

Developing a roadmap for implementing digital transformation to improve the resilience of port operations

Desenvolvendo um roteiro para implementar a transformação digital para melhorar a resiliência das operações portuárias

Elaboración de una hoja de ruta para aplicar la transformación digital a fin de mejorar la resiliencia de las operaciones portuarias

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ABSTRACT

The aim of this study is to create a comprehensive guide for achieving operational resilience in port operations through digital transformation. Port activities face significant challenges on a global scale, stemming from the complexity of operations and the occurrence of undesirable events that can disrupt the continuity of operations. To understand the current practices of digital transformation for operational resilience, this study draws upon systems theory, resource-based theory, and dynamic capabilities theory as foundational frameworks. The "fit-for-purpose" methodology is employed to adapt the method (cross-referencing) and the approach (metanarrative) in order to align with the research objective. The findings reveal that a roadmap for digital transformation, with a focus on resilience, consists of three key narratives: (1) evaluation and planning, which involves identifying goals, strategies, acquiring resources, and establishing governance; (2) implementation, which includes testing and integrating new technologies, as well as training employees; and (3) monitoring and evaluation, which entails tracking and assessing progress, and making necessary adjustments. Furthermore, the effectiveness of these steps is contingent upon gradually scaling projects, prioritizing critical challenges, and obtaining support from stakeholders.

Keywords: digital transformation, resilience, port operations, roadmap.

RESUMO

O objetivo deste estudo é criar um guia abrangente para alcançar a resiliência operacional nas operações portuárias por meio da transformação digital. As atividades portuárias enfrentam desafios significativos em escala global, decorrentes da complexidade das operações e da ocorrência de eventos indesejáveis que podem interromper a continuidade

das operações. Para entender as práticas atuais de transformação digital para resiliência operacional, este estudo baseia-se na teoria dos sistemas, na teoria baseada em recursos e na teoria das capacidades dinâmicas como estruturas fundamentais. A metodologia "fit-for-purpose" é empregada para adaptar o método (referência cruzada) e a abordagem (metanarrativa) a fim de alinhar-se ao objetivo da pesquisa. As descobertas revelam que um roteiro para a transformação digital, com foco na resiliência, consiste em três narrativas principais: (1) avaliação e planejamento, que envolve a identificação de metas, estratégias, aquisição de recursos e estabelecimento de governança; (2) implementação, que inclui testes e integração de novas tecnologias, bem como treinamento de funcionários; e (3) monitoramento e avaliação, que envolve o acompanhamento e a avaliação do progresso e a realização dos ajustes necessários. Além disso, a eficácia dessas etapas depende do escalonamento gradual dos projetos, da priorização dos desafios críticos e da obtenção do apoio das partes interessadas.

Palavras-chave: transformação digital, resiliência, operações portuárias, roteiro.

RESUMEN

El objetivo de este estudio es crear una guía completa para lograr la resiliencia operativa en las operaciones portuarias a través de la transformación digital. Las actividades portuarias se enfrentan a importantes retos a escala mundial, derivados de la complejidad de las operaciones y de la aparición de sucesos indeseables que pueden interrumpir la continuidad de las operaciones. Para comprender las prácticas actuales de transformación digital para la resiliencia operativa, este estudio se basa en la teoría de sistemas, la teoría basada en los recursos y la teoría de las capacidades dinámicas como marcos fundacionales. La metodología "fit-for-purpose" se emplea para adaptar el método (referencias cruzadas) y el enfoque (metanarrativa) con el fin de alinearlos con el objetivo de la investigación. Los resultados revelan que una hoja de ruta para la transformación digital, centrada en la resiliencia, consta de tres narrativas clave: (1) evaluación y planificación, que implica la identificación de objetivos, estrategias, adquisición de recursos y establecimiento de la gobernanza; (2) implementación, que incluye la prueba e integración de nuevas tecnologías, así como la formación de los empleados; y (3) supervisión y evaluación, que implica el seguimiento y la valoración de los progresos, y la realización de los ajustes necesarios. Además, la eficacia de estos pasos depende de la ampliación gradual de los proyectos, la priorización de los retos críticos y la obtención del apoyo de las partes interesadas.

