, and M. Sharma. "Deep Learning for Manufacturing Sustainability: Models, Applications in Industry 4.0 and Implications." *International Journal of Information Management Data Insights* 2, no. 2 (2022). https://doi.org/10.1016/j.jjimei.2022.100107.

Jayashree, S., M.N.H. Reza, C.A.N. Malarvizhi, and M. Mohiuddin. "Industry 4.0 Implementation and Triple Bottom Line Sustainability: An Empirical Study on Small and Medium Manufacturing Firms." *Heliyon* 7, no. 8 (2021). https://doi.org/10.1016/j.heliyon.2021.e07753.

Kannankutty, M., and A.M. Menon. "Implementing Cognitive Procurement and Its Influence on Supply Chain During the Era of Digital Transformation in Oil and Gas Industry 4.0." In *Society of Petroleum Engineers - Abu Dhabi International*

Petroleum Exhibition and Conference, ADIP 2021, 2021. https://doi.org/10.2118/207211-MS.

Kumar, Pramod, Jaiprakash Bhamu, and Kuldip Singh Sangwan. "Analysis of Barriers to Industry 4.0 Adoption in Manufacturing Organizations: An ISM Approach." *Procedia CIRP* 98 (2021): 85–90. https://doi.org/10.1016/j.procir.2021.01.010.

Kumar, Pravin, Rajesh Kr Singh, and Vikas Kumar. "Managing Supply Chains for Sustainable Operations in the Era of Industry 4.0 and Circular Economy: Analysis of Barriers." *Resources, Conservation and Recycling* 164 (January 2021): 105215. https://doi.org/10.1016/j.resconrec.2020.105215.

Kumar, S., and R.R. Mallipeddi. "Impact of Cybersecurity on Operations and Supply Chain Management: Emerging Trends and Future Research Directions." *Production and Operations Management*, 2022. https://doi.org/10.1111/poms.13859.

Kumar, S., R.D. Raut, E. Aktas, B.E. Narkhede, and V.V. Gedam. "Barriers to Adoption of Industry 4.0 and Sustainability: A Case Study with SMEs." *International Journal of Computer Integrated Manufacturing*, 2022. https://doi.org/10.1080/0951192X.2022.2128217.

Kumar, S., R.D. Raut, K. Nayal, S. Kraus, V.S. Yadav, and B.E. Narkhede. "To Identify Industry 4.0 and Circular Economy Adoption Barriers in the Agriculture Supply Chain by Using ISM-ANP." *Journal of Cleaner Production* 293 (2021). https://doi.org/10.1016/j.jclepro.2021.126023.

Lu, Yang. "Industry 4.0: A Survey on Technologies, Applications and Open Research Issues." *Journal of Industrial Information Integration* 6 (June 2017): 1–10. https://doi.org/10.1016/j.jii.2017.04.005.

Luthra, S., and S.K. Mangla. "Evaluating Challenges to Industry 4.0 Initiatives for Supply Chain Sustainability in Emerging Economies." *Process Safety and Environmental Protection* 117 (2018): 168–79. https://doi.org/10.1016/j.psep.2018.04.018.

Marinas, M., M. Dinu, A.G. Socol, and C. Socol. "The Technological Transition of European Manufacturing Companies to Industry 4.0. Is the Human Resource Ready for Advanced Digital Technologies? The Case of Romania." *Economic Computation and Economic Cybernetics Studies and Research* 55, no. 2 (2021): 23–41. https://doi.org/10.24818/18423264/55.2.21.02.

Masood, Tariq. "Industry 4.0: Challenges and Success Factors for Adopting Digital Technologies in Airports," 2021.

Masood, Tariq, and Paul Sonntag. "Industry 4.0: Adoption Challenges and Benefits for SMEs." *Computers in Industry* 121 (October 2020): 103261. https://doi.org/10.1016/j.compind.2020.103261.

Mittal, Shivika, Erik O. Ahlgren, and P.R. Shukla. "Barriers to Biogas Dissemination in India: A Review." *Energy Policy* 112 (January 2018): 361–70. https://doi.org/10.1016/j.enpol.2017.10.027.

