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Control Towers: the Key to Unlocking Supply Chain 4.0 Potential and Transforming Latin America

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Summary

Purpose – Explore the role of control towers in Latin American supply chains. The aim is to answer the following questions: What are the benefits and challenges of implementing control towers in Latin American supply chains? How can control towers be used to improve the visibility, resilience and sustainability of Latin American supply chains?
Findings – Control towers can be effective in improving the visibility, resilience and sustainability of Latin American supply chains.
Design/methodology/approach – A case study of a relevant company in the fight against COVID-19 and diagnoses of neglected diseases in Latin America was developed. The company implemented a control tower to improve the visibility and resilience of its supply chain. Data were collected through interviews with employees of the company subject of this study, with professionals from other companies present in Latin America, and also through analysis of internal documents. Data was analyzed using a qualitative approach, including content and discourse analysis.
Research limitations/implications – This study has some limitations, as it is based on a single case, and a questionnaire with some Brazilian companies operating in Latin America, limiting the generalization of the results. Furthermore, the research was carried out in a specific context – companies operating in Latin America –, which may limit its relevance to other companies and regions.
Practical implications – The results have practical implications for companies and organizations operating in Latin America. Control towers can be an effective tool to improve the visibility, resilience and sustainability of supply chains in the face of the various factors affecting the region; It is also a way to increase local productivity compared to developed countries.
Originality/value – This is an original study as it is unique in its approach, as it explores the role of control towers in Latin American supply chains. The study is also valuable because it provides *insights* into how control towers can be used to improve the visibility, resilience and sustainability of supply chains to manage recent technological, environmental/social disruptions and generate public policies that can facilitate the development of technologies in the region.

Keywords: Control towers; Supply chain; Resilience; Disturbance; Technology; Environmental; Social, Latin America; Innovation; Collaboration; Maturity; Visibility; Industry 4.0.

1. Introduction

This article explores the role of control towers in Latin American and Brazilian supply chains, amid global challenges such as the COVID-19 pandemic, war in Ukraine and logistical problems. The search for visibility and operational control has become crucial for business survival.

The definition of supply chain, according to Ballou (2006), is the transformation of small companies into global corporations, generating an urgent need to manage data

for strategic decisions. Authors emphasize the importance of resilience in supply chains (Lücker and Seifert, 2017; Shashi *et al* ., 2020; Ali *et al* ., 2017; Chowdhury and Quaddus, 2016). The integration of short, medium and long-term strategies is essential and, in this sense, Industry 4.0 has introduced innovative technologies to dominate supply chains.

To create resilience, it is crucial to adopt strategies aligned to different time horizons. Industry 4.0 offers valuable technologies to improve supply chains, providing competitive advantage. Authors highlight the relevance of these technologies in the effective management of operations such as creating resilience (Asdecker and Felch, 2018; Byrne *et al* ., 2018; Dallasega *et al.* , 2018; Dossou, 2018; Fareri *et al* ., 2020; Galati and Bigliardi, 2019; Garrido-Hidalgo *et al* ., 2019; Manavalan and Jayakrishna, 2019; Radanliev *et al* ., 2018; Ralston and Blackhurst, 2020; Remko, 2020; Tiwari and Shringi, 2021).

According to Patsavellas *et al* (2021), the implementation of resilience strategies, such as resource reconfiguration, risk management, supply continuity and supply chain visibility, reflect the essential complexity and preparation to operate in the current environment. However, digitalization and the search for resilience present challenges, as pointed out by Vlachos (2021), Patsavellas (2021) and Gupta (2022). These challenges include internal/external *software* misalignments , poor data quality and integration, budget constraints, data ownership issues, resistance to breaking down functional silos, lack of specialized systems in supply chain control towers, lack of commitment management, ineffective decision making, inaccurate inventory control systems, ineffective supplier management, infrequent implementation of risk management strategies, lack of resources and management capacity, need for specialized talent, high cost of maintaining inventory security, lack of information sharing, lack of trust and lack of supply chain visibility.

These deficiencies, mainly the lack of visibility of supply chains for the government, result in product losses, failure to serve the needy population and contribute to corruption in Latin America due to lack of transparency (Ali *et al.* , 2017b; Shashi *et al* ., 2020; Patsavellas *et al* . (2021).

