Innovations and smart technologies at Brazilian ports

Inovações e tecnologias inteligentes nos portos brasileiros

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Abstract

Innovations can help ports become smarter and more effective and differentiate themselves from competitors. This study aims to explore the current state of innovations and smart technologies at Brazilian ports. The study sampled sixteen ports, representing 70% of port movements in Brazilian public ports in 2021. This is an exploratory and descriptive field study involving qualitative analysis. The results show that the surveyed ports are seeking strategies to innovate. Only one of the surveyed ports had a registered patent. Half of all ports had agreements with educational/research institutions, companies, or other ports for developing innovations. By contrast, no port engaged in technology transfer contracts with educational/research institutions, companies, or other ports. Few surveyed ports collaborated with HUBs, laboratories, or innovation centres. The three most widely used smart technologies at the surveyed ports were cloud computing, automated systems, and drone
technologies. This study shows that Brazilian ports are undergoing a transformation process, but they find themselves in different stages of maturity regarding the appropriation and development of new technologies. New technologies are still incipient for some ports, while others have yet to adopt them. For example, only a few surveyed ports used smart technologies such as the Internet of Things, blockchain technology, or automated systems. Innovations and the inclusion of new technologies can generate benefits, but they require time and financial resources.

**Keywords:** Innovation. Technology. Ports.

**Resumo**

As inovações podem ajudar os portos a se tornarem mais inteligentes e eficazes e a se diferenciarem dos concorrentes. Este estudo tem como objetivo explorar o estado atual das inovações e tecnologias inteligentes nos portos brasileiros. O estudo teve como amostra dezesseis portos, representando 70% dos movimentos portuários nos portos públicos brasileiros em 2021. Trata-se de um estudo de campo exploratório e descritivo envolvendo análise qualitativa. Os resultados mostram que os portos pesquisados estão buscando estratégias para inovar. Apenas um dos portos pesquisados possuía patente registrada. Metade dos portos tinha acordos com instituições de ensino/pesquisa, empresas ou outros portos para o desenvolvimento de inovações. Por outro lado, nenhum porto se envolveu em contratos de transferência de tecnologia com instituições de ensino/pesquisa, empresas ou outros portos. Poucos portos pesquisados colaboraram com HUBs, laboratórios ou centros de inovação. As três tecnologias inteligentes mais utilizadas nos portos pesquisados foram computação em nuvem, sistemas automatizados e tecnologias de drones. Este estudo mostra que os portos brasileiros estão passando por um processo de transformação, mas encontram-se em diferentes estágios de maturidade quanto à apropriação e desenvolvimento de novas tecnologias. Novas tecnologias ainda são incipientes para alguns portos, enquanto outros ainda não as adotaram. Por exemplo, apenas alguns portos pesquisados usaram tecnologias inteligentes, como Internet das Coisas, tecnologia blockchain ou sistemas automatizados. As inovações e a inclusão de novas tecnologias podem gerar benefícios, mas demandam tempo e recursos financeiros.

**Palavras-chave:** Inovação. Tecnologia. Portos.
Introduction

Ports are widely recognized as essential factors in countries' economic growth, and this is justified by several implications that can be attributed to their development process. Firstly, this development process makes it possible to connect cities and regions worldwide, thus promoting the progress of international trade. Secondly, ports are important centers that can contribute to regional development by exporting local goods and logistical services. Thirdly, they can accelerate the integration of a country's domestic economy into the international economy and become critical factors in attracting new industries (Cavalli et al., 2021).

Ports serve as reference centers that promote regional development. They need to respond quickly to new changes in the economic market by seeking tools and initiatives that streamline their operations and highlight their competitive advantages (Quintana et al., 2016). Through innovation, ports can make their strengths and unique features clear and distinguish themselves from other ports.

Innovation in ports encompasses new technologies and processes for handling and moving cargo, mechanisms for planning and policymaking, and financing, implementing, upgrading, managing, and operating infrastructure systems (Hall et al., 2013).

The maritime and logistics industries are traditional sectors which tend to be more reactive than proactive, mainly due to the long life cycles of the assets used in maritime transport and port infrastructure. However, in recent decades, there has been a shift towards more innovative ports, driven primarily by collaborations between port authorities and technology providers (Deloitte, 2021).

The widespread adoption and increasing diffusion of digital technologies are reshaping various activities in organizations and throughout society. According to the authors, the goals of the smartPORT initiative include reducing energy consumption and emissions, developing predictive maintenance scenarios for port-related infrastructure, and improving traffic and parking space management (Petrikina et al., 2017).

