

# Chief Information Officer's Role for IoT-based Digital Transformation in Colombian SMEs

## Rol del Director de Información para la Transformación Digital basada en IoT en las PYMES colombianas

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**Abstract.** The Internet of Things (IoT) solutions can benefit small and medium enterprises (SMEs) by complementing existing digital technologies. However, digital transformation represents complexity for SMEs because they lack technology readiness. In Colombia, there are initiatives to massify the IoT, but the regulatory environment does not favour IoT adoption. Likewise, the Chief Information Officer (CIO) role is still weak. This document aims to present the value of having a CIO lead IoT-based digital transformation in Colombian SMEs. To this end, we conducted a literature review about IoT adoption in SMEs and the role of the CIO in managing digital transformation. In addition, we studied the public policies in force that addressed digital transformation in Colombia and designed a case study to explain the IoT adoption process that an SME in the trading sector can follow. As a result, we outline three strategic functions of the CIO to lead IoT-based digital transformation in SMEs. Based on the case study, we proposed a digital transformation strategy for SMEs in the trading sector that can inspire the formulation of public policies focused on strengthening the role of the CIO for IoT adoption in small and medium enterprises.

**Keywords:** CIO, Digital transformation, IoT adoption, SMEs, Technology readiness.

**Resumen.** Las soluciones de Internet de las cosas (IoT) pueden beneficiar a las pequeñas y medianas empresas (PYME) al complementar las tecnologías digitales existentes. Sin embargo, la transformación digital representa complejidad para las pymes porque carecen de preparación tecnológica. En Colombia existen iniciativas para masificar el IoT, pero el entorno regulatorio no favorece la adopción del IoT. Asimismo, el rol del Director de Información (CIO) aún es débil. Este documento tiene como objetivo presentar el valor de tener un CIO que lidere la transformación digital basada en IoT en las pymes colombianas. Con este fin, realizamos una revisión de la literatura sobre la adopción de IoT en las pymes y el papel del CIO en la gestión de la transformación digital. Además, estudiamos las políticas públicas vigentes que abordaron la transformación digital en Colombia y diseñamos un caso de estudio para explicar el proceso de adopción de IoT que puede seguir una pyme del sector comercial. Como resultado, describimos tres funciones estratégicas del CIO para liderar la transformación digital basada en IoT en las pymes. Con base en el caso de estudio, propusimos una estrategia de transformación digital para las PYMES del sector comercio que puede inspirar la formulación de políticas públicas enfocadas en fortalecer el rol del CIO para la adopción de IoT en las pequeñas y medianas empresas.

**Palabras clave:** Adopción IoT, CIO, Preparación tecnológica, Pymes, Transformación digital.

**Paper type:** Research paper.

## 1 Introduction

The Internet of Things is a technological trend linked to digital transformation that can benefit small and medium enterprises (Dutta et al., 2020) by complementing existing Information and Communication Technologies (ICT) (International Telecommunication Union, 2018). Vial (2019) defines digital transformation as “a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies” (Vial, 2019). IoT-based digital transformation is aligned with adopting IoT applications,

articulated with other enabling technologies such as cloud computing, big data, and artificial intelligence (Liu et al., 2021). In this sense, considering the flexibility of small and medium enterprises (Levy & Powell, 1998), the incorporation of emerging technologies, such as IoT technologies, could materialise based on a digital transformation strategy aligned with the economic sector of the company (Matt et al., 2015). However, deploying IoT applications implies additional challenges for companies (Łabędzka, 2021), which require the support of the Chief Information Officer to lead and manage IoT-based digital transformation (Gartner, 2017; Thoomkuzhy & Nazeh, 2018).

In Colombia, the National Government is particularly interested in increasing digital technology adoption, fostering digital innovation, and developing digital economy skills (Departamento Nacional de Planeación, 2018), as evidenced primarily by public policies such as the National Policy for Digital Transformation and Artificial Intelligence (Consejo Nacional de Política Económica y Social, 2019). However, based on the results of the Survey of Information and Communication Technologies in Companies conducted by the Colombian Bureau of Statistics, there is still a lag in companies' digital transformation because the entrepreneurs are unaware of the functionalities and benefits of digital technologies (Departamento Administrativo Nacional de Estadística, 2019). In this sense, considering the role of small and medium enterprises in the Colombian economy, which account for 80% of employment (Organisation for Economic Co-operation and Development, 2019a), the need for public policies focused on SMEs having a CIO to guide IoT-based digital transformation grows (Gong et al., 2019).

This document aims to present the importance of the CIO position in leading IoT-based digital transformation in Colombian SMEs. Likewise, we highlight the effect of public policies favouring a digital ecosystem that integrates the key actors to adopt digital technologies in the business environment. Therefore, we attempt to answer a research question regarding the role of the CIO in small and medium enterprises: What are the strategic functions of CIOs to achieve IoT-based digital transformation for Colombian SMEs? To achieve that, this paper presents a literature review to explore studies focused on IoT adoption in small and medium enterprises and the role of the CIO in managing digital transformation processes. Then, the methodology is presented. The results section outlines a summary of ICT policies for digital transformation in Colombia, the strategic functions of the CIO for IoT adoption in SMEs, and a case study to explain the IoT adoption process that an SME in the trading sector can follow. The discussion section interprets the research findings presenting the theoretical and practical implications. Finally, the conclusions are presented.