In this context, visibility emerges as a crucial element for resilience. According to Dybskaya and Sergeev (2019), having visibility in the supply chain means measuring and monitoring performance in four main resources: agility, resilience, reliability and responsibility. This is where the advanced concept of control, monitoring and management of complex supply chains emerges, known as *"Supply Chain Control Tower"* (SCCT), or in Portuguese, Supply Chain Control Towers (TCCS), as presented by Patsavellas *et al* . (2021), Dybskaya and Sergeev (2019), Shamroukh (2021), Kumar *et al* . (2023). Originating from aviation control towers, these towers are crucial for monitoring and managing complex supply chains (Dybskaya and Sergeev, 2019; Shamroukh, 2021).

The multifaceted use of technology in the supply chain can automate processes, especially in logistics, resulting in significant gains in efficiency and reliability (Bowersox *et al* ., 2002). Furthermore, technology plays an essential role in efficiently collecting, analyzing and sharing information throughout the supply chain.

Digital platforms and information systems enable rapid data sharing between different parties, improving visibility and coordination (Chopra and Meindl, 2010). The use of technology also simplifies data-driven decision-making in the supply chain, with analysis tools identifying trends, patterns and opportunities, contributing to more influential and strategic decisions (Rushton *et al.* , 2014). Introducing sustainable practices into the supply chain provides significant benefits, such as building trust and brand image, increasing customer loyalty, reducing costs through efficiency, and

mitigating risks associated with chain continuity or regulatory violations (Carter and Rogers, 2008).

Control towers in the supply chain have a rather recent history, initially isolated and linear, offering limited *insights* into specific areas such as transportation, logistics or warehousing, often as resource-constrained on-premises *software solutions.*

However, the rise of cloud computing, combined with technologies such as artificial intelligence, machine learning, IoT and predictive/prescriptive analytics, has transformed this landscape. Today's control towers provide comprehensive visibility, acting as command centers that bring companies closer to their suppliers, enabling proactive service delivery to customers. Sharabati (2022) highlights DHL's daily integration of supply chain control towers, coordinating logistics activities globally to reduce inventories and manage risks.

Companies such as Walmart, Intel, Cisco, Klabin, Vibra Energia and BP Bunge also use these towers to coordinate processes, monitor activities and share data between different functions. In addition to companies, governments, such as the Korean one, adopt Supply Chain Control Towers (TCCS) to deal with crises and improve operations. Therefore, our main research problem is: **What is the role of control towers in Latin American supply chains?** And, its objectives are: **to analyze the maturity level of supply chains; analyze the maturity level of control towers; identify the advantages and disadvantages.**

2. Literature review

2.1 Concepts of control towers in supply chains

In the context of supply chains, the precise definition of a control tower may vary, depending on the particularities of the chain in question and specific management needs. At its core, however, a supply chain control tower can be understood as an integrated center of systems, processes and technologies that provides real-time visibility, monitoring and control of supply chain operations (Christopher, 2016).

A conceptual definition perspective is presented here, although it is important to highlight that this topic still represents an unexplored frontier in many sectors of the economy. Furthermore, the definition is not an immutable truth, but rather a concept in constant evolution and adaptation.

Table 1. Control tower concept in supply chains

Author/year	Concept/definition of control tower
Karkula (2018)	The tower is a central system at the appropriate technological level, intended for organizing processes, acquiring and analyzing supply chain data to ensure better transparency.

