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Affinity matrix assesses digital twin factors in Spanish ports for informed decisions

Nicoletta González-Cancelas[1,*], Javier Vaca Cabrero[1], Alberto Camarero Orive[1] and **Luca Rizzetto[2]**

[1] Department of Transport, Territorial and Urban Planning Engineering, Polytechnical University of Madrid, 28040 Madrid, Spain

[2] Department of Civil, Building and Environmental Engineering, Sapienza University of Rome, 1303 Roma, Italy

*E-mail address: nicoleta.gcancelas@upm.es

ABSTRACT

Digitalization has drastically changed the way businesses and industries operate, and ports are no exception. The digitalization of ports involves the adoption of digital technologies to optimize the management of port operations, improve efficiency and reduce costs. One of the most exciting developments in the digitalization of ports is the creation of digital twins. In the case of ports, a digital twin is a virtual replica of port operations, using real-time data to simulate and optimize port processes. Digital twins are created using technologies such as the Internet of Things (IoT), artificial intelligence (AI), and augmented reality (AR). For example, sensors installed in the port can collect real-time data on traffic flow, workload, and the status of port equipment and infrastructure. This data is used to create a virtual replica of the port that can be used to analyze and improve the performance of port operations, allowing port managers to make more informed decisions and optimize port processes. In addition, digital twins can be used to simulate different scenarios and make accurate predictions about the impact of changes on port operations. The aim of this paper is, using an affinity matrix, to evaluate the relationship between the different factors of digital twins in the Spanish port system and to use it as a guide and aid to decision-making.

***Keywords*:** Affinity matrix, Digitalization, Spanish ports, Digital twins

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1. INTRODUCTION

Digitalization has drastically changed the way businesses and industries operate, and ports are no exception. The digitalization of ports involves the adoption of digital technologies to optimize the management of port operations, improve efficiency and reduce costs.

One of the most exciting developments in the digitalization of ports is the creation of “digital twins”. A digital twin is an accurate and detailed digital representation of a physical object or system in real time. In the case of ports, a digital twin is a virtual replica of port operations, using real-time data to simulate and optimize port processes.

Digital twins are created using technologies such as the Internet of Things (IoT), artificial intelligence (AI), and augmented reality (AR). For example, sensors installed in the port can collect real-time data on traffic flow, workload, and the status of port equipment and infrastructure. This data is used to create a virtual replica of the port that can be used to analyze and improve the performance of port operations.

Digital twins can provide a complete and accurate view of port operations, enabling port managers to make more informed decisions and optimize port processes. In addition, digital twins can be used to simulate different scenarios and make accurate predictions about the impact of changes on port operations.

The digitalization of ports, including the use of digital twins, is transforming the way ports are managed and operated, resulting in greater efficiency, reduced costs, and improved decision-making.

The aim of this paper is to use an affinity matrix to evaluate the relationship be-tween the different factors of digital twins in the Spanish port system and to use it as a guide and decision aid.

2. STATE OF THE ART

A digital twin is a virtual representation of a physical system or process that is used to model, monitor, and analyze its behavior. It is based on the collection of real-time data from the sensors of the physical system and is used to simulate and analyze their behavior in different scenarios. This allows users to predict and fix problems before they occur in the real world and optimize system performance. [1]

Digitalization and digital twins are closely related. Digitalization is the process of transforming traditional processes and systems into digital processes and systems. Digital twins are an important part of digitization, as they represent a digital model of a physical object or system in the real world. [2]

Digitization enables the creation and use of "digital twins" by providing the technology and data needed to create an accurate model of an object or system. Digital twins, on the other hand, allow for a better understanding and management of objects and systems in the real world, which in turn allows for better digitization. [3]

Digitalization and digital twins are closely related and mutually supportive. Digitization allows for the creation and use of digital twins, while digital twins allow for better digitization of objects and systems in the real world. [4]

Although digitalization and digital twins are closely related, there are some key differences between the two concepts.

