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Empirical Study of Information Technology in Supply Chain Management: Barriers and Risks

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Abstract

The article focuses on technology adoption in Supply Chain Management (SCM) and the barriers encountered when technology is implemented, and provides a comprehensive picture of the barriers and risks that arise. The knowledge gained from this study would be helpful to organizations that plan to implement information technology in SCM. The paper starts with a brief examination of the notion, definition, and use of technology in SCM. Then, an empirical model is proposed, the model analyzes the barriers at the time of the adopting technology in SCM. A classification predicted model was constructed to predict the variables that have the most significant influence and that can represent the biggest barriers in the adoption of information technology in SCM for a period of four years (2016 – 2019). Finally, the article proposes some recommendations that could be implemented to improve the competitiveness and performance of the SCM by reducing the barriers and risks encountered.

Keywords: IT Risks in SCM, IT Barriers in SCM, IT in Supply Chain Management.

JEL Classification: C, C49.

1. Introduction

The main objective of the barrier and risk analysis presented in this article is to highlight the threats that make the supply chain system vulnerable. The study analyses barriers and risks aimed at promoting technologies in SCM. The analysis should be seen to become more proactive, addressing relevant vulnerability issues before critical events, incidents, or accidents occur. This can be understood as part of the transformation in technology adoption in SCM, which can allow decision-makers to discover new areas of risk factors before implementing and operating technologies in SCM.

There are numerous barriers to applying new technologies; these barriers contain, but are not restricted to, a deficiency of a trained labour force that understands these technologies, inefficient legislation and controls, an inefficient performance framework, and short-term corporate goals (Pravin et al., 2020). The top five barriers

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to the manufacturing industry are lack of technical expertise and training, lack of research and development capabilities, the popularity of traditional technology, high initial investment in state-of-the-art technology, and fear of additional workload and loss of flexibility. in their quest to adopt and implement sustainable supply chain innovation practices (Himanshu et al., 2020). In the early stages of process technology, it is often difficult to match specific configurations of production equipment with the characteristics of the final product, increasing the interdependence between manufacturing and research and development activities (Gray et al., 2015). Tolerances are high, and production output is usually low, resulting in additional processing costs and material waste, where recovery costs can exceed labor costs in high-tech industries (Bohn et al., 1999). Moreover, engineers often have to visit the troubleshooting workshop, increasing process downtime and lowering production rates (Fuchs et al., 2010). Better tools and automated processes can increase the reliability of the technology and allow the production of larger volumes at a lower cost (Featherston et al., 2017); new sensors and measuring instruments accelerate the ability to find potential defects in companies' products that could not otherwise be detected (Hoyssa et al., 2009); the new software modeling tools allow a quick pre-evaluation of the various design options without the cost of extensive prototyping and mechanical testing (Nightingale, P., 2000); shared data platforms and standardized interfaces can accelerate the learning speed of the research community and allow for the specialization of providers (Wamba et al., 2015; Tassey, 2000). Despite their benefits, SCMs face significant barriers to adoption. Adoption costs constitute a significant factor. The technologies must be compatible with the pre-existing SCM processes and routine; they are often subject to network externalities and must become an industry standard before experiencing widespread adoption. Additionally, the SCM must also be approved by the appropriate regulatory agency in highly regulated industries, as existing industry standards may not be good enough to ensure product safety (Bonnín Roca et al., 2017). SCM offers organizations the approach to maintain their competitiveness in the global/global market, and the approach has also been inspired by organizations to improve their quality control, maintain quality products, improve industrial networks, and customer satisfaction. One of the critical factors in improving competitiveness is increasing quality performance to a world-class standard.

Increased SCM performance, which includes inventory management and quality control, will become weaker, as developing operational and management skills and improving IT and technology are also essential elements for improving SCM performance. As difficulties have arisen in the introduction of IoT technology, such as the lack of IoT platform development staff, standardization, integration with the existing system, professional workforce, expenses, detail management, and operation, it has become necessary for us to exercise or greater come up with solutions (Kangbae et al., 2016). Complex technologies offer substantial economic benefits, are difficult to invent and imitate, and refuse rapid dissemination. This duality motivates the idea that the competitive advantages of the regions and, consequently, their economic growth must have their origin in their capacity to produce and use complex technologies.