Ports and terminals have evolved and entered the fifth stage of evolution, characterized by their digital transformation and alignment with Industry 4.0 practices since the 2010s. The pillars of Industry 4.0, including the Internet of Things and sensing solutions, cybersecurity, horizontal and vertical system integration, cloud computing, 3D printing and additive manufacturing, big data and business analytics, and augmented reality and simulation and
modelling, are already mature in some areas of the port and maritime industry. In contrast, others remain in their earliest stages of development (Zarzuelo et al., 2020).

The conservative profile of the maritime industry has always made technological and technical advancements challenging issues. Recently, new technologies such as the Internet of Things, Automatic Data Identification Systems, and automation systems have been introduced to the maritime sector. Although most changes have been incremental, some new solutions could result in radical changes for the entire maritime transportation sector (Bavassano et al., 2020).

It is known that technology can facilitate operations and promote effective management within transportation networks and freight transportation systems while also providing information and guidance for transportation system users (Vural et al., 2020). Also, Information Technology can help companies become smarter and increase profitability and operational efficiency in competitive global markets (Ribeiro et al., 2021).

The use of technologies such as the Internet of Things (IoT), sensors, cloud computing platforms, big data analytics, artificial intelligence (AI), GPS tracking systems, radar, drones, real-time monitoring, and smart grids, among others, is essential to develop a forward-looking port logistics model. These technologies allow the collection, processing, monitoring, and analysis of data and information related to economic, environmental, social, and technological aspects at ports (D'Amico et al., 2021).

Leading ports have successfully implemented new technologies to integrate their port resources, resulting in reduced waste and increased global influence and economic value. The Internet of Things enables vehicles, devices, and other items embedded with sensors and actuators to exchange data across a network, which has been extensively applied in commercial ports. For example, cruise-assisting transportation systems can simultaneously manage port electricity, water, and energy use (Shee et al., 2018).

Although the maritime sector has been traditionally conservative and reluctant to change, it has become increasingly receptive to the opportunities offered by new information and communication systems and technologies. This is because they improve operational efficiency, enhancing the port's competitive advantage in the market (Bocayuva, 2021).

Despite the important role of innovation in the shipping industry, academic research on the topic is fragmented and usually focuses on specific cases. At the same time, few attempts have been made towards generalizations (Koukaki & Tei, 2020).

Several studies in academic literature address innovation and technology in ports. Some of them focus on American ports (Gracia et al., 2022; Mileski et al., 2018), while others
The study conducted by Gracia et al. (2022) identifies the best governance practices promoted in ports and analyzes these practices in 24 Latin American ports. The results indicate that two of the most frequently cited governance practices are digitalization and coordination among the stakeholders of the port logistics community.

The study by Mileski et al. (2018) reviewed automatic identification systems aboard ships for cyber issues and weaknesses at the Port of Houston (US). The authors indicate that the maritime industry is increasingly impacted by the Internet of Things through the automation of ships and port activities. This increased automation creates new security vulnerabilities for the maritime industry in cyberspace. Any obstruction in the global supply chain due to a cyberattack can cause catastrophic problems in the global economy. The results showed inconsistent information on the location of the ships at the same time in the port.

Gurzhiy et al. (2021) highlighted the use of digitalization to reduce traffic congestion at three major ports, namely Shanghai, Hamburg, and Rotterdam. The effectiveness of this approach can be achieved through Artificial Intelligence (in the case of Shanghai) or by automating core business processes (in the case of Hamburg and Rotterdam). The results of these studies suggest that better collaboration can be achieved by creating an integrated and interconnected system for goods transportation infrastructures, which includes all types of transportation and cargo owners, along with a unified information environment on technological interactions between various transport modalities and transport processes for participants in a modern distribution network. This system can guarantee volumes and quality transportation services.

Cavalli et al. (2021) proposed a pilot technology model to increase the competitiveness, efficiency, and sustainability of ports. The study was implemented in the Port of Livorno, Italy. The study demonstrates that 5G networks and related new technologies can aid in the facilitation and achievement of more efficient port operations. These changes can result in significant improvements, making ports more sustainable and aiding them in fulfilling their role.

Kapkaeva et al. (2021) conducted a case study on the Port of Hamburg. They emphasized that the Hamburg Port Authority is an exemplary instance of efficiently and sustainably implementing new IT solutions. Additionally, the port serves as a solution center.
for maritime and coastal navigation, security, rail port, property management, and economic matters.