In terms of scope, digitalization is a broader process that encompasses the transformation of traditional processes and systems into digital processes and systems, while "digital twins" are a specific tool within digitalization that is used to represent a digital model of a physical object or system. [5]

The goal of digitalization is to transform traditional processes and systems into digital processes and systems to improve efficiency and effectiveness, while the goal of digital twins is to provide an accurate digital representation of a physical object or system to improve the understanding and management of that object or system. [6]

If we talk about usage, digitalization is used in a wide variety of sectors, including healthcare, finance, logistics, and many others, while "digital twins" are mainly used in industry, engineering, and manufacturing. [7]

In nature, digitalization is a continuous process that evolves over time, while "digital twins" are precise and static digital models of physical objects or systems. [8]

Digitalization and "digital twins" are closely related, but they are different concepts with different objectives and scopes. Digitalization is a broad process that encompasses the transformation of traditional processes and systems into digital processes and systems, while "digital twins" are a specific tool within digitalization that is used to represent a digital model of a physical object or system.

Digital twins have both advantages and disadvantages. Here are some of the main ones. [9]:

Advantages:

- Improved decision-making: Digital twins allow for better understanding and visualization of objects and systems in the real world, which in turn allows for more informed and effective decision-making.
- Improved efficiency and effectiveness: Digital twins allow for the simulation and testing of changes and updates before implementing them in the real world, which can improve the efficiency and effectiveness of objects and systems.
- Cost reduction: By enabling simulation and testing of changes before implementing them in the real world, digital twins can help reduce the costs associated with implementing changes in the real world.
- Improved innovation: Digital twins allow the exploration of new ideas and solutions in a safe and controlled way before implementing them in the real world.

Inconvenience:

- Cost: Creating and maintaining digital twins can be costly, especially if a large amount of accurate and up-to-date data is required.
- Complexity: Creating and maintaining digital twins can be complicated and require a great deal of technical knowledge and skills.
- Lack of accurate data: The accuracy of digital twins depends on the quality and accuracy of the data used to create them, so a lack of accurate data can negatively affect the accuracy of the digital twin.
- Security and privacy challenges: Digital twins can pose a security and privacy risk if proper steps are not taken to protect the data and information associated with them.

Digital twins offer several advantages, such as improved decision-making, efficiency and effectiveness, cost reduction, and innovation, but they also have some drawbacks, such as costs, complexity, lack of accurate data, and security and privacy challenges.

2. 1. Use and evaluation of digital twins in transport

The use of "digital twins" in the transport sector has become increasingly popular in recent years. A "digital twin" is a digital model that represents a physical object or system in real time. In the transport sector, "digital twins" are used to simulate and monitor vehicle fleets, transport infrastructures and safety systems. [10]

The evolution of the use of "digital twins" in the transport sector has been driven by the growing demand for efficiency and safety in transport management. With the help of connected sensors and data analytics technologies, digital twins can provide real-time information on the location, speed and performance of vehicles, as well as the state of transport infrastructure. This allows transport companies to make informed decisions about optimizing their fleets and preventative maintenance of their infrastructures. [11]

In addition, "digital twins" are also used in the transport sector to simulate and evaluate the safety of vehicles and infrastructure. For example, emergency situations can be simulated to assess the system's response and improve preparedness for risk situations. [12]

The evolution and use of "digital twins" in the transport sector has led to greater efficiency, safety and optimization in transport management. This use is expected to continue to grow in the future as technology advances and becomes more accessible. [13]

In the maritime sector, "digital twins" are also gaining popularity. These digital models are used to simulate and monitor ships, ports, and other maritime infrastructure. [14]

As in the transport sector, "digital twins" in the maritime sector are based on the collection of real-time data through connected sensors. This allows maritime companies to have a real-time view of the location, performance, and safety of their ships and infrastructure. [14]

In addition, digital twins are also used to simulate emergency situations and assess the system's response, helping to improve safety in the maritime sector. They can also be used to simulate and evaluate the efficiency of ports and logistics in managing ocean shipments. [15]

Digital twins are revolutionizing the maritime industry by providing real-time insight and more accurate assessment of the location, performance and safety of ships and other maritime infrastructure. This allows maritime companies to make more informed decisions and improve their efficiency and safety in managing their operations. [16]