## 2 Literature review

In terms of digital transformation, SMEs in both developed and developing countries are exploring ways to adopt emerging technologies that promise significant competitive and productivity benefits. Concerning the Internet of Things adoption in small and medium enterprises, the number of documents in the literature shows that IoT adoption in SMEs is an emerging study area. Abazi (2016) described the process and benefits of the transition from traditional information and communication technologies to emerging technologies such as the Internet of Things in small and medium enterprises. Through a literature analysis, Varaniūtė *et al.* (2018) identified the preconditions for IoT adoption in SMEs, demonstrating that companies might create new business models by implementing IoT solutions. Grandon *et al.* (2018) used the Unified Technology Acceptance and Use of Technology Model (UTAUT) to determine the factors influencing the intention to adopt IoT solutions in Chilean SMEs. Thoomkuzhy and Nazeh (2018) examined the CIO's key employment capacities, basic skills, and competencies for cloud and IoT-based organizations. Parra Sánchez and Guerrero (2020), based on the Technology-Organization-Environment Model (TOE), presented four variables that affect IoT adoption in small and medium enterprises. The authors highlighted the CIO as the leader of the digital transformation process of SMEs.

In another study, Quigley and Burke (2013) presented how SMEs might improve their business operations without significantly high costs by implementing low-cost Internet of Things solutions. Reil *et al.* (2020) focused on the implications of the Internet of Things on SMEs' organizational and individual levels, emphasizing that the company's history, size, and leadership culture are critical for changes in organizational structures. Mitake *et al.* (2021) developed a method for explaining the impact of IoT deployment on life cycle costs to facilitate IoT adoption in SMEs. Nylander *et al.* (2017) explained that companies without in-house expertise in software, sensors and actuators, big data, or IoT business models face numerous obstacles in implementing IoT technologies. Forsstrom *et al.* (2020) developed an open-

source IoT platform for SMEs that considered security and privacy issues. Pappas *et al.* (2021) compared decision-making factors that may influence IoT adoption in Greek accommodation SMEs. Ramos *et al.* (2021) identified the driving and restraining variables as well as the level of readiness of Philippine manufacturing SMEs to embrace IoT in their operations.

Although extensive literature on the Internet of Things, its technologies, and application domains is available, there is a critical shortage of scientific literature focused on IoT adoption in SMEs. The literature has emphasized the challenges SMEs face in IoT-based digital transformation, considering that they do not exploit digital technologies and limit themselves to adopting emerging technologies. The selected documents highlight the theoretical aspects of the Internet of Things and the complexity of implementing IoT solutions in organizations, providing practical alternatives for small and medium enterprises. Some studies have presented the factors that affect decision-making for IoT adoption in SMEs. Likewise, the need for companies to have a CIO to guide the IoT-based digital transformation is also appreciated. Despite the difficulties that characterize SMEs, they have adapted and implemented digital technologies over the years due to their flexibility. They have leveraged the countries' economies thanks to formal employment and their contribution to gross domestic product. In this sense, SMEs require greater investment in fostering skills, innovation, and technology to increase wages and productivity. Specifically, IoT can help SMEs grow, strengthen their business model based on the successful monetization of data, and enhance their competitiveness and productivity.

### 3 Methodology

This study used a reflexive approach to present the importance of the CIO position in leading IoT-based digital transformation in Colombian SMEs. Initially, we conducted a literature review to explore studies focused on IoT adoption in small and medium enterprises and the role of the CIO in managing digital transformation processes. The literature review is based on the structured approach proposed by Webster and Watson (2002) to determine the source material available in academic databases. The literature review was conducted by searching in Scopus using the following descriptors identified in thesaurus or scientific documents previously studied: digital transformation, IoT adoption, small and medium enterprises, and Chief Information Officer. The selected documents provided the theoretical and practical implications of IoT adoption in small and medium enterprises from 2013 until 2021. During the exploratory phase, we also studied documents published by Gartner, Inc., the World Economic Forum, and ITU-T Recommendations published by the Telecommunication Standardization Sector (ITU-T) of the International Telecommunication Union.

The next step was the search and analysis of public policies in force that address digital transformation in Colombia. Among them stand out laws, decrees, CONPES documents (i.e., policy instruments through which the National Government establishes guidelines for the development of the country in economic and social matters), and the National Development Plan (2018–2022). In the documents studied, we identified the purpose of the policy, the digital technologies mentioned, and whether the policy considered aspects related to the Chief Information Officer. Similarly, we explored documents and statistics published by the Ministry of National Education, the Ministry of Science, Technology, and Innovation, and the Ministry of Information and Communication Technologies, and reports published by the Colombian Bureau of Statistics that present how Colombian companies have adopted digital technologies. Finally, we identified the current initiatives focused on promoting IoT adoption in the country.

Based on the documents studied, we presented a summary of ICT policies for digital transformation in Colombia, we defined the three strategic functions of CIOs to achieve IoT-based digital transformation for small and medium enterprises, and we designed a case study to exemplify the IoT adoption process that an SME in the trading sector can follow based on a digital transformation strategy. The case study is based on the experience obtained from a study that targeted small and medium enterprises from the trading sector registered and affiliated with the Chamber of Commerce of Bucaramanga (Colombia). The International Standard Industrial Classification (ISIC) was employed as a selection criterion to identify SMEs with Section G: Wholesale and retail trade; repair of motor vehicles and motorcycles registered in the commercial register (Department of Economic and Social Affairs, 2008). We considered companies with more than five years of existence, sales of more than one billion Colombian pesos, renewed on March 31, 2021, and belonging to the affiliate network of the Chamber of Commerce of Bucaramanga.