A study by Bracke (2021) describes a cloud-based IoT integration platform that is scalable and multi-tenant. This platform was used in the EU H2020 PortForward project, with a focus on three critical capabilities that are required for successful IoT integration within a port environment. The first capability is interoperability among various wireless technologies and data formats. The second capability is multi-tenancy, which ensures appropriate data isolation among the various stakeholders operating within port premises. The last capability is scalability, which enables the platform's performance to adapt according to data volume patterns and ensures stability in response time and service time.

A study by Muñuzuri et al. (2020) detailed the operational use of an Internet of Things system for a Spanish port. The model was designed to optimize, manage, and monitor container transport operations in an intermodal corridor, which combined rail schedules and land navigation at ports. The model efficiently exchanged supply chain data, providing real-time information and traceability. The model's three pillars were smart transportation (security, privacy, optimization), sustainability (reducing carbon emissions and promoting efficient energy use), and integration (enhancing intermodal efficiency and reliability).

The study conducted by Ferretti and Schiavone (2016) aimed to contribute to the existing literature on the exploitation of the Internet of Things (IoT) using an illustrative case study of the Port of Hamburg. The results showed that adopting IoT technologies redesigns and improves the performance of all the main business processes analyzed, particularly those related to the organization's technology and information. The redesign of IoT-driven business processes must be strategically planned by the port management and requires the involvement of all the port stakeholders. In some cases, it may be necessary to hire external professional partners.

Thus, identifying digital transformation processes for the Brazilian port sector is relevant and necessary, given the scarcity of studies on this subject in Brazil. This study aims to identify the innovation and digital transformation processes at Brazilian public ports.

**Smart Technologies in the Port Sector**

Port information systems and technologies play significant roles in collecting, exchanging, and distributing important information to all involved agents, especially stakeholders (Kapkaeva et al., 2021).
Digital transformations bring about significant changes to businesses, particularly with respect to their digital support and communication processes, as well as new ways of creating value through digital data innovations. Current port logistics systems are highly centralized and offer limited opportunities for multi-stakeholder collaboration. Moreover, these systems lack traceability and transparency and do not adequately secure information stored and exchanged during operational processes, which can negatively impact port productivity and operations (Ahmad et al., 2021; Hausberg et al., 2019).

Some ports have already implemented initiatives and system solutions to manage port operations, allowing for collaboration and data sharing among various stakeholders, as well as traceability. These solutions include blockchain and cloud computing technologies (Vasconcellos & Oliveira, 2019).

The complexity of port terminal operations and intermodal transfers has introduced new information and communication technologies to assist stakeholders in multi-criteria decision-making processes. More recently, systems based on the Internet of Things (IoT) have led to additional automation improvements (Muñuzuri et al., 2020).

Technology is currently changing at a very fast pace. Executives have struggled to keep up with the variety of technology initiatives aimed at building high-performance supply chains. Data is a disruptive technology driver, and radical technologies can increase supply chain efficiency and controls (Aryal et al., 2020).

From an economic standpoint, port digitization adds and redistributes value for the port community. Benefits can be viewed directly in the case of clear improvements to logistics processes in terms of efficiency and optimization, new job creation in the port area, and an increase in GDP. Alternatively, benefits can be viewed indirectly in improving the quality of life. For example, a yard optimization system based on 5G technology could improve air quality by reducing ship stop times at the dock and optimizing port systems to reduce accidents (Pagano et al., 2022).

According to a Deloitte study on the European port industry, technological changes can promote more efficient use of infrastructure, greater transparency for users and stakeholders, and better health and safety controls (Deloitte, 2021).

Today, smart technologies are driving significant transformations in logistics and transportation. Smart technologies include artificial intelligence and data science technological applications, such as machine learning, big data, and autonomous cognitive awareness for objects, to support information and communication technologies like the Internet of Things and blockchain. Many smart technology applications have shown
promising potential for increasing the efficiency and effectiveness of various logistics operations and transportation systems (Chung, 2021).

Innovative technologies (like blockchain or autonomous transportation) have promoted digital transformations in the maritime transportation sector. A lack of awareness of how digital transformations affect businesses and the lack of standards and cooperation among stakeholders are barriers that can hold back digital transformations (Tijan, 2021).