In ports, digital twins are also gaining ground as a tool for optimising and improving management. "Digital twins" in ports are used to simulate and monitor activity in the port, including ship arrival and departure, cargo handling, and infrastructure management. [17]

As in other sectors, "digital twins" in ports rely on real-time data collection through connected sensors and data analytics technologies. This allows port authorities and maritime companies to have a real-time view of activity in the port and make informed decisions on management optimization. [18]

In addition, "digital twins" in ports are also used to simulate and evaluate efficiency in cargo management and logistics, contributing to improving the efficiency and competitiveness of the port. They can also be used to simulate emergency situations and assess system response, helping to improve security in the port. [16]

Digital twins in ports are revolutionizing port management by providing real-time insight and more accurate assessment of port activity. This allows port authorities and maritime

companies to improve efficiency and safety in the management of their operations and increase their competitiveness in the maritime sector. [19]

Digital twins in ports and the wider maritime sector use a variety of data analytics technologies to collect, process, and analyze data in real-time. Some of these technologies include [20] :

- Big Data: This technology is used to collect and store large amounts of data in real-time. It allows users to analyze and visualize data to identify patterns and trends.
- Cloud data analytics: With the increase in the amount of data generated by sensors in ports and ships, cloud data analytics is becoming an important tool for data management and analysis.
- Artificial intelligence and machine learning: These technologies are used to automate and improve data analysis. For example, they can be used to analyze patterns in in-port activity or ship performance and predict future situations.
- Internet of Things (IoT): IoT is used to collect real-time data from connected sensors in ports and ships. This data can be used to monitor activity in the port and to evaluate the performance and safety of ships.

Digital twins in ports and the maritime sector use a combination of data analytics technologies to collect, process and analyze data in real time and improve management and efficiency in the maritime sector. [21]

There are many ports around the world that are using "digital twins" to improve management and efficiency in their operations. Some examples include [16]

- Ports of Singapore: Singapore is one of the leading ports in the adoption of digital twins. Singapore's ports are using "digital twins" to simulate and monitor activity at the port and to assess efficiency in cargo management and logistics.
- Rotterdam Ports: Rotterdam is one of the largest ports in Europe and is using "digital twins" to monitor and optimize cargo management and logistics.
- Ports of Hamburg: Hamburg is a major port in Germany and is using "digital twins" to improve efficiency in cargo management and logistics and to monitor activity at the port.
- Ports of Shanghai: Shanghai is one of the largest ports in China and is using "digital twins" to improve efficiency in cargo management and logistics and to monitor activity at the port.

These are just a few examples of ports that are using "digital twins". With the rise of technology and the adoption of digital twins around the world, we are likely to see an increase in the use of digital twins in ports in the future.

In Spain, some ports that are using "digital twins" include:

- Port of Barcelona: The Port of Barcelona is using "digital twins" to improve cargo management and logistics and to monitor activity at the port.
- Port of Algeciras: The Port of Algeciras is using "digital twins" to improve efficiency in cargo management and logistics and to monitor activity at the port.
- Port of Valencia: The Port of Valencia is using "digital twins" to monitor and optimize cargo management and logistics and to improve efficiency at the port.

These are just a few examples of Spanish ports that are using "digital twins". With the rise of technology and the adoption of digital twins around the world, we are likely to see an increase in the use of digital twins in Spanish ports in the future. [22]

The future of "digital twins" in the port sector is very promising. The use of digital twins is expected to continue to grow and improve in the coming years, and they will be used for a wide range of applications in ports. Some of the future trends include. [23] :

- Greater integration with the Internet of Things (IoT): Digital twins are expected to be increasingly integrated with sensors and IoT devices in ports to obtain a greater amount of real-time data and improve efficiency in cargo management and logistics.
- Increased automation: Digital twins allow for the automation of many of the manual tasks in ports, increasing efficiency and reducing human error.
- Improved planning and optimization: Digital twins allow for better planning and optimization of operations in ports, increasing efficiency and reducing costs.
- Greater collaboration and coordination: Digital twins allow for greater collaboration and coordination between the different actors in ports, which improves the efficiency and effectiveness of operations.

