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Port Intelligence: How the Internet of Things Can Optimize
OPERATIONAL EFFICIENCY OF PORTS
SMART PORTS: HOW THE INTERNET OF THINGS OPTIMIZES PORT OPERATIONAL EFFICIENCY
PORT INTELLIGENCE: HOW THE INTERNET OF LAS THINGS CAN OPTIMIZE
THE OPERATIVE EFFICIENCY OF LOS PUERTOS

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SUMMARY:
This study addressed the modernization of the port sector through the advancement of digital technologies, emphasizing the role of smart ports and the Internet of Things in optimizing logistics operations. From this perspective, the overall objective of this work was to analyze how the Internet of Things contributed to optimizing port operational efficiency in the context of smart ports, considering its impacts on monitoring, automation, and logistics decision-making. The methodology was developed based on a qualitative, descriptive, and exploratory approach, through bibliographic research conducted using scientific articles in Portuguese, published in the last ten years and fully available in open and free databases such as SciELO and Google Scholar. The results showed that the Internet of Things favored greater visibility of operations, process automation, cargo tracking, predictive maintenance, data integration, and improved operational safety, contributing to cost reduction and more efficient use of port infrastructure. It was also found that the implementation of this technology depended on investments in digital infrastructure, interoperability between systems, data protection, and professional training. It was concluded that the Internet of Things represents a strategic resource for strengthening smart ports, making port operations more integrated, efficient, and competitive.

Keywords: Smart ports. Internet of Things. Port operational efficiency.

ABSTRACT:
The present work addressed the modernization of the port sector through advances in digital technologies, with an emphasis on the role of smart ports and the Internet of Things in optimizing logistics operations. From this perspective, the general objective of this work was to analyze how the Internet of Things contributed to optimizing port operational efficiency in the context of smart ports, with a focus on its impacts on monitoring, automation, and logistics decision-making. The methodology was developed using a qualitative, descriptive, and exploratory approach through bibliographic research based on scientific articles in Portuguese published in the last ten years, fully available in open, free databases such as SciELO and Google Scholar. The results showed that the Internet of Things favored greater operational visibility, process automation, cargo tracking, predictive maintenance, data integration, and improved operational safety, contributing to cost reduction and more efficient use of port infrastructure. The implementation of this technology also depends on investments in digital infrastructure, interoperability between systems, data protection,
and professional training. The conclusion was that the Internet of Things is a strategic resource for strengthening smart ports, making port operations more integrated, efficient, and competitive.
Keywords: Smart ports. Internet of Things. Port. Operational efficiency.

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1. INTRODUCTION

In recent decades, the port sector has undergone noticeable transformations due to...
The advancement of digital technologies and the growing need to increase efficiency levels,
Security and integration of logistics operations. In this scenario, ports have ceased to be...
understood only as physical structures aimed at moving cargo, they have become
analyzed as strategic environments for the circulation of goods, information, and services.
The expansion of international trade, the pressure to reduce operating costs, and the demand
The need for greater agility in logistics flows has driven the search for technological solutions capable of...
to respond to the contemporary challenges of port activity. It was in this context that the concept
The concept of smart ports has gained prominence, associated with the adoption of digital tools aimed at...
Real-time monitoring, process automation, and improved decision-making.

Among these innovations, the Internet of Things stood out as one of the most significant technologies.
promising for the modernization of the port environment. Based on the connection between sensors,
devices, machines, and computerized systems, the IoT has enabled the collection, processing, and
Continuous data sharing, promoting greater visibility of operations and contributing
for more efficient coordination of logistics activities. In the port environment, this
Technology has been applied in different areas, such as cargo tracking,
Equipment monitoring, vehicle flow control, yard management, supervision.
of environmental conditions and predictive asset maintenance. In this way, the connectivity between
Objects and systems were understood as a central element for increasing productivity and reducing costs.
operational failures and expanding the responsiveness of ports to market demands.
global.

The discussion about smart ports was also related to the broader movement of
The digital transformation observed in logistics chains and production systems. The incorporation
Technologies such as the Internet of Things, big data, artificial intelligence, and automation have become
to redefine managerial and operational practices in different economic sectors, especially
in those characterized by high complexity and dependence on infrastructure, as is the case of
port logistics. In this sense, IoT has been recognized not only as a technical innovation,
but also as a strategic resource for integrating information, improving processes and
Strengthening organizational competitiveness. Studies on logistics and operational management have indicated
that connectivity between devices has facilitated greater accuracy in monitoring
activities, which supported faster and more informed decisions (Lopes; Moori, 2021).

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Despite the advantages associated with adopting the Internet of Things, its implementation in
The modernization of the port sector did not happen automatically, nor was it without difficulties.
The technological advancements required investments in digital infrastructure, system integration, and skills development.
professional and adaptation of management models. Other challenges also arose related to
information security, interoperability between platforms, data reliability
collected and to institutional resistance to organizational changes. In port environments, where
Multiple agents, simultaneous operations, and high logistical complexity coexist,
The incorporation of new technologies demanded careful planning and coordination between different [groups/entities].
sectors. Thus, the discussion about the benefits of IoT needed to be accompanied by an analysis.
A critique of its limitations, obstacles, and specific conditions of application.