## 4 Results

In this section, we present a summary of ICT policies for digital transformation in Colombia, the strategic functions of the CIO for IoT adoption in SMEs, and a case study to explain the IoT adoption process that an SME in the trading sector can follow.

### 4.1 ICT policies for digital transformation in Colombia

With the emergence of new digital technologies, the CIO has taken a leading role in technology adoption (Gong et al., 2019; Singh, 2015). According to Gartner, the Chief Information Officer is an actor who "oversees the people, processes, and technologies within a company's IT organisation to ensure they deliver outcomes that support the goals of the business" (Gartner, 2021). In the Colombian context, the Decree 415 of 2016 focused on ensuring that government organisations have a CIO, establishing the guidelines for institutional strengthening in information and communication technologies through positioning the leaders of IT areas (Ministerio de Tecnologías de la Información y las Comunicaciones, 2016). Likewise, the National Development Plan (2018–2022) states that digital transformation should occur not only in government entities. Digital transformation should be a priority in companies, universities, and homes, implying the increase of Internet connectivity in the Colombian territory and the training of digital talent to use available digital technologies (Departamento Nacional de Planeación, 2018).

Table 1 presents the public policies in force addressing Colombia's digital transformation. In fact, the National Government has a particular interest in promoting digital transformation, reflected mainly in public policies, such as the National Policy for Digital Transformation and Artificial Intelligence (Consejo Nacional de Política Económica y Social, 2019), the National Policy of Electronic Commerce (Consejo Nacional de Política Económica y Social, 2020), and the Program for the Digital Transformation of Justice in Colombia (Consejo Nacional de Política Económica y Social, 2021). However, ICT policies in rigour are directed mainly to governmental entities, briefly mentioning the Internet of Things. For example, the National Policy for Digital Transformation, its purpose is Artificial Intelligence adoption as a key accelerator of digital transformation (Consejo Nacional de Política Económica y Social, 2019). Still, it does not consider other technological trends essential for digital transformation, such as the Internet of Things, Cloud Computing, and Big Data (International Telecommunication Union, 2018). In this sense, the need arises for a digital transformation policy that includes several emerging technologies capable of strengthening mature technologies such as electronic commerce or enabling technologies to deploy IoT solutions

**Table 1.** ICT policies for digital transformation in Colombia.

ICT policies	Description
Law 1955 of 2019, issues the 2018-2022 National Development Plan "Pact for Colombia, Pact for Equality."	Indicates that governmental entities must incorporate digital transformation into their action plans, focusing on expanding telecommunications to promote access to information and communication technologies, and the digital government policy for integrating procedures through the portal <a href="http://www.gov.co">www.gov.co</a> (Congreso de Colombia, 2019a).
Law 1978 of 2019, modernization of the Information and Communication Technologies Sector.	Modernise the ICT Sector from financing plans, programs, and projects to promote the development of content, digital applications, and the massification of digital services (Congreso de Colombia, 2019b).
Decree 1078 of 2015, amendments introduced to the Single Regulatory Decree of the Information and Communications Technology Sector.	Single Regulatory Decree of the Information Technology and Communications Sector establishes digital services, which refers to the solutions and processes that enable the digital transformation of government entities to achieve adequate interaction with the Colombian citizens (Ministerio de Tecnologías de la Información y las Comunicaciones, 2015).
Decree 415 of 2016, the definition of guidelines for institutional strengthening in information and communication technologies.	Establishes that government entities must have a director of information technology and systems responsible for executing ICT plans, programs, and projects. The decree gives the guidelines for institutional strengthening in information and communication technologies by

ICT policies	Description
	positioning IT area leaders (Ministerio de Tecnologías de la Información y las Comunicaciones, 2016).
Decree 1008 of 2018, general guidelines of the Digital Government Policy.	Establishes general guidelines of the Digital Government Policy for Colombia to consolidate competitive citizens through information and communication technologies in a safe digital environment (Ministerio de Tecnologías de la Información y las Comunicaciones, 2018).
Conpes 3975: National Policy for Digital Transformation and Artificial Intelligence.	Promotes the generation of social and economic value in Colombia through the strategic use of digital technologies in the public and private sectors to boost productivity, promote citizens' well-being, and generate enablers for digital transformation (Consejo Nacional de Política Económica y Social, 2019).
Conpes 4012: National Policy of Electronic Commerce.	Formulates the National Electronic Commerce Policy that aims to promote electronic commerce in companies and citizens to increase the country's social and economic value (Consejo Nacional de Política Económica y Social, 2020).
Conpes 4024: Program for the Digital Transformation of Justice in Colombia.	Promote the digital transformation of justice in Colombia through a program that aims to increase the effectiveness, efficiency, and transparency of the Justice System to resolve judicial processes and improve the legal needs of citizens (Consejo Nacional de Política Económica y Social, 2021).