Pereira das Neves, E., D. Nogueira da Silva, L.C. Paschoarelli, and F. Moreira da Silva. "Fashion Segment and Industry 4.0: Brazilian Textile and Clothing Industry – Perspective into the New Industrial Paradigms." In *Industry 4.0 - Shaping The Future of The Digital World - Proceedings of the 2nd International Conference on Sustainable Smart Manufacturing, S2M 2019*, 41–46, 2019. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85117571941&partnerID=40&md5=8461b760d0d3b57aa784e10adae5c219.

Pessot, E., A. Zangiacomi, C. Battistella, V. Rocchi, A. Sala, and M. Sacco. "What Matters in Implementing the Factory of the Future: Insights from a Survey in

European Manufacturing Regions." *Journal of Manufacturing Technology Management* 32, no. 3 (2021): 795–819. https://doi.org/10.1108/JMTM-05-2019-0169.

Pourmehdi, M., M.M. Paydar, P. Ghadimi, and A.H. Azadnia. "Analysis and Evaluation of Challenges in the Integration of Industry 4.0 and Sustainable Steel Reverse Logistics Network." *Computers and Industrial Engineering* 163 (2022). https://doi.org/10.1016/j.cie.2021.107808.

Rad, Fakhreddin F., Pejvak Oghazi, Maximilian Palmié, Koteshwar Chirumalla, Natallia Pashkevich, Pankaj C. Patel, and Setayesh Sattari. "Industry 4.0 and Supply Chain Performance: A Systematic Literature Review of the Benefits, Challenges, and Critical Success Factors of 11 Core Technologies." *Industrial Marketing Management* 105 (August 2022): 268–93. https://doi.org/10.1016/j.indmarman.2022.06.009.

Rajesh Karthik, R., and M.A. Millath. "A Study and Analysis on Sustainable Business Models for Indian Automotive Industry." *International Journal of Advanced Science and Technology* 28, no. 19 (2019): 953–59.

Raut, R.D., A. Gotmare, B.E. Narkhede, U.H. Govindarajan, and S.U. Bokade. "Enabling Technologies for Industry 4.0 Manufacturing and Supply Chain: Concepts, Current Status, and Adoption Challenges." *IEEE Engineering Management Review* 48, no. 2 (2020): 83–102. https://doi.org/10.1109/EMR.2020.2987884.

Sartori, J.T.D., G.F. Frederico, and H. de Fátima Nunes Silva. "Organizational Knowledge Management in the Context of Supply Chain 4.0: A Systematic Literature Review and Conceptual Model Proposal." *Knowledge and Process Management* 29, no. 2 (2022): 147–61. https://doi.org/10.1002/kpm.1682.

Saucedo-Martínez, Jania Astrid, Magdiel Pérez-Lara, José Antonio Marmolejo-Saucedo, Tomás Eloy Salais-Fierro, and Pandian Vasant. "Industry 4.0 Framework for Management and Operations: A Review." *Journal of Ambient Intelligence and Humanized Computing* 9, no. 3 (June 2018): 789–801. https://doi.org/10.1007/s12652-017-0533-1.

Sharma, M., S. Kamble, V. Mani, R. Sehrawat, A. Belhadi, and V. Sharma. "Industry 4.0 Adoption for Sustainability in Multi-Tier Manufacturing Supply Chain in Emerging Economies." *Journal of Cleaner Production* 281 (2021). https://doi.org/10.1016/j.jclepro.2020.125013.

Sharma, V., R.D. Raut, M. Hajiaghaei-Keshteli, B.E. Narkhede, R. Gokhale, and P. Priyadarshinee. "Mediating Effect of Industry 4.0 Technologies on the Supply Chain Management Practices and Supply Chain Performance." *Journal of Environmental Management* 322 (2022). https://doi.org/10.1016/j.jenvman.2022.115945.

Sindhu, S., and R. Kumar. "Modeling the Challenges for Agri-Food Supply Chain 4.0: Tism Approach." *Advanced Series in Management* 27 (2022): 31–51. https://doi.org/10.1108/S1877-636120220000027003.

Soldatos, J., O. Lazaro, and F. Cavadini. *The Digital Shopfloor: Industrial Automation in the Industry 4.0 Era: Performance Analysis and Applications*. *The Digital Shopfloor: Industrial Automation in the Industry 4.0 Era Performance Analysis and Applications*, 2019. https://doi.org/10.13052/rp-9788770220408.

Sood, S.K., K.S. Rawat, and G. Sharma. "Role of Enabling Technologies in Soft Tissue Engineering: A Systematic Literature Review." *IEEE Engineering Management Review*, 2022, 1–10. https://doi.org/10.1109/EMR.2022.3195923.

