

# Evaluation of the Technological Maturity of the Internet of Things in Industrial Companies in the Buenos Aires Metropolitan Area, Argentina

<https://doi.org/10.18041/1900-3803/entramado.1.13065>

**Andrés Felipe Solis-Pino**

Universidad del Cauca, Popayán, Colombia



**Pablo H. Ruiz**

Universidad del Cauca, Popayán, Colombia



**Alicia Mon**

Universidad Nacional de La Matanza, Buenos Aires, Argentina



**Cesar Alberto Collazos-Ordoñez**

Universidad del Cauca, Popayán, Colombia



## Abstract

The Internet of Things has the potential to transform industrial operations; however, its adoption faces challenges related to organizational readiness and a lack of empirical evidence in Latin America. This research focuses on the Buenos Aires Metropolitan Area in Argentina, where industrial companies play a significant role in the country's economy. This article presents an empirical assessment of the technological maturity of the Internet of Things in industrial companies in this region. A quantitative, exploratory, and cross-sectional approach was used with 37 companies, using the ATLANTIS multidimensional maturity model as a reference framework. The results revealed a difference in overall maturity between large companies and SMEs, with the former showing greater competence, especially in device management and connectivity components. While commonalities were identified in business integration, areas such as regulatory compliance and contextualization presented opportunities for improvement for both groups. Correlation analysis confirmed a strong interdependence between the technological and organizational dimensions ( $p = 0.77$ ) and overall maturity. In addition, Principal Component Analysis identified different maturity profiles, differentiating companies with a technological focus from others with a more holistic vision. Regarding practical implications, the results suggest that the successful adoption of the Internet of Things requires alignment between technological infrastructure and organizational culture. Therefore, SMEs are advised to prioritize connectivity and device management capabilities, while public policymakers should design strategies that promote regulatory compliance and security standards to close the maturity gap in the region.

## Keywords

Internet of Things; Technological Maturity; Industrial Companies; Technology Adoption; Maturity Model.

## Registration

Research article  
Received: 25/09/2025  
Accepted: 11/12/2025  
Published: 08/01/2026

## Evaluación de la madurez tecnológica del Internet de las Cosas en empresas industriales del Área Metropolitana de Buenos Aires, Argentina

### Resumen

El Internet de las Cosas tiene el potencial de transformar las operaciones industriales, pero su adopción en América Latina enfrenta desafíos relacionados con la preparación organizativa y la escasa evidencia empírica. El artículo se centra en el Área Metropolitana de Buenos Aires, Argentina, donde las empresas industriales desempeñan un papel importante en la economía del país. Se presenta la evaluación empírica de la madurez tecnológica del Internet de las Cosas en 37 empresas. Se usó un enfoque cuantitativo, exploratorio y transversal, utilizando el modelo de madurez multidimensional ATLANTIS. Los resultados revelaron una diferencia en la madurez general entre las grandes empresas y las PYMES, mostrando las primeras una mayor competencia, en la gestión de dispositivos y los componentes de conectividad. Si bien se identificaron puntos comunes en la integración empresarial, áreas como el cumplimiento normativo y la contextualización presentaban oportunidades de mejora para ambos grupos. El análisis de correlación confirmó una fuerte interdependencia entre las dimensiones tecnológica y organizacional ( $p = 0.77$ ) y la madurez general. El Análisis de Componentes Principales identificó perfiles de madurez, diferenciando empresas con un enfoque tecnológico de otras con una visión más holística. Los resultados sugieren que la adopción exitosa del Internet de las Cosas requiere una alineación de la infraestructura tecnológica con la cultura organizacional. Se recomienda a las PYMES priorizar capacidades en conectividad y gestión de dispositivos, y a los responsables de políticas públicas diseñar estrategias que fomenten el cumplimiento normativo y los estándares de seguridad para cerrar la brecha de madurez tecnológica en la región.

### Palabras clave

Internet de las Cosas; madurez tecnológica; empresas industriales; adopción de tecnología; modelo de madurez.

### License



### How to cite this article / Cómo citar este artículo

SOLIS-PINO, Andrés Felipe; RUIZ, Pablo H.; MON, Alicia; COLLAZOS-ORDOÑEZ, Cesar Alberto. of Things in Industrial Companies in the Buenos Aires Metropolitan Area, Argentina. En: Entramado. Enero - junio, 2026. vol. 22, no. 1. p. 1-19. e-13065 <https://doi.org/10.18041/1900-3803/entramado.1.13065>

## 1. Introduction

The Internet of Things (IoT) represents a network of interconnected computing devices equipped with sensors, actuators, and communication interfaces that enable the autonomous acquisition, processing, and transmission of data in heterogeneous technological ecosystems ([Elgazzar et al., 2022](#); [Solis-Pino, Ruiz, Mon, and Collazos, 2024c](#)). Forecasts indicate that by 2029, there will be approximately 36.5 billion connected IoT devices ([Chen et al., 2024](#)), underscoring the growing influence of this technology in various sectors, including smart homes and business operations ([Kumar, Tiwari, and Zymbler, 2019](#)). In this regard, the IoT offers numerous advantages to businesses, transforming their operations and competitive strategies, and leading to improved operational efficiency through the automation of routine tasks and the minimization of manual intervention ([Nagy, Olah, Erdei, Mate, and Popp, 2018](#)). It also enables data collection, providing valuable insights into operations and customer behavior ([Javaid, Haleem, Singh, Rab, and Suman, 2021](#)), among other benefits.

Despite these advantages, IoT adoption entails several challenges, including security vulnerabilities ([Azrou, Mabrouki, Guezzaz, and Kanwal, 2021](#)), managing massive data influxes ([Wu, 2021](#)), and ensuring interoperability ([Brous, Janssen, and Herder, 2020](#)). Finally, another significant challenge lies in companies' ability to accurately assess the technological maturity of the IoT and the current integration of this technology into their organizational frameworks ([Kulkarni, Gokhale, and Dandannavar, 2023](#)).

In this regard, accurately assessing the technological maturity of the IoT within organizations is important because it facilitates informed decision-making regarding resource allocation ([Benotmane, Elhari, and Kabbaj, 2023](#)), provides a clear picture of the organization's current situation, and the steps needed to move forward with the IoT ([Solis Pino, Ruiz, Mon, Collazos, and Moreira, 2024](#)). It also provides a competitive advantage by optimizing these technologies, increasing productivity, enabling real-time data analysis, and improving customer satisfaction ([Ahmetoglu, Cob, and Ali, 2022](#)). Finally, assessing the technological maturity of the IoT helps identify the potential risks associated with its implementation and integration issues with existing processes ([Jæger and Halse, 2017](#)). This knowledge leads to more effective strategic planning, a greater competitive advantage, and promotes business growth.

However, in Argentina, especially in the Buenos Aires Metropolitan Area (AMBA), industrial companies play a crucial role in the economy, as they are vital for economic growth and job creation ([Rougier, 2008](#)). These types of organizations drive the country's economic growth, as well as its technological and social development ([Ayalu, Abbay, and Azadi, 2023](#)). The adoption of IoT in Argentine and Latin American companies is hampered by several challenges, including inadequate organizational preparation for the implementation of the technology ([Parra-Sánchez, Talero-Sarmiento, and Guerrero, 2021](#)), limited empirical evidence on the adoption of this technology in the Latin American context ([Grandon, Ibarra, Guzman, Ramirez-Correa, and Alfaro-Perez, 2018](#)), and insufficient government support for its adoption ([Mishrif and Khan, 2023](#)), all of which constitute significant obstacles for these types of organizations.

Although various maturity models and frameworks have been proposed to measure IoT maturity ([Solis Pino et al., 2024c](#)), they often lack universal standardization, require contextual adaptation ([Solis Pino et al., 2024c](#); [Solis Pino, Ruiz, Mon, and Collazos, 2024](#)), and often do not address human and organizational aspects ([Solis Pino, Ruiz, Mon, and Collazos, 2024a](#)). Therefore, the implementation of tools that enable the accurate determination of the technological maturity of the IoT in organizational contexts is crucial and represents a significant advancement in the field ([Solis Pino et al., 2024](#)). In response to this need, the authors previously developed ATLANTIS ([Solis Pino, Ruiz, Mon, and Collazos, 2024b](#)), a multidimensional maturity model for IoT, designed to assess technological maturity holistically, considering various organizational perspectives. Based on this context, the following research question arises: What is the current level of technological maturity regarding the adoption and implementation of the Internet of Things in industrial companies within the Buenos Aires Metropolitan Area when evaluated through a multidimensional framework? Consequently, this research's main objective is to evaluate IoT's technological maturity in

various industrial organizations in the AMBA in Argentina using the ATLANTIS tool, thus providing empirical evidence to the domain.

Beyond its descriptive scope, this study offers contributions to the field of IoT adoption. From a theoretical perspective, it provides contextual validation of the multidimensional ATLANTIS model within the Latin American industrial landscape, a region often underrepresented in empirical literature on technological maturity. In practice, the results serve as a roadmap for business leaders, particularly within SMEs, enabling them to identify bottlenecks in connectivity and device management, while highlighting the need to align technological infrastructure with organizational culture. Regarding public policy, the empirical evidence presented helps policymakers design targeted strategies that promote regulatory compliance and security standards, thereby closing the digital divide between large and small companies in the region.