Digital twins are expected to have a positive impact on the future of port management and become a valuable tool for improving efficiency and effectiveness in port operations. [24]

3. METHODOLOGY AND ANALISYS OF THE RESULTS

The aim is to obtain a simple graphic representation of the main elements of digital twins in Spain and their possible classification, but always trying to make a visual and understandable representation that shows a picture of the situation understandable by any actor in the port system.

The methodological scheme developed is represented in Figure 1:

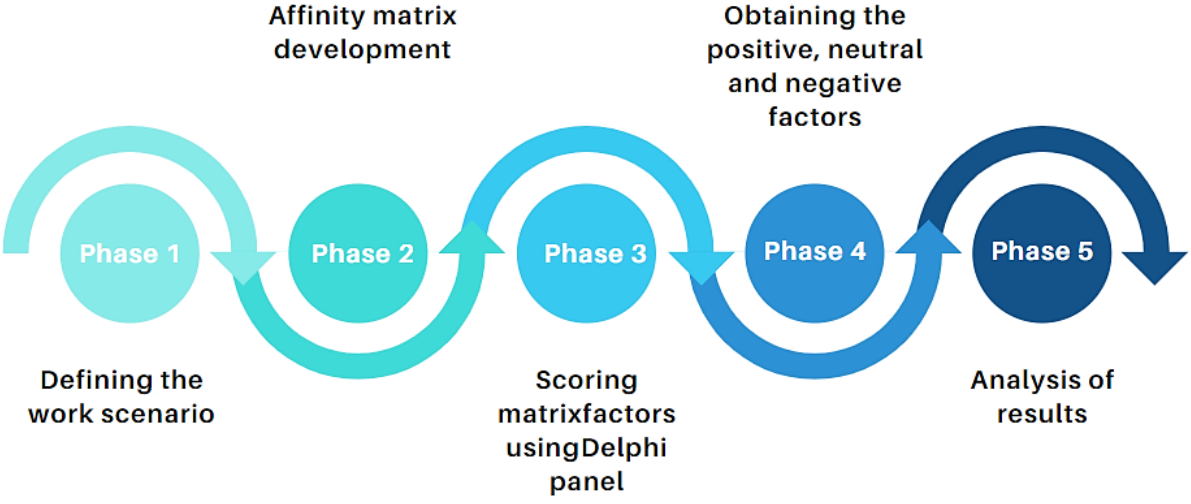

Figure 1. Methodological scheme. Source: own source.

An affinity matrix is a planning tool used to organize and classify large amounts of information or ideas into related topic groups. It is also known as a KJ diagram, KJ matrix, correlation matrix, K-J diagram, or K-J method. [25]

The affinity matrix is commonly used in problem-solving and group decision-making processes. Instead of just brainstorming and letting ideas flow in a disorganized way, the affinity matrix helps participants organize and categorize related ideas. [26]

The process begins with brainstorming in which participants write down their ideas on sticky notes, each idea on a separate note. Participants then sort and organize the sticky notes into related thematic groups, creating a visual diagram that shows how the different ideas are related. [25]

Participants then discuss the ideas, identify relationships between them, and create a list of the most important or priority ideas to address in the decision-making process. The affinity matrix helps create a more structured and organized process for group decision-making (Figure 2). [27]

