

Digital Transformation of Latin American Customs with Blockchain

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Abstract

The use of paper in customs procedures generates inefficiencies, delays, and additional costs that negatively impact international trade. This study examines the impact of paper-based processes in the customs operations of Mexico's main trading partners in Latin America, revealing significant disparities among countries. For instance, Argentina reports document compliance times of up to 8 days, while El Salvador stands out for its efficiency, with processes taking as little as 13 hours. However, despite these differences, all customs administrations in the region share common deficiencies that highlight the urgent need for digital transformation. The research combines a quantitative analysis of document compliance times with a qualitative case study of the CADENA project, an innovative initiative led by the Inter-American Development Bank (IDB) and based on Blockchain technology. CADENA has proven to be an effective solution for modernizing customs processes, enabling secure and efficient data exchange between customs authorities, as well as real-time traceability of Authorized Economic Operator (AEO) certificates. The results of the project demonstrate that Blockchain not only reduces processing times but also automates procedures through the use of smart contracts, enhancing transparency and data integrity. Furthermore, CADENA has optimized the management of Mutual Recognition Agreements (MRAs), establishing itself as a cornerstone for the development of Customs 4.0. In conclusion, Blockchain technology emerges as a key enabler for the digital transformation of customs, streamlining processes, reducing costs, and strengthening regional competitiveness. It is recommended to expand the implementation of CADENA and explore new use cases, such as the generation of digital documents, to further advance toward more efficient and sustainable customs management.

Keywords: Digital Transformation, Customs, Blockchain, Efficiency

1. Introduction

The introduction in recent years, the term "digital transformation" has gained significant relevance in the business world. This concept refers to the transition from analog to digital processes with the aim of optimizing business operations. In the context of international trade, this trend has been no exception, giving rise to the emergence of the term TradeTech. TradeTech refers to the application of advanced technologies, such as Artificial Intelligence, Robotics, Blockchain, Distributed Ledger Technology, the Internet of Things, and 3D Printing, among others, to modernize and streamline customs processes. Its implementation seeks to enhance operational efficiency and significantly reduce the time associated with customs procedures. One of the primary challenges that TradeTech aims to address is improving the efficiency of supply chains, transforming their operations to make them smarter and more agile. This involves the transition from analog to digital processes, particularly in replacing paper-based systems with automated solutions at border crossings. This

shift is crucial, as the reliance on paper in customs procedures is one of the factors that slows down international trade. Currently, paper plays a fundamental role in customs procedures, as it provides a level of transparency and certifies the authenticity of customs declarations. However, its use also entails significant drawbacks, such as increased time required for the verification of procedures. These delays can lead to hold-ups in the delivery of goods, negatively impacting the efficiency of global trade.

In light of the above, the research question guiding this study is as follows:

- What is the impact of paper use in customs procedures, and how can Blockchain technology contribute to improving their efficiency?

The use of paper at border crossings represents a significant obstacle to international trade, as it extends the time required to complete documentation to over a week, generates additional costs, and complicates verification processes. Although physical

documentation ensures a level of transparency for customs authorities, its reliance limits the dynamism of trade and hinders its growth. In this context, the adoption of advanced technologies, such as Blockchain, emerges as a promising solution. This technology has the potential to streamline border crossings, reduce waiting times, and eliminate the need for paper documentation, thereby improving the efficiency of international trade without compromising the integrity and transparency of customs transactions.

The implementation of Blockchain in customs procedures offers substantial benefits. Its immutable nature ensures transparency, while its traceability capabilities enable detailed tracking of operations. Furthermore, automation through smart contracts accelerates the verification of information in a matter of minutes or even seconds. These features not only simplify customs processes but also strengthen trust and efficiency in commercial operations.

The ability for instant verification and the immutability of Blockchain reduce waiting times and provide a solid foundation for data integrity, reinforcing the reliability of customs procedures. In this regard, the adoption of this technology emerges as a key tool for optimizing and modernizing customs processes, promoting efficiency and trust in international trade. Thus, Blockchain marks a decisive step toward the transition to smart customs, paving the way for a more agile and secure global trade environment.

The primary objective of this research is to evaluate the impact of paper use in customs procedures and analyze how Blockchain technology can contribute to improving their efficiency. To achieve this, the following specific objectives have been established:

- Investigate the document review times of Mexico's main trading partners in Latin America to assess the current efficiency of these processes.
- Evaluate the benefits of Blockchain technology in optimizing customs procedures, focusing on its contribution to improving efficiency and streamlining operations in customs.
- Conduct a case study on a Blockchain-based project in the customs sector in Latin America, analyzing the problem addressed, the solution implemented, and the results obtained.