Finally, this study is divided into Section 2, which details the methodology and procedures performed to estimate technological maturity with the ATLANTIS model. Section 3 presents the main findings of the research, utilizing both descriptive and inferential techniques. Section 4 interprets and contextualizes the results within the framework of the relevant literature to highlight the work's originality and contribution. Section 5 then acknowledges some limitations of the study for greater methodological rigor. Finally, section 6 outlines the main conclusions, discusses their theoretical and practical implications, and outlines recommendations for future studies in the area.

## 2. Theoretical background

To interpret the technological maturity of industrial companies in the AMBA region, it is necessary to review the evolution of the IoT within the industrial paradigm and the frameworks established to measure its adoption.

### *The Internet of Things in the industrial context*

The integration of the IoT in the industrial sector, often referred to as the Industrial Internet of Things (IIoT), is a fundamental element of Industry 4.0. Theoretically, the IIoT changes the industrial operating model from linear and automated processes to interconnected, data-driven ecosystems (Nagy et al., 2018). By equipping physical assets with sensors and communication interfaces, organizations can help bridge the gap between the physical and digital worlds, enabling real-time monitoring, predictive maintenance, and autonomous decision-making (Elgazzar et al., 2022).

In this regard, the literature suggests that the adoption of these technologies is not just a technical improvement, but a complex process of organizational transformation. As Javaid et al. (2021) point out, the value of the IoT lies in its ability to generate useful information from massive data flows. However, this potential poses significant challenges, such as data interoperability, cybersecurity risks, and the need for new governance structures (Azroul et al., 2021). Therefore, analyzing IoT adoption requires a perspective that goes beyond hardware acquisition to consider how the technology integrates with business strategy and compliance frameworks.

### *Technology maturity models as diagnostic tools*

Maturity models have become established in academic literature as fundamental instruments for assessing an organization's status on its evolutionary path toward a desired target state (Solis Pino et al., 2024c). These models, which have their origins in software engineering (e.g., Capability Maturity Model Integration), have evolved to address digital transformation processes. In the context of the IoT, a maturity model serves as a roadmap, helping organizations identify their current capabilities, ranging from basic connectivity to AI-driven autonomous optimization, and the gaps that impede progress (Benotmane et al., 2023).

Despite proposals for maturity models, recent systematic reviews indicate a lack of standardization, with many existing frameworks focusing predominantly on technical layers (sensors and networks) and neglecting the soft dimensions that facilitate technology adoption ([Solis Pino et al., 2024](#)). This gap underscores the need for frameworks that account for the heterogeneity of industrial environments, particularly in developing regions such as Latin America, where economic and infrastructure constraints differ from those in the contexts in which most models are developed ([Parra-Sánchez et al., 2021](#)).

The multidimensional approach of the ATLANTIS model

To address the limitations of purely technical assessments, this study uses the multidimensional maturity model ATLANTIS. Theoretical consensus increasingly supports the view that the success of digital transformation depends on the alignment of three fundamental dimensions:

- Technological: covers device management, connectivity, and cloud/edge processing.
- Organizational: involves business integration, security protocols, and regulatory compliance.
- Human: focuses on workforce adaptation and cultural readiness.

The ATLANTIS model is based on the taxonomy proposed and adapted by Pino et al. ([Solis Pino et al., 2024b](#)) to implement these dimensions in measurable components. By assessing maturity across these dimensions, it is possible to distinguish between companies that possess technology and those that have the organizational maturity to leverage it as a competitive advantage. Consequently, this theoretical position frames the subsequent empirical analysis of industrial companies in the AMBA region.

### 3. Materials and methods

This research used a non-probabilistic convenience sampling method to conduct a quantitative, exploratory, cross-sectional study of 37 industrial companies in the AMBA between June and July 2024. The methodological design was adapted from Mon and Del Giorgio in ([Mon and Giorgio, 2022](#)), who effectively implemented similar instruments to measure technological maturity in the context of Information and Communication Technologies in the Province of Buenos Aires. The methodological structure was based on applying the ATLANTIS multidimensional maturity model, specifically designed to evaluate the adoption and implementation of IoT technologies in industrial organizations through a structured questionnaire using a Likert scale. Data analysis involved the application of descriptive and inferential statistical techniques, implemented through specialized software. Past software ([Solis, Revelo luna, Campo Ceballos, and Gaviria López, 2021](#)) was utilized for advanced statistical analysis. The R programming language, along with the tidyverse, ggplot2, and FactoMineR packages, was employed to perform multivariate analysis and create graphical representations of the data ([Kassambara, 2019](#)).

This methodological approach aims to assess the technological maturity level of IoT in organizations, identify patterns and relationships between the various dimensions evaluated, and provide an overview of the current state of IoT adoption in the AMBA's industrial sector.

#### *Description of the multidimensional maturity model - ATLANTIS*

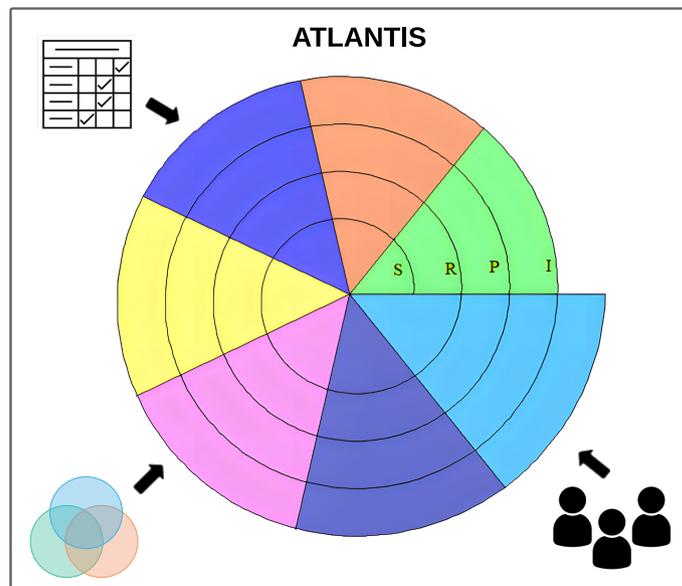
ATLANTIS is a multidimensional maturity model explicitly designed to assess the adoption and implementation of IoT technologies in industrial small and medium-sized enterprises (SMEs) ([Solis Pino et al., 2024b](#)). This proposal addresses a knowledge gap identified in the domain, specifically the lack of a comprehensive and tailored tool for this type of organization that considers the global nature of IoT, particularly in industrial environments ([Solis Pino et al., 2024c](#)). Unlike existing maturity models that focus primarily on specific technological aspects or isolated case studies, ATLANTIS also incorporates organizational and human dimensions based on an accepted taxonomy ([Hatton, 2023](#)), providing a more comprehensive, holistic,

and detailed assessment of IoT in organizations. This multidimensional approach aligns with the growing consensus among experts that the successful adoption of the IoT depends not only on technical capabilities but also on the organization's preparedness and the workforce's adaptation (Solis Pino et al., 2024).

In this regard, ATLANTIS (Figure 1) considers three fundamental dimensions: organizational, technological, and human, each of which is further divided into seven principal components, namely:

- **Device management:** evaluates the processes and practices involved in deploying, configuring, managing, and maintaining IoT devices within an organization.
- **Connectivity management:** evaluates the organization's capabilities related to data collection, including protocols, standards, data volume management, and downtime considerations.
- **Cloud/edge management:** evaluates how organizations process and manage data generated by IoT devices, including data analytics, cloud computing, and artificial intelligence (AI) integration.
- **Enterprise integration management:** Evaluates the integration of IoT into business processes, systems, and strategies, including use cases, data integration, and technology interoperability.
- **Security:** Evaluates the security challenges and risks associated with the implementation and operation of IoT systems, including security controls, policies, and procedures.
- **Compliance:** evaluates the organization's adherence to relevant regulations and ethical considerations when implementing IoT solutions, specifying governance processes, policies, and structures.
- **Contextualization:** evaluates the organization's readiness and understanding of the various environmental and operational contexts for implementing IoT solutions, including adaptation to specific requirements, constraints, and challenges.

Finally, each component is further subdivided into specific metrics, which are classified into four maturity levels: static, reactive, proactive, and innovative. This granular structure enables a detailed assessment of an organization's strengths and weaknesses in relation to IoT adoption within its organizational framework.



**Figure 1.** Proposal for the ATLANTIS multidimensional maturity model.

**Note:** Taken from (Solis Pino et al., 2024b).

### *Context of the study area*

Argentina's industrial sector is a significant component of the national economy, characterized by diverse activities and regional variations ([Niembro and Calá, 2024](#)). The country has a population of approximately 45 million, with a significant portion residing in urban areas. The AMBA alone accounts for almost a third of the population, making it a hub for industrial activities. Quantitatively, the industrial sector accounts for approximately 20% of Argentina's Gross Domestic Product (GDP), with key industries including automobile manufacturing, food processing, textile production, and chemical synthesis ([Bravo, 2021](#)). The country has a well-established manufacturing base. Despite economic challenges such as inflation and currency volatility, the sector remains resilient, driven by domestic demand and exports ([Ha, Kose, and Ohnsorge, 2019](#)).