From this perspective, the problem addressed in this work was formulated based on the following question:
How has the Internet of Things optimized port operational efficiency in the context of...
Smart ports? This question proved to be very relevant, as the adoption of technologies
Connecting the port sector represented not only an instrumental change, but also a
A transformation in the way operations are planned, monitored, and executed. Investigate this issue.
It allowed us to understand how the use of sensors, smart devices, and integrated systems
It contributed to improving operational performance, reducing waste, and expanding control.
logistics and making ports more prepared for the demands of the contemporary economy.

The rationale for conducting this study was based, firstly, on its relevance.
The economic and logistical importance of ports for regional, national, and international development. How?
As strategic points for the circulation of goods, ports play an essential role in
The dynamics of trade and the supply chain, so that improvements in its efficiency...
Operational factors have a direct impact on competitiveness, logistics costs, and the quality of...
services provided. Thus, understanding the potential of the Internet of Things in this context.
It proved relevant to analyze modernization paths capable of making processes more
Agile, secure, and integrated.

Furthermore, the topic is relevant due to its current importance in the field of Analysis and Development.
of Systems, since it involves the practical application of digital technologies in a large sector.
structural relevance. The study made it possible to relate concepts of connectivity, automation,
monitoring data and integrating systems into concrete port management problems.
highlighting how technological solutions can generate significant operational impacts.
It also proved important in encouraging reflection on the role of intelligent systems.
in solving complex logistical challenges, bringing academic training closer to the demands
real market conditions and ongoing digital transformations. In this sense, recent literature has pointed out

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that the Internet of Things has taken on an increasingly strategic role in optimizing processes and in strengthening operational performance in logistics and organizational environments (Agostino; Ristow; Rodriguez, 2021).

When discussing smart ports as spaces of convergence between infrastructure, Technology and management: the study sought to highlight the digital transformation of port activity. It depends not only on the adoption of modern equipment, but also on the ability to integrate. Data, processes, and decisions in an efficient and strategic way.

The overall objective of this work is to analyze how the Internet of Things has contributed for the optimization of port operational efficiency, within the context of concepts recognized up to the Currently, there is significant research in the literature on smart ports, considering their impacts on monitoring, in Automation and logistics decision-making. Specifically, the aim was to identify... main concepts and applications of the Internet of Things in the port environment, with emphasis on the technologies used in smart ports; examine how the adoption of devices Connected systems, sensors, and automated systems have contributed to process improvement. operational tasks, such as cargo handling, equipment control, and logistics management. port infrastructure; and to assess the benefits and challenges of implementing the Internet of Things in ports. considering aspects such as efficiency, cost reduction, operational safety and integration of data.

2. THEORETICAL FRAMEWORK

2.1 Smart ports: concepts, characteristics and evolution

The modernization of ports was driven by the need to make operations more efficient. Faster, more integrated and safer logistics in the face of the growth of international trade and... intensification of the flow of goods. In this scenario, ports came to be understood not only as embarkation and disembarkation areas, but also as strategic structures for The circulation of goods, information, and services. Technological evolution applied to this sector. This fostered the emergence of the smart port concept, associated with the use of digital tools. capable of expanding the capacity for monitoring, coordinating, and managing port activities. Thus, the transformation of ports accompanied a broader movement towards digitalization. of supply chains, in which connectivity and data processing have taken on a central role.

The concept of a smart port has been linked to the incorporation of digital technologies that They enabled greater integration between physical infrastructure, information systems, and...

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operational processes. In general terms, this model involved the use of technological resources. focused on automation, real-time monitoring, and data analysis, aiming to improve the performance of operations. This perspective brought the port environment closer to discussions about smart cities, since both contexts were based on the articulation between technology, connectivity and efficient management of available resources (João; Souza; Serralvo, 2019).

When considering the characteristics of a smart port, elements such as the following stood out. Connectivity between devices, continuous data sharing, automation of routines, Integration between different logistics agents and faster response capacity in the face of failures. or operational variations. This model assumed a more dynamic and driver-oriented management. information, allowing detailed tracking of cargo, vehicles, equipment and... traffic flows. Thus, port intelligence is no longer limited to technical knowledge. of the operation and also came to depend on the ability to collect, interpret and use data from A strategic approach to improving decision-making.

Furthermore, the evolution of smart ports has been directly linked to the advancement of... Emerging technologies applied to the logistics sector. Among these technologies, the following stood out: Internet of Things, cloud computing, *big data,* artificial intelligence and systems automated control systems. The combined use of these resources has contributed to transforming the port environment in an increasingly connected and data-driven space, strengthening the competitiveness and operational efficiency. In this context, digital transformation was understood as a process that went beyond simply acquiring modern equipment, requiring also changes in organizational culture, information management and coordination of logistics activities (Lopes; Moori, 2021).

Historically, port development has occurred in stages marked by different levels of Mechanization, computerization, and technological integration. Initially, these prevailed. predominantly manual operations, with a low level of automation and a strong dependence on human intervention in virtually all phases of the process. Subsequently, the incorporation of Machines, management *software ,* and electronic systems have begun to change this scenario, reducing Some operational limitations are being addressed, while expanding the capacity to control activities. More Recently, with the consolidation of digital transformation, ports have begun to incorporate connected devices, sensors, and smart platforms, which made it possible to Development of more precise, traceable, and interdependent operations.