The research paper begins with a brief review of technology's concept, definition, and use. The second part of the paper highlights the technologies used in SCM. Subsequently, Sections three and four present the barriers and risks encountered in SCM following the use of the technology. In the last part, an empirical model is proposed that analyzes the barriers and risks in adopting technology in SCM. Finally, the article proposes some recommendations that could be implemented to improve the competitiveness and performance of the SCM by reducing the barriers and risks encountered.

2. Information Technology in Supply Chain Management

Proper alignment and integration between key supply chain actors and increased visibility and transparency will ensure an adequate forecast of resources (people, materials, and equipment), enhancing resource/process optimization, market alignment, and employment growth work.

Over the last decade, the use and evolution of technology in SCM have become inevitable, mainly because it is vital for increasing the organizational efficiency and its level of competitiveness (Heuser et al., 2008) that has promoted the adoption of technology in SCM. Technological evolution is highlighted by well-known applications such as Enterprise Resource Planning (ERP), Warehouse Management Systems (WMS), Systems Management Systems (TMS), and Intelligent Transportation Systems (ITS) (Hasan et al., 2013). The new advanced technology in SCM may require something like the great need for transparency (supply chain visibility); SCM integrity check (right products at the right time, quantity, location, and correct cost) (Macaulay et al., 2015); Dynamic "reconfigurability" of supply networks, in particular by reviewing service level agreements with upstream suppliers and contacting them (Carvalho et al., 2011). The demand for highly personalized products and services is constantly growing. Inbound and outbound logistics must adapt to this changing environment.

Warehouses have always been a vital center in the flow of goods within a supply chain. It should also serve as a critical source of competitive advantage for logistics suppliers. Introducing "smart" management during the proper adoption and implementation of Warehouse Management Systems (WMS) will transform warehouse activities into the future requirements of inbound logistics (Schrauf et al., 2016). The necessary integration among the various actors and stakeholders of the SCM will ensure complete coordination and alignment. Shipments will be able to communicate their position and expected arrival time to the intelligent warehouse management system, which will be able to select and prepare a docking slot, optimizing just-in-time and just-in-sequence delivery. At the same time, the RFID sensors will reveal what has been delivered and send the tracking and tracking data to the entire SCM.

Necessary to increase the level of customer service. The WMS will automatically allocate storage space according to the specifics of the delivery and will demand suitable equipment to transfer the goods to the precise setting autonomously. Once the pallets are moved to the assigned location, the labels will send signals to WMS to offer real-time distinguishability into inventory points, avoiding overpriced inventory circumstances and improving management decision capacity for adjustments that could be made.

A transport management system (TMS) is part of the SCM focused on transport logistics. A TMS allows interactions between an order management system (WHO) and a distribution center (DC) or warehouse. These systems have been named to support firms in controlling and managing rising transport costs, integrating with other supply chain technologies, and managing electronic communications with customers, trading partners, and carriers. A TMS system is essential for a company to use GPS technology to locate its vehicles accurately. At the same time, on the road, monitor the movement of goods, negotiate with carriers, strengthen shipments, and use the advanced functionality of the platform, and interact with Intelligent Transport Systems (ITS). Major software companies are rapidly moving their TMS solutions to the cloud, thus drastically reducing the number of on-site installations (Cunnane, 2017). TMS redefines companies' strategies, as the latest TMS solutions provide better end-to-end supply chain visibility; with amplified usage of mobile devices and services, which will integrate smartphone applications that drivers can use to create visibility places where there are specific trucks whenever they are needed.

As an increase of physical items is equipped with barcodes, RFID tags, or sensors, transportation and logistics companies can perform real-time monitoring of the movement of physical objects from a source to a destination along the entire supply chain, including production, transportation, and distribution. The IoT also offers promising solutions to transform transportation systems and automotive services (Qin et al., 2013). IoT technologies make it possible to track the current location of each vehicle, monitor its movement, and predict its future location.

The Intelligent Transport System (ITS) is a new field that can work together to achieve a common goal in different areas of transport systems, such as transport management, control, infrastructure, operations, policies, and control methods. ITS adopts new technologies such as computing hardware, positioning system, sensor technologies, telecommunications, data processing, virtual operation, and planning techniques. Integrating virtual technologies is a new issue in transport and plays a vital role in overcoming the problems of a global world. SITs are essential to increase safety and reliability, speed, and traffic flow and reduce risks, accident rates, carbon emissions, and air pollution. An intelligent transport system offers cooperation solutions and a reliable transport platform.