The AMBA manufacturing sector faces several challenges, including economic instability, limited access to financing, and the need for infrastructure improvements ([Versino, Guido, Gorenstein, and Vidosa, 2023](#)). However, growth opportunities exist through increased innovation, public-private partnerships, and leveraging Argentina's human capital ([Godfrid, Radnic, Vaisman, and Zimányi, 2022](#)). The adoption of IoT technology in Argentina is on the rise, driven by the need for efficiency and innovation in various industries, particularly in smart manufacturing, predictive maintenance, and supply chain optimization ([Becerra et al., 2012](#); [group LACalytics, 2020](#)). Research and development in IoT is also reinforced by collaboration between universities, postgraduate academic programs, research institutions, and private companies ([Grosman, Braude, Rovira, and Patiño, 2021](#)). These factors, combined with strategic economic initiatives, position Argentina, particularly the AMBA, as a promising player in the South American IoT domain, with challenges still to overcome ([Sánchez and Ramoscelli, 2018](#)).

### *Data collection and analysis procedure*

For the data collection process from AMBA organizations, a non-probabilistic sample of organizations ([Dobrowolska and Sliž, 2022](#)) was used during June and July 2024, with 37 companies. The non-probabilistic nature of the sample was due to the apparent difficulties in identifying all organizations in the country ([Solis Pino et al., 2024b](#)). In addition, the need to obtain opinions from workers with specific characteristics, such as knowledge of the IoT domain, required non-random convenience sampling of participants, as seen in other studies with similar characteristics ([Mon and Giorgio, 2022](#)).

In this regard, all participants in the maturity model application had at least one year of work experience in their respective organizations, which covered various industrial, technological, and educational sectors with different scales of operation. Regarding the sectoral distribution, the sample reflects the heterogeneous nature of the productive ecosystem in the AMBA region. The participating organizations operate across diverse sectors, ensuring a broad perspective on IoT maturity. The Technology and Software Development sector predominantly leads the composition. This is followed by Professional and Financial Services, as well as Commerce and Retail. The sample also includes representation from the Education and Research, Manufacturing, and Healthcare sectors. Of this sample, approximately 60% were employees of SMEs, while the remaining 40% belonged to larger companies. This distribution enabled a broader comparison of the results, accurately assessing technological maturity in terms of the adoption and implementation of IoT across different operational scales and levels of resource availability within organizations ([Ormazabal, Sarriegi, Rich, Viles, and Gonzalez, 2021](#)).

Data was collected using a structured questionnaire (ATLANTIS implementation) aimed at employees of the aforementioned organizations who performed various IoT-related functions in their daily work. Participants received an introduction to the maturity model and the instrument through digital media, where the maturity of the organizations to which they belonged was assessed using a Likert scale ([Oke and Arowoija, 2021](#)).

The data collection process was conducted in three key stages. The first stage consisted of the introduction of ATLANTIS and its specific elements. The second stage was a self-assessment, where each company member evaluated their organization using ATLANTIS as a reference framework, allowing for firsthand data

to be obtained on the implementation and use of IoT in various business contexts. Finally, in the third stage, the experts' responses were compiled and analyzed to determine each organization's overall maturity level in adopting the IoT, using the weighting system detailed in the following section.

### *Operationalization of the ATLANTIS Model: Scoring System*

This section presents a weighted scoring system designed to assess the level of maturity in organizations adopting IoT using the ATLANTIS maturity model, which has been reported in previous studies ([Solis Pino et al., 2024b](#)). This weighting system is scalable, allowing for the individual evaluation of each organization's metric, component, dimension, and overall score. It provides an objective assessment of IoT technology at various levels of granularity, offering organizations detailed information to enhance IoT implementation and address their shortcomings.

The weighting system is objective, as it establishes the relative importance of each metric, component, and dimension for successful adoption and implementation, based on expert opinions. Additionally, the weighting is straightforward to understand, emphasizing ease of comprehension and application for evaluators and participating organizations, thereby ensuring broad applicability and ease of use.

Each metric is evaluated individually and assigned a score ranging from 1 to 4, depending on the level of maturity demonstrated ([Table 1](#)).

**Table 1.**  
Scoring System for the ATLANTIS Model Maturity Levels.

Level	Score
Static	1
Reactive	2
Proactive	3
Innovative	4

**Note:** Own elaboration.

However, the components, which represent specific functional areas within the IoT ecosystem (e.g., device management, security), are evaluated by weighting the scores of their constituent metrics. These weights ([Table 2](#)) are expressed as a percentage of the total possible points in ATLANTIS. These weights were determined by aggregating the judgments of experts (n=8) with experience in the academic field of IoT, using a survey as a data collection tool. The resulting weights are:

**Table 2.**  
Component Weighting within the ATLANTIS Model.

Component	Weight (%)
Device management	20%
Connectivity management	20%
Cloud/edge management	15%
Business integration management	20%
Security	15%
Compliance	5%
Contextualization	5%

**Note:** Own elaboration.

The score for each component ( $C_i$ ) is calculated as the sum of the scores for its individual metrics multiplied by the component's weight ( $W_i$ ) ([Equation 1](#)).

$$C_i = W_i * \sum (\text{Component metric score}) \quad (1)$$

Regarding the dimensions, the score is the total sum of all the scores obtained for each metric in that dimension, resulting in a dimensionless value. Finally, the organization's overall score (G) is the sum of the scores of the seven components, with a maximum possible score of 100 points ([Equation 2](#)).

$$G = \sum C_i \quad (2)$$

Where  $i = 1$  to 7.

### *Analysis of IoT technological maturity data in AMBA organizations*

Standard software tools were used to process the data collected through the ATLANTIS maturity model. Microsoft Excel was used to organize, clean, and calculate the data. In contrast, PAST software was used to perform advanced statistical analyses, including hypothesis testing, correlation analysis, and metric validation, which allowed for a detailed and accurate assessment of the technological maturity of IoT in industrial companies in the AMBA. Additionally, the R programming language was utilized to perform advanced analyses, including Principal Component Analysis (PCA) ([Fadhullah, Imran, Ismail, Jaafar, and Abdullah, 2022](#)), hypothesis testing, and correlation analysis. In particular, an analytical pipeline was implemented that incorporated the tidyverse packages for data manipulation and transformation, ggplot2 for generating graphical visualizations, rstatix for performing statistical tests, and FactoMineR for calculating multivariate statistics ([Kassambara, 2019](#)).

A descriptive data analysis was performed to determine the distribution of maturity scores among the participating companies, providing an overview of IoT maturity within the dataset. In addition, inferential analyses such as PCA and K-means ([Kartini, Lubis, Rahmad, and Safitra, 2024](#)) were performed to identify significant relationships between variables, allowing maturity to be segmented by different organizational sizes. Finally, for the correlation analysis, normality tests were applied to the response variables, which were found to have a non-parametric distribution, justifying non-parametric correlation tests, specifically Spearman's coefficient ( $\rho$ ) ([Solis et al., 2021](#)).

The procedure for analyzing data on technological maturity in AMBA organizations included an initial phase of data cleaning and validation, ensuring the consistency and integrity of the information collected through the surveys. Next, the ATLANTIS weighting system calculated individual scores for each metric, component, and dimension. Descriptive statistics were then generated for each component and dimension. Next, comparative analyses were performed between different groups of companies to identify patterns and differences in IoT maturity using multivariate analysis. Correlations between the different dimensions and components of ATLANTIS were then examined to identify potential relationships between the various areas of maturity. Finally, graphs and tables were created to visually represent the analysis results, facilitating the interpretation and communication of the information.