This modernization trajectory was also related to demands for greater efficiency. and predictability in supply chains. In an increasingly interconnected logistics environment, Ports have ceased to function as isolated units and have become integrated into complex networks of

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transportation, storage, and distribution. As a consequence, port efficiency has increased.
to depend not only on local infrastructure, but also on the ability to communicate between
different systems and agents are involved in the movement of goods. Recent literature
It has shown that the digitalization of logistics has allowed for greater synchronization between processes, favoring
operational performance gains and better use of available resources (Agostino;
Ristow; Rodriguez, 2021).

Another important aspect in defining smart ports was the centrality of the flow of
Information. Port operations involve multiple stages and different actors, such as operators,
Transport companies, port authorities, warehousing companies, and regulatory bodies. In
In traditional structures, the fragmentation of information made it difficult to coordinate processes and
This compromised operational agility. In the context of smart ports, however, the use of technologies...
Integrated systems facilitated the continuous flow of data, allowing for greater transparency and a reduction in costs.
Bottlenecks and faster responses to unforeseen events. This change represented not only a
technical advancement, but also a new management logic based on connectivity and decision-making.
Evidence-based decision.

A smart port is not defined solely by the presence of modern machinery or...
sophisticated software, but through the efficient articulation between material resources, digital systems and
management practices. This coordination has become crucial for dealing with challenges such as the increase
due to the volume of cargo, the need to reduce costs, the pressure for sustainability and the
The need for greater operational security. In studies on digital transformation and new models.
In business studies, it was observed that connectivity between devices and systems contributed to
to reconfigure production and logistics environments, favoring smarter forms of management and...
operation (Silva et al., 2023).

Therefore, the evolution of smart ports reflected the shift from one operational model to another.
one focused on mechanization to one driven by connectivity, automation, and use.
Strategic information. This process redefined the role of ports in the economic dynamics.
contemporary, transforming them into technologically integrated spaces and increasingly
dependent on digital solutions to achieve greater efficiency. By understanding the concepts, the
The characteristics and evolution of this model made it possible to analyze more clearly how the
The Internet of Things has become part of this context and has begun to play a significant role in...
Optimizing port operational efficiency.

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2.2 Internet of Things: fundamentals and applications in the logistics sector

The Internet of Things was understood as a set of technologies that enabled... connection between physical objects, sensors, devices and digital systems through networks of communication systems capable of collecting, transmitting, and processing data in real time. This logic of Connectivity has transformed the relationship between the physical world and the informational environment. enabling equipment, machinery, and operational structures to interact in a way Automated and intelligent. In the field of logistics, this innovation has acquired particular relevance because... It facilitated the continuous monitoring of processes, the expansion of control over assets, and... generating useful information to improve management.

In conceptual terms, IoT was based on the integration between sensors, software, connectivity and analytical capabilities, forming an ecosystem in which objects have ceased to... to move beyond simply performing mechanical functions and also take on communicational and informational roles. This meant that different devices could collect location, temperature, and other data. speed, performance, consumption and operating conditions, transmitting this information to platforms capable of organizing and interpreting them. The literature highlighted that the Internet of Things It represented an important step in the digital transformation by promoting greater visibility and Intelligence in organizational and productive environments (Godoi; Araújo, 2019).

The functioning of the Internet of Things depended on an architecture composed of Interconnected elements. First, sensors and devices installed in physical objects. They made it possible to capture data from the environment or from the very functioning of the... equipment. Subsequently, this data began to be transmitted through communication networks, such as wireless internet, radio frequency, or other connectivity technologies. After that transmission, the information was stored and processed in computer systems, which It enabled the generation of automated alerts, reports, diagnoses, and commands. Thus, IoT did not It was not limited to the existence of connected devices, but also involved a continuous flow of data that expanded monitoring and decision-making capabilities.

This dynamic was particularly important in the logistics sector, which is characterized by the need... to coordinate complex operations, distribute resources efficiently, and reduce delays and losses. and failures. The use of the Internet of Things in this context made it possible to monitor, in real time, the transportation of goods, vehicle performance, storage conditions and use of the equipment. In this way, the connectivity between objects fostered a broader view and detailed operational planning, strengthening strategic logistics management and increasing capacity. in response to unforeseen operational events (Lopes; Moori, 2021).

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In the logistics environment, connected devices have begun to perform various functions. various services, ranging from cargo tracking to monitoring the physical condition of products. Sensitive sensors installed in containers, trucks, forklifts, warehouses, and control centers. distribution allowed for the continuous acquisition of data on location, temperature, humidity, vibration and travel time. This information contributed to improving the control of movement of goods and to reduce risks associated with loss, damage and interruptions. in the operational flow. Furthermore, automated data collection has made it possible to replace some of the... Manual controls reduce human error and increase the reliability of information.