Sunmola, F.T., P. Burgess, and A. Tan. "Building Blocks for Blockchain Adoption in Digital Transformation of Sustainable Supply Chains." In *Procedia Manufacturing*, 55:513–20, 2021. https://doi.org/10.1016/j.promfg.2021.10.070.

Tortorella, G., R. Miorando, and A.F. Mac Cawley. "The Moderating Effect of Industry 4.0 on the Relationship between Lean Supply Chain Management and Performance Improvement." *Supply Chain Management* 24, no. 2 (2019): 301–14. https://doi.org/10.1108/SCM-01-2018-0041.

Tortorella, G.L., R.F. Miorando, C.E. Fries, and A.M.C. Vergara. "On the Relationship between Lean Supply Chain Management and Performance Improvement by Adopting Industry 4.0 Technologies." In *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 2018:2475–84, 2018. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85066935630&partnerID=40&md5=11598495d9a2ec25fcd42e4da7943547.

Tran-Dang, H., and D.-S. Kim. "The Physical Internet in the Era of Digital Transformation: Perspectives and Open Issues." *IEEE Access* 9 (2021): 164613–31. https://doi.org/10.1109/ACCESS.2021.3131562.

Vieira, R.C., and A.M. De Melo. "Smart Manufacturing: The Manufacturing Strategy and Affordances Perception Influency." In *Towards Sustainable Technologies and Innovation - Proceedings of the 27th Annual Conference of the International Association for Management of Technology, IAMOT 2018*, 2018. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85085668799&partnerID=40&md5=c45f9f3d3d20476fa2d43d4c8c5844f6.

Wamba, S.F., and M.M. Queiroz. "Industry 4.0 and the Supply Chain Digitalisation: A Blockchain Diffusion Perspective." *Production Planning and Control* 33, no. 2–3 (2022): 193–210. https://doi.org/10.1080/09537287.2020.1810756.

Weerabahu, W.M.S.K., P. Samaranayake, D. Nakandala, and H. Hurriyet. "Digital Supply Chain Research Trends: A Systematic Review and a Maturity Model for Adoption." *Benchmarking*, 2022. https://doi.org/10.1108/BIJ-12-2021-0782.

Witkowski, Krzysztof. "Internet of Things, Big Data, Industry 4.0 – Innovative Solutions in Logistics and Supply Chains Management." *Procedia Engineering* 182 (2017): 763–69. https://doi.org/10.1016/j.proeng.2017.03.197.

Yadav, G., S. Luthra, S.K. Jakhar, S.K. Mangla, and D.P. Rai. "A Framework to Overcome Sustainable Supply Chain Challenges through Solution Measures of Industry 4.0 and Circular Economy: An Automotive Case." *Journal of Cleaner Production* 254 (2020). https://doi.org/10.1016/j.jclepro.2020.120112.

Yadav, S., D. Garg, and S. Luthra. "Analysing Challenges for Internet of Things Adoption in Agriculture Supply Chain Management." *International Journal of Industrial and Systems Engineering* 36, no. 1 (2020): 73–97. https://doi.org/10.1504/IJISE.2020.109121.

Zangiacomi, A., E. Pessot, R. Fornasiero, M. Bertetti, and M. Sacco. "Moving towards Digitalization: A Multiple Case Study in Manufacturing." *Production Planning and Control* 31, no. 2–3 (2020): 143–57. https://doi.org/10.1080/09537287.2019.1631468.

Zangiacomi, A., M. Sacco, E. Pessot, A. De Zan, and M. Bertetti. "A Perspective for the Implementation of a Path Towards the Factory of the Future: The Italian Case." In *2018 IEEE International Conference on Engineering, Technology and Innovation, ICE/ITMC 2018 - Proceedings*, 2018. https://doi.org/10.1109/ICE.2018.8436386.

Zhang, A., V.G. Venkatesh, J.X. Wang, V. Mani, M. Wan, and T. Qu. "Drivers of Industry 4.0-Enabled Smart Waste Management in Supply Chain Operations: A

Circular Economy Perspective in China." *Production Planning and Control*, 2021. https://doi.org/10.1080/09537287.2021.1980909.

Appendix A: "Title of appendix"

…

…

Appendix B: "Title of appendix"

…

…