To achieve these objectives, a mixed-methodological approach was adopted, combining quantitative and qualitative research. In the quantitative component, a statistical analysis of the times associated with document compliance in import processes was conducted. In the qualitative component, a detailed case study of the CADENA project was carried out, using reports and documentation related to this initiative as primary sources.

2. Theoretical Framework

According to the World Economic Forum (2022), TradeTech is defined as the set of technologies designed to enhance the efficiency, inclusivity, and sustainability of global trade. These technologies, which include Artificial Intelligence, Robotics,

Blockchain, Distributed Ledger Technology, the Internet of Things, and 3D Printing, among others, have the potential to accelerate international trade, benefiting both consumers and businesses [1]. Their impact ranges from improving transparency to increasing efficiency in commercial processes.

As noted by Gobel (2022), TradeTech pursues two main objectives [2]. The first is to facilitate the transition of commercial processes from an analog to a digital format. The second is to optimize and coordinate international trade through the implementation of technological innovations, aiming to create smoother and more seamless commercial processes.

One of the primary challenges of the global supply chain is the excessive use of paper in customs procedures, which causes delays in the delivery of goods to the end consumer. In this context, Blockchain technology emerges as a promising solution. According to Belu (2020), Blockchain enables the efficient storage of international trade documents, allowing importers, exporters, banks, and customs authorities to access and verify information online, eliminating the need for paper [3]. Furthermore, documents are generated automatically, minimizing manual intervention and ensuring that any modifications are recorded.

Port operators receive a single version of documents as soon as they are uploaded to the network, eliminating the need to share multiple copies with various organizations [4]. According to Yaren (2020), the use of Blockchain in customs procedures establishes a single source of truth, improving risk assessment and reducing administrative costs. Additionally, sharing data through Blockchain facilitates end-to-end information flow [5,6]. Smart contracts, on the other hand, have the potential to automatically add relevant information to Blockchain-based ledgers for document presentation and validation [7].

As stated by Rehmani (2021), Blockchain technology is a distributed and decentralized digital ledger, meaning that information is stored across multiple devices without relying on a centralized entity [8]. Among its key benefits are:

- Decentralization: It is not controlled by a central entity, giving users full control over their data.
- Transparency: Anyone can track the history of transactions, ensuring clarity in operations.
- Immutability: Once a transaction is validated, it cannot be altered.
- Security: Operations are verified through consensus methods, using encryption and verified connections with previous transactions [9].
- Traceability: It allows tracking of any transaction in the ledger [8].
- Availability: Being distributed and decentralized, the ledger is accessible to all nodes.
- Automation: Smart contracts automatically trigger transaction steps or processes when predefined conditions are met, reducing human intervention and reliance on third parties [9].

The functioning of Blockchain is based on several essential steps. Users initiate a transaction on the network, which may involve contracts, cryptocurrencies, or information records. This transaction is converted into a block, which is distributed to all network participants. Each participant reviews and validates the block through a consensus algorithm to ensure agreement. Once validated, the block is added to the network, marking the transaction as complete. Importantly, once added and validated, the block becomes permanent and immutable, ensuring transparency and security [10].

Smart contracts are computer programs that automate tasks under predefined conditions, executing automatically based on the rules encoded in the blockchain. Unlike traditional contracts, they not only establish terms but also execute automatically. They operate on IF-THEN logic, setting conditions and corresponding actions, offering advantages such as transparent records, transaction autonomy, reduced fraud, and increased trust. Additionally, they are cost-effective by eliminating intermediaries and reducing costs [11]. Blockchain oracles are essential for smart contracts, as they enable real-time interaction with external data, facilitating the communication of real-world information and allowing decisions based on this data [12].

Currently, there are four types of Blockchain: public, private, consortium, and hybrid. Public Blockchain is decentralized, open, and pseudo-anonymous, with transparency and security based on incentives. However, it has disadvantages such as total transparency, slowness, high energy consumption, and vulnerability to 51% attacks. Private Blockchain stands out for its high security, fast transactions, and centralized control, making it efficient in organizational environments. Nonetheless, it faces challenges such as vulnerability to attacks, trust issues, and the risk of data manipulation by authorities.