SCM is encouraged to develop sectoral market strategies that allow their corporations to take advantage of technology development while maintaining sufficient flexibility, where possible, to move where appropriate. However, it is often challenging to switch technologies once implemented. Modern SCM is a complex network that connects organizations, industries, and economies. Virtually all SCMs operate in a network of business and multiple relationships.

The increased use of IT, the globalization of SCM, and the integration of companies' networks into "smart businesses" have helped reduce the exposure of SCM to a catastrophic disaster. The challenge for SCM is to recognize the full scope of technology and the barriers it faces and then mitigate and manage them. Barriers can only be managed if the organization and network have the necessary supply chain capabilities (i.e., skills, processes, and contingencies).

Technological innovation and customer requirements for sophisticated technology and services promote the emergence of new challenges, which are increasingly changing SCM. The emergence of technology has promoted new challenges in SCM, which may require technological changes, such as the great need for transparency (supply chain visibility) and integrity control in supply chains (right products, at the right time, place, quantity, and the correct cost). This transformation will dramatically influence how the SCM will be managed following the new incentives and the environment and context configuration.

3. Barriers Encountered in Supply Chain Management Following the Use of Technology

Any condition that hinders progress or the achievement of a goal is defined as a barrier. It is essential to study and highlight barriers as they belong to technological integration, as this knowledge could guide ways to improve technological integration. A developed EMS will encourage a common approach to problem-solving and lead to cost reductions, improved product quality, and exports. The digital technologies used in the supply chain are constantly evolving, so the skills needed to support the technologies must also evolve. For this reason, many companies target more general skill sets, more suitable for dynamic work environments.

Predictive analytics and inventory and network optimization are two critical areas in the digital transformation of the supply chain. The technology value is determined by the increasing accumulation of data and the ability to extract valuable information from this data. In the field of technology, SCM tends to expand its talent groups in data analysis to allow access to these technologies in all sectors of activity. The cost of implementation is a significant barrier to adopting supply chain technologies. The costs include the implementation of automation and sensors and the maintenance of the networks and storage space needed to communicate and collect the data that these systems generate, as well as investing in analytical tools and skills to understand everything. The respondents also identified a lack of qualified talent as a significant barrier to progress.

According to the annual reports published by MHI, the most highlighted barriers identified to the use of technology in SCM are:

- Deficiency of a clear business case to justify the investment: used during the complete life cycle, from initial decisions to implementation, and later project evaluation. A business case is an important tool for "reaping the benefits." The business case can be used as evidence of agreements concluded before and during the execution of a project.

- Deficiency of adequate talent to use technology effectively: technological skills are no longer just focused on IT; they need to be mixed between organizational functions and coupled with "soft skills" to achieve the success of the digital transformation. Also, a critical factor is the degree of knowledge of the SCM processes.
- Deficiency of understanding of the technological landscape: the technologies bring substantial design and integration challenges, which also pose risks for SCM. An in-depth understanding through a current analysis of technology design and integration and the identification of challenges can eliminate these barriers faced by SCM.
- Deficiency of access to capital to make investments: many factors cause a lack of access to capital to make investments (low credit score, inability to borrow from traditional sources of financing, operational problems are affecting cash flow).
- Not wanting to invest due to economic uncertainty: there is always uncertainty about the future, which means it is more challenging to make future-oriented decisions. In the face of an increasingly uncertain future, SCM should wait until there is more certainty in making an important decision. The SCM expects to make an investment, delay research projects, or postpone employment until the economy's future is more precise.

4. Risks Encountered in Supply Chain Management Following the Use of Technology

SCM can face many risks, for example, weaknesses and potential risks within SCM regarding the ability to meet customer needs (uncertainty arises when supply and demand are out of balance) and the fragility of SCM to external events/threats. The aim is to identify potential risk areas and implement appropriate actions to limit this risk in the SCM.