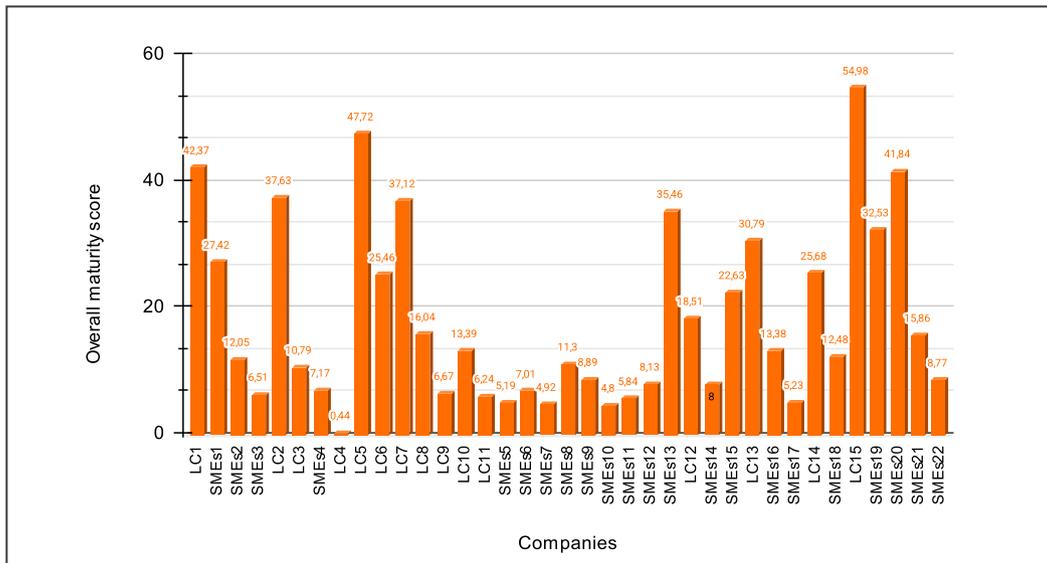
## **4. Results**

Based on the ATLANTIS model, this section presents the empirical findings from evaluating the technological maturity of IoT in 37 industrial companies within the AMBA. The results are organized into three parts. First, a descriptive analysis provides an overview of the overall maturity scores, comparing the performance of LCs and SMEs across the model's key components. Second, a correlation analysis is presented to examine the statistical relationships between the different dimensions and components of IoT maturity. Finally, the section applies PCA and K-means clustering to identify the distinct maturity patterns and profiles of the participating organizations.

### *Overview of IoT Maturity in the AMBA*

This section presents a general analysis of the results obtained from the sample of 37 companies in the AMBA using the ATLANTIS maturity model and the weighting system described above ([Figure 2](#)). In general terms, Large Companies (LCs) obtain significantly higher overall scores than SMEs. In particular,

the maximum score for a large company is 54.98 (LC15) and the minimum is 0.44 (LC4), indicating considerable dispersion in the level of digital maturity among LCs. In the case of SMEs, the maximum score is 41.8, and the minimum is 4.8, reflecting a high variability similar to that observed in LCs, but with lower maximum values. This suggests that large companies have a significantly higher overall score than SMEs, indicating that they are more advanced in IoT technological maturity than SMEs, with the difference being statistically significant ( $p < 0.05$ ), suggesting that this observation is not a result of chance.

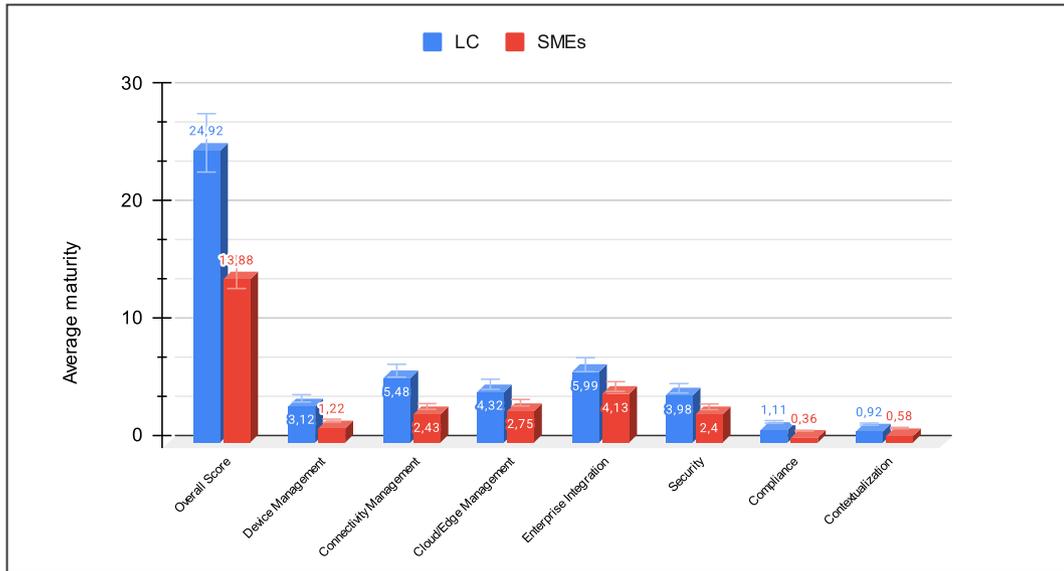


**Figure 2.** The overall IoT maturity score was distributed among the companies analyzed (n=37) and calculated using the ATLANTIS model.

**Note:** Own elaboration.

A stark maturity gap was evident, with large companies (average score: 24.92) scoring nearly double that of SMEs (12.64), a statistically significant difference ( $p < 0.05$ ), showing a difference of approximately 12 points on the assessment scale. When breaking down the maturity scores by component in LCs (Figure 3), it is evident that the highest scores are associated with device management, connectivity management, and business integration. In contrast, the compliance and contextualization components have significantly lower scores in this type of organization. For SMEs, the components with the highest average scores are connectivity management and business integration, while the compliance and contextualization components have the lowest scores, a pattern similar to that observed in large companies. There is a significant gap of approximately 12 points between the two groups. Specifically, LCs obtained an average of 3.12 points in the Device Management component compared to 1.12 points for SMEs, suggesting a significantly greater capacity for handling and managing IoT infrastructure for larger organizations. Connectivity Management presents one of the most pronounced gaps, with averages of 5.48 and 2.43 points for LCs and SMEs, respectively, indicating substantial disparities in data management and communication protocol capabilities.

Although the difference persists in the Cloud/Edge Management component, a less pronounced gap is observed, with large companies averaging 4.32 points and SMEs 2.75 points. Regarding the Business Integration component, both business groups demonstrate their best performance, averaging 5.89 points for large companies and 4.13 points for SMEs, indicating a greater maturity in incorporating IoT into existing business processes and systems. Finally, the Security component reveals a worrying gap, with LCs averaging 3.98 points compared to 2.40 points for SMEs, which is particularly relevant considering the critical nature of security in IoT implementations. Compliance is one of the weakest components for both groups, with averages of just 1.11 points for LCs and 0.36 points for SMEs, indicating an urgent need for improvement in regulatory and governance aspects related to IoT adoption.

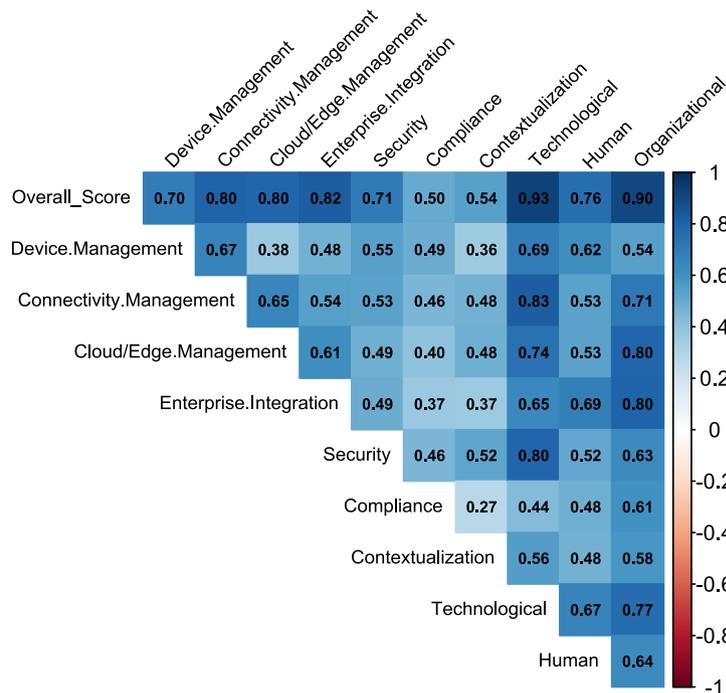


**Figure 3.** Components of the AMBA organization segment IoT technological maturity.

**Note:** Own elaboration.

### Correlation between variables of interest

This section presents the statistical correlations (Figure 4) between the different study variables on the technological maturity of the IoT measured using the ATLANTIS model as a reference framework. In this regard, prior to applying the correlation tests, the evaluation of the data's normality using statistical tests revealed a non-parametric nature, which justified the use of Spearman's correlation coefficient ( $\rho$ ) as a measure of association.



**Figure 4.** Spearman's correlation matrix between the components and dimensions of IoT technological maturity.

**Note:** Own elaboration.

The analysis revealed strong, significant positive correlations between the overall maturity score and both the technological ( $\rho = 0.92$ ) and organizational ( $\rho = 0.90$ ) dimensions. The correlation with the human dimension was moderate but also significant ( $\rho = 0.75$ ). Regarding the overall score and its components, a higher correlation is observed with connectivity management ( $\rho = 0.80$ ) and business integration ( $\rho = 0.82$ ), respectively. In contrast, the compliance and contextualization components show the weakest correlations concerning this overall score. In addition, a high positive correlation was identified between the technological and organizational dimensions ( $\rho = 0.76$ ), while the human dimension shows moderate correlations with the technological and organizational dimensions.