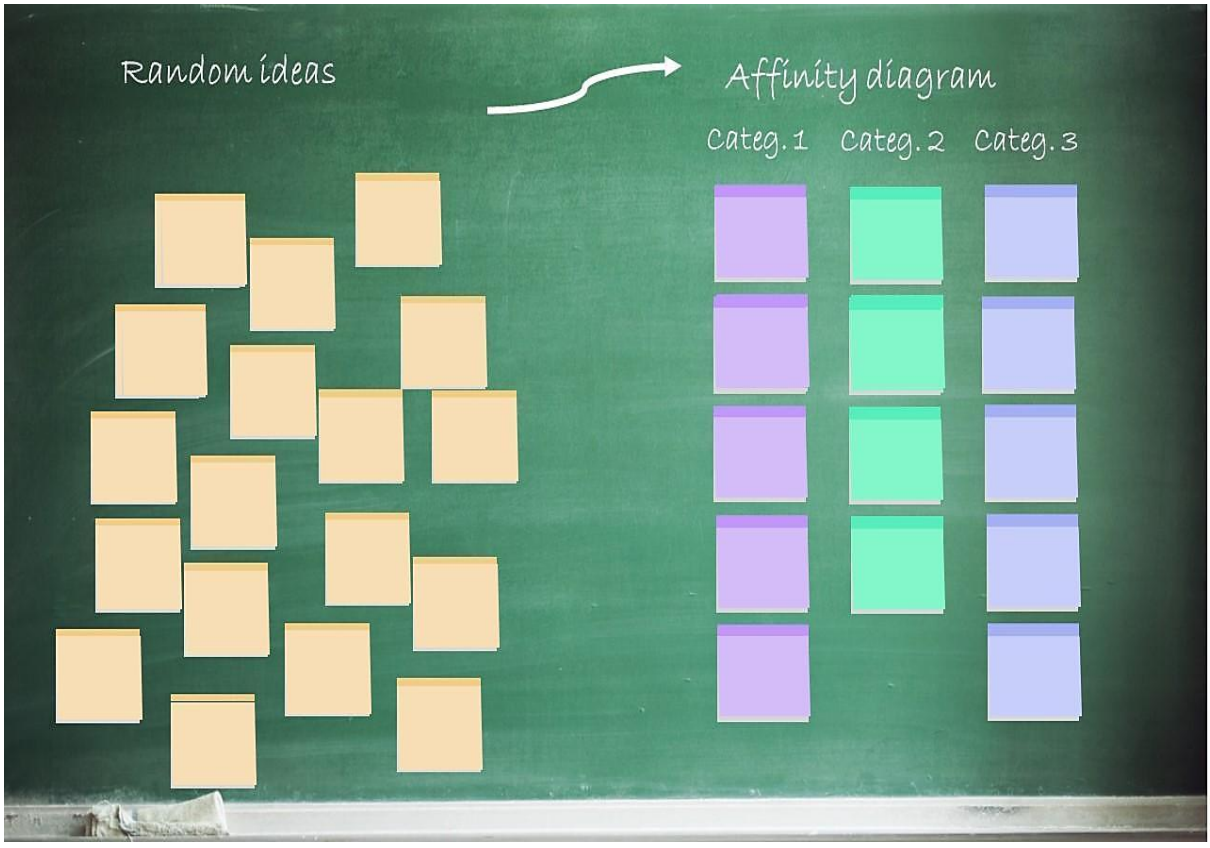

Figure 2. How the affinity matrix works. Source: own source.

The affinity matrix is a useful planning tool for organizing large amounts of in-formation or ideas into related focus groups, helping participants discuss and prioritize ideas in a more structured and organized group decision-making process.

It is possible to group the factors in the affinity matrix based on their relationship or similarity. The grouping proposed by the panel of experts is (Figure 3):