The lack of visibility and control in the SCM can lead to a lack of trust, which increases the risk to the supply chain. Lack of confidence in the SCM can increase the risk. In an effective risk environment, the first thing is to create awareness, which develops when a firm recognizes that it is at risk in a better place of supply and realizes the potentially severe consequences of these disruptions. Awareness must be developed internally at several levels of management so that resources can be allocated and appropriate processes and tools for risk management can be developed and implemented. The second element is prevention to reduce the impact of supply chain disruptions.

The third element is remediation; the SCM needs to take action to recover from a disturbance when it occurs and should consider how it could shorten the duration of the disturbance and minimize its impact. The last element is knowledge management; SCM professionals need to learn from experience when an interruption occurs. Past events should be captured, which will allow SCM professionals to assess whether their strategies have been appropriate and allow management to review what has happened and, in essence, provide information.

According to the annual reports published by MHI, the most highlighted barriers identified to the use of technology in SCM are:

- Cultural aversion to risk: for similar SCM processes, such as making a purchase, SCM processes can be constructed differently depending on the cultural group. Different cultures think differently when presented with risky options due to various cultural environments, such as the community environment, values , and social interactions that could explain these risk responses.
- Cybersecurity: SCM requires a collaborative partnership between people and organizations, leading to several barriers. Through the relationships created, SCM exposes itself to sensitive aspects of the business.

A first step in protecting SCMs from such risks is to identify them. A form of risk comes from Cloud service providers who store confidential data, and these entities invest significantly in the security of their systems. Without solid security, the Internet of Things (IoT) allows attackers to access SCM systems, so these devices should not be overlooked. IoTs have sensors that connect them to the Internet for communication purposes and are common in supply chains because they can help predict machine failures and inventory management. Despite their functional value, they are a popular attack vector that can give attackers access to sensitive data.

5. Empirical Model

The third part of the article describes the application of the empirical approach to investigate the variables associated with barriers to the adoption of technology in SCM. The main objective is to acquire a model that provides a better framework of variables and dynamics that lead to barriers to adopting technology in SCM. The resulting empirical knowledge can be understood as those cases in which new information and knowledge are acquired. It is essential to consider that when modelling is applied to any logistics system, flexibility must be considered.

Root-Mean-Square Error (RMSE): The term average square root error (RMSE) is the square root of the average square error (MSE). RMSE calculates the variances between the values predicted by a hypothetical model and the observed values. It calculates the quality of the match among the real data and the projected model. RMSE is one of the most commonly used measures of goodness for matching generalized regression models (Salkind, 2010).

The mean square root error (RMSE) was used as a standard statistical metric to measure model performance in research studies. Each statistical measure condenses a large amount of data into a single value. It provides a single projection of model errors, emphasizing a particular aspect of the model's performance error characteristics. Moreover, in data assimilation, the sum of square errors is often defined as the cost function that must be minimized by adjusting the model parameters. In such applications, penalizing significant errors by the terms defined with the smallest square proves to be very effective in improving the model's performance.

5.1 Data

The studies were carried out with data processed over a period of 4 years, starting with 2016 and until 2019, extracted from the MHI annual reports.

Table 1. Hypotheses for IT barriers and risks in SCM

Hypothesis	Description
H1	Deficiency of a clear business case to justify the investment
H2	Deficiency of adequate talent to use technology effectively
H3	Cultural aversion to risk
H4	Cybersecurity
H5	Deficiency of understanding of the technological landscape
H6	Deficiency of access to capital to make investments
H7	Not wanting to invest due to economic uncertainty

Source: Own processing based on data from https://www.mhi.org/publications/report.

5.2 Analysis

Comparisons are limited to individual time series. The tables below represent the average RMSE on barriers to technology adoption in SCM. RMSE is analogous to the standard deviation (MSE invariance) and measures the extent to which the residues are distributed. RMSE is a quadratic equation counting rule that measures the typical degree of error. Because errors are square before they are mediated, RMSE gives a relatively high weight to significant errors. RMSE is most beneficial when big errors are predominantly undesirable.

The calculation of the RMSE and MSE for the dataset is as follows:

$$MSE = \frac{\sum_{i=1}^{n} |\hat{y}_n - y_n|}{n} \quad (1)$$

$$RMSE = \sqrt{\frac{\sum_{n-1}^{n} (\hat{y}_n - y_n)^2}{n}} \quad (2)$$

where:

$\hat{y}_n$ – means predictive assessment;

y_n – means the actual evaluation of the test data set;

n – is the number of evaluation prediction pairs between the test data and the prediction result.