Likewise, the role of the CIO is still weak. In this sense, we evidenced the need for public policies focused on SMEs having a CIO. Considering that in Colombia, the adoption of digital technologies has been limited in small and medium enterprises (Organisation for Economic Co-operation and Development, 2019b), one of the proposals of this document is to promote alliances between the members of the digital ecosystem, such as the Ministry of Information and Communication Technologies and the Chambers of Commerce. This way, the digital ecosystem can define programs and initiatives aimed at small and medium enterprises, providing a customised digital transformation plan. Although there are already Business Digital Transformation Centres to stimulate the approach of SMEs to the Chambers of Commerce, such support can be one of the benefits of being a company registered in the Chamber of Commerce. Besides, with the support of the Universities, mainly academic programs and research groups focused on ICT, it is possible to establish contact with companies and address their problems. For this reason, although an SME, due to financial limitations, cannot hire a professional for the position of CIO, it can undertake a digital transformation process with the support of the Chamber of Commerce.

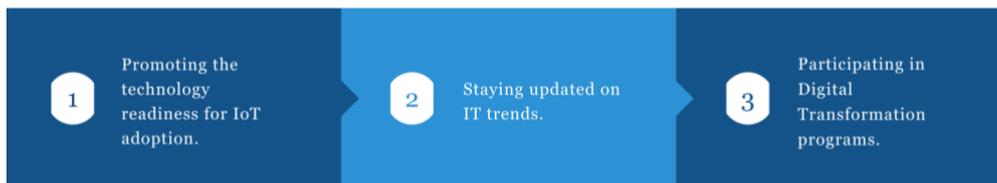
#### 4.2 Functions of the CIO for IoT adoption in SMEs

Although ICT policies in Colombia have focused mainly on government entities, efforts have been identified to help SMEs face the process of digital transformation. Taking Decree 415 of 2016 as a reference (Ministerio de Tecnologías de la Información y las Comunicaciones, 2016), small and medium enterprises can follow similar guidelines to have a Chief Information Officer to guide digital transformation. The preceding implies that changes are reflected not only in the budget allocation for a new top position in charge of information technology initiatives and strategy but also in the investment by companies in the adoption of digital technologies. In this sense, the CIO will be strategic in decision-making to generate a differentiating strategy based on technological innovation (Hsu & Liu, 2019). For IoT-based digital transformation, it is necessary to have a profile capable of leading the formulation and execution of IoT projects aligned with the needs of the company. In this sense, the CIO must know about emerging technologies such as IoT technologies, Artificial Intelligence, and Data Analytics. For the above reasons, there is a need for an ICT policy focused on training professionals for digital transformation.

According to the Ministry of National Education, in Colombia, there are 157 professional programs, 82 master's degrees, and seven doctorates related to Information Technology (Sistema Nacional de Educación de la Educación Superior, 2021). Regarding research, 328 research groups (6% of the national total) belong to science, technology, and innovation activities in Information and Communication Technologies, with 1091 associated researchers (Ministerio de Ciencia Tecnología e Innovación, 2021). Although the digital ecosystem in Colombia tries to be at the forefront of technological change, the educational sector must contemplate the training of the CIO through a curricular reform that impacts ICT programmes at all educational levels. Likewise, connecting universities with companies lets students

acquire experience in the real world. Regarding initiatives to promote IoT adoption, we identified the Centre for the Fourth Industrial Revolution (C4IR), whose purpose is the articulation of actors, the generation of culture and appropriation, and the development of projects and pilots in Artificial Intelligence, Blockchain, and the Internet of Things (C4IR, 2022).

Considering the generalities mentioned about the digital ecosystem in Colombia and the need to promote the adoption of emerging technologies in small and medium enterprises, below, we present three strategic functions of CIOs to achieve IoT-based digital transformation in Colombian SMEs (see Figure 1).



**Figure 1.** Strategic functions of CIOs to achieve IoT-based Digital Transformation in Colombian SMEs

**Promoting the technology readiness for IoT adoption.** Technology readiness is essential for adopting digital technologies in companies, defined as the “*ability to adopt, use, and benefit from information and communication technologies, adapting to technological change to continue being competitive*” (Parra-Sánchez, 2022). For example, introducing the electronic invoice (an evolution of the traditional invoice) is a mandatory requirement for companies that provide transaction support for selling goods and services (Ministerio de Hacienda y Crédito Público, 2020). Such changes affect how things are done in the company, forcing entrepreneurs to adopt new digital technologies in line with the provisions of the National Government. The massification of the electronic invoice has been achieved thanks to the socialisation of benefits, elements to issue the electronic invoice, and steps to generate the electronic invoice. This technological solution implies that the company and its clients face a technology adoption process. In this case, the National Directorate of Taxes and Customs supports entrepreneurs, even offering a free software solution for electronic invoicing. Based on this experience, something similar can happen with IoT adoption in SMEs. However, the complexity of the adoption process is even greater. Although local efforts are made, government support is necessary.

For IoT adoption in SMEs, the technology readiness depends on financing options to modernise the technological infrastructure according to the requirements of the IoT solution and the training of company personnel who will use the technological solution. In contrast to the electronic invoice with a digital ecosystem leveraged by the National Government, the IoT ecosystem is still blurred and lacks regulations supporting its mass use. Although there are efforts in academia and the business sector, there is no clear strategy focused on the Internet of Things. As we mentioned, the national digital transformation policy focuses on Artificial Intelligence, leaving aside the Internet of Things (Consejo Nacional de Política Económica y Social, 2019). In addition, considering that IoT can accelerate the progress of the Sustainable Development Goals (World Economic Forum, 2017), collaborative work between academia, industry, and the government is required to support the execution of an IoT strategy with social impact. In this way, the role of the CIO is even more important because his job is to help the company go through an IoT-based digital transformation, which will help the company grow, improve its business model, and protect the environment.