Blockchain is one of the technologies that can support digital transformation in industries in many aspects. This sophisticated technology can provide a decentralized, transparent, and secure environment for organizations and businesses (Alahmadi et al., 2021). Blockchain can be used to transparently and immutably record all movements and changes of ownership for transport, crane, or intralogistics vehicles. This transparency can help certify, identify, and report properly functioning equipment, potential malfunctions, and uncertified or harmful assets. Maintenance, repairs, and overhauls protect against vessel damage and accidents during its life cycle by recording both scheduled and unscheduled maintenance activities (Ahmad et al., 2021).

Relevant investments are also a barrier to the adoption of new technologies. According to D'Amico et al. (2021), port cities require significant financing to acquire, assemble, and maintain technological features such as real-time monitoring stations for water and energy consumption, GPS tracking systems for trucks, ships, and industrial vehicles, cameras on cranes, poles, antennas, and buildings, as well as distributed sensors at docks and water mains. These requirements represent barriers for smaller or less developed port cities.

Methodology

This is an exploratory and descriptive field research study involving qualitative analysis. The research design was elaborated by considering three interviews with port managers and the study by Zarzuelo et al. (2020), which reviews the state of the art of these emerging technologies, summarizing how ports and terminals are deploying specific projects in the new era of smart ports and Ports 4.0. A questionnaire with 21 questions was used, including three open-ended questions and eighteen multiple-choice questions. The data collection instrument was Google Forms. Respondents were not identified in the questionnaire, ensuring the respondents' anonymity. The questionnaire covered the following topics: the profile of the respondents; patents or software registered; collaboration between ports and universities; technology transfer contracts, collaboration with HUBs, laboratories,
or innovation centers; participation in startup incubators or acceleration projects; innovations focused on sustainability; managers' perceptions of port innovation and the inclusion of new technologies for the port sector.

The Brazilian port sector comprises 37 public ports, 19 of which are managed by unions via dock companies, which are part of the Port Authority. The other 18 remaining ports are managed by either states or cities via specific legal legislation (Sousa et al., 2020).

The population of the study consisted of thirty-five Brazilian public ports. The ports of Cachoeira do Sul and Estrela were excluded from the population since they changed their port authority and did not provide any data. The questionnaire link and request to fill it out were sent to all public ports via email, the port websites, a specific platform for accessing information from the federal government (integrated platforms for ombudsman services and information), or specific state government platforms.

We collected answers from March 06, 2021, to December 03, 2021. The study sample consisted of sixteen ports, and the port authority was the respondent in two questionnaires. The port authority responses considered all ports under its management. These sixteen ports were responsible for 70% of port movements in Brazilian public ports in 2021, according to data from ANTAQ (2022). Thus, the sample was significant.

**Results**

This study aims to investigate the current status of innovations and smart technologies at Brazilian ports. The sample consisted of sixteen ports with diverse commercial profiles located in the Northeast, North, Southeast, and South regions of Brazil. Half of the respondents were from technology or innovation departments, 40% from environmental departments, and 10% from management or related areas.

The findings of this study reveal that only one port had a registered patent for an integrated monitoring system, which was implemented in 2020. None of the other surveyed ports developed or registered patents related to port activities.

Regarding agreements with educational/research institutions, companies, or other ports for developing innovations, 50% of the ports had some agreement for this purpose, while none engaged in technology transfer contracts.

Only 19% of the surveyed ports collaborated with HUBs, laboratories, or innovation centres, and only 13% had organized or participated in startup incubators or accelerator projects. Likewise, only 19% of the ports sponsored employee participation in national or
international events on innovation. However, 56% of all ports held activities or events that encouraged and influenced employees to maintain an innovative attitude or discuss innovations within their sector.

We also asked specific questions on innovations focused on sustainability. The results show that few ports have employed innovations developed specifically for sustainability. However, one item mentioned was surveillance and monitoring systems to help prevent incidents. Three ports reported that they were in the process of implementing innovations for sustainability.

Innovations focused on sustainability (social, environmental and economic) can bring about significant gains to the company and its surroundings. It is essential to highlight that eco-innovations can be strategies for developing low-carbon economies, seeking sustainable development, and initiatives focused on mitigating and adapting to environmental impacts, especially climate change (Pinsky et al., 2015).

US companies devote significant resources to developing new methods for reducing or treating emissions, recycling, reusing waste, using renewable energy, and employing other environmental protection methods. It has been highlighted that new patents are granted every year for environmental innovations (Brunnermeier & Cohen, 2003).