Trzuskawska-Grzesińska (2017)	Planning and execution system, which effectively deals with resource restrictions and/or containment, as well as deviations in the process, aiming to execute corrective and preventive actions in real time.
Akben and Özel (2017)	Supply chain control tower system is a system that tries to make the external environment visible to the business. It's initiative; provides "end-to-end" visibility, eliminating system latency, across all transactions and events to quickly save and assist planners against disruptions and deviations from demand and operations plans.
Fekpe and Administration (2021)	It is the ability to track deliveries in real time, which in turn helps make the delivery process more efficient.
Tsertou *et al* . (2016)	A supply chain control tower is a central *hub* with technology to work with data and provide enhanced visibility for decision-making aligned to strategic objectives.
Barbosa-Povoa e Pinto (2020)	Provides supply chain visibility and delivers the information needed to support decision making in real time, structured like an airport control tower. It is a unified system, in a single physical location, that helps in the implementation of critical decisions, with an impact on the entire supply chain.
Vlachos (2021)	It is a central *hub* with the technology, organization and processes needed to capture and use supply chain data to provide greater visibility for short- and long-term decision-making that is aligned with strategic objectives.
Shamroukh, (2021)	A supply chain control tower is a sophisticated, cutting-edge *software* that consolidates and centralizes the various complex processes and activities of any supply chain system, thus building a *hub* that tracks, manages, organizes and carries out the operation well. -successful.
Kumar *et al.* (2023)	A TCCS is much more than a traditional control, it includes people, processes, new ways of working, technology infrastructure and data that, combined, can help enable a company to proactively orchestrate across its supply chain functions. and broader supply networks, aiming to increase the company's value.
Gupta (2022)	Supply chain control tower is a concept that results in the combination of people, processes, data, organization and technology. Control towers capture and use (near) real-time operational data from across the entire business ecosystem to provide enhanced visibility and improve decision-making.

After this initial analysis of some definitions, it becomes evident that this topic, in fact, can present several nuances.

In view of this, it is proposed to share the interpretation of the author of this study on this concept, based both on the Brazilian context and on accumulated practical experiences: " *It is a centralized ecosystem of processes, systems and people that enables real-time visibility, monitoring and control of all operations within the supply chain."*

2.2 Objectives of control towers

Control towers play a fundamental role in supply chain management, providing tools and data that help organizations optimize processes and improve operational performance. Its function is broad and adaptable to the specific needs of each organization, covering monitoring, measurement, evaluation and implementation of corrective and preventive actions, in addition to responding to customer demands. Often, control towers report

internally and externally to initiate continuous improvement processes (Roque Júnior *et al* ., 2019; Shamroukh, 2021).

In a challenging context for companies and governments, especially in Latin America, with complex supply chains and dependence on Asian countries, this **efficient approach** increases companies' visibility and maturity in supply chains, promoting a cycle of continuous improvement (Roque Júnior *et al.* , 2019). Control towers are becoming centers of innovation in supply chains, aligning with the concept of Supply Chain 4.0, as highlighted by Frederico *et al.* (2019) therefore, they enable the maximization of profitability with a focus on suppliers and customers, directly impacting the strategy. The transition to this chain demands transparency, collaboration and planning. In this context, control towers play an essential role in integrating systems through the combination of technologies such as Internet of Things (IoT), RFID, GPS, ERP, WMS, TMSs, AIs, and other corporate platforms. This integration enhances the investments already made by companies.

The crucial role of control towers aims to regulate the supply chain, maximizing service, reducing cycle time and optimizing resources (Trzuskawska-Grzesińska, 2017). Meeting the three levels of supply chain operation – strategic, tactical and operational – control towers enable aligned decisions in the short and long term (Karkula, 2018).

The study by Sharabati (2022) highlights that supply chain control towers impact the dimensions of competitive advantage, with the greatest effect manifesting itself in quality, followed by reliability and, finally, responsiveness.

2.3 Control tower structures

Control towers in supply chain management comprise several structures that play a crucial role in the efficient implementation and operation of these systems. These structures provide the necessary basis for the configuration and alignment of control towers, addressing the specific needs of each organization. Some of these structures include hierarchical, modular, network, information flow, process, among others, as highlighted in the literature (see Table 2).