Palabras clave: transformación digital, resiliencia, operaciones portuarias, hoja de ruta.

1 INTRODUCTION

Port operations involve a complex and interconnected network of activities that facilitate the movement of goods and people through ports. These ports serve as crucial

gateways for global trade, and their efficient functioning is of utmost importance to the economic well-being of nations (Millefiori *et al.*, 2021). The scope of port operations is extensive and encompasses several tasks (Yau *et al.*, 2020). One such task is ship traffic management, which focuses on ensuring the safe and efficient arrival and departure of ships to and from port. This involves coordinating and monitoring the movement of ships, implementing navigational aids, and managing port traffic to minimize congestion and maximize efficiency.

One of the most important operational challenges encompasses global supply chain disruptions caused by events such as the COVID-19 pandemic that have resulted in congestion and delays at ports. Additionally, the growing impact of climate change has led to an increase in extreme weather events such as hurricanes and typhoons, posing a threat to port infrastructure and disrupting operations (Izaguirre *et al.*, 2021). On the other hand, a relevant strategic challenge involves the digitalization of the port sector. Port operators are undergoing a digital transformation, adopting new technologies such as automation, artificial intelligence, and blockchain (Ahmad *et al.*, 2021). However, this digitalization process brings its own set of challenges, such as the need to invest in new technologies and staff training.

To address these challenges, port operators are implementing several initiatives. This includes investing in new infrastructure and technologies, such as automated cranes and terminal management systems. In addition, they are adopting new operating procedures to increase efficiency and alleviate congestion. Theoretically, the main challenge is the complexity of port operations (Sirotic; Jugovic, 2023). Port operations involve a wide range of stakeholders and activities, and are interconnected with other transport and logistics systems (Russell; Ruamsook; Roso, 2020). This complexity makes it difficult to develop theoretical models that can accurately capture the resilience of port operations. In addition, port operations are dynamic and constantly changing. This makes it difficult to develop robust theoretical models that can be applied to different contexts.

Since recent studies indicate that digital transformation can help improve the visibility and transparency of operations, increase agility and adaptability, and strengthen collaboration and coordination along the supply chain, the objective of this work is to develop propositions for a route of implementation of digital technologies towards the

resilience of port operations. The research question that is intended to be answered is: what are the relevant steps for establishing a digital transformation implementation process that enables and increases the resilience of port operations? In this sense, the methodology used in this study was adapted to the purpose in question (i.e., fit-for-purpose methodology) (Sameti, 2022), using a cross-referencing method (Yanagihara; Fujihara, 2021) and a metanarrative approach (Hunter, 2019). These methods were found to be adequate for conducting a comprehensive literature review in a field characterized by intricate subjects and continuous development.

2 THEORETICAL BACKGROUND

2.1 PORT OPERATIONS

The existing body of knowledge on port operations is vast and continuously expanding. A plethora of literature, including academic research, industry reports, and government publications, is available on this subject. This literature covers a wide range of topics, such as port planning and design, ship traffic management, cargo handling, warehousing, customs and border control, port security, port economics and finance, port environmental impacts, and port sustainability.

Port planning and design requires a comprehensive understanding of factors such as the location of the port, the types of cargo to be handled, and the expected traffic levels (Sweeney; Becker, 2020). This knowledge assists in the efficient and effective planning and design of ports. Vessel traffic management systems play a crucial role in ensuring the safe and smooth arrival and departure of ships at major ports. These sophisticated systems are in place to manage and regulate vessel traffic, contributing to the overall efficiency of port operations. In addition, port operators are continuously exploring and implementing innovative cargo handling technologies to increase efficiency (Di Vaio; Varriale, 2020). This wide range of cargo handling options allows for the effective management of different types of cargo, meeting the diverse needs of port operations.