Consortium Blockchain is used for business collaboration, offering decentralization, fast transactions, and high security, complying with regulations and being resistant to 51% attacks. However, it has limitations in decentralization and transparency. Finally, hybrid Blockchain combines the best of public and private Blockchains, maintaining data privacy despite having public access [13].

3. Materials and Methods

This study examines the impact of paper use in customs procedures and the potential of Blockchain technology to enhance efficiency in the customs processes of Mexico's main trading partners in Latin America. The research adopts a qualitative approach based on the case study method, following the framework proposed by Chang et al. (2019), who argue that this method is particularly useful for analyzing complex phenomena in their real-world context, especially when seeking to understand how and why certain technological solutions can transform traditional processes [14].

The case study focuses on the CADENA project, a Blockchain-based initiative implemented in five Latin American countries

(Mexico, Costa Rica, Peru, Chile, and Colombia) and led by the Inter-American Development Bank (IDB). This project addresses the challenges associated with cross-border data exchange in the context of the Authorized Economic Operator (AEO) program, using a hybrid Blockchain platform to streamline and secure customs processes.

The case study approach allows for an in-depth and detailed analysis of the problem, the implemented solution, and the results achieved in the CADENA project. Through this method, the study aims to understand how Blockchain technology can optimize customs procedures, reduce document review times, and improve efficiency in international trade. Additionally, it analyzes the specific benefits of Blockchain implementation, such as transparency, immutability, and automation through smart contracts.

Data is collected through the documentary review of technical reports, academic publications, and official documentation provided by the IDB. This approach enables a rigorous assessment of the feasibility and impact of Blockchain technology on customs processes, offering valuable insights for the modernization of customs administrations in Latin America.

4. Results

The excessive use of paper in customs procedures represents a significant obstacle to the global supply chain, as it slows down processes, causes delays in the delivery of goods, and undermines operational efficiency. According to McDaniel (2019), the movement of goods across borders involves the meticulous preparation of documentation at each stage of the process, with verifications carried out by multiple entities, which increases complexity and the time required [15].

In this regard, Radl and Sotelo (2021) emphasize that processing international trade operations at a border crossing involves, on average, the exchange of approximately 36 documents and up to 240 copies when financing is considered [16]. Furthermore, a single container shipment can generate up to 200 communications, with administrative costs estimated at 15% to 20% of the total cost of transporting the goods [17]. These figures highlight the magnitude of the problem and the inherent inefficiency of paper-based processes.

The reliance on paper in customs procedures not only contributes to delays in the delivery of goods but also creates disruptions in the supply chain, affecting its fluidity and competitiveness. To assess the effectiveness of customs procedures in Latin America, this research focuses on analyzing the time required by customs authorities to conduct document reviews in Mexico's main trading partners in the region. To quantify this indicator, the time to import in terms of document compliance will be used, with data provided by the World Bank (2023b) [18].

Document compliance is a process that encompasses the acquisition, preparation, processing, and submission of

documents related to shipments, including both electronic and printed documents required by government agencies. The time is measured in hours, where one day equals 24 hours, and the data is pre-sented according to the survey year [19]. This indicator will allow for an evaluation of the efficiency of customs processes and their impact on the supply chain.

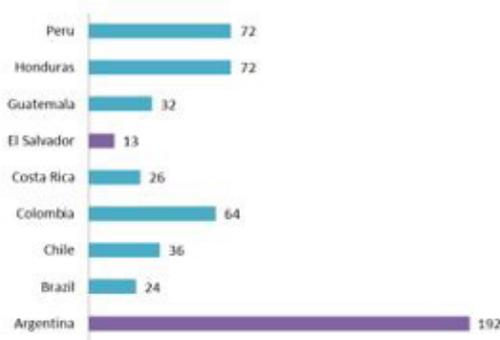


Figure 1: Time for Documentary Compliance to Import, 2018

Figure 1 highlights that Argentina faces a prolonged customs process, with a document compliance time of 8 days (192 hours), significantly affecting importers and the country's macroeconomic efficiency. In contrast, El Salvador demonstrates greater agility, with a processing time of just 13 hours, although it still falls short of optimal efficiency levels. Overall, all of Mexico's trading partners in Latin America exhibit deficiencies in document compliance, underscoring the negative impact of physical paper use on the efficiency of customs processes.