The strong correlation between the technological and organizational dimensions ( $\rho = 0.77$ ) suggests that IoT technological advancement is tightly coupled with organizational maturity in organizations in the AMBA. Therefore, companies with high overall technological maturity tend to have significantly developed technological and organizational capabilities. Although the human dimension is important, it shows more moderate correlations, which could indicate a more independent development from the other two dimensions.

In terms of specific components, device management, connectivity management, and business integration consistently show high correlations with the overall maturity score, suggesting that they are critical to ensuring a company's overall maturity. This is to be expected, as these components are intrinsically linked in implementing IoT solutions; therefore, effective device management often requires adequate connectivity and infrastructure for data processing and analysis. In contrast, components with lower relative scores, such as compliance and contextualization, show the weakest correlations, identifying them as potential areas for improvement in organizations, regardless of their scale.

Finally, it is essential to emphasize the strong correlation between business integration and the organizational dimension ( $\rho = 0.80$ ), which supports the hypothesis that business integration is a significant factor in organizational maturity, as defined in the ATLANTIS model. This highlights the importance of acquiring technology and implementing it within production processes. Finally, the moderate correlations of the security component with other components suggest its cross-cutting nature, as it impacts various maturity dimensions without showing a predominant dependence on a single specific dimension.

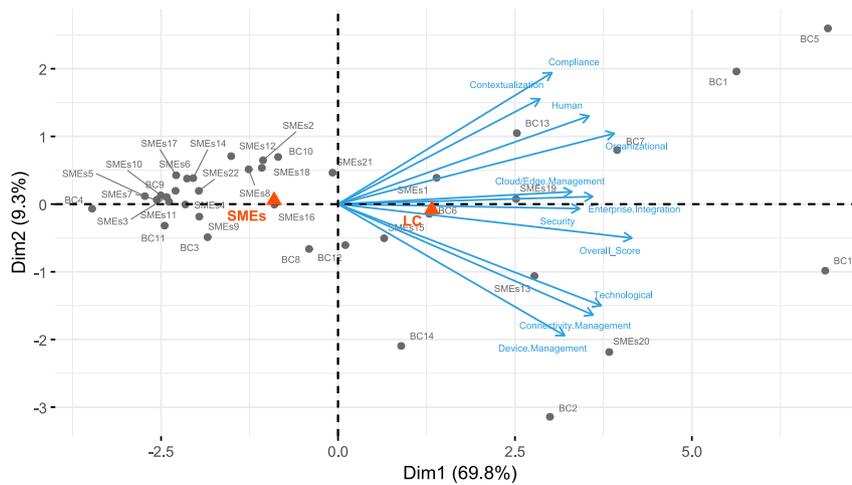
### *Identification of IoT Maturity Patterns through Principal Component Analysis and Clusters*

A PCA was performed to explore the relationship between variables of interest that are not detectable at first glance ([Figure 5](#)). In this regard, the analyzed dataset comprises 37 individuals and 11 variables. After graphical analysis, no outliers were detected. Likewise, the inertia of the first dimensions allows us to identify significant relationships between the variables and suggests the number of dimensions to be studied. The first two dimensions explain 79.13% of the total inertia of the dataset, indicating that 79.13% of the total variability of the cloud of individuals (or variables) is represented in the plane. The decomposition of the total variance revealed that the first component captures 69.83% of the variability, suggesting that this axis is the primary carrier of relevant information. Therefore, the description will focus on these components. Finally, it is important to note that the correlation values (R-squared) and the associated low p-values indicate a statistically significant relationship between each variable and Dimension 1, suggesting that these relationships are not random.

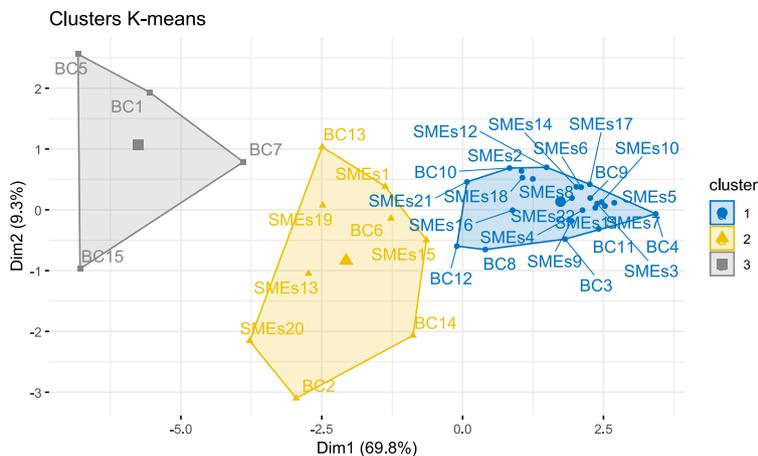
About the analysis, it can be inferred that Dimension 1 of the PCA establishes a clear opposition between two groups of companies. At one extreme, with strongly positive scores, are companies such as LC15, LC2, SMEs20, LC5, LC1, SMEs13, and LC7. At the opposite extreme, with a strongly negative score, is the company LC4. In this sense, within the group of companies ([Figure 6](#)) with positive scores, two subgroups with similar technological maturity patterns can be identified, although with different emphases. For example, there is Subgroup 1 (LC2, SMEs20, SMEs13), which is characterized by high values in variables such as Technological Dimension, and the components of Device Management, Security, and Connectivity Management, with the technological dimension variable being the most influential, suggesting that these

companies excel in the implementation and management of IoT technologies themselves, including device infrastructure, system security, and efficient connectivity management. In addition, their overall maturity score (Overall\_Score) is also high.

Subgroup 2 (LC15, LC5, LC1, LC7) shows high values in a broader set of variables, including the Contextualization component, and the Human and Organizational dimensions, followed by Compliance, Overall Score, Business Integration, Cloud/Edge Management, Connectivity Management, Security, and Technology, which are generally more comprehensive aspects. This indicates that, in addition to having good technology and implementing adequate security, these companies demonstrate greater maturity in understanding the context of IoT applications, preparing their human capital, and adopting an organizational structure suitable for implementing these technologies. They also place greater importance on regulatory compliance and the integration of IoT into their business processes. This subgroup has the highest overall maturity values in the dataset. In contrast, company LC4, located at the negative end of Dimension 1, is characterized by low values in all the variables analyzed, suggesting a lower level of technological maturity regarding IoT adoption in all dimensions evaluated by the ATLANTIS model.



**Figure 5.** A biplot graph between individuals (organizations) and the variables studied (components and dimensions).  
**Note:** Own elaboration



**Figure 6.** Identification of company clusters according to their IoT maturity profile using K-means.  
**Note:** Own elaboration

It is essential to note the high correlation ( $r = 0.98$ ) between Dimension 1 of the PCA and the Overall Score, indicating that Dimension 1 accounts for a significant portion of the variability in the overall technological maturity of the analyzed companies. In other words, this dimension summarizes the overall level of IoT adoption and maturity in these organizations. Likewise, the high correlations of the Organizational ( $r = 0.93$ ,  $p < 0.001$ ) and Technological ( $r = 0.89$ ,  $p < 0.001$ ) dimensions indicate that these two dimensions are the primary drivers of variability in IoT technological maturity in the AMBA. Consequently, differences in how companies approach organizational aspects and technological implementation are key factors in distinguishing them. Regarding the components, the high correlations of Connectivity Management ( $r = 0.86$ ,  $p < 0.001$ ), Business Integration ( $r = 0.86$ ,  $p < 0.001$ ), and the Human dimension ( $r = 0.85$ ,  $p < 0.001$ ) suggest that how companies manage data collection, integrate IoT into their operations, and prepare their staff are also important factors contributing to heterogeneity in technological maturity in the dataset. Finally, the lowest correlation observed for the Contextualization component ( $r = 0.68$ ,  $p < 0.001$ ) suggests that, while understanding the context and regulatory policies is relevant, it is not the primary factor that distinguishes companies in terms of technological maturity in this specific sample of industrial companies in the AMBA.

## 5. Discussion of results

This study evaluates the technological maturity of IoT in different industrial organizations in the AMBA by applying the ATLANTIS maturity model. The descriptive analysis reveals that large companies are significantly more mature in their adoption of IoT than SMEs, a finding consistent with previous research ([Zamani, 2022](#)). Higher scores across several key dimensions of the ATLANTIS model provide evidence for this. In particular, LCs demonstrate statistically significant superiority in device management and connectivity components, suggesting that they have better infrastructure and processes to handle the technical aspects of IoT. In contrast, no differences were found in the cloud/edge management, business integration, security, and compliance components, indicating that, in these areas, SMEs and large companies have comparable capabilities ([Solis Pino et al., 2024](#)), which differs from previous results ([Parra-Sánchez et al., 2021](#)), which suggested that Latin American companies struggle mainly with the organizational integration of IoT. Therefore, SMEs could optimize their capabilities in device management and connectivity to achieve levels of technological maturity similar to those of large companies, always considering their economic limitations. The above results can serve as a basis for developing specific strategies and public policies aimed at enhancing the technological maturity of the IoT across various types of companies ([Solis Pino et al., 2024](#)).