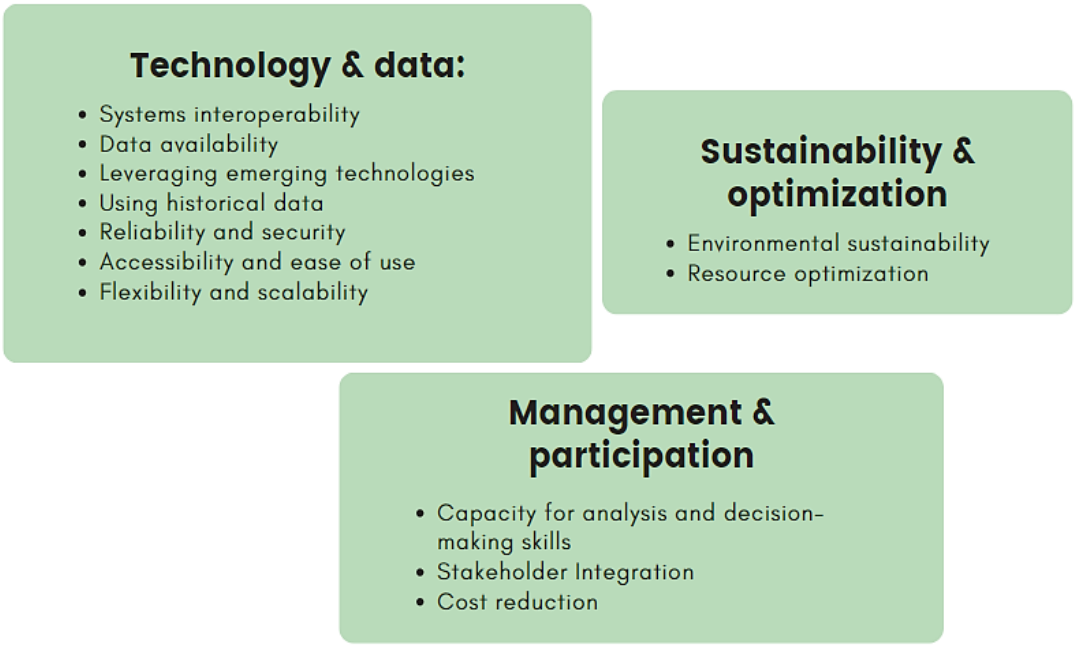

Figure 3. Affinity matrix. Source: own source.

The description of the indicators is as follows:

Technology & Data

- System interoperability: This refers to the ability of different systems or platforms to exchange data and communicate with each other seamlessly.
- Data availability: refers to the existence of relevant and up-to-date data for use in port operations and decision-making.
- Leveraging Emerging Technologies: This refers to the port's ability to take advantage of new technologies and trends in the market to improve its operations.
- Use historical data: This refers to the port's ability to collect, store, and use historical data to improve future operations.
- Reliability and security: refers to the importance of data and system security, and reliability in the delivery of services and operations.
- Accessibility and ease of use: This refers to the ease of access to the systems and platforms used, as well as the ease of use for users.
- Flexibility and scalability: This refers to the ability of systems and platforms to adapt and grow based on the changing needs of the port.

Sustainability & Optimization

- Environmental sustainability: refers to the port's ability to operate sustainably and reduce its environmental impact.
- Resource optimization: This refers to the port's ability to optimize the use of its resources and reduce unnecessary costs.

Management & Participation

- Analytical and decision-making skills: This refers to the ability of port managers and operators to analyze the available data and make decisions based on it.
- Stakeholder integration: This refers to the port's ability to integrate all stakeholders, such as customers, suppliers, regulatory bodies, and other actors into its operations.
- Cost reduction: This refers to the port's ability to reduce costs in its operations, without compromising quality or efficiency.

A panel of experts has scored the score for each factor of the affinity matrix on a scale of 1 to 5, with 1 being very successful and 5 very successful for the Spanish port system, the following scores can be shown (from these to assemble a cool graph with a hierarchy of scores):

- System interoperability: 4
- Data Availability: 4
- Analytical and decision-making skills: 3
- Leveraging Emerging Technologies: 2
- Use of historical data: 3
- Reliability and safety: 4
- Accessibility and ease of use: 3
- Flexibility and scalability: 3
- Environmental sustainability: 2
- Resource optimization: 3
- Stakeholder Integration: 4
- Cost reduction: 3

This matrix represented in Table 1 can help identify the factors that may influence the success or failure of the implementation of Digital Twins in ports. Positive factors can help you define the benefits you can reap from Digital Twins, while negative factors allow you to identify challenges you need to face. Neutral factors may not have a direct impact on the implementation of Digital Twins in ports, but it is important to take them into account when making decisions.