Another relevant aspect was the possibility of integrating IoT into broader systems of management and planning. The data generated by the connected devices could be integrated into logistics control platforms, business software, and analytical tools, which favored A more precise and evidence-based administration. In this scenario, the Internet of Things It is no longer seen as an isolated resource and has become part of an integrated digital infrastructure. capable of supporting decisions regarding maintenance, routing, inventory control, yard management and Use of infrastructure. Studies on logistics systems have shown that this integration has expanded the operational coordination capacity and strengthened process efficiency by reducing informational asymmetries and increase the predictability of activities (Agostino; Ristow; Rodriguez, 2021).

The application of IoT to logistics has also been associated with the automation of repetitive tasks and to create smarter operational flows. Instead of relying exclusively on human intervention to record incidents, verify transport conditions, or identify Due to deviations, connected systems began to perform some of these functions automatically. It made it possible, for example, to issue alerts when certain equipment presented a risk of... failure, when a load deviated from its planned route or when environmental conditions exceeded acceptable parameters. With this, logistics began to operate with greater preventive capacity, Reducing waste and improving the use of time and resources. (emphasis added)

In addition to operational gains, the Internet of Things has brought significant impacts to management. Strategic supply chain technology. By making flows more visible and measurable, technology contributed to strengthening the integration between suppliers, carriers, logistics operators and customers. This led to faster decisions, better alignment between the stages of the supply chain, and greater Transparency in monitoring operations. In research on logistics and performance. Operationally, it was observed that IoT positively influenced strategic management by enabling more coordinated, agile processes driven by reliable data (Lopes; Moori, 2021).

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However, incorporating the technology required attention to important challenges. The implementation of IoT presupposed investments in connectivity infrastructure and security. Information, data storage, and integration between diverse systems. Furthermore, the large... The amount of data generated by connected devices demanded technical capacity for the processing and interpreting this information.

Thus, the Internet of Things has established itself as a strategic technology for the sector. Logistics, by allowing greater control, integration, and automation of operations. Its fundamentals. They were based on the connectivity between objects, the continuous generation of data, and the use of these. Information to improve processes and decisions. Understanding these fundamentals was essential for analyzing, in a more specific way, how IoT has come to be applied to the context of smart ports and how they contributed to the optimization of port operations (Galegale et al., 2016).

2.3 The application of the Internet of Things in smart ports

The application of the Internet of Things in smart ports occurred as part of a broader process of digital transformation of logistics operations and modernization of Port infrastructure. Instead of relying solely on manual controls, communications Due to fragmented activity and limited monitoring, ports began incorporating sensors. connected devices, automated systems, and digital platforms capable of collecting and Sharing information in real time. This change allowed for greater visibility of the flows. operational and contributed to the construction of more integrated environments, in which decisions Decisions began to be made based on up-to-date data and continuous monitoring.

In the port context, the Internet of Things has been applied to connect equipment, cargo, vehicles, physical structures and management systems, creating a communication network capable of to increase operational efficiency. This process facilitated detailed monitoring of Activities related to loading, unloading, storage, and internal circulation, reducing errors. resulting from a lack of information or delays in identifying problems. By integrating Thanks to sensors and digital systems, ports have begun to operate with greater precision and capacity. response, strengthening logistics control practices and process automation (Agostino; Ristow; Rodriguez, 2021).

One of the most relevant applications of IoT in smart ports has been monitoring in Real-time monitoring of operations. Sensors installed on handling equipment, containers, Vehicles and circulation areas began to provide continuous data on location, time of...

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Operation, operating conditions, and cargo flow. With this, it became possible to identify
Identify bottlenecks more quickly, anticipate delays, and adjust routines more dynamically.

In addition to monitoring, the Internet of Things has also been applied to automation.
Equipment and processes. Cranes, forklifts, weighing systems, access gates and
Inspection devices began to operate with the support of sensors and communication mechanisms.
allowing tasks to be performed with less manual intervention. This automation did not mean...
Not the complete elimination of human intervention, but rather the reorganization of activities to reduce errors.
operational goals include increasing productivity and improving the predictability of routines. In studies on
Automation at the Port of Santos has shown that technological advancements in dockside equipment are significant.
This was associated with the expectation of operational gains and greater control over port activities.
(Nardi; Lima; Silva, 2023).

Another important application of IoT was the tracking of cargo along the way.
different stages of the port logistics process. The use of smart labels, sensors of
Location and connected devices made it possible to track the movement of the containers since
From entry into the port to loading or retrieval. This tracking has fostered greater transparency.
In operations, it reduced the risk of losses and misplacements and strengthened control over delivery times.
The movement and handling of goods. In highly complex port environments,
This ability to locate and monitor assets in real time represented a significant advancement.
for the efficiency and reliability of the services provided.

The Internet of Things has also contributed to the control of internal logistics flow.
especially in vehicle circulation areas, yard organization, and planning of
Space occupancy. By collecting data on truck entry and exit, the availability of
In areas such as waiting times and internal movement, connected systems have come to support a
More rational management of port infrastructure. This type of application reduced the
It reduced congestion, improved the distribution of operations, and contributed to making the environment more...
Fluid and predictable. In analyses of maritime traffic control systems and port management,
It was observed that the expansion of information control promoted greater security and better
performance of circulation and logistics coordination operations (Silva; Moreira, 2024).