In terms of correlations, the strong relationship between the overall score and the technological components indicates that technological capabilities are a determining factor in achieving high maturity ([Lezama-Nicolás, Rodríguez-Salvador, Río-Belver, and Bidosola, 2018](#)) in the adoption of IoT in ATLANTIS, so companies that invest in infrastructure, data management, and connectivity are more likely to achieve greater overall maturity. Similarly, the strong correlation between the organizational dimension and overall maturity underscores that technology alone is insufficient. Successful IoT adoption requires a supportive organizational environment where structure, processes, and culture are aligned with technological goals, as noted in ([Benotmane et al., 2023](#); [Solis Pino et al., 2024a](#)). In contrast, the moderate correlations observed with the Compliance and Contextualization components could indicate areas where AMBA companies could focus their efforts to strengthen their technological maturity, suggesting a lack of attention to the regulatory and ethical aspects ([Bouchikhi, Weerts, and Clavien, 2024](#)) associated with IoT implementation, as well as a limited understanding of particular environmental and operational contexts, factors that could differentiate higher levels of maturity (United Nations Educational, Scientific and Cultural Organization).

The application of PCA and cluster analysis using K-means allowed us to identify more complex and heterogeneous maturity patterns than a descriptive analysis would reveal, where Dimension 1 suggests that overall technological maturity, driven mainly by the Organizational and Technological dimensions, is the most important factor in differentiating AMBA companies in their adoption of IoT according to the ATLANTIS model. The human dimension, although significant, has a slightly lesser differentiating influence in this first principal component. This aligns with the correlations, which suggest that, although the human

factor is relevant ([Hughes-Lartey, Li, Botchey, and Qin, 2021](#)), its development can progress relatively independently of technological and organizational advances, utilizing specific strategies to enhance the training and adaptation of the workforce to IoT technology. In terms of clusters, the identification of two main subgroups with different emphases (one focused on technological aspects and the other with a more comprehensive vision) indicates the diversity of strategies and approaches in the adoption of IoT in industrial companies in the AMBA, which shows the heterogeneity within the industrial sector regarding the use of IoT. Consequently, the need to design differentiated public policies to promote the adoption of IoT must be emphasized, considering the observed heterogeneity ([Qiu, Chen, Li, Atiquzzaman, and Zhao, 2018](#)).

However, the strong correlations between the components suggest that technological maturity in AMBA companies is developing comprehensively, where progress in one area is typically associated with improvements in other areas ([Gaur and Ramakrishnan, 2019](#)). Likewise, the clear differentiation between clusters suggests the existence of a significant technological gap between companies with higher and lower degrees of IoT adoption and development. These results reinforce the idea that successful IoT adoption requires a holistic approach that considers both technological and organizational aspects, as well as human aspects to a lesser extent. Failing to consider any of these dimensions could limit the potential of IoT adoption ([Solis Pino et al., 2024a](#)).

An unexpected, though plausible, result is the relatively weaker correlation of the Security component with the overall maturity score compared to other components. While security is important in the context of IoT, this could indicate that, in the early stages of adoption, companies prioritize functionality and integration over security, postponing its implementation or considering it a secondary aspect in the initial phases, as indicated in ([Azroul et al., 2021](#)), where it is mentioned that the size of the organization influences the security capacity in IoT implementations.

The study's implications highlight the interdependence between technological infrastructure and organizational readiness, underscoring the effectiveness of isolated technical investments. For practitioners, the results provide a roadmap, indicating that SMEs should prioritize basic connectivity and device management to help close the existing maturity gap, while large enterprises require a refocus on regulatory compliance and security to mitigate identified organizational risks. Consequently, policymakers are urged to move from generic incentives for adoption to specific frameworks that impose appropriate governance standards, enabling the industrial digital transformation in the region to be equitable and secure.

Finally, the results of this research provide concrete empirical evidence on the maturity of the IoT in the specific context of industrial companies in a South American region, offering contextual validation of the ATLANTIS model as a valuable tool for assessing the maturity of the technology. Additionally, identifying specific maturity patterns and the correlations observed between the dimensions provides valuable insights for companies, enabling them to pinpoint their strengths and weaknesses and focus their efforts on areas that require greater attention. Ultimately, these results can be beneficial for policymakers, as they offer valuable insights for developing initiatives that promote a more equitable and effective adoption of IoT in the industrial sector, particularly among SMEs.

### *Threats to validity*

This research collected information on the technological maturity of IoT in AMBA-Argentina companies. However, the study has some limitations and threats to validity that must be recognized and addressed.

- Selection bias: While necessary under the study's constraints, using non-probabilistic convenience sampling introduces potential selection bias. The 37 industrial companies in the AMBA that participated were not selected randomly, which means that the sample may not represent the total population of industrial companies in the region. To mitigate this, a precise definition of the target population (industrial companies in the AMBA with specific relevant characteristics) was made, which helps to understand the limitations of generalization.

- **Response Bias:** Data were collected via self-administered questionnaires, making the results susceptible to response bias. Additionally, participants' understanding of IoT-related terms and concepts may vary, which can impact the accuracy of their responses. To mitigate this, workers from different IoT-related functions within each organization were involved to triangulate responses. Besides, the questionnaire questions were written neutrally, avoiding loaded language and leading questions that could elicit specific responses.
- **Geographic and Temporal Bias:** The findings are specific to industrial companies in the AMBA region during a narrow timeframe (June-July 2024) and may not generalize to other regions or periods. While valuable information about the region is provided, it may not reflect patterns in other Argentine industrial centers or countries with different economic, regulatory, and cultural conditions.
- **Sector Bias:** The study focused on industrial companies, so the findings may not be generalizable to companies in other economic sectors with different technology adoption dynamics and varying levels of IoT maturity. To mitigate this, future work recognizes the need to extrapolate this type of study to other geographic regions with different characteristics.

## 6. Conclusions and future work

This research presents a quantitative assessment of the technological maturity of IoT in industrial organizations within the AMBA (Argentina), using the ATLANTIS maturity model. It provides valuable empirical evidence, allowing for the identification of specific strengths and weaknesses in the adoption of IoT by organizations. The research yielded several significant findings that contribute to understanding the adoption and implementation of IoT in industrial environments across Latin America. The main result is that there is a heterogeneous landscape, with a clear distinction in overall maturity between LCs and SMEs (with an average of 24.92 points compared to 12.64 for SMEs), where larger organizations demonstrate greater sufficiency, particularly in important components such as device management and connectivity, areas where SMEs have significant gaps, suggesting that the availability of resources plays an important role in achieving higher levels of IoT maturity. In contrast, overall maturity in the business integration component emerges as a common strength in both organizations, indicating that IoT is actively incorporated into their core processes.

A strong correlation was found between overall maturity and the technological and organizational dimensions ( $\rho = 0.76$ ), highlighting the interdependence between technology adoption and the structural readiness of the company. This suggests that mere investment in technology does not guarantee maturity if it is not accompanied by adequate organizational adaptation. In contrast, the human dimension showed moderate correlations with other aspects, suggesting that, although important, human factors can be developed independently of technical and organizational advances. Next, the low correlations between the Security component and overall maturity indicate that organizations may prioritize functionality and integration over security concerns in their IoT implementations, raising relevant considerations for policymakers and industry leaders regarding the need to emphasize security in IoT adoption strategies.

The application of PCA and cluster analysis revealed more complex maturity patterns, identifying two subgroups of companies with high maturity but with different approaches to IoT adoption. One group focuses primarily on technological aspects, while the other takes a more holistic perspective, integrating human and organizational dimensions. This differentiation highlights the diversity of strategies that organizations in the region are pursuing to achieve IoT maturity, as well as the need for differentiated public policies to encourage IoT adoption, given the heterogeneity of the industrial sector.

Finally, future work should expand on these results by addressing the geographical limitations of the study and exploring the specific maturity patterns identified using the ATLANTIS model in greater detail. Research should go beyond the AMBA and conduct comparative studies with other Latin American industrial centers, validating whether the gaps between SMEs and large companies, particularly in device management and connectivity, are consistent across the region. In addition, longitudinal studies are essential for capturing

the evolution of IoT maturity over time, specifically to investigate the underlying causes of the weak correlation observed in the security component. This allows us to determine whether this is due to a lack of risk awareness or resource prioritization during early adoption. Finally, future research should focus on the human dimension, which has shown relative independence in this study, to analyze how workforce adaptation strategies can catalyze maturity, even when technical infrastructure is limited, thereby enabling the design of specific policy interventions to support the SME sector.