Port operations involve a multitude of stakeholders and activities, and are intrinsically intertwined with other transport and logistics systems (Notteboom; Pallis;

Rodrigue, 2022). This complexity poses difficulties in developing a comprehensive understanding of port operations. Another challenge stems from the dynamic nature of port operations. These operations are constantly evolving in response to advancements in technology, changing regulations, and changing market conditions. This makes it challenging to stay up-to-date with the latest trends and developments in port operations.

2.2 PORT RESILIENCE AND OPERATIONS

The most pertinent theoretical perspectives on operational resilience can be broadly categorized into two distinct approaches: systems theory and the resource-based view. Systems theory perceives organizations as intricate systems composed of interconnected components (Sony; Naik, 2020). This perspective proves valuable in understanding operational resilience, as it allows us to discern how disruptions can permeate the entire organization, affecting multiple departments and functions. On the other hand, the resource-based view focuses on the resources possessed by organizations and how these resources can be utilized to gain a competitive advantage (Barney; Hesterly, 2019). This point of view proves beneficial in understanding operational resilience, as it allows us to realize how organizations can employ their resources to absorb disruptions and recover quickly.

Systems theory has been instrumental in the formulation of several theoretical models of operational resilience. One such model is the absorption capacity model, which posits that organizations can increase their operational resilience by cultivating their absorption capacity (Caiazza *et al.*, 2021). Absorptive capacity refers to an organization's ability to identify, assimilate, and apply new knowledge. Another theoretical model rooted in systems theory is the resilience engineering framework (Mayar; Carmichael; Shen, 2022). This framework emphasizes the design of systems to be more resilient to disruptions and identifies four key resilience strategies: (1) prevention; (2) mitigation; (3) response; (4) Recovery.

Similarly, the resource-based view (RBV) has contributed to the development of several theoretical models of operational resilience that emphasize the role of resources. One of these models is known as the dynamic capabilities model. According to this

model, organizations can increase their operational resilience by cultivating dynamic capabilities (Essuman; Boso; Annan, 2020). These dynamic capabilities refer to an organization's ability to perceive and influence its surrounding environment.

The RBV framework offers valuable insights into the factors that contribute to the resilience of port operations. Firstly, it underlines the importance of resources in enabling businesses to achieve a competitive advantage. In the case of resiliency of port operations, this implies that ports that possess and efficiently manage critical resources are better equipped to withstand and recover from disruptions (Hussein; Song, 2023). Secondly, the RBV highlights the importance of resource heterogeneity, indicating that not all resources are equally valuable in terms of enabling businesses to achieve a competitive advantage. In the context of the resilience of port operations, this suggests that ports should prioritize the development and management of resources critical to their resilience, such as infrastructure, human capital, and technology.

2.3 DIGITAL TRANSFORMATION FOR THE RESILIENCE OF PORT OPERATIONS

Digital transformation theory highlights several significant trends that are driving the need for digital transformation. These trends encompass the rise of the digital economy, the growth of e-commerce, the emergence of new technologies, and evolving customer expectations (Lanzolla *et al.*, 2020). The global economy is progressively transitioning to digitalization, resulting in a shift in demand from physical to digital goods and services. This transformation requires organizations to adapt their business models to meet changing consumer preferences. E-commerce is experiencing rapid growth and revolutionizing the way consumers engage in shopping activities. As a consequence, organizations must modify their business strategies to align with the evolving needs of digital consumers.

Digital transformation theory also highlights several obstacles that organizations encounter when implementing digital transformation. These obstacles encompass legacy systems, digital skills gap, and cultural change (Pereira *et al.*, 2022). Many organizations have legacy systems that are incompatible with digital technologies. To effectively

implement digital transformation, these systems must be upgraded or replaced entirely. There is a shortage of digital skills in the workforce. Organizations should allocate resources to training and development initiatives to improve the digital proficiency of their employees. Finally, digital transformation requires a cultural shift within organizations. Employees must be open to embracing new technologies and adopting new ways of working in order to successfully navigate digital transformation.