Figure 1 presents the main innovations being applied in the ports of the present study. Regarding innovations in ports, respondents mentioned the importance of innovations and highlighted some technologies applied mainly to the operational area, such as integrated monitoring systems, reading OCR plates, and digital document protocol. It is noticed that the ports are also concerned with innovations in other aspects, such as databases for improving operational procedures for air quality, water reuse, effluent management, and bathymetry and electronic information system from the federal government.

Fig. 1. Innovation and technologies in the Brazilian ports

Revista Gestão e Secretariado (GeSec), São Paulo, SP, v. 14, n. 5, 2023, p. 7373-7390.
According to Cerceau et al. (2014), ports can constitute self-sufficient areas and boost the development of other regions. As engines of local economic development, ports can act as levers for implementing policies or strategies on a regional scale. Innovation is a collective learning and socially integrated process; therefore, there is a relationship between innovations and the regions in which they occur. Innovations are the key source of competitive advantage for respective regions (Mudronja et al., 2019).

Given the importance of innovation developed in ports and their potential to stimulate regional companies, we sought to identify managers’ perceptions of innovation in the ports where they work. The results show that half of all surveyed managers (50%) stated that their port was innovative compared to other Brazilian ports.

In contrast, the results indicate that the majority of managers (94%) did not consider Brazilian ports to be innovative when compared to international ports.

Fig. 2. Perception of innovation relative to other Brazilian ports
Note: 1 = strongly disagree, 5 = strongly agree.

In contrast, the results indicate that the majority of managers (94%) did not consider Brazilian ports to be innovative when compared to international ports.
According to a KPMG study, several technologies should be implemented for long-term value via digital business transformation. The 2019 ranking identified key technologies, including the Internet of Things, robotic process automation, artificial intelligence, cognitive computing, and machine learning (KPMG, 2019).

Figure 4 illustrates the usage of smart technologies in ports for various areas and activities. The most commonly used technologies include cloud computing (88%) and automated systems/drones (56%). In terms of regional analysis, the ports in the Southeast employ more technology. Specifically, all surveyed ports in the Southeast used cloud computing, and 86% of them used automated systems and drones for some port operations. However, only one port in the Northeast employed all the technologies highlighted in this study. Approximately 60% of ports in the Northeast used cloud computing, while 40% used automated systems and drones for some activities.
The current port logistics handling systems lack traceability, transparency, and security in information exchange during operational processes. The emerging blockchain technology offers a solution by providing decentralized, intermediary-free, and immutable data from trusted on-chain transactions (Ahmad et al., 2021). However, implementing this technology requires significant investment, which may hinder its expansion in the sector (Bavassano et al., 2020).

Within the maritime transportation industry, some ports have undergone significant digital transformations, such as the port of Rotterdam and the port of Singapore, while others lag behind (Tijan, 2021). Large ports and terminals in Europe and Asia, such as Amsterdam, Rotterdam, Hamburg, and Singapore, have embarked on ‘4.0 projects.' In contrast, smaller environments, including those in America, are yet to catch up with these emerging technologies (Zarzuelo et al., 2020).

Modern port infrastructure can address various issues, such as employee, ship, and vehicle identification, container tracking, truck calls, and train configuration (Kapkaeva et al., 2021).

Cloud computing was the most preferred technology among the surveyed ports, with thirteen ports using it in operations and other areas. Seven ports used automated systems for environmental and safety purposes, and four ports for operational tasks. Six ports also utilized drones for environmental and security purposes. The table below illustrates these findings (Table 1).

<table>
<thead>
<tr>
<th>Technologies/Area</th>
<th>Operational</th>
<th>Administrative and Training</th>
<th>Environmental and Security</th>
<th>Maintenance and Inspection</th>
<th>None</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud computing</td>
<td>13</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td>Automated systems</td>
<td>4</td>
<td>2</td>
<td>7</td>
<td>2</td>
<td>7</td>
<td>22</td>
</tr>
<tr>
<td>Artificial intelligence</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>Internet of things</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>14</td>
<td>17</td>
</tr>
<tr>
<td>Drones</td>
<td>3</td>
<td>-</td>
<td>6</td>
<td>2</td>
<td>7</td>
<td>18</td>
</tr>
<tr>
<td>Robots</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>Autonomous equipment</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>Blockchain technologies</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>26</strong></td>
<td><strong>7</strong></td>
<td><strong>16</strong></td>
<td><strong>8</strong></td>
<td><strong>89</strong></td>
<td><strong>146</strong></td>
</tr>
</tbody>
</table>

Table 1. Technologies used by Brazilian ports per area/department.