#### *About the authors*

##### **Andrés Felipe Solis-Pino**

Research Professor, Corporación Universitaria Comfacauca, Popayán, Colombia  
Doctorate in Electronic Sciences, Universidad del Cauca, Popayán, Colombia  
asolis@unicomfacauca.edu.co <https://orcid.org/0000-0003-3342-0776>

##### **Pablo H. Ruiz**

Research Professor, Corporación Universitaria Comfacauca, Popayán, Colombia  
Doctorate in Electronic Sciences, Universidad del Cauca, Popayán, Colombia  
pruiz@unicomfacauca.edu.co <https://orcid.org/0000-0003-2098-2614>

##### **Alicia Mon**

Research Professor, Universidad Nacional de La Matanza, Buenos Aires, Argentina.  
PhD in Computer Languages and Systems, Universidad Rey Juan Carlos, Madrid, España  
aliciam@matanza.edu.co <https://orcid.org/0000-0001-6365-9943>

##### **Cesar Alberto Collazos-Ordoñez**

Research Professor, Universidad del Cauca, Popayán, Colombia  
PhD in Computer Science, Universidad de Chile, Chile.  
ccollazos@unicauca.edu.co <https://orcid.org/0000-0002-7099-8131>

#### *Data Availability*

The authors declare that the article contains all the data necessary and sufficient for understanding the research.

#### *Disclosure statement*

The authors declare that there is no potential conflict of interest related to the article.

#### *Disclaimer*

The authors declare that the views, opinions, or interpretations expressed in the article are personal and do not represent an official position of their institutions.

#### *Funding*

This paper has been supported by the project 6131 Collaborative Group Decision for knowledge acquisition in agriculture using AI techniques - Contrato de financiamiento de recuperación contingente No. 112721-182- 2023

#### *Co-authorship*

**Andrés Felipe Solis-Pino:** Conceptualization, Methodology, Software, Validation, Investigation, Formal analysis, Writing-original draft, Writing-review & editing.

**Pablo H. Ruiz:** Conceptualization, Methodology, Software, Validation, Investigation, Formal analysis, Writing- original draft, Writing-review & editing.

**Alicia Mon:** Conceptualization, Methodology, Validation, Investigation, Formal analysis, Writing- original draft, review & editing.

**Cesar Alberto Collazos-Ordoñez:** Conceptualization, Methodology, Software, Validation, Investigation, Writing— original draft, Writing-review & editing.

## References

1. AHMETOGLU, S.; COB, Z.C.; ALI, N. A Systematic Review of Internet of Things Adoption in Organizations: Taxonomy, Benefits, Challenges and Critical Factors. In: Applied Sciences (Switzerland). 2022. vol. 12. no. 9. <https://doi.org/10.3390/app12094117>.
2. AYALU, Getachew; ABBAY, Aradom Gebrekidan; AZADI, Hossein. The role of micro- and small-scale enterprises in enhancing sustainable community livelihood: Tigray, Ethiopia. In: Environment, Development and Sustainability. 2023. vol. 25. no. 8. p. 7561–7584. <https://doi.org/10.1007/s10668-022-02359-7>.
3. AZROUR, Mourade; MABROUKI, Jamal; GUEZZAZ, Azidine; KANWAL, Ambrina. Internet of Things Security: Challenges and Key Issues. In: Security and Communication Networks. 2021. vol. 2021. no. 1. p. 5533843. <https://doi.org/10.1155/2021/5533843>
4. BECERRA, Martín; MARINO, Santiago; MASTRINI, Guillermo; DRAGOMIR, Marius; THOMPSON, Mark; BERMEJO, Fernando. Mapping digital media: Argentina. Buenos Aires. 2012. <http://dx.doi.org/10.13140/RG.2.2.30272.05124>.
5. BENOTMANE, Meryem; ELHARI, Kaoutar; KABBAJ, Adil. A review and analysis of current IoT maturity and readiness models and novel proposal. In: Scientific African. 2023. vol. 21. p. e01748. <https://doi.org/10.1016/j.sciaf.2023.e01748>.
6. BOUCHIKHI, Maeva El; WEERTS, Sophie; CLAVIEN, Christine. The internet of things deployed for occupational health and safety purposes: A qualitative study of opportunities and ethical issues. In: PLOS ONE. dic 2024. vol. 19. no. 12. p. e0315671. <https://doi.org/10.1371/journal.pone.0315671>
7. BRAVO, Victor. Argentine Energy Policy During the Period 2014–2018. In: Oil and Natural Gas Economy in Argentina: The case of Fracking. Cham: Springer International Publishing. 2021. pp. 79–248. [https://doi.org/10.1007/978-3-030-65520-4\\_2](https://doi.org/10.1007/978-3-030-65520-4_2).
8. BROUS, P.; JANSSEN, M.; HERDER, P. The dual effects of the Internet of Things (IoT): A systematic review of the benefits and risks of IoT adoption by organizations. In: International Journal of Information Management. 2020. vol. 51. <https://doi.org/10.1016/j.ijinfomgt.2019.05.008>
9. CHEN, Xiao; HU, Haoyu; ZHOU, Jiacheng; LI, Yuan; WAN, Lei; CHENG, Zhen; CHEN, Junwei; XU, Jun; ZHOU, Ru. Indoor photovoltaic materials and devices for self-powered internet of things applications. In: Materials Today Energy. 2024. vol. 44. p. 101621. <https://doi.org/10.1016/j.mtener.2024.101621>
10. DOBROWOLSKA, Emilia; SLIŹ, Piotr. ICT Technology Implementation and the Level of Process Maturity in an Organization. In: European Management Studies (previously: problemy zarządzania-management issues). 2022. vol. 20. no. 2 (96). p. 31–47.
11. ELGAZZAR, Khalid; KHALIL, Haytham; ALGHAMDI, Taghreed; BADR, Ahmed; ABDELKADER, Ghadeer; ELEWAH, Abdelrahman; BUYYA, Rajkumar. Revisiting the internet of things: New trends, opportunities and grand challenges. In: Frontiers in the Internet of Things. 2022. vol. 1. <https://doi.org/10.3389/friot.2022.1073780>.
12. FADHULLAH, Widad; IMRAN, Nor Iffah Najwa; ISMAIL, Sharifah Norkhadijah Syed; JAAFAR, Mohd Hafidz; ABDULLAH, Hasmah. Household solid waste management practices and perceptions among residents in the East Coast of Malaysia. In: BMC Public Health. ene 2022. vol. 22. no. 1. p. 1. <https://doi.org/10.1186/s12889-021-12274-7>
13. GAUR, L.; RAMAKRISHNAN, R. Developing internet of things maturity model (IoT-MM) for manufacturing. In: International Journal of Innovative Technology and Exploring Engineering. 2019. vol. 9. no. 1. p. 2473–2479. <https://doi.org/10.35940/ijitee.A4168.119119>
14. GODFRID, Juan; RADNIC, Pablo; VAISMAN, Alejandro; ZIMÁNYI, Esteban. Analyzing public transport in the city of Buenos Aires with MobilityDB. In: Public Transport. jun 2022. vol. 14. no. 2. p. 287–321. <https://doi.org/10.1007/s12469-022-00290-8>.
15. GRANDON, E.E.; IBARRA, A.A.; GUZMAN, S.A.; RAMIREZ-CORREA, P.; ALFARO-PEREZ, J. Internet of Things: Factors that influence its adoption among Chilean SMEs [Internet de las Cosas: Factores que influyen su adopción en Pymes chilenas]. In: Iberian Conference on Information Systems and Technologies, CISTI. 2018. pp. 1–6. <https://doi.org/10.23919/CISTI.2018.8399183>.
16. GROSMAN, Nicolás; BRAUDE, Hernán; ROVIRA, Sebastián; PATIÑO, Alejandro. Made in Latam: How smart manufacturing can give Latin America new hope for industrialization. <https://repositorio.cepal.org/entities/publication/30d95d59-4c67-40ca-aeb1-56d07c96d516>
17. GROUP LACALYTICS. Industry 4.0 and the future of work: Argentina, Brazil, Chile and the EU – state of affairs, opportunities and challenges – IFAIR. <https://ifair.eu/2020/08/24/industry-4-0-and-the-future-of-work-argentina-brazil-chile-and-the-eu-state-of-affairs-opportunities-and-challenges/>.
18. HA, J.; KOSE, M.A.; OHNSORGE, F. Inflation in Emerging and Developing Economies: Evolution, Drivers, and Policies. World Bank Publications. 2019. <https://books.google.com.co/books?id=ReqKDwAAQBAJ>.