**Staying updated on IT trends.** One of the CIO's responsibilities is to stay updated on new digital technologies that enter the market. Likewise, awareness of the existing regulations in the country associated with digital transformation, the digital economy, and ICT adoption may benefit the company. One way of keeping up to date with emerging technologies is the review of reports published by telecommunications organisations and leading companies in the ICT sector, such as Gartner Inc., IDATE DigiWorld, the International Telecommunication Union, and McKinsey & Company. The Chief Information Officer can be an engineer with IT management, project management, and computer information systems knowledge or a Master of Business Administration degree emphasising IT. In this way, the CIO can face a digital transformation process and contact key players in the digital ecosystem to access technological solutions. Although the limitations of SMEs regarding the budget for hiring a CIO are one of the main barriers to digital transformation, it is expected that SMEs become familiar with these roles to the extent that they base business processes on digital technologies. Then, SMEs will gradually have a CIO as part of their team, leading the deployment of technological solutions.

**Participating in Digital Transformation programs.** Entities such as the Ministry of Information and Communication Technologies and the Chambers of Commerce offer free training programmes and informative talks to strengthen the capacities of companies. In this sense, the organization's CIO needs to pay attention to the information published on the entities' Web pages and actively participate in training programs and informative talks, which are an ideal space to establish contact with other CIOs and technology companies. An example is the Business Digital Transformation Centres, whose purpose is to accompany Colombian companies in their digital transformation process by adopting digital technologies as a long-term strategy, to help them improve their productivity and competitiveness. The participation of SMEs in this type of initiative allows them to have a closer relationship with the key players in the digital ecosystem. Figure 2 presents key players in the digital ecosystem. The articulation of universities with companies and the national government is vital to defining strategies that support SMEs and citizens, in general, to face technological change and promote digital skills development.



Figure 2. Digital ecosystem for IoT adoption in SMEs

#### 4.3 Case study: IoT adoption in SMEs in the trading sector

This case study was designed to explain the IoT adoption process that an SME in the trading sector can follow. The SME is located in Colombia, which is a developing economy. The company maintains a traditional business model. Among the hired personnel, the SME does not have a CIO. The CEO of the company has been leading the adoption of digital technologies in the organization. In this sense, considering the company's need to advance in digital technology adoption to enhance its business model through competitive advantages, the CEO needs to have a support staff. Thus, he can hire a professional with knowledge of information technology to assume the role of CIO to lead the IoT-based digital transformation. If the CEO does not hire a CIO, he can choose to outsource the service and hire expert consultants in digital transformation. On the other hand, the CIO can request the services provided by the Chamber of Commerce or the Business Digital Transformation Centres to diagnose the company in terms of technology readiness and receive guidance from adopting digital technologies aligned with the business model.

In this case study, we will focus on the option in which the CEO hires a CIO. In this sense, the CIO will begin by reviewing the company's capabilities to achieve an adequate technology readiness level. The company has high-speed Internet access, computers, software solutions, and a social media presence and has invested in the modernization and maintenance of its ICT infrastructure. The company does not implement electronic commerce, cloud computing, data analytics, or the Internet of Things. In this sense, the company requires greater knowledge to promote the adoption of digital technologies. They have not invested in hiring external consultants to adopt digital technologies, only in maintenance issues. The employees lack digital skills and are not motivated to use digital technologies. In summary, the organisation has a low or medium level of technology readiness to proceed with IoT-based digital transformation. The organisation needs more knowledge to understand the potential of digital technology adoption. Also, they need to consider the investment in mature and emerging technologies in the short or medium term.

The company must move from a traditional business model to a business model based on digital technologies to perform a successful digital transformation. The first step is determining the technology readiness level and defining the best digital transformation strategy that meets the company's needs. Specifically, SMEs in the trading sector can benefit from adopting e-commerce and IoT technologies. This way, they can potentiate their main economic activity: transferring and exchanging new or used goods or

products at retail or wholesale. In this regard, a crucial function of the CIO is to identify the digital technologies that fit the company, and that can be deployed in the short or medium term (considering that the company needs to allocate a budget for adopting digital technologies and staff training). After that, the adoption of electronic commerce is executed. Subsequently, the CIO recognises the possible options available in the market for the company to deploy IoT-based solutions to complement electronic commerce solutions (see Figure 3).