Another key aspect was the integration of data from different sources. In
In a smart port, IoT did not act in isolation, but rather in conjunction with management systems.
Logistics platforms, planning software, and analytical tools. This integration enabled
To gather previously scattered information and transform it into useful knowledge for decision-making.
In this way, managers and operators gained access to more comprehensive control panels.

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capable of indicating the state of operations, pointing out failures, suggesting adjustments, and facilitating planning. of corrective or preventive actions.

This ability to generate continuous data also favored predictive maintenance of port equipment. Through sensors that monitored temperature, vibration, the Performance and wear of machines have made it possible to identify early signs of failure and To schedule interventions before unexpected shutdowns occur. This application of IoT was... This is especially relevant in an environment where the unavailability of equipment compromises... directly impacts productivity and operational safety. The literature on the Internet of Things and Logistics management indicated that the automated generation of operational information expanded the possibilities for preventive and predictive maintenance, contributing to better utilization. of assets and to reduce costs resulting from unplanned interruptions (Lopes; Moori, 2021).

In addition to technical and operational gains, the application of IoT in smart ports also... reinforced a new management culture based on connectivity, integration, and intensive use of information. The port came to be understood as a digital ecosystem, in which objects, People and systems interacted continuously to ensure greater efficiency, safety, and quality. in the services.

Therefore, the application of the Internet of Things in smart ports has been associated with the creation of more monitored, automated, and integrated operations. From cargo tracking to... In predictive maintenance and logistics flow control, IoT has come to play a role. fundamental in the organization of the contemporary port environment. By allowing the collection and Continuous data processing; this technology has helped to reduce errors, optimize resources, and... Strengthen decision-making. In discussions about digital transformation and connectivity in In organizational environments, it has been observed that the Internet of Things has become established as one of the key tools for reconfiguring operational practices and enhancing the intelligence of systems logistics (Godoi; Araújo, 2019).

2.4 Contributions of the Internet of Things to port operational efficiency

The incorporation of the Internet of Things in the context of smart ports has contributed to a significant way to increase port operational efficiency, especially by expanding the capacity for monitoring, automation, and integration of logistics activities. In a sector characterized by intense cargo circulation, by the need for synchronization between different Due to agents and the reliance on quick responses, the use of connected devices has become...

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To provide more suitable conditions for process control, thereby improving operational efficiency. It ceased to depend exclusively on physical infrastructure and became directly related. to the ability to capture, process, and use data strategically.

Among the main contributions of IoT to port efficiency, the improvement stood out. operational visibility. By enabling real-time monitoring of cargo, equipment, Regarding vehicles and internal flows, this technology has facilitated the identification of faults, delays, and bottlenecks. with greater speed. This enabled more precise and timely interventions, reducing waste. saving time and increasing the fluidity of operations. Studies on logistics systems have shown that... Connectivity between devices and the continuous flow of information have strengthened coordination. of the activities and contributed to superior operational performance (Agostino; Ristow; Rodriguez, 2021).

Another important aspect was the reduction in operational costs. With automated collection With the availability of data and increased control over assets, it has become possible to optimize the use of... equipment, avoid unnecessary travel, reduce downtime, and improve Taking advantage of port infrastructure. In addition, the automation of certain tasks. This helped to minimize human error and reduce rework, which also had an impact on... streamlining the resources used in operations.

The influence of IoT on cost reduction has also been associated with predictive maintenance. of equipment. Sensors installed in machines and structures made it possible to monitor indicators. performance, wear and operation monitoring, making it possible to identify early signs of failure. before they caused more serious disruptions. This maintenance model reduced downtime. Unexpected failures increased equipment availability and prevented losses resulting from them. unplanned interruptions. In the field of logistics management, it has been found that the use of Connected technologies have fostered greater operational predictability and better utilization of resources. physical assets (Lopes; Moori, 2021).

The Internet of Things has also contributed to increased port productivity. automation of routines, continuous cargo tracking, and integration between the different stages of the process. The operation facilitated the execution of processes with greater speed and a smaller margin of error. In Instead of relying on manual records or fragmented communication between departments, operations They began to rely on more consistent information flows, capable of guiding decisions in real-time. This resulted in greater responsiveness to unforeseen events and better Synchronization between loading, unloading, storage, and internal circulation.

These productivity gains were reinforced by the integration between IoT and systems. port management. When the data collected by the sensors began to interact with the

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With planning and control platforms, managers were able to visualize the entire set of operations. with greater clarity and dynamism. This integration made it possible to define priorities, redistribute resources, Reorganize workflows and adjust processes more quickly. In analyses of the relationship between IoT and In terms of operational performance, it was observed that the strategic use of connectivity favored decisions. more efficient and strengthened logistics management in complex environments (Lopes; Moori, 2021).

The improvement of operational safety constituted another significant contribution of the Internet of Things. Things in the ports. Constant monitoring of equipment, circulation areas and conditions. environmental assessments made it possible to identify risks in advance, allowing for preventive actions and faster corrective actions. In a space marked by the movement of heavy loads, by due to the circulation of large vehicles and the intense interaction between people and machines, the Expanding operational control was a decisive factor in reducing accidents and increasing safety. reliability of activities. Thus, efficiency was not limited to increasing speed or Productivity, but it also included the ability to operate more safely.