Table 2 . Other shapes of control tower structures

Author	Structure
Trzuskawska-Grzesińska (2017)	1-Supply chain perception layer. 2-Business layer of supply chains. 3-Layers of information operations control. 4- Information service platform. 5- Information labor layer.
Handfield *et al* . (2020a)	Detection and prevention, response, relief, recovery, data management.
Akben and Özel (2017)	1-Supply chain business layer. 2- Information perception layer. 3-Layer computing control. 4-Layer information service platform. 5-Tier of quality workforce.
Shou-Wen *et al.* (2013)	1-Supply chain business layer. 2- Information perception layer. 3-Layer of information operation control. 4-Layer information service platform. 5-Layer of information labor

Geilgens (2021)	It presents the structure of the Control Tower offered by IBM: 1- Supply chain business network. 2-Supply chain intelligence services. 3- Supply chain applications (supplier management, inventory management, order management)

Each structure has its advantages and challenges, and it is crucial to adapt it to the specific characteristics of the company and the business context. It is worth mentioning that the structure of control towers is subject to evolution over time, as the organization acquires maturity in supply chain management, incorporates new technologies and improves its practices. It is a continuous process of learning and improvement, in which structured control towers must adjust to changes and challenges in the business environment (Roque Júnior *et al* ., 2021).

In the context of Latin America, the choice of the appropriate structure for the control tower gains even more relevance, given the specific characteristics of the countries, such as the lack of infrastructure, large distances to be covered and notable logistical challenges compared to the Europe and North America, which have a more robust logistics infrastructure.

Furthermore, supply chains in Latin America often involve multiple partners – national or international – such as suppliers, manufacturers, distributors and retailers, making coordination and integration even more complex due to the diversity of products traded between countries or blocks like Mercosur.

2.4 Application of supply chain control tower to logistics

The literature uses several terms to refer to the control tower, including "supply chain control tower" (Trzuskawska-Grzesińska, 2017). Furthermore, the configurations of these towers are dynamic and distinct, varying according to the strategy adopted by the organization. Among the options, the logistics control tower with an emphasis on transportation is the most cited, as indicated by Akben and Özel (2017), Liotine (2019) and Trzuskawska-Grzesińska (2017). In contrast, the supply chain control tower seeks a more comprehensive view, considering transportation, inventory, purchasing, costs and other end-to-end operations.

Table 3 . Application of control towers

Application of control towers	Analysis capabilities	Operational skills
Transport	– Order on time; – Transportation costs; – Performance of the transporter or delivery person; – Occurrences.	– Sequence, track; – Exception management in time-related transport stages; – Supply of digital stub; – Optimization for transportation only, such as preventative maintenance, vehicle idling – Order-focused shipping.
Supply chain	– Complete and punctual orders; – Total cost to serve (activity cost, transportation cost, supplier costs, etc.);	– End-to-end visibility of the supply chain, manufacturing, distribution, transportation, etc.; – Exception management at any stage of the supply chain;

	– Performance of suppliers, logistics operators and internal resources; – End-to-end occurrences.	– Optimization in transportation, internal capabilities and dynamics of stocks and service level; – Boarding order and services.
Foreign trade	– Imports or exports on time; – Import or export costs; – Qualification of suppliers; – Suppliers evaluation; – occurrences	– Visibility of the process from collection point to destination. – Sequence and track. – Exception management in time-related transport stages. – Optimization for transport only. – Order-focused shipping. – Temperature monitoring and geolocation.

Control towers must be able to provide information about typical disruptions in supply chain processes. The table below highlights some of these situations that can be monitored through indicators, KPIs alerts and specifies the sectors that require these responses.

The examples presented illustrate how the control tower uses the pillars of people, processes and systems to meet the needs of companies in relation to strategy.

2.5 Challenges in implementing control towers in the supply chain

Implementing real-time supply chain visibility can bring benefits, but faces significant challenges due to several interrelated factors spanning individual, organizational, technological and environmental categories.

The table below highlights some opportunities and challenges that will be explored below.

Table 4. Opportunities and challenges

Author/Year	Opportunities	Challenges
Karkula (2018)	Transparency, integration, automation, forecasting, system flexibility, flexible management capacity and punctuality.	Highly qualified team with experience using the appropriate tools.
Dybskaya and Sergeev (2019)	End-to-end visibility, advanced control and management automation.	Limited visibility of supply chain management, simple decision-making support with often delayed alerts, centralized planning without executing changes in real time, lack of scalability and difficult integration of IT systems and making it difficult to reuse existing connections with partners .
Trzuskawska -Grzesińska (2017)	Brings added value to operations, dedicated structure, process monitoring, measurement, evaluation, corrective and preventive actions	Dedicated teams and processes, infrastructure and customized support systems.
Pan *et al.* (2019)	Improves integration capacity.	Superior operational performance is not associated with the implementation of