These results emphasize the critical importance of improving efficiency in customs procedures, particularly through the implementation of emerging technologies, when evaluating trade relations between Mexico and its Latin American partners. According to Radl and Sotelo (2021), paper-based document exchange is estimated to reduce the potential of international trade by 15%. However, the digitization and modernization of customs and logistics processes could recover this lost percentage, significantly boosting regional trade [15].

The implementation of Blockchain technology in customs procedures emerges as a promising solution to streamline these processes. A notable example is the CADENA project in Latin America. Led by the Inter-American Development Bank (IDB) in collaboration with customs authorities from five countries (Mexico, Costa Rica, Peru, Chile, and Colombia), this project began in February 2018 as a Blockchain-based proof of concept. CADENA addresses the challenges of managing cross-border data exchange among companies in Latin America and the Caribbean, demonstrating the potential of this technology to optimize customs processes [20].

This project focuses on addressing the issues associated with the implementation of Mutual Recognition Arrangements (MRAs) in the context of the Authorized Economic Operator (AEO) program. Although the AEO program provides significant benefits

to certified companies, the lack of an efficient mechanism for the automated and secure exchange of AEO certification data between countries hinders the effectiveness of MRAs. This problem is exacerbated by the increasing number of MRAs and the signing of new plurilateral or multilateral agreements, which compromises the ability to grant customs benefits in a timely and effective manner. As a result, trade facilitation and the security of international supply chains are negatively impacted.

Currently, the mechanism for companies to access MRA benefits involves data exchange via email with the AEO program managers in each customs administration. This process consists of the monthly submission of an Excel file containing information about AEO-certified companies. The received data is incorporated into the customs risk management systems, assigning a lower risk rating to AEO importers whose trading partners in exporting countries are also AEO-certified. However, this manual and inefficient method limits the overall effectiveness of the process.

The main objectives of this project are (IDB, 2020) [20]:

- To provide a solution that facilitates data exchange, adhering to international standards set by the World Customs Organization (WCO), using its data model and applying the Harmonized Identification Number (TIN).
- To establish an automated and reliable mechanism for exchanging AEO data between customs authorities.
- To make available a tool that enables real-time sharing of updates to AEO certificates.
- To integrate AEO data with the risk management systems of customs administrations.

To achieve these objectives, the CADENA project was implemented, based on a hybrid Blockchain that combines elements of public and private chains. This choice benefits both public and private sector actors. The selected Blockchain is LACChain, built on Hyperledger Besu and based on Ethereum. LACChain is characterized as public, decentralized, transparent, low-cost, non-cryptocurrency-based, non-anonymous (allowing for regulation), and with privacy functionalities enabled [21]. Additionally, it uses the Proof of Authority (PoA) protocol, where transaction validation is based on the identity of the nodes, granting the right to generate blocks to those that have demonstrated authenticity. This approach highlights the importance of identities in the Blockchain context [22].

LACChain networks consist of two main groups of nodes: core nodes and satellite nodes, each with specific roles and functions.

Core Nodes:

1. Validator Nodes:

- Participate in the consensus protocol and are responsible for generating new blocks.
- Are exclusively connected to each other and to boot nodes to ensure network security and efficiency.

2. Boot Nodes:

- Serve as the link between validator nodes and satellite nodes.
- Listen to writer nodes, transmit information to validator nodes, and update satellite nodes on newly generated blocks.
- Are responsible for creating new nodes in the network, providing the essential information for their operation.

Satellite Nodes:

1. Writer Nodes:

- Issue transactions to the network.
- Communicate transactions to boot nodes, which then relay them to validator nodes.
- Are connected to boot nodes and other writer nodes.

2. Observer Nodes:

- Have read-only permissions on the blockchain.
- Are exclusively connected to boot nodes [23].

According to LACNet (2023), LACChain is an Ethereum-based network, meaning that transactions require the payment of a fee called "GAS." However, LACChain has eliminated the underlying cryptocurrency "ether" and the associated transaction fees. Instead, it uses a protocol that dynamically allocates GAS to authorized writer nodes, depending on network load [22]. GAS is not distributed directly to users but is managed through smart contracts. Writer nodes allow end users to use their node and GAS to conduct transactions, with a distribution algorithm based on membership levels. This approach aims to balance access and network usage, improving the efficiency and sustainability of permissioned public Blockchain platforms.