In the port environment, security was also linked to the improvement of systems. Traffic control and more precise management of internal and external movements. The use of Connected technologies have made it possible to track movements, waiting times, and patterns of circulation, favoring the reduction of operational conflicts and more efficient planning of flows. In studies on the relevance of maritime traffic control systems, it was highlighted that The expansion of informational capacity has contributed both to security and to better performance of port operations (Silva; Moreira, 2024).

Finally, the Internet of Things has contributed to the overall optimization of port infrastructure. by promoting the more rational use of available spaces, equipment, and resources. Starting from Continuous analysis of the data made it possible to better understand the operational patterns. Identify critical points and plan interventions that are more suited to the port's actual needs. This strengthened an evidence-based management approach, capable of supporting improvements. continuous and more strategic decision-making.

2.5 Challenges of implementing the Internet of Things in smart ports

Although the Internet of Things has contributed significantly to the modernization of ports, its implementation in port environments has also been marked by technical challenges, structural and organizational aspects. The adoption of this technology did not depend solely on the installation of sensors, connected devices and digital platforms, but it also required conditions institutional and operational systems capable of sustaining its continuous and efficient functioning.

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Due to the complexity of the port sector, which involves multiple agents and simultaneous operations
With the high volume of information circulating, the incorporation of IoT demanded planning and coordination.
and ongoing investments.

One of the main challenges was the need for adequate technological infrastructure.
For the IoT to function efficiently, the existence of networks became indispensable.
stable communication, data storage systems, compatible equipment and
platforms capable of processing large volumes of information in real time. In many
In certain contexts, the limitations of this infrastructure compromised the full exploitation of its potential.
offered by technology, making it difficult to integrate the different components of the environment.
port infrastructure. Furthermore, technological modernization required considerable financial investments.
which represented an obstacle for organizations with budgetary constraints or low
capacity for structural renewal.

The requirement for high investments was not limited to the acquisition of equipment, but
It also included maintenance costs, system upgrades, and infrastructure adaptation.
Physical and digital. In ports that still operated with traditional or partially traditional structures.
With computerized technologies, the implementation of IoT has implied broad changes, including the redesign of
processes and the incorporation of new management tools. Studies on digital transformation and
New technological models indicated that the adoption of the Internet of Things depended on the capacity
institutional to articulate, in an integrated way, technical, organizational and financial resources (Silva
et al., 2023).

Another important challenge was related to information security and data protection.
generated by connected devices. How the IoT operates through the collection, transmission and
continuous storage of information, exposure to cyber risks, system failures and
Unauthorized access has also increased. In the port environment, this problem has become much more pronounced.
relevance, because of the circulation of data on cargo, operations, asset location and flows
Logistics involves strategic information for the functioning of activities. Therefore, the
The expansion of connectivity has required robust digital security measures, access control, and...
monitoring the integrity of systems.

Concern about information security was also linked to reliability.
of the data used in decision-making. If the data were collected improperly,
transmitted with errors or processed without consistent criteria, the operational results of
IoT could be compromised. This meant that the efficiency provided by connectivity could be jeopardized.
It depended, to a large extent, on the quality of the information produced and the security of the systems.
that supported it. Research on the Internet of Things and digital transformation has shown that the

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The benefits of this technology were directly contingent on the ability to process the data.
with precision, safety and reliability (Godoi; Araújo, 2019).

Interoperability between systems has also proven to be a significant challenge in
Implementation of IoT in smart ports. The port environment brings together different stakeholders,
companies, equipment and management platforms, often developed by suppliers.
distinct and structured according to different technical standards. In this context, the integration between
Systems have not always been simple, which can lead to incompatibilities, communication failures, and...
Difficulties in sharing information. The lack of standardization compromised the...
The fluidity of the processes limited the potential for truly integrated management.

Furthermore, the difficulty of integrating systems directly impacted coordination.
of the operations. When the information remained scattered across disconnected platforms, the
Decision-making has become slower and less precise, reducing the ability to respond to...
Operational problems. The literature on logistics systems has shown that the Internet of Things
It achieved better results when linked to articulated and capable informational environments.
to share data in real time between the various sectors and agents involved (Agostino;
Ristow; Rodriguez, 2021).

Another challenging aspect was related to professional training and adaptation.
Organizational. The implementation of IoT has modified work routines and required new skills.
The techniques changed the way operators and managers interacted with the systems.
port workers. Thus, technological modernization did not depend solely on equipment and software,
but also the preparation of teams to use, interpret and manage the new tools.
available. In many cases, resistance to change, a lack of specialized training, and
Difficulty adapting to new processes constituted significant barriers to the consolidation of
technology.

This issue has become even more relevant because the adoption of IoT has involved a
Transformation in organizational culture. Instead of practices heavily based on experience.
Based on empirical methods and manual controls, ports began to demand a more structured management approach.
driven by data, connectivity, and automation. This shift required not only technical training, but also...
also institutional openness to review traditional processes and incorporate new forms of
Coordination and decision-making. In studies on automation in port operations,
It was observed that the introduction of advanced technologies altered the dynamics of work and generated
Ambivalent perceptions among operators, combining expectations of operational gains with
concerns related to functional and organizational adaptation (Nardi; Lima; Silva, 2023).