		comprehensive information system resources such as control towers.
Akben and Özel (2017)	Customer satisfaction, decision making, cost reduction, protection, development.	Limited visibility, non-updated decision support, multi-planned and decentralized execution, non-scalable, non-reusable commercial partner links and high cost of information technologies intended for the project.
Liotine, (2019)	Technologies such as Artificial Intelligence can play a valuable role in decision-making processes in a control tower environment.	Limitations in technology, such as serialization, impact on control tower visibility, and the lack of some level of regulation or governance, which is desirable to regulate interaction and avoid conflicts of interest.
Tsertou *et al.* (2016)	They can be implemented in different architectures, such as in centralized locations for many customers in a shared way, dedicated on-site or remote for a specific customer.	Requires knowledge of high-value-added software technology applications and resources.
Handfield *et al.* (2020)	Need to hire and retain the best talent for operation and development of the control tower.	Maintenance of a structure in a location with the availability of hiring and retaining qualified labor, in such locations the costs are higher.
Kumar *et al.* (2023)	Visibility, scenario modeling, customer-focused, sustainable, agile, resilient networks, service levels and personalized experiences for each type of customer.	He presented no challenges in his analysis.

2.6 Maturity for implementation of control towers

Successfully implementing a supply chain control tower requires maturity of both the organization and the chain itself. However, understanding this journey is often challenging, leading to the creation of unrealistic timelines and unmet expectations. The maturity proposal by Deanna M. Rainwater of *Tata Consultancy Services* (TCS) suggests an approach divided into four phases: 1. Discovery assessment; 2. Enabling the control tower; 3. Construction of the control tower; 4. Enabling advanced features.

The stages of this journey are outlined in four stages: 1. Functional excellence; 2. Internal integration; 3. External integration; and, 4. Orchestration. According to Kumar *et al.* (2023), many companies face challenges when seeking visibility across the entire supply network, resulting in difficulty extracting the desired value. To overcome these obstacles, Kumar *et al* . (2020) highlight essential pillars for control towers in supply chains, including: the use of case-oriented resources, new ways of working, flexible architecture and strategy, and robust data governance. Modularity is crucial, allowing the tower to evolve with the business and quickly adapt to market changes.

The implementation plan proposed by Vlachos (2021) and Mukherjee (2023) involves three phases: 1. Initiation; 2. Live; and, 3. Continuous improvement. Supply chain control towers are underpinned by core technologies grouped into three main categories: 1. Long-term technologies (EDI, XML, RFID, 5G, IoT, *blockchain*); 2. Mediation technologies (Cloud platforms, cargo tracking applications); and, 3. Intensive technologies (Big data, Data science, *Analytics* /BI, Predictive and prescriptive analysis,

Scenario modeling, AI/Machine learning) (Vlachos, 2021; Zurron and Lima Junior, 2021; Gupta, 2022).

2.7 Return on investment (ROI) in supply chain control towers

Control towers in the supply chain represent significant investments in financial terms, time and effort. Assessing the Return on Investment (ROI) is crucial to measuring the impact of implementing these towers.

In the 2021 State of Logistics Annual Report, " *The Great Reset* ," released by the *Council of Supply Chain Management Professionals* (CSCMP), it is highlighted that a control tower can reduce supply chain costs by 10 to 20%. Companies that adopted control towers achieved significant results, such as a 3 to 5% reduction in logistics costs and a 10 to 20% improvement in labor efficiency (Kumar *et al* ., 2023). Deloitte reports a case where a control tower optimized material flows, improved availability and achieved a 212% ROI, with payback in less than a year. In addition to reducing operational costs, productivity increases with greater visibility and coordination in the supply chain. This translates into shorter cycle times, improved scheduling and routing, better equipment usage and less downtime. Kumar *et al.* (2023) also highlights optimizations in capital efficiency, with a reduction of 5 to 15% in inventories and 8 to 15% in destruction/donation/discount.