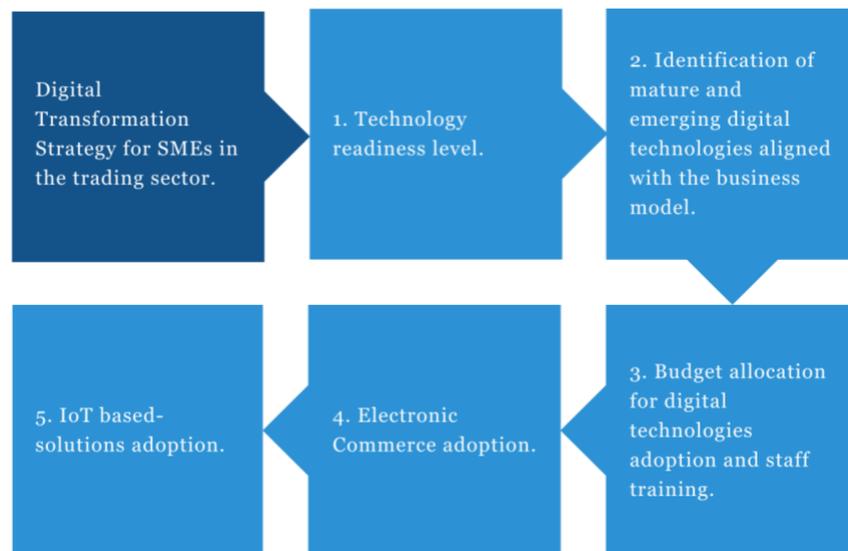


Figure 3. Digital transformation strategy for SMEs in the trading sector

## 5 Discussion

We interpret the research findings in this section, presenting the theoretical and practical implications.

### 5.1 Theoretical implications

This document is a valuable resource for academics and researchers in IoT-based digital transformation, managers of small and medium enterprises, the Chamber of Commerce, the Ministry of Information and Communication Technologies, and key players in the digital ecosystem to massify the Internet of Things. The literature review allowed us to appreciate the interest of SMEs in adopting the Internet of Things. Considering SMEs' financial and technological limitations, the factors that affect the adoption of emerging technologies were appreciated. Regarding the role of the CIO as a leader in digital transformation, it is evident that it has been taking centre stage during the fourth industrial revolution. Although the role of the CIO within government organizations has been considered in Colombia, new ICT policies are expected to consolidate it as a key employee for small and medium enterprises to design and execute the digital transformation strategy. In this sense, in response to the research question, three strategic functions of CIOs were defined to achieve IoT-based Digital Transformation in Colombian SMEs: promoting the technology readiness for IoT adoption, staying updated on IT trends, and participating in digital transformation programs.

### 5.2 Practical implications

During the research development, specifically in the study of ICT policies, the scarcity of policies that focus on adopting the Internet of Things was identified. Although there are initiatives in the country to massify the Internet of Things, the regulatory environment does not favour the adoption of the Internet of Things.

In this sense, the ICT Ministry is expected to promote the formulation of new policies focused on the Internet of Things, and the strengthening of the digital ecosystem, considering small and medium enterprises as beneficiaries of IoT solutions. In this sense, the case study presented is a guide SMEs can follow to adopt IoT solutions. It is important to highlight that the case study describes the technology readiness level of a company in the trading sector registered in the Chamber of Commerce of Bucaramanga. It should be noted that at the time of the study, the company did not have the role of Chief Information Officer and the manager provided the answers.

The results of this study help us understand that the CIO plays a crucial role in SMEs, taking the lead in adopting digital technologies. The CIO can identify opportunities for business improvement and search for technological solutions aligned with the economic sector of the organization. In this sense, ICT policies in Colombia are expected to strengthen the CIO's role in guiding SMEs' digital transformation process. This way, the national government's programs focused on digital transformation businesses can support the CIO role. With the guidance provided by national programs, the CIO can define a digital transformation strategy, establishing contact with key players in the digital ecosystem for its execution. Establishing alliances is essential for SMEs to continue contributing to the Colombian economy by entering a broader market, creating a competitive advantage, and improving communication with customers.

## 6 Conclusions

In this article, we presented the importance of the CIO as a key player in leading the digital transformation process in small and medium enterprises. To this end, we defined the digital ecosystem for IoT adoption in SMEs and designed a digital transformation strategy for SMEs in the trading sector. From the point of view of public policies, after studying the ICT policies for digital transformation in Colombia, we suggest that the government must guarantee the continuity of existing digital transformation programs and the creation of new national and regional strategies so that SMEs can be beneficiaries. Likewise, considering the financial limitations of SMEs, the new policies are expected to favour financing options for adopting digital technologies. Additionally, in the Colombian context, the need to strengthen the digital ecosystem in the training of IT professionals who can occupy the role of CIO in SMEs is appreciated. In this sense, forming alliances between universities, companies, and the national government is imperative to strengthen the IoT digital ecosystem.

This study is a starting point for supporting IoT-based digital transformation in small and medium enterprises. Although the study focuses on the ICT policies in Colombia, it can serve as an example for similar developing economies. The case study and the proposed digital transformation strategy focus on SMEs in the trading sector. In this sense, as part of future work, it is expected to design a digital transformation strategy that can be applied to any SME, regardless of the economic sector to which it belongs. The designed digital strategy aims to show how IoT technologies can complement existing technological solutions in companies, highlighting the importance of knowing the company's technology readiness level. Likewise, it is expected to continue deepening the design of the CIO profile for the adoption of the Internet of Things and its adaptability to face emerging digital technologies.