Lower RMSE values specify a better fitting model, RMSE is a good measure of how the model accurately predicts the answer, and is the most crucial matching criterion if the model's primary purpose is prediction.

Table 2. Barriers in technology adoption in SCM (2016)

Hypothesis	Actual	Square difference (SE)	Squared Error
H1. Deficiency of a clear business case to justify the investment	43	4.333	18.778
H2. Deficiency of adequate talent to use technology effectively	38	-0.667	0.444
H3. Cultural aversion to risk	35	-3.667	13.444
MSE	**10.8888**		
RMSE	**3.2998**		

Source: Own processing based on data from https://www.mhi.org/publications/report.

The value of RMSE is 3.2998 in 2016 (Table 2) resulting from the adoption of technologies in SCM.

Table 3. Barriers in technology adoption in SCM (2017)

Hypothesis	Actual	Square difference (SE)	Squared Error
H1. Deficiency of a clear business case to justify the investment	44	-4.333	18.778
H5. Deficiency of understanding of the technological landscape	45	-3.333	11.111
H6. Deficiency of access to capital to make investments	56	7.667	58.778
MSE	**29.5555**		
RMSE	**5.4365**		

Source: Own processing based on data from https://www.mhi.org/publications/report.

The RMSE value is 5.4365 in 2017 (Table 3) resulting from the adoption of technologies in SCM.

Table 4. Barriers in technology adoption in SCM (2018)

Hypothesis	Actual	Square difference (SE)	Squared Error
H1. Deficiency of a clear business case to justify the investment	28.2	3.780	14.288
H5. Deficiency of understanding of the technological landscape	24.4	-0.020	0.000
H6. Deficiency of access to capital to make investments	21.5	-2.920	8.526
H2. Deficiency of adequate talent to use technology effectively	22	-2.420	5.856
H4. Cyber security	26	1.580	2.496
MSE	**6.2336**		
RMSE	**2.4967**		

Source: Own processing based on data from https://www.mhi.org/publications/report.

The value of RMSE is 2.4967 in 2018 (Table 4) resulting from the adoption of technologies in SCM.

Table 5. Barriers in technology adoption in SCM (2019)

Hypothesis	Actual	Square difference (SE)	Square d Error
H5. Deficiency of understanding of the technological landscape	27	10.286	105.796
H2. Deficiency of adequate talent to use technology effectively	26	9.286	86.224
H1. Deficiency of a clear business case to justify the investment	19	2.286	5.224
H6. Deficiency of access to capital to make investments	14	-2.714	7.367
H7. Not willing to invest because of economic uncertainty	11	-5.714	32.653
H3. A cultural aversion to risk	10	-6.714	45.082
H4. Cyber security	10	-6.714	45.082
MSE	**46.7755**		
RMSE	**6.8392**		

Source: Own processing based on data from https://www.mhi.org/publications/report.

The value of RMSE is 6.8392 in 2019 (Table 5) resulting from the adoption of technologies in SCM.

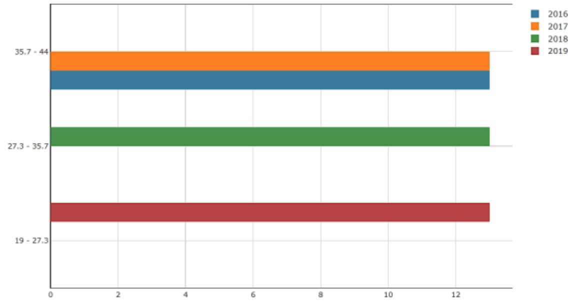
This research used RMSE for comparative results over a period of four years (2016-2019). The RMSE value had the highest value of 6.84 in 2019 (Table 5) and the lowest value of 2.50 in 2018 (Table 4), which determines that the model applied in 2018 is the most slightly prone to errors.

5.3 Determine the Barriers in Adoption of IoT in SCM

The classification model predicted the variables that have the most significant influence and that can represent the biggest barriers to the adoption of information technology in SCM for a period of four years (2016 – 2019). Azure Machine Learning was used. The main goal of the classification model is to predict the most significant barriers that can arise when implanting IoT in SCM.