In the case of the CADENA project, each participating customs administration in the region requires a writer node that generates transactions through the application. This structure ensures the necessary infrastructure for the system's operation. On one hand, core nodes are maintained by the entities participating in LACChain. On the other hand, customs administrations have independence and autonomy to operate through their satellite node, which they can also use for other Blockchain applications beyond CADENA. This allows for the scalability of Blockchain functionality in customs. Additionally, the structure is flexible enough to incorporate new customs administrations as they sign additional Mutual Recognition Arrangements (MRAs). LACChain offers a unique opportunity by providing sustainability, scalability, and additional functionalities for CADENA and, more broadly, for customs administrations, facilitating transnational data exchange [19].

According to the IDB (2020), CADENA functions as a platform that facilitates data exchange between customs administrations in the context of the Authorized Economic Operator (AEO) certification. Once a company obtains AEO certification in Country A, its data is uploaded to the CADENA application, following an approval flow by various customs officials in Country A. Customs Administration B, which has an MRA with Country A, receives email notifications, allowing its officials to access the certified company's data through CADENA. Additionally, customs

administrations can automate the connection between the AEO certification management module and CADENA via APIs, and even link it to a Single Window for Foreign Trade. Furthermore, CADENA can integrate with customs risk management systems to grant benefits to AEO-certified companies' operations, reducing the level of inspection required.

The CADENA project offers three main benefits: improved implementation of bilateral or multilateral agreements, optimized management of AEO programs in customs administrations, and enhanced supply chain security through real-time notifications of AEO certifications, suspensions, and cancellations. These benefits translate into greater efficiency and transparency in customs and international trade processes. The results obtained from the CADENA project demonstrate that information exchange can be effectively conducted using Blockchain technology, ensuring the reliability and security of the process. The uploaded and shared information remains constantly available, ensuring access at all times. Additionally, secure and reliable data exchange between customs administrations is achieved, strengthening international cooperation. One of the most notable aspects is the ability to track changes in the status of AEO certificates, providing a clear and updated record of modifications, which facilitates traceability and control.

The application also ensures data transparency, with precise control over who can access the data, preventing unauthorized manipulation. Similarly, it guarantees the integrity of stored data, protecting it against alterations or losses. Another significant result is the ability to quickly activate or suspend MRA benefits, allowing for agile adaptation to operational needs. Moreover, efficient digitization and automation of data exchange between MRA parties are achieved by digitizing the status of AEO certificates, simplifying and streamlining processes. Finally, CADENA contributes to the creation of a digital identity that legitimizes companies as trustworthy and secure entities, supporting the records uploaded to the solution (IDB, 2020). This aspect not only strengthens companies' reputations but also promotes a safer and more transparent international trade environment [19].

5. Discussion

The results of this study highlight the urgent need for digital transformation in Latin American customs, particularly in the context of paper-based documentary procedures, which generate significant inefficiencies in international trade. The research has shown that, despite differences in documentary compliance times between countries such as Argentina (8 days) and El Salvador (13 hours), all of Mexico's trading partners in the region face common challenges related to delays and reliance on manual processes. These inefficiencies not only affect the competitiveness of businesses but also limit the potential for regional trade growth.

The CADENA project, based on Blockchain technology, emerges as an innovative and effective solution to address these challenges. The implementation of this technology has proven to be a key catalyst for the modernization of customs, enabling secure and

efficient data exchange between countries, as well as real-time traceability of Authorized Economic Operator (AEO) certificates. These advancements are fundamental for the transition toward Customs 4.0, a concept that integrates advanced technologies to optimize trade processes and enhance regional competitiveness.

Blockchain technology has demonstrated its ability to reduce documentary review times, automate processes through smart contracts, and improve data transparency and integrity. In the case of CADENA, the implementation of a hybrid Blockchain, based on LACChain, has enabled the creation of a decentralized and secure system that facilitates information exchange between customs authorities. This approach not only streamlines processes but also strengthens trust among stakeholders by ensuring the immutability and traceability of data.

One of the most notable aspects of CADENA is its ability to improve the management of Mutual Recognition Agreements (MRAs). By digitizing and automating the exchange of data related to AEO certificates, the project has simplified processes that previously relied on manual and cumbersome methods, such as sending Excel files via email. This not only reduces processing times but also minimizes human errors and enhances operational efficiency.