19. HATTON, Matt. A new taxonomy for IoT reveals new roles and opportunities. Transforma Insights. 2023. <https://transformainsights.com/research/reports/new-taxonomy-iot>.
20. HUGHES-LARTEY, Kwesi; LI, Meng; BOTCHEY, Francis E.; QIN, Zhen. Human factor, a critical weak point in the information security of an organization's Internet of things. In: Heliyon. 2021. vol. 7. no. 3. <https://doi.org/10.1016/j.heliyon.2021.e06522>
21. JÆGER, Bjørn; HALSE, Lise Lillebrygfjeld. The IoT Technological Maturity Assessment Scorecard: A Case Study of Norwegian Manufacturing Companies. In: H. Lödding, R. Riedel, K.-D. Thoben, G. von Cieminski, and D. Kiritsis (eds.), *Advances in Production Management Systems. The Path to Intelligent, Collaborative and Sustainable Manufacturing*. Cham: Springer International Publishing. 2017. pp. 143–150.
22. JAVAID, Mohd; HALEEM, Abid; SINGH, Ravi Pratap; RAB, Shanay; SUMAN, Rajiv. Internet of Behaviours (IoB) and its role in customer services. In: *Sensors International*. 2021. vol. 2. p. 100122. <https://doi.org/10.1016/j.sintl.2021.100122>
23. KARTINI, Ani; LUBIS, Muharman; RAHMAD, Basuki; SAFITRA, Muhammad Fakhrol. Advancing Digital Maturity in Healthcare Through Comprehensive Integration of Business Intelligence, K-Means Clustering, and Python Programming. In: P. M. Lee and G. M. Lee (eds.), *Selected Papers from the 10th International Conference on E-Business and Applications 2024*. Singapore: Springer Nature Singapore. 2024. pp. 83–94.
24. KASSAMBARA, Alboukadel. *Practical Statistics in R for Comparing Groups: Numerical Variables*. nov 2019. 204 p.
25. KULKARNI, P.M.; GOKHALE, P.; DANDANNAVAR, P.S. Internet of Things (IoT) Adoption: Challenges Among Small and Medium Scale Enterprises (SMEs). In: *EAI/Springer Innovations in Communication and Computing*. 2023. p. 125–134. [https://doi.org/10.1007/978-3-031-07654-1\\_9](https://doi.org/10.1007/978-3-031-07654-1_9)
26. KUMAR, Sachin; TIWARI, Prayag; ZYMBLER, Mikhail. Internet of Things is a revolutionary approach for future technology enhancement: a review. In: *Journal of Big Data*. dic 2019. vol. 6. no. 1. p. 111. <https://doi.org/10.1186/s40537-019-0268-2>
27. LEZAMA-NICOLÁS, René; RODRÍGUEZ-SALVADOR, Marisela; RÍO-BELVER, Rosa; BILDOSOLA, Iñaki. A bibliometric method for assessing technological maturity: the case of additive manufacturing. In: *Scientometrics*. dic 2018. vol. 117. no. 3. p. 1425–1452. <https://doi.org/10.1007/s11192-018-2941-1>
28. MISHRIF, Ashraf; KHAN, Asharul. Technology adoption as survival strategy for small and medium enterprises during COVID-19. In: *Journal of Innovation and Entrepreneurship*. 2023. vol. 12. no. 1. p. 53. <https://doi.org/10.1186/s13731-023-00317-9>
29. MON, Alicia; GIORGIO, Horacio René Del. Analysis of Industry 4.0 Products in Small and Medium Enterprises. In: *Procedia Computer Science*. 2022. vol. 200. p. 914–923. <https://doi.org/10.1016/j.procs.2022.01.289>
30. NAGY, Judit; OLAH, Judit; ERDEI, Edina; MATE, Domician; POPP, Jozsef. The Role and Impact of Industry 4.0 and the Internet of Things on the Business Strategy of the Value Chain-The Case of Hungary. <https://doi.org/10.3390/su10103491>
31. NIEMBRO, Andrés; CALÁ, Carla Daniela. Regional structural change in Argentina (1996–2019): Concepts, measurements and unequal trajectories over the business cycle. In: *Regional Science Policy and Practice*. 2024. vol. 16. no. 8. p. 100068. <https://doi.org/10.1016/j.r spp.2024.100068>.
32. OKE, A.E.; AROWOIYA, V.A. Evaluation of internet of things (IoT) application areas for sustainable construction. In: *Smart and Sustainable Built Environment*. 2021. vol. 10. no. 3. p. 387–402. <https://doi.org/10.1108/SASBE-11-2020-0167>
33. ORGANIZACIÓN DE LAS NACIONES UNIDAS PARA LA EDUCACIÓN, LA CIENCIA Y LA CULTURA. *The ethical implications of the Internet of Things (IoT): report adopted in September 2021*. Paris: Paris : UNESCO, 2023.
34. ORMAZABAL, Marta; SARRIEGI, Jose M.; RICH, Elliot; VILES, Elisabeth; GONZALEZ, Jose J. Environmental Management Maturity: The Role of Dynamic Validation. In: *Organization and Environment*. 2021. vol. 34. no. 1. p. 145–170. <https://doi.org/10.1177/1086026620929058>.
35. PARRA-SÁNCHEZ, Diana Teresa; TALERO-SARMIENTO, Leonardo Hernan; GUERRERO, Cesar Dario. Assessment of ICT policies for digital transformation in Colombia: technology readiness for IoT adoption in SMEs in the trading sector. In: *Digital Policy, Regulation and Governance*. ene 2021. vol. 23. no. 4. p. 412–431. <https://doi.org/10.1108/DPRG-09-2020-0120>
36. QIU, Tie; CHEN, Ning; LI, Keqiu; ATIQUZZAMAN, Mohammed; ZHAO, Wenbing. How Can Heterogeneous Internet of Things Build Our Future: A Survey. In: *IEEE Communications Surveys and Tutorials*. 2018. vol. 20. no. 3. p. 2011–2027. <https://doi.org/10.1109/COMST.2018.2803740>
37. ROUGIER, MARCELO. *Industria y empresas en la Argentina, siglo XX (presentación)*. In: *Estudios Ibero-Americanos*. 2008. vol. 34. no. 2. p. 7–12. <https://www.redalyc.org/pdf/1346/134612633002.pdf>
38. SÁNCHEZ, Marisa Analia; RAMOSCELLI, Gustavo. Value creation from the internet of things: exploratory study in Buenos Aires province. In: *Revista Científica Visión de Futuro*. 2018. vol. 22. no. 1. p. 170–187. [https://www.scielo.org.ar/scielo.php?script=sci\\_arttext&pid=S1668-87082018000100005](https://www.scielo.org.ar/scielo.php?script=sci_arttext&pid=S1668-87082018000100005)

39. SOLIS, Andrés Felipe; REVELO LUNA, David Armando; CAMPO CEBALLOS, Diego Andrés; GAVIRIA LÓPEZ, Carlos Alberto. Correlación del contenido de clorofila foliar de la especie *Coffea arabica* con índices espectrales en imágenes. In: Biotecnología en el Sector Agropecuario y Agroindustrial. 2021. vol. 19. no. 2. p. 51–68. <https://doi.org/10.18684/bsaa.v19.n2.2021.1536>
40. SOLIS PINO, Andrés Felipe; RUIZ, Pablo H.; MON, Alicia; COLLAZOS, Cesar Alberto. Systematic literature review on mechanisms to measure the technological maturity of the Internet of Things in enterprises. In: Internet of Things. 2024a. p. <https://doi.org/10.1082>. <https://doi.org/10.1016/j.iot.2024.101082>
41. SOLIS PINO, Andrés Felipe; RUIZ, Pablo H.; MON, Alicia; COLLAZOS, Cesar Alberto. ATLANTIS: A multidimensional maturity model for evaluating the adoption of the internet of things in industrial SMEs. In: Internet of Things. 2024b. p. 101457. <https://doi.org/10.1016/j.iot.2024.101457>.
42. SOLIS PINO, Andrés Felipe; RUIZ, Pablo H.; MON, Alicia; COLLAZOS, Cesar Alberto. Mechanisms for measuring technology maturity on the Internet of Things in enterprises: A systematic literature mapping. In: Internet of Things. 2024c. vol. 25. p. 101100. <https://doi.org/10.1016/j.iot.2024.101100>.
43. SOLIS PINO, Andrés; RUIZ, Pablo; MON, Alicia; COLLAZOS, Cesar. A bibliometric analysis of the landscape of measuring technology maturity in the enterprise internet of things. In: International Journal of Electrical and Computer Engineering (IJECE). 2024. vol. 14. no. 4. p. 4697–4713 <https://doi.org/10.11591/ijece.v14i4.pp4697-4713>.
44. SOLIS PINO, Andrés Felipe; RUIZ, Pablo H.; MON, Alicia; COLLAZOS, Cesar Alberto; MOREIRA, Fernando. Analysis of Enterprise Internet of Things Maturity Models: A Review. In: Applied Sciences. 2024. vol. 14. no. 21. <https://doi.org/10.3390/app14219859>.
45. VERSINO, Mariana; GUIDO, Luciana; GORENSTEIN, Silvia; VIDOSA, Regina. La promoción de tecnologías 4.0 para las Pequeñas y Medianas Empresas argentinas. In: Ciencia, tecnología y política. dic 2023. vol. 6. no. 11. p. 103. <https://doi.org/10.24215/26183188e103>.
46. WU, Yulei. Cloud-Edge Orchestration for the Internet of Things: Architecture and AI-Powered Data Processing. In: IEEE Internet of Things Journal. 2021. vol. 8. no. 16. p. 12792–12805. <https://doi.org/10.1109/JIOT.2020.3014845>
47. ZAMANI, Seyedeh Zahra. Small and Medium Enterprises (SMEs) facing an evolving technological era: a systematic literature review on the adoption of technologies in SMEs. In: European Journal of Innovation Management. 2022. vol. 25. no. 6. p. 735–757. <https://doi.org/10.1108/EJIM-07-2021-0360>