3 METHODOLOGICAL PROCEDURES

The fit-for-purpose methodology is a versatile research design approach that highlights the importance of customizing research methods to meet the particular requirements of the search query. This methodology is based on the notion that there is no universal research approach that can be applied to all research scenarios, and that the most effective research methods will differ depending on the context of the research (Sameti, 2022). The fit-for-purpose methodology is an advantageous strategy for conducting research, as it allows researchers to customize their research methods according to the specific requirements of their research investigation. This customization helps to ensure the relevance and usefulness of the research, as well as the reliability and validity of the findings.

Cross-referencing is a research technique that involves the connection of multiple sources to demonstrate their interrelationship (Yanagihara; Fujihara, 2021). This can be achieved by citing one source within another. The importance of cross-referencing in academic research lies in its ability to allow researchers to pinpoint the sources of their information, which is crucial for academic integrity and to allow readers to evaluate the sources themselves. In addition, cross-referencing allows researchers to substantiate their arguments with evidence, demonstrating that their claims are supported by existing literature.

The systematic review method known as the metanarrative approach to research aims to amalgamate research findings from various paradigms and traditions. This approach is especially appropriate for topics that have been studied using diverse conceptualizations and methodologies (Hunter, 2019). The metanarrative approach to

research is a systematic review method that aims to amalgamate research results from various paradigms and traditions. This approach is particularly useful for topics that have been studied using different methodologies and conceptualizations. Initially, the relevant literature is identified and analyzed to understand the various ways in which the research topic has been studied. Subsequently, the findings of the different studies are synthesized into a comprehensive and coherent narrative that emphasizes the similarities and differences between the studies and identifies any gaps in the literature.

Chart 1 indicates the literature and themes identified for the formation of the digital transformation guide for the resilience of port operations.

Chart 1 – Cross-references for model construction: categorization

Theme	References
Evaluate and plan	Zhou <i>et al.</i> (2021); Tijan <i>et al.</i> (2021); Hein; Schubert (2021).
Implement	De la Peña Zarzuelo; Soeane; Bermúdez, (2020); Liu; Gu; Chen (2023); Verschuur; Koks; Hall (2020); Notteboom; Pallis; Rodrigue (2021).
Monitor & Measure	Shaw <i>et al.</i> (2019); Del Giudice <i>et al.</i> , (2022); Gu; Liu (2023).

Source: Based on Yarovy; Kudriavtsev (2022).

4 RESULTS AND DISCUSSION

4.1 PHASE 1: EVALUATE AND PLAN

a) Assess the current state of digital transformation in the port

Assessing the current condition of digital transformation within the port requires an examination of the port's existing use of digital technologies, along with an analysis of its proficiency and deficiencies in terms of digital maturity.

b) Identify the port's resilience targets

Is the port currently facing resilience challenges that require specific attention? How can digital transformation be used to address these challenges effectively?

c) Develop a digital transformation strategy

The formulation of a comprehensive strategy is imperative to outline the port's comprehensive vision for digital transformation, encompassing both the long-term perspective and the precise steps to be taken to realize that vision.

(d) Secure funding and resources

To successfully undergo digital transformation, it is imperative to allocate resources and investments to both technological advancements and human capital. To effectively execute its digital transformation strategy, the port must prioritize securing essential funding and resources.

e) Establish a governance structure

Determine the individual or entity responsible for overseeing the digital transformation process. Determine the method of decision-making and the means of monitoring progress.

Recent literature indicates that the formulation of the digital transformation strategy requires the outlining of the port's enduring vision for digital transformation, along with the precise measures that will be implemented to realize that vision (Liao; It; Pan, 2023). It is imperative that the strategy is congruent with the overall resilience objectives of the port and should be based on a pragmatic assessment of the port's existing digital capacities and available resources.