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The complexity of the port environment itself also stood out as a challenge, in which The implementation of new technologies needs to consider logistical, regulatory, and other factors. These are very specific operational tasks. Ports handle customs inspections and cargo movement. of diverse natures, safety standards, environmental requirements and intense coordination between actors public and private sectors. This means that any technological innovation process depends on broad participation. Institutional coordination and reconciliation between different interests and requirements. In this way, the adoption of the Internet of Things was not just a technical decision, but also a... A strategic choice that involved governance, planning, and the ability to coordinate between various sectors.

Therefore, the challenges of implementing the Internet of Things in smart ports They range from infrastructure limitations and investment costs to issues related to information security, interoperability between systems, professional training and Organizational adaptation. These factors highlighted the digital transformation in the port sector. It did not occur in a linear or automatic way, but required structural and managerial conditions. specific obstacles were necessary for their benefits to materialize. Understanding these obstacles was fundamental for critically analyzing the limits and possibilities of IoT in improving Port operational efficiency.

3. MATERIALS AND METHODS

The methodology of this work was developed based on a qualitative approach, of descriptive and exploratory in nature, through bibliographic research. This choice was justified by... The objective is to understand how the Internet of Things is being applied in the context of ports. Intelligent technologies and how this technology has contributed to optimizing efficiency. Port operations. The bibliographic research allowed for the gathering, systematization, and analysis of productions. scientific studies already published on the subject, favoring the construction of a consistent theoretical basis. for the proposed discussion.

For the study, scientific articles published in language [language name] were selected. Portuguese data from the last ten years, available in full in open and free databases, with emphasis on SciELO and Google Scholar. As inclusion criteria, works were considered which addressed topics related to the Internet of Things, digital transformation, automation, and logistics. intelligent supply chain, technological innovation and operational efficiency, with emphasis on applications in the port environment.

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The bibliographic material was collected using descriptors such as "Internet of "Things", "IoT", "smart ports", "port operational efficiency", "smart logistics", "Port automation" and "digital transformation in ports." After selecting the publications, An analytical reading of the texts was carried out, with the aim of identifying central, main concepts. Technological applications, operational benefits, and challenges related to IoT implementation. in the port sector.

Next, the literature data were organized by theme, which made it possible to... The interpretation of the content in light of the work's objectives. The analysis focused on... understanding the contributions of the Internet of Things to real-time monitoring, the process automation, systems integration, logistics control and decision-making support decisions in the port environment. Therefore, the methodology adopted provided a broad perspective. and grounded in the topic, contributing to the critical construction of the discussion throughout the study.

4. RESULTS AND DISCUSSION

Analysis of the literature revealed that the Internet of Things has come to occupy a position... strategic in the debate on port modernization, especially due to its ability to integrate data, Equipment and processes in complex operational environments. In the context of ports. intelligent, the results identified indicated that the adoption of sensors, connected devices Digital systems provided greater visibility into operations, which helped to reduce costs. To identify failures, improve cargo tracking, and increase efficiency in infrastructure use.

The reviewed studies showed that IoT has established itself as one of the main foundations. Technological aspects of digital transformation in logistics, precisely because they allow for monitoring. Continuous flow and the generation of real-time information. In broader logistics systems, the authors They identified significant gains in traceability, operational control, and integration between the stages of the supply chain, which also applied to the port environment. By enabling the With precise tracking of cargo, assets, and processes, the Internet of Things has facilitated decision-making. Faster and more well-founded, reducing uncertainties and increasing operational predictability. (Agostino; Ristow; Rodriguez, 2021).

One of the most relevant results found in the literature was the improvement in visibility. of operations. In traditional port environments, some of the operational problems stemmed from fragmentation of information, slow communication between departments, and difficulty of To accurately locate cargo, equipment, and vehicles. With the introduction of technologies

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With the systems being connected, it became possible to monitor internal traffic and usage in real time. infrastructure and the operational status of various assets.

In addition to operational visibility, the literature revealed that IoT has contributed directly to The automation of routines and the reduction of manual tasks. In various logistics applications, Sensors and intelligent systems have begun to replace manual records, repetitive inspections, and... Less precise controls resulted in greater speed and fewer errors. This The movement was particularly important in the port sector, where efficiency depends on coordination between loading and unloading, storage, access control, and circulation of Vehicles and equipment movement. By automating some of these processes, the Internet of Things... Coisas strengthened a more fluid and synchronized operational logic, capable of reducing rework and increase productivity (Lopes; Moori, 2021).

Another recurring point in the analyzed results was the contribution of IoT to... Cargo tracking and control of the port logistics chain. Installation of devices. Intelligent systems in containers, vehicles, and storage areas have expanded the ability to locate goods, track transit times and monitor operational conditions. relevant. This more detailed control helped reduce losses, delays, and failures of communication between the agents involved.

The role of IoT in optimizing the use of port resources was also highlighted. Studies have shown that real-time monitoring of equipment, of The management of spaces and circulation flows has favored a more rational management of the available infrastructure. This occurred because the data captured by the sensors made it possible to identify bottlenecks and redistribute operations, adjust usage schedules, and avoid prolonged periods of inactivity. With this, the Operational efficiency has become a result not only of increased speed of activities, but also the better use of existing resources. This aspect resonated with the literature that It linked connectivity and logistics performance to expanding management capacity and to Strengthening organizational efficiency (Lopes; Moori, 2021).