The results of the predicted values for variable "*H1. Deficiency of a clear business case to justify the investment"* indicates that in 2019, the percentage to represent a barrier in IoT adoption in SCM decreased compared to 2016. In 2016 the percentage is 35.7-44% to encounter this barrier, compared to 2019, when the percentage is 19-27.3% (see Figure 1).

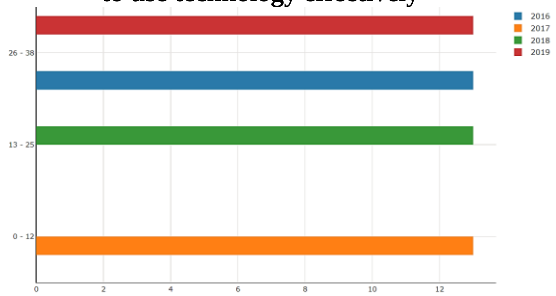
Figure 1. Prediction of variable H1. Deficiency of a clear business case to justify the investment



Source: Own processing based on data from https://www.mhi.org/publications/report.

For the second variable "*H2. Deficiency of adequate talent to use technology effectively"* in 2017, it was the most possible to encounter this barrier, with a percentage of approximately 12%. Through the year the percentage increased, and in 2019 has the value of 26-38%. (see Figure 2)

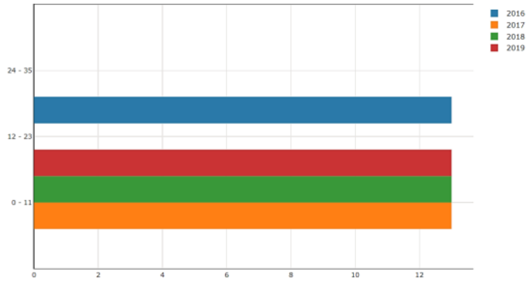
Figure 2. Prediction of variable H2. Deficiency of adequate talent to use technology effectively



Source: Own processing based on data from https://www.mhi.org/publications/report.

The results of predicted values for the variable "*H3. Cultural aversion to risk*" indicates that in 2016, the highest percentage to encounter this barrier in the adoption of IoT with a value of 24-35%. For the next three years, the values remained constant and decreased compared with 2016 (approximatively 13%) (see Figure 3).

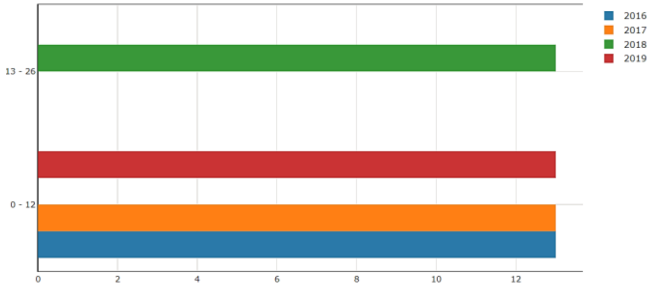
Figure 3. Prediction of variable H3. Cultural aversion to risk



Source: Own processing based on data from https://www.mhi.org/publications/report.

The results of predicted values for the variable "*H4. Cybersecurity*" indicates a growth from 2016 to 2019. If in 2016 and 2017 the percentage for this variable was around 8%, in 2018 the values increased to 18-26%. When comparing 2018 with 2019, in 2019 it was a decrease of how possible to have the Cybersecurity as a barrier (9-17%) (see Figure 4).

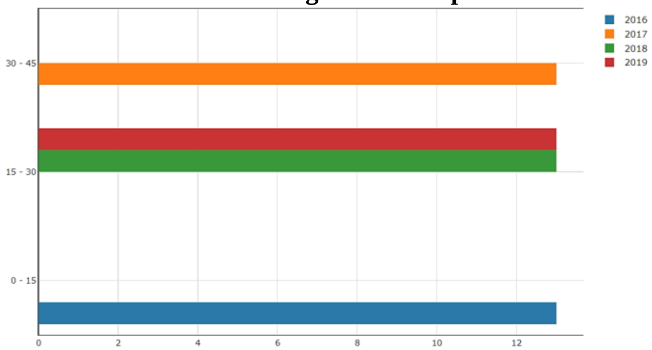
Figure 4. Prediction of variable H4. Cybersecurity



Source: Own processing based on data from https://www.mhi.org/publications/report.