4.2 PHASE 2: IMPLEMENT

a) Testing new technologies

To ensure the successful implementation of new technologies on a larger scale, it is imperative that the port initially conducts pilot testing on a smaller scale. This preliminary phase allows for the assessment of the feasibility and effectiveness of the technologies prior to their widespread deployment.

b) Integrate new technologies with existing systems

To avoid the formation of siloed systems and fragmentation, it is imperative that the port ensures the seamless integration of new technologies into the pre-existing infrastructure.

c) Train and qualify employees

Employees must undergo training to acquire the necessary proficiency in utilizing emerging digital technologies. Additionally, the port must allocate resources to enhance

the skills of its employees, thereby ensuring their ability to effectively contribute to the digital transformation process.

d) Manage Changes

To minimize disruption and ensure employee alignment with the process, effective change management is crucial for the port amid the potentially disruptive nature of digital transformation.

Current research demonstrates that digital technologies offer several opportunities to increase operational resilience (Marcucci *et al.*, 2022). One such opportunity is the use of AI and ML to develop predictive analytics models. By employing these models, organizations can proactively identify potential disruptions before they materialize, allowing them to implement preventative measures and mitigate the impact of such disruptions. Another way digital technologies improve operational resilience is through the application of big data analytics. This approach increases visibility and transparency into operations, enabling organizations to quickly and effectively identify and respond to disruptions.

4.3 PHASE 3: MONITOR AND MEASURE

a) Monitor the progress of the digital transformation process

This encompasses the monitoring of crucial indicators, such as the assimilation of new technologies, the analysis of profitability and the influence on resilience.

b) Measure the effectiveness of the digital transformation strategy

It is imperative that the port conducts periodic assessments of its digital transformation strategy to verify its ongoing alignment with the port's resilience objectives and monitor its progress.

c) Make adjustments as necessary

To achieve its resilience goals, the port must be willing to modify its digital transformation approach as needed.

Recent work indicates that data on these metrics can be collected by ports using various methods, including surveys, interviews, and focus groups (Inkinen; Helminen; Saarikoski, 2019). Once collected, this data can be utilized by the ports to monitor their

progress over time and identify areas that need improvement. By assessing digital transformation for operational resilience, ports can identify areas where progress has been made and areas that still need improvement. This valuable information can be utilized to enhance your digital transformation strategy and ensure that digital technologies are being utilized in the most efficient way to increase your resilience.

The indicated benchmarks also suggest the critical factors for the success of digital transformation towards operational resilience. It is recommended to start with a few specific projects and scale gradually as experience is gained. Additionally, it is important to focus on addressing the most critical resilience challenges and gaining buy-in from all stakeholders, including employees, customers, and regulators.

5 FINAL CONSIDERATIONS

Digital transformation is a crucial factor for ports to achieve resilience in the face of increasing disruptions. By investing in digital technologies and transforming their operations, ports can increase their visibility, agility, and adaptability. This can be achieved through the use of sensors, data analytics, cloud computing, big data, artificial intelligence (AI), blockchain, and digital platforms. Improved visibility and transparency can help ports identify and respond to disruptions faster and more effectively. Increased agility and adaptability can enable ports to respond to disruptions faster and adapt their operations to changing conditions. Additionally, improved collaboration and coordination with other stakeholders in the global supply chain can help ports better manage disruptions and reduce their impact on the global supply chain.

Implementing digital transformation in ports is not without its challenges. One of the major obstacles is the presence of legacy systems that are incompatible with digital technologies, requiring upgrades or replacements. Additionally, there is a shortage of digital skills in the workforce, requiring ports to invest in training and development to upskill their employees. In addition, digital transformation requires a cultural shift within ports, with employees needing to be open to embracing new technologies and ways of working. Despite these challenges, the benefits of digital transformation for port resilience are evident. Ports that invest in digital transformation will be better equipped

to withstand and recover from disruptions, as well as maintain their competitiveness in the global economy.



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