These improvements are in line with industry demands, as evidenced by the 2022 " *Third-Party Logistics Study* ," where 60% of shippers listed control towers as the top technology requirement for 3PL providers. This unprecedented classification highlights the growing importance of control towers in operational efficiency and in responding to the sector's technological demands.

In general terms, this study addresses specific challenges facing control towers in Latin America, exploring how they improve visibility and resilience in supply chains in the face of global technological, environmental and social issues.

Using the methodology that will be presented below, a case study of a non-profit company diagnosing neglected diseases in Latin America is presented. The subsequent section connects the case study findings to *insights* from a survey of Latin American companies of different sizes and ends with final considerations and suggestions for future research.

3. Methodology

The case study is a research method that generally uses qualitative data, collected from real events, with the aim of explaining, exploring or describing current phenomena within their own context. It is characterized by being a detailed and exhaustive study of a few, or even a single object, providing in-depth knowledge (Yin, 2015).

The research was conducted in five distinct stages: 1. Research design; 2. Research design; 3. Data preparation and collection; 4. Analysis; and, 5. Preparation of reports. In the first stage, the topic of control towers in Latin America was defined, presenting the research question and specific objectives. The novelty and scarcity of literary exploration on the topic in Latin America stood out. This article seeks to explore the case study of a relevant company in tackling COVID-19 and diagnosing neglected diseases in the region, providing *insights* into the Latin American market's actions to reverse the status quo.

Propositions play a crucial role in this case study, guiding the scope of the research, data collection and analysis. Three central propositions are outlined:

1. The gradual implementation of control towers in Latin American supply chains represents an opportunity to improve visibility and resilience, making them more efficient and competitive, given regional complexity and challenges;
2. The implementation of control towers must be adapted to the specific needs of companies, considering complexity and local resources;
3. Control towers play a crucial role in improving the sustainability of Latin American supply chains, given the complexity and fragmentation of these chains in the region.

The research protocol, consisting of a theme, research question, propositions, unit of analysis and data collection instruments, including bibliographic review, primary and secondary data, questionnaires and interviews, was used to confirm or refute the propositions and answer the questions of research. The triangulation of methods, employing different data collection and analysis techniques, strengthened the validity of the results.

Qualitative analysis was conducted using the content analysis technique. The final report compiles the research findings, providing a comprehensive overview of the implementation of control towers in Latin American supply chains.

The case study unit of analysis is a non-profit institution focused on diagnostic testing, which was widely active during COVID-19 and had a logistics control tower. The company responded to the questionnaire, which was shared via social media to other professionals working in logistics from companies present in Brazil and Latin America; 60.7% of respondents hold the position of manager, director, vice ceo and CEO; 82.6% from the southeast and south of Brazil. Below are the answers to the questionnaire administered using a 7-point *Liket scale.*

Question	Answer% I agree, I strongly agree, I completely agree
1. Does implementing a Control Tower improve supply chain efficiency?	100
2. Do Control Towers generate resilience in the supply chain?	95.6
3. Is the technology used in Control Towers easy to integrate with existing systems?	73.9
4. Does the use of Control Towers help mitigate risks in the supply chain?	100
5. Does implementing a Control Tower require a significant investment?	69.5
6. Is the return on investment in Control Towers high?	82.5
7. Do Control Towers improve communication between different parts of the supply chain?	95.7
8. Are Control Towers a necessity in today's business environment?	91.3
9. Can the Control Tower be effectively used in any industry?	91.2
10. Does implementing a Control Tower increase customer satisfaction?	100
11. Do Control Towers increase visibility across the supply chain?	100
12. Do Control Towers contribute to supply chain sustainability?	95.7
13. Is the formation of specialized teams necessary for the effective functioning of Control Towers?	91.3
14. Do Control Towers help reduce operational costs?	100
15. Do Control Towers help improve demand forecasting?	87

16. Is implementing a Control Tower a time-consuming process?	65.2
17. Do Control Towers help improve inventory management?	91.3
18. Does implementing a Control Tower improve the organization's overall performance?	95.7
19. Are Control Towers effective in dealing with supply chain disruptions?	95.7
20. Do Control Towers play a critical role in supply chain digital transformation?	95.7
21. Do control towers focus on transportation?	52.1
22. Are the control towers focused on the operational part?	60.8
23. Are the control towers focused on the analysis part?	95.7