For the variable "*H5. Deficiency of understanding of the technological landscape"* through the years, the values increased in what concerned the adoption of IoT in SCM. If in 2016 the percentage for this variable was approximately 15%, in 2018 the values increased to 30-45%. When comparing 2018 with 2019, in 2019 it was a decrease and the values were around 15-30%. (9-17%). (see Figure 5).

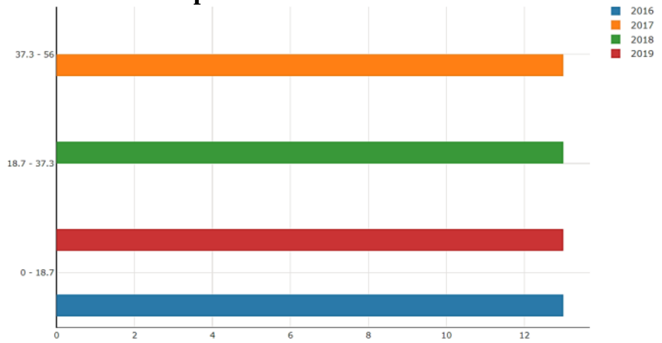
Figure 5. Prediction of variable H5. Deficiency of understanding of the technological landscape



Source: Own processing based on data from https://www.mhi.org/publications/report.

For the variable "*H6. Deficiency of access to capital to make investments"* through the years the values fluctuated from approximately 18.7% in 2016 and 2019 to 18.7-37.3% in 2018 and 37.3-56% in 2017 (see Figure 6).

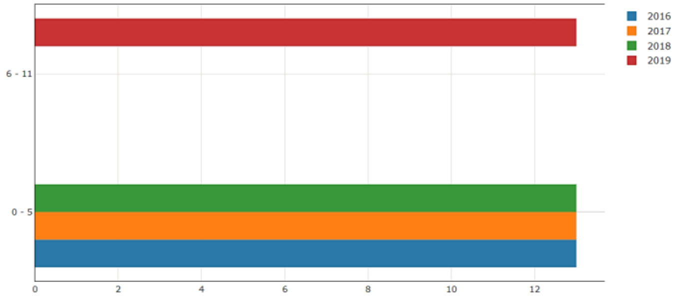
Figure 6. Prediction of variable H6. Deficiency of access to capital to make investments



Source: Own processing based on data from https://www.mhi.org/publications/report.

The results for the last variable analysed, "*H7. Not willing to invest because of economic uncertainty*" are indicating that the values have constantly increased through the years. From approximately 3% in 2016 to 8-16% in 2019 (see Figure 7).

Figure 7. Prediction of variable H7. Not willing to invest because of economic uncertainty



Source: Own processing based on data from https://www.mhi.org/publications/report.

Analysing all the seven variables indicated above has resulted that the overall biggest barrier in the adoption of IoT in SCM is the "Deficiency of a clear business case to justify the investment", even though the percentage have decreased significatively in 2019. In 2019 the most significant impediment is represented by the "Deficiency of adequate talent to use technology effectively" and, respectively, "Deficiency of understanding of the technological landscape". The lowest impediment is represented by "Not willing to invest because of economic uncertainty", followed by "Cyber security concerns" and "Cultural aversion to risk".

6. Conclusions

SCM professionals must therefore take positive steps to identify and manage barriers and risks. They even learn from previous experiences and events, using them to improve your understanding and resilience of SCM. The buyer should constantly check how well the current SCM process is working and whenever there is a non-compliance event, it should be analysed. Learn from the experience of others. Shorter life cycles, driven by changing technology, contribute to the volatility and unpredictability of demand in SCM. Several key recommendations can be concluded on how broader and faster adoption and implementation of technologies in SCM can be supported: (1) the need to improve knowledge for talent creation in technology use and business development in SCM; (2) SCM decision-makers need a more sophisticated decision support framework to introduce or not the technology available in the SCM; (3) an improvement could be achieved through funding mechanisms to make investments and overcome periods of economic uncertainty; and (3) a security improvement to prevent cyber-attacks. Addressing these challenges could strengthen confidence in the adoption of SCM technologies, helping to better understand risks and barriers so that they can be mitigated.

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