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## References

- Abazi, B. (2016). An approach to the impact of transformation from the traditional use of ICT to the Internet of Things: How smart solutions can transform SMEs. *IFAC-PapersOnLine*, 49(29), 148–151. <https://doi.org/10.1016/j.ifacol.2016.11.091>
- C4IR. (2022). *Centro para la Cuarta Revolución Industrial de Colombia*. <https://c4ir.co/>
- Congreso de Colombia. (2019a). *Ley 1955 de 2019*. [https://normograma.mintic.gov.co/mintic/docs/ley\\_1955\\_2019.htm#147](https://normograma.mintic.gov.co/mintic/docs/ley_1955_2019.htm#147)
- Congreso de Colombia. (2019b). *Ley 1978 de 2019*. [https://www.funcionpublica.gov.co/eva/gestornormativo/norma\\_pdf.php?i=98210](https://www.funcionpublica.gov.co/eva/gestornormativo/norma_pdf.php?i=98210)
- Consejo Nacional de Política Económica y Social. (2019). *Documento CONPES 3975. Política nacional para la Transformación Digital e Inteligencia Artificial*. [https://www.mintic.gov.co/portal/604/articulos-107147\\_recurso\\_1.pdf](https://www.mintic.gov.co/portal/604/articulos-107147_recurso_1.pdf)
- Consejo Nacional de Política Económica y Social. (2020). *Documento CONPES 4012. Política Nacional de Comercio Electrónico*. <https://colaboracion.dnp.gov.co/CDT/Conpes/Economicos/4012.pdf>
- Consejo Nacional de Política Económica y Social. (2021). *Documento CONPES 4024. Concepto favorable a la nación para financiar el Programa para la Transformación Digital de la Justicia en Colombia - Fase 1*. <https://colaboracion.dnp.gov.co/CDT/Conpes/Econ%C3%B3micos/4024.pdf>
- Departamento Administrativo Nacional de Estadística. (2019). *Encuesta de Tecnologías de la Información y las Comunicaciones en Empresas*. [https://www.dane.gov.co/files/investigaciones/boletines/entic/bol\\_entic\\_empresas\\_2019.pdf](https://www.dane.gov.co/files/investigaciones/boletines/entic/bol_entic_empresas_2019.pdf)
- Departamento Nacional de Planeación. (2018). *Plan Nacional de Desarrollo 2018-2022 “Pacto por Colombia, pacto por la equidad.”* <https://colaboracion.dnp.gov.co/CDT/Prensa/Resumen-PND2018-2022-final.pdf>
- Department of Economic and Social Affairs. (2008). *International Standard Industrial Classification of All Economic Activities (ISIC), Rev.4*. [https://unstats.un.org/unsd/publication/seriesm/seriesm\\_4rev4e.pdf](https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf)
- Dutta, G., Kumar, R., Sindhvani, R., & Singh, R. K. (2020). Digital transformation priorities of India’s discrete manufacturing SMEs – a conceptual study in perspective of Industry 4.0. *Competitiveness Review: An International Business Journal*, 30(3), 289–314. <https://doi.org/10.1108/CR-03-2019-0031>
- Forsstrom, S., Jennehag, U., & Guan, X. (2020). A Plain Low Threshold IoT Platform for Enabling New IoT Products from SMEs. *2020 IEEE International Workshop on Metrology for Industry 4.0 & IoT*, 390–394. <https://doi.org/10.1109/MetroInd4.0IoT48571.2020.9138303>
- Gartner. (2017). *Three Strategies to Achieve Better-Than-Planned Outcomes for IoT Projects*. <https://www.gartner.com/doc/3820163>
- Gartner. (2021). *Gartner Glossary: Chief Information Officer (CIO)*. <https://www.gartner.com/en/information-technology/glossary/cio-chief-information-officer>
- Gong, Y., Janssen, M., & Weerakkody, V. (2019). Current and Expected Roles and Capabilities of CIOs for the Innovation and Adoption of New Technology. *20th Annual International Conference on Digital Government Research on - Dg.o 2019*, 462–467. <https://doi.org/10.1145/3325112.3325214>
- Grandon, E. E., Ibarra, A. A., Guzman, S. A., Ramirez-Correa, P., & Alfaro-Perez, J. (2018). Internet of Things: Factors that influence its adoption among Chilean SMEs. *2018 13th Iberian Conference on Information Systems and Technologies (CISTI)*, 1–6. <https://doi.org/10.23919/CISTI.2018.8399183>
- Hsu, H.-T., & Liu, F.-C. (2019). How Chief Information Officer Drives Innovation? *ICIS 2019 Proceedings*, 1–9. [https://aisel.aisnet.org/icis2019/governance\\_is/governance\\_is/20/](https://aisel.aisnet.org/icis2019/governance_is/governance_is/20/)