The last two questions of the questionnaire are relevant when classifying the maturities of logistics or supply control towers and the maturity level of supply chains. See if:

24-Analyzing your control tower, do you consider it to be mature? Source: Zurron and Lima Junior (2021)	
Level 1	4.3%
Level 2	13%
Level 3	34.8%
Level 4	21.7%
I do not have information to be able to assess the level of maturity	26.1%

25- Look at the images below and define your company's maturity level based on the skills presented	
Early stage	9.5%
Pre-intermediate	4.8%
Intermediary	33.3%
Pre Advanced	23.8%
Advanced	14.3%
I do not have information to be able to assess the level of maturity	14.3%

3.1 Big-picture model for 4-element, multi-dimensional supply chains

For this article, in order to better understand the impact of control towers and the moment in which we are impacted by technologies, we suggest the creation of an expanded vision model for supply chains, based on the work of Roque Júnior et *al.* . (2019), Roque Júnior *et al* . (2021) and, Roque Júnior *et al* . (2023). The model below is made up of four elements: 1. Vision; 2. Complexity; 3. Maturity; and, 4. Resilience, with multiple relationships, challenges and multiple dimensions.

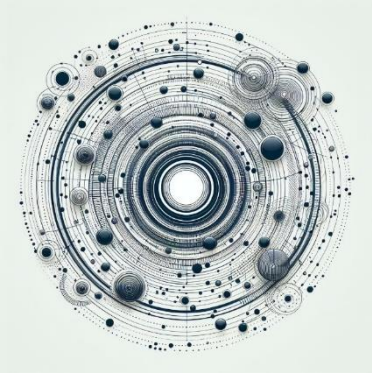
Circle in the center: represents the vision model. Vision is the ability to understand the current and future state of supply chains, as well as identify opportunities and threats.

Outer circles: represent complexity, maturity and resilience and their dimensions. Complexity is a measure of the difficulty of managing a supply chain. Maturity is the level of experience, sophistication and efficiency of a supply chain's operations. Resilience is the ability of a supply chain to adapt and respond to disruptions.

Dotted lines: represent the relationships between elements. Vision is related to all other elements. Vision can help understand complexity, develop maturity and increase resilience.

The balls in the figure represent the dimensions spread out and, each one, at a level and its attributes which form the dimension.

Figure 1. Extended 4-element, multi-dimensional view model



The application of this qualitative model is based on the response of the company under study, identifying the elements of the model, analyzing the complexity, maturity and resilience in its operation.

Based on previous articles, the authors of this study already have the answer to these items, remaining pending and adaptation of the last element, the vision that is materialized in the creation of the supply chain control tower and interconnecting all present elements, technologies, people, systems and infrastructure.

4. Discussion

The results of the questionnaire reveal a positive view regarding the implementation of control towers in supply chain management. The complete agreement (100%) on the role of control towers in improving efficiency, mitigating risks and increasing customer satisfaction suggests a largely favorable perception regarding the positive impact of this technology.

The high agreement (95.6%) on the ability of control towers to generate resilience in the supply chain is a significant indicator, highlighting the importance of this technology in adapting to disturbances and maintaining operational continuity.

The issue of technological integration (73.9%) points to an awareness of the challenges, but there is still a majority who perceive relatively easy integration with existing systems.

Agreement on significant investment (69.5%) suggests recognition of the need for substantial resources for implementation. However, the high agreement on a high ROI (82.5%) indicates that, despite the initial investment, organizations realize sustainable financial benefits.

The consistency in responses indicates that Control Towers play a vital role in several areas, from communication and visibility to cost reduction and improved demand forecasting. However, there is noticeable variation in responses regarding the focus on transportation, operability and analytics, indicating that organizations may have different approaches when implementing control towers.