Furthermore, CADENA has demonstrated that Blockchain technology can be a cornerstone for supply chain security. By providing real-time notifications about changes in AEO certificates, the project strengthens customs' ability to manage risks and ensure the integrity of trade operations. This is particularly relevant in a global context where security and transparency are increasingly important for international trade actors.

The results of this study have significant implications for public policy and customs management in Latin America. First, it is recommended to expand the CADENA project to more countries in the region to maximize its impact and promote greater trade integration. Interoperability between customs authorities in different countries is essential to creating a more fluid and efficient trade environment.

Second, it is crucial to explore new use cases for Blockchain technology in the customs domain. For example, the generation of digital documents, the automated management of permits, and integration with other foreign trade platforms could expand the benefits of this technology. Additionally, the adoption of international standards, such as those proposed by the World Customs Organization (WCO), would facilitate the implementation of Blockchain-based solutions in different contexts. Finally, it is important to emphasize that the digital transformation of customs is not just a technological issue but also a cultural and organizational one. To achieve successful adoption of these technologies, it is necessary to train customs officials, foster collaboration between the public and private sectors, and promote a culture of innovation within customs institutions.

Although this study has provided valuable insights into the potential of Blockchain technology in customs, it is important to acknowledge its limitations. First, the analysis has focused on a specific case study (CADENA), which limits the generalizability of the results. Future research could expand the scope of the study by including more projects and countries to assess the feasibility and impact of Blockchain in different contexts.

Additionally, the study has primarily relied on secondary data, such as technical reports and official documentation. It would be beneficial to complement these findings with primary data, such as interviews with customs officials and key stakeholders of the CADENA project, to gain a more comprehensive perspective on the challenges and opportunities associated with Blockchain implementation.

In conclusion, this study has demonstrated that Blockchain technology is a powerful tool for the digital transformation of customs in Latin America. Its ability to improve efficiency, transparency, and security in customs processes makes it a fundamental pillar for the modernization of international trade. However, to maximize its potential, it is necessary to address the technical, organizational, and cultural challenges associated with its implementation. The expansion of projects like CADENA and the exploration of new use cases are key steps toward a more efficient and competitive future for customs in the region.

6. Conclusions

The results of this study reveal notable deficiencies in the document review processes of Mexico's main trading partners in Latin America. Argentina recorded the longest document compliance time, at 8 days (192 hours), while El Salvador stood out with just 13 hours. Despite these variations, all Latin American customs administrations exhibit delays in document compliance, underscoring the urgent need to advance toward digital transformation in the customs sector. The reliance on manual and paper-based processes not only slows down international trade but also limits the region's competitiveness. In this context, Blockchain technology emerges as a key solution to modernize customs, driving their transition toward more efficient and digitized models.

The CADENA project has successfully demonstrated how Blockchain technology can serve as a catalyst for digital transformation in the customs domain. This project ensures efficient data exchange, establishing a secure channel between customs administrations and enabling precise traceability of Authorized Economic Operator (AEO) certificates. Among its main advantages are transparency, access control, and the ability to activate or suspend benefits immediately, significantly simplifying Mutual Recognition Arrangement (MRA) processes. Furthermore, efficient digitization and automation are combined with the creation of a reliable digital identity, strengthening the legitimacy of companies and promoting supply chain security. These advancements are fundamental to the digital transformation of customs, as they enable the migration from outdated analog processes to integrated and automated digital systems.

In this regard, CADENA represents a crucial step for Mexico and the region toward the transition to Customs 4.0, a concept that integrates advanced technologies to streamline trade exchanges automatically and efficiently. This model is a cornerstone of digital transformation, as it not only optimizes customs processes but also lays the groundwork for greater regional integration and smoother international trade. However, to maximize its potential, it is crucial to expand its integration with more Latin American countries and explore diverse use cases, such as the generation of digital documents, automated permit management, and interoperability with other foreign trade platforms. These steps would allow for a comprehensive evaluation of the project's efficiency and solidify its role as a catalyst for digital transformation in the customs sector.

Despite the inherent challenges of implementing new technologies, CADENA demonstrates that Blockchain technology is essential for driving more effective, intelligent, and secure trade. Its adoption not only optimizes customs processes but also contributes to the digital transformation of customs, aligning their operations with the principles of the fourth industrial revolution. This technological advancement enables customs administrations to modernize, reduce operational costs, improve transparency, and offer more agile services to international trade stakeholders. Ultimately, the digital transformation of customs is not just a necessity but an opportunity to strengthen the region's competitiveness in the global arena.

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