Regarding the technologies managers consider important for port applications, the results show that most port managers recommend the technologies highlighted in the study. All respondents indicated that cloud computing, automated systems, artificial intelligence, and the Internet of Things could be applied in several areas.
However, some respondents did not recommend certain technologies for port applications. Four respondents mentioned robots and blockchain technologies, while autonomous equipment was mentioned by three respondents. The recommended technologies were more widely applied in the operational area and less in the administrative and training areas.

<table>
<thead>
<tr>
<th>Technologies/Area</th>
<th>Operational</th>
<th>Administrative and Training</th>
<th>Environmental and Security</th>
<th>Maintenance and Inspection</th>
<th>None</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud computing</td>
<td>16</td>
<td>8</td>
<td>13</td>
<td>8</td>
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<td>45</td>
</tr>
<tr>
<td>Automated systems</td>
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<td>5</td>
<td>10</td>
<td>6</td>
<td>-</td>
<td>37</td>
</tr>
<tr>
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<td>16</td>
<td>4</td>
<td>12</td>
<td>10</td>
<td>-</td>
<td>42</td>
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<tr>
<td>Internet of things</td>
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<td>13</td>
<td>10</td>
<td>-</td>
<td>41</td>
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<tr>
<td>Drones</td>
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<td>2</td>
<td>11</td>
<td>11</td>
<td>-</td>
<td>39</td>
</tr>
<tr>
<td>Robots</td>
<td>10</td>
<td>1</td>
<td>7</td>
<td>5</td>
<td>4</td>
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<tr>
<td>Autonomous equipment</td>
<td>13</td>
<td>-</td>
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<td>Blockchain technologies</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>25</td>
</tr>
<tr>
<td>Total</td>
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<td>27</td>
<td>78</td>
<td>59</td>
<td>11</td>
<td>288</td>
</tr>
</tbody>
</table>

Table 2. Recommended technologies for application at ports per area/department

The final question on the questionnaire was left open for comments. Based on the responses, we found that ports are undergoing changes and consider innovation important. Many respondents identified universities as potential partners in building more innovative ports and expressed interest in adopting new technologies in their operations. For instance, one respondent stated, "We are in the process of establishing agreements with universities to incorporate innovative practices and bring research closer to the port" (Port 5). Another respondent mentioned, "The port authority is actively seeking to update itself with technological standards to enhance competitiveness, service delivery, and excellence for our customers" (Port 8). A third respondent commented, "I believe that the findings of this research could encourage ports to explore ways to integrate new technologies into their daily operations" (Port 16).

The comments reveal that universities are viewed as important partners for fostering innovation in ports, and there is a general interest in adopting new technologies to improve port operations.

**Conclusion**

The results of this study indicate that the surveyed ports are actively seeking strategies for innovation and are in various stages of digital transformation. Only one of the surveyed
ports had a registered patent, while half of all ports had partnerships with educational/research institutions, companies, or other ports to develop innovations.

Innovation can be a key factor in highlighting a company's differentiators and making them more visible to stakeholders. Once a high level of innovation is achieved, companies tend to remain at the forefront of innovation and distance themselves further from competitors with more conservative profiles. Developing new technologies can also promote digital transformations within the port sector. The study found that half of all surveyed managers believed their port was innovative compared to other Brazilian ports. In contrast, most did not believe their port was innovative compared to other international ports.

Cloud computing was the most preferred technology among ports, mostly applied in the operational area/department. The preference for using this technology in the operational area is directly related to its positive effects on port operational productivity. Automated systems were mainly applied in the environmental and safety areas and operational areas. Drones were most commonly used in environmental and security areas.

This study demonstrates that Brazilian ports are undergoing a transformation process, but they are at different stages of maturity regarding the adoption and development of new technologies. While some ports are still in the early stages, others have yet to adopt new technologies. For example, only a few surveyed ports used smart technologies such as the Internet of Things, blockchain technology, or automated systems. Although including new technologies can generate benefits, they require time and financial resources.

Given the importance of the port sector to the Brazilian economy, this study is relevant and timely. The research provides insights that can help incorporate new technologies in Brazilian ports. However, the study is limited to the Brazilian public port sector, and it is recommended to be applied to other ports or port terminals. Additionally, future research could focus on identifying the existing barriers to innovation in this sector.

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