In terms of operational safety, the results indicated that the Internet of Things It provided greater control over risky situations in the port environment. Monitoring continuous flow of traffic areas, machinery, environmental conditions, and cargo movement. It allowed for the earlier identification of anomalies, contributing to preventive actions and Corrective maintenance. In a sector that deals with heavy loads, large equipment, and intense... With the circulation of people and vehicles, this type of control has taken on central importance. Security, In this case, it proved to be an inseparable component of efficiency itself, since operational failures

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Accidents can disrupt operations, generate additional costs, and compromise reliability.
from the port to the different agents in the logistics chain.

This relationship between efficiency and safety has been reinforced by studies that have analyzed systems.
control of maritime traffic and management of circulation in port areas. The evidence
They showed that the use of monitoring and control technologies contributed to organizing
to improve workflows, reduce operational conflicts, and increase coordination capacity.
activities. Although not all control technology is directly related to IoT, the logic
Continuous monitoring and data integration was at the heart of this process, indicating
that the operational intelligence of ports increasingly depends on the coordination between infrastructure
physical and informational infrastructure (Silva; Moreira, 2024).

Another important finding of the research was related to predictive maintenance. The literature
pointed out that the continuous collection of temperature, vibration, wear and performance data of
The equipment made it possible to identify early signs of failures, making it possible to plan interventions.
before more serious disruptions occur. In the port context, this functionality has proven to be...
if particularly relevant, given the unavailability of cranes, of systems of
Internal transport and handling equipment can directly compromise the
productivity and increased operating costs.

At the same time, the results and discussion showed that the benefits of IoT are not...
They materialized in a uniform or automatic way. The literature revealed that the potential for
Optimizing operational efficiency was contingent upon the existence of digital infrastructure.
appropriate for the integration between systems and the institutional capacity to transform data into action.
managerial. When these conditions were not present, technology tended to produce results.
limited or fragmented. Thus, it became evident that the simple acquisition of devices
Connected systems, in themselves, did not guarantee the creation of a smart port. Efficiency depended on...
The articulation between technology, planning, management, and professional qualification, as pointed out by
studies on digital transformation and new organizational models based on IoT (Silva et al.,
2023).

In this sense, the discussion highlighted that the implementation of the Internet of Things required
Cultural and organizational changes. In many cases, the challenges were not limited to the dimension
technical aspects, but also the adaptation of work routines, team building, and acceptance.
The institutional transformation towards more data-driven management models. This means that the transformation
The digitalization of ports should not be interpreted as an exclusively technological process, but rather
as a reconfiguration of the operational logic itself. The evidence indicated that the best
Results occurred when IoT adoption was accompanied by strategic integration.

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Investment in training and review of internal processes, which allowed the data generated if they effectively translated into operational improvements.

The literature also suggested that the discussion about smart ports should be included in a broader movement of logistical innovation and economic competitiveness. The growing pressure for cost reduction, increased agility, and greater reliability in workflows. The transport of goods has led ports to assume a more dynamic role in global supply chains. In this scenario, IoT emerged as a tool capable of strengthening the strategic position of ports, by expanding their responsiveness, their integration with other modes of transport, and their efficiency in The treatment of operations. The discussion, therefore, indicated that port modernization was not... It's not just a matter of technological updating, but also a requirement for inclusion. competitive landscape of contemporary logistics systems (Galegale et al., 2016).

Finally, the results obtained allowed us to affirm that the Internet of Things contributed to This significantly improves port operational efficiency by facilitating real-time monitoring. Real-world automation, process automation, cargo tracking, predictive maintenance, and integration of... data and greater security in operations. However, the analysis also demonstrated that these Benefits depend on specific structural, organizational, and managerial conditions, without which which technologies tend not to reach their full potential.

FINAL CONSIDERATIONS

This work has allowed us to understand that the Internet of Things has played a role. relevant in the modernization of smart ports and in optimizing operational efficiency. port. The analysis developed showed that the connectivity between sensors, devices, Equipment and systems facilitated greater monitoring of operations and automation of processes. Cargo tracking, data integration, and decision support. In this way, it was verified- I know that IoT has contributed to making the port environment more dynamic, predictable, and aligned with... contemporary demands of logistics and global trade.

The results also demonstrated that the benefits of the Internet of Things are not... They were limited to increasing productivity, but also involved reducing operational costs. Improved safety, more efficient equipment maintenance, and more rational use of resources. port infrastructure.

It was concluded, therefore, that the Internet of Things represented an essential tool for Strengthening smart ports, contributing to the development of more efficient operations. integrated, efficient, and competitive. Furthermore, the study reinforced the importance of expanding the

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academic discussions on the topic, especially in the Brazilian context, considering that the Technological innovation in the port sector is becoming increasingly necessary to respond to meet the demands for efficiency, sustainability and logistical development.

During the preparation of this work, the authors used the ChatGPT tool from OpenAI (GPT-4 version) to enhance text clarity and fluency and perform grammar checking. After using this tool, the author critically reviewed and edited the content. assuming full responsibility for the accuracy and originality of the text.

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