Here are the indicators in each column for Digital Twins in ports:

Positive factors:

- Improved efficiency and productivity: Digital Twins can improve efficiency and productivity by enabling better resource management, more accurate planning, and greater process automation.
- Increased security and risk reduction: Digital Twins can improve security in ports by enabling the identification of risks and the implementation of preventive measures.
- Improved decision-making: Digital Twins can improve decision-making by providing more accurate, real-time data, allowing for better process understand-ing and greater predictability.
- Increased planning and design capability: Digital Twins can improve planning and design by enabling scenario simulation and evaluation of alternatives prior to implementation.

- Improved asset and resource management: Digital Twins can improve asset and resource management by providing a detailed, up-to-date view of asset and re-source status and usage.
- Increased customer satisfaction and improved user experience: Digital Twins can improve customer satisfaction by enabling better planning and coordination of services and greater transparency in processes.

Neutral factors:

- Lack of knowledge or training in the technology: A lack of knowledge or training in the technology of the Digital Twins may not have a direct impact on their im-plementation, but it is important to keep this in mind to ensure proper adoption and use of the technology.
- Need for a major upfront investment: The need for a major upfront investment may not be a positive or negative factor, as it depends on the port's ability and willingness to invest in technology.
- Data availability: Data availability may not be a positive or negative factor, as it depends on the port's ability and readiness to collect, store, and share data.
- Limited scalability: Limited scalability may not be a positive or negative factor, as it depends on the needs and growth plans of the port.
- Infrastructure and connectivity requirements: Infrastructure and connectivity requirements may not be a positive or negative factor, as it depends on the capac-ity and willingness of the port to invest in infrastructure and ensure adequate connectivity.
- Environmental and social impact: Environmental and social impact may not be a positive or negative factor, as it depends on how Digital Twins are implemented and their impact on the environment and community.

Negative factors:

- Implementation costs: Implementation costs can be a negative factor if the port does not have the necessary resources to invest in technology.
- Resistance to change: Resistance to change can be a negative factor if port staff are not willing or trained to adopt and use Digital Twin technology.
- Interoperability with existing systems: Lack of interoperability with existing sys-tems can be a negative factor if Digital Twins cannot be properly integrated with systems already in use at the port.
- Cybersecurity risks: Digital Twins can be vulnerable to potential cybersecurity risks, so it's important to have adequate security measures in place in their im-plementation.
- Dependency on external vendors: Implementing Digital Twins may require reli-ance on third-party vendors for development and maintenance, which can be challenging in terms of cost and reliability.
- Potential conflicts with dock workers: The implementation of Digital Twins can change the way port operations are conducted, which can result in potential con-flicts with dock workers.

4. CONCLUSIONS

It has been achieved using an affinity matrix with respect to the factors of digital twins in the Spanish port system to obtain a tool to help decision-making.

Digital ports are undergoing a significant transformation thanks to the imple-mentation of advanced technologies, such as artificial intelligence, IoT, and automa-tion.

Managers should make the use of emerging technologies a priority in their ports, so they should improve the port's ability to take advantage of new technologies and market trends.

Likewise, environmental sustainability is one of the pillars to be promoted, so that the port can operate sustainably and reduce its environmental impact.

To improve their operations, managers must take advantage of the benefits of system interoperability, data availability, reliability and security, and stakeholder in-tegration.

Digital twins offer a great opportunity to improve efficiency and productivity in Spanish ports. By creating a virtual replica of port processes and infrastructure, digital twins enable better management and monitoring of resources, as well as more in-formed decision-making.

Some of the advantages of digital twins in Spanish ports include better capacity planning and resource management, reduced downtime, and increased security in port operations. In addition, digital twins also allow for better coordination between the different actors in the logistics chain and the optimization of cargo logistics.

However, the implementation of digital twins also presents some challenges, such as the need for accurate and up-to-date data, investment in technology, and training staff in managing digital twins. In addition, it is important to take into account the privacy and security aspects in the management of the data used in digital twins.

Digital twins offer great potential to improve efficiency and productivity in Span-ish ports, although their implementation requires careful planning and investment in technology and staff training. If properly addressed, digital twins can be a valuable tool to improve the competitiveness of Spanish ports in the global market.

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