However, it is notable that the perception about the maturity of control towers presents a diversity of responses, with 26.1% of participants indicating that they do not have information to assess the level of maturity when analyzing the maturity of control towers. The results show a diverse distribution, with the majority located at maturity levels 3 and 4. This diversity suggests that organizations are at different stages in their technology implementation and adoption journeys. Furthermore, responses about the

company's maturity level, based on presented skills, indicate a relatively even distribution between the intermediate and pre-advanced stages.

Based on the data and responses to the questionnaire, the conclusions for the three propositions outlined are positive, as can be seen below:

Proposition 1: The data reveals that complete agreement (100%) on the effectiveness of control towers in improving supply chain efficiency, mitigating risks (95.6%) and increasing customer satisfaction (100%) . The data presented indicates that there is a strong positive perception about the potential of these towers to improve operations. This suggests that gradual implementation may be an effective strategy to improve the visibility and resilience of Latin American supply chains.

Proposition 2: The variation in responses regarding significant investment (69.5%) suggests that there is awareness of the need for substantial resources for implementation. However, the high agreement on a high return on investment (ROI) (82.5%) indicates that, despite the initial investment, organizations realize sustainable financial benefits. This suggests that adapting to the specific needs of companies may be viable, considering the perceived benefits.

Proposition 3: Agreement on the ability of control towers to contribute to supply chain sustainability (95.7%) suggests that these towers are perceived as a positive element to address the complexity and fragmentation of Latin American chains. Therefore, there is evidence that control towers can play a crucial role in improving the sustainability of these chains.

These results provide valuable *insights* for understanding the current scenario of control tower adoption in Latin America, highlighting both the perceived benefits and the challenges and variations in the implementation and maturity of this technology.

The proposed expanded vision model enriches the understanding of the role of control towers in Latin American supply chains. By integrating elements of vision, complexity, maturity and resilience, the model offers a holistic approach.

The survey results indicate that a clear vision is crucial to addressing the challenges of logistical complexity in the region, while driving operational maturity and resilience. Improved understanding of these elements provides valuable *insights* for companies seeking to optimize their supply chains and maximize the benefits of control towers, validating the importance of this theoretical model for addressing regional challenges.

5. Conclusion

We conclude that the topic is relevant to Latin American countries.

The specific objectives were achieved based on the questionnaire, the case study and the expanded 4-element vision model, as can be seen in the conclusions below.

With the discussion of the first specific objective **“to analyze the maturity level of supply chains”** , it was possible to identify a diversity of maturity in Latin American supply chains. Responses indicate that organizations are at different stages in their control tower implementation and adoption journeys, suggesting the need for a strategic and adaptive approach to meet the different needs and challenges present in the region.

In the second objective **“to analyze the maturity level of control towers”** , the results pointed to a varied distribution, with the majority located at levels 3 and 4 of maturity. This diversity suggests that organizations are progressively adopting this technology, but at different paces. The heterogeneity in maturity highlights the importance of a gradual implementation adapted to the specific circumstances of companies in Latin America.

In the third specific objective, the vision is positive of the advantages of control towers, including improvements in efficiency, resilience, customer satisfaction and reduced operating costs. However, there is also awareness of challenges, such as the need for significant investments and the complexity of technological integration.

Based on the above, it is possible to answer the main research objective, where control towers play a significant role in the management of supply chains in Latin America. The responses indicate a positive perception regarding the benefits provided by this technology, such as improved efficiency, resilience, customer satisfaction and reduced operational costs.

These favorable evaluations highlight the strategic importance of control towers in adapting and optimizing supply chains in a region marked by diverse complexities and challenges. The investment challenge will be a limitation, however, the market is expanding. The global Control Towers market, valued at US$7.31 billion in 2022, is forecast to see notable growth with a compound annual rate of 21.3% from 2023 to 2030, according to data from Grand View Research (2023).

Finally, this work presented some limitations which are expected to be overcome by future research, namely: low response rate to the questionnaire, it is not possible to estimate the number of control towers in the region, which does not allow comparisons, as it is a topic recent the number of articles researched limits the literature review. The company under study also represents a single case, making it necessary to introduce more case studies.

It is recommended for future articles to expand the scope of the theoretical model and refine it based on a comparative case study, long-term analysis, sustainability analysis and, also, a study on Technology Adoption in Latin America.

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