- International Telecommunication Union. (2018). *Measuring the Information Society Report 2018*. <https://www.itu.int/en/ITU-D/Statistics/Pages/publications/misr2018.aspx>
- Łabędzka, J. (2021). Industry 4.0 — policy-based approaches to efficient implementation in SMEs. *Engineering Management in Production and Services*, 13(4), 72–78. <https://doi.org/10.2478/emj-2021-0032>
- Levy, M., & Powell, P. (1998). SME Flexibility and the Role of Information Systems. *Small Business Economics*, 11, 183–196. <https://doi.org/10.1023/A:1007912714741>
- Liu, Y., Ni, Z., Karlsson, M., & Gong, S. (2021). Methodology for Digital Transformation with Internet of Things and Cloud Computing: A Practical Guideline for Innovation in Small- and Medium-Sized Enterprises. *Sensors*, 21(16), 5355. <https://doi.org/10.3390/s21165355>
- Matt, C., Hess, T., & Benlian, A. (2015). Digital Transformation Strategies. *Business & Information Systems Engineering*, 57(5), 339–343. <https://doi.org/10.1007/s12599-015-0401-5>
- Ministerio de Ciencia Tecnología e Innovación. (2021). *La Ciencia en Cifras. Grupos de investigación reconocidos*. <https://minciencias.gov.co/la-ciencia-en-cifras/grupos>
- Ministerio de Hacienda y Crédito Público. (2020). *Decreto 358 de 2020*. [https://www.dian.gov.co/impuestos/factura-electronica/Documents/Decreto\\_358\\_05032020.pdf](https://www.dian.gov.co/impuestos/factura-electronica/Documents/Decreto_358_05032020.pdf)
- Ministerio de Tecnologías de la Información y las Comunicaciones. (2015). *Decreto 1078 de 2015*. [https://normograma.mintic.gov.co/mintic/docs/decreto\\_1078\\_2015.htm](https://normograma.mintic.gov.co/mintic/docs/decreto_1078_2015.htm)
- Ministerio de Tecnologías de la Información y las Comunicaciones. (2016). *Decreto 415 de 2016*. <https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=68717>
- Ministerio de Tecnologías de la Información y las Comunicaciones. (2018). *Decreto 1008 de 2018. Política de Gobierno Digital*. [https://www.mintic.gov.co/portal/604/articulos-74903\\_documento.pdf](https://www.mintic.gov.co/portal/604/articulos-74903_documento.pdf)
- Mitake, Y., Tsutsui, Y., Alfarihi, S., Sholihah, M., & Shimomura, Y. (2021). A life cycle cost analysis method accelerating IoT implementation in SMEs. *Procedia CIRP*, 104, 1424–1429. <https://doi.org/10.1016/j.procir.2021.11.240>
- Nylander, S., Wallberg, A., & Hansson, P. (2017). Challenges for SMEs entering the IoT world: success is about so much more than technology. *ACM International Conference Proceeding Series*, 1–7. <https://doi.org/10.1145/3131542.3131547>
- Organisation for Economic Co-operation and Development. (2019a). *OECD Reviews of Digital Transformation: Going Digital in Colombia*. OECD. <https://doi.org/10.1787/781185b1-en>
- Organisation for Economic Co-operation and Development. (2019b). *OECD Reviews of Digital Transformation: Going Digital in Colombia*. OECD. <https://doi.org/10.1787/781185b1-en>
- Pappas, N., Caputo, A., Pellegrini, M. M., Marzi, G., & Michopoulou, E. (2021). The complexity of decision-making processes and IoT adoption in accommodation SMEs. *Journal of Business Research*, 131, 573–583. <https://doi.org/10.1016/j.jbusres.2021.01.010>
- Parra-Sánchez, D. T. (2022). *A framework for IoT adoption in small and medium enterprises* [Doctoral Thesis, Universidad Autónoma de Bucaramanga]. <https://repository.unab.edu.co/handle/20.500.12749/16729>
- Parra-Sánchez, D. T., & Guerrero, C. D. (2020). Decision-making IoT adoption in SMEs from a technological perspective. *2020 15th Iberian Conference on Information Systems and Technologies (CISTI)*, 1–6. <https://doi.org/10.23919/CISTI49556.2020.9141045>
- Quigley, M., & Burke, M. (2013). Low-cost Internet of Things digital technology adoption in SMEs. *International Journal of Management Practice*, 6(2), 153–164. <https://doi.org/10.1504/IJMP.2013.055828>
- Ramos, P. N., Enteria, M. L. B., & Norona, M. I. (2021). Readiness Model Development in the Adoption of Internet of Things (IoT) among Philippine Manufacturing SMEs Using Force Field Analysis Approach and Structural Equation Modelling. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 2178–2190.
- Reil, H., Rimbeck, M., Leyer, M., & Stumpf-Wollersheim, J. (2020). Understanding the consequences of adopting the Internet of Things in small- and medium-sized enterprises. *Proceedings of the 24th Pacific Asia Conference on Information Systems: Information Systems (IS) for the Future, PACIS 2020*. <https://aisel.aisnet.org/pacis2020/227>
- Singh, K. D. (2015). Chief information officer's role - addressing agenda beyond role definition. *International Journal of Information Systems and Change Management*, 7(4), 338–352. <https://doi.org/10.1504/IJISCM.2015.075644>
- Sistema Nacional de Información de la Educación Superior. (2021). *Consulta de Programas. Sistema Nacional de Información para la Educación superior en Colombia*. <https://hecaa.mineducacion.gov.co/consultaspublicas/programas>
- Toomkuzhy, J. G., & Nazeh, M. (2018). A Paradigm Shift on the role of CIO's in Cloud and IOT based Organizations. *JOIV: International Journal on Informatics Visualization*, 2(4–2), 323–335. <https://doi.org/10.30630/joiv.2.4-2.187>
- Varaniūtė, V., Vitkauskaitė, E., & Tarute, A. (2018). Peculiarities of IoT-based business model transformations in SMEs. *Proceedings of the International Conference on Electronic Business (ICEB)*, 439–446. <https://aisel.aisnet.org/iceb2018/52/>
- Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems*, 28(2), 118–144. <https://doi.org/10.1016/j.jsis.2019.01.003>

Webster, J., & Watson, R. T. (2002). Analyzing the Past to Prepare for the Future: Writing a Literature Review. *MIS Quarterly*, 26(2), xiii–xxiii. <https://www.jstor.org/stable/4132319>

World Economic Forum. (2017). *IoT for Sustainable Development Project*. <https://widgets.weforum.org/iot4d/index.html>