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Experience In Digital Control At Some Major Container Seaports In The World

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Abstract:
Background*: This article delves into an innovative approach for transforming traditional container seaports into sustainable digital hubs, optimizing land utilization for enhanced productivity. This strategy is applicable to a wide range of container ports worldwide, encompassing both compact facilities and sprawling mega-ports. While digital control represents just one facet of the broader digital transformation process, it plays an indispensable role in ushering humanity into the era of digital technology. The creation of sustainable ports not only ensures their resilience during pandemics but also serves as a crucial lifeline during disaster scenarios, facilitating the distribution of essential resources like food, water, and medicine, as well as the uninterrupted operation of hospitals and medical facilities.*
Materials and Methods*: When starting to conduct research on this field of numerical control in container seaports, the researcher used both quantitative, qualitative and mixed methods of the two. From there, bring the clearest and most direct view of the effects and future development directions of digital control.*
Results*: By implementing a sustainable digital control strategy for seaports, we can effectively mitigate the environmental impact stemming from activities within the ports, including maritime traffic, cargo handling, and road and rail transportation. Significantly, this approach enhances gender equality and empowers women within the context of sustainable seaports, where responsibilities are shared equitably, providing women with increased opportunities to cultivate and showcase their talents.*
Conclusion:*This study introduces a novel concept for revitalizing container seaports by integrating digital technology more efficiently, making them smarter and more sustainable through numerical control. Simultaneously, it stimulates the growth of container seaport operations, contributing to the economic advancement of both specific regions and the nation as a whole*
Key Word*: smart container seaport, ocean economy, sustainability, digitalization, numerical control*
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I. Introduction

The ocean economy plays a pivotal role in bolstering the GDP of coastal nations, and within this context, seaports, including container seaports, function as pivotal hubs in the commodity production cycle. These seaports not only drive economic prosperity but also serve as guardians of national security and territorial integrity on the homeland. Seaport trade involves a multitude of stakeholders, ranging from domestic and international business consumers to maritime operators. To usher in a smarter and more sustainable era in the transportation of goods, seaport infrastructure must undergo adjustments, upgrades, and reconstructions, both in terms of transshipment operations on vessels and on land. This transition paves the way for seamless integration between road and maritime systems. In the wake of the rapid technological advancements of the Fourth Industrial Revolution and the advent of the Fifth Industrial Revolution (as noted by Hokey Min in 2022), today's container seaports face mounting pressure to implement digital control technologies aimed at resolving challenges within seaports, particularly those related to traffic flow management within port facilities. Both theoretical analysis and practical studies have confirmed that digitally controlled intelligent container terminals significantly reduce response times for port users, enhance asset utilization within the port, and amplify the visibility of logistics services by digitally managing equipment and machinery while seamlessly integrating digital platforms into various maritime operations, minimizing human intervention. The contemporary development of seaports, including smart container seaports, places a strong emphasis on their capacity to handle surging traffic volumes and the intricate distribution of freight through diverse transport routes. Digital technologies, automation, IoT, cloud computing, and numerical control are progressively supplanting human involvement in various spheres of social life, ranging from everyday transactions like purchasing goods and banking to more intricate and sensitive domains such as healthcare and education. This progression has given birth to the concept of the "Smart container seaport."

Container seaports are ideally equipped to handle the transshipment of large and heavy cargo via colossal container vessels that cannot be transported by road. Larger seaports serve as pivotal focal points and

transshipment hubs for maritime activities, while smaller ports, particularly those seamlessly connected to road and rail transport networks, become vital sources of goods through short-distance maritime transport via inland waterways. Hence, the construction of a smart container seaport, incorporating numerical control technologies, represents a strategic move toward sustainable development, making a substantial contribution to international trade, benefiting businesses, and advancing the welfare of the entire nation.

This study seeks to present models, theoretical frameworks, and global experiences in the development of digital control systems for container seaports. It aims to illustrate the explicit linkage between digital control in smart container seaports and smart cities, showcase strategies for enhancing the efficiency and synchronization of equipment and technologies in container seaports, and highlight digital control software technologies that expedite logistics operations within these ports.

Additionally, the article discusses the influence of local government in shaping the choice of digital control technologies at seaports and the strategies underpinning their development. A critical emphasis is placed on sustainable development, particularly in the context of integrating renewable energy sources within the seaport area. This integration is deemed a pivotal focus, with a clear and swift implementation orientation, even in areas where economic potential for digital control development may be limited.

II. Material And Methods

This Karaś (2020) provides a comprehensive understanding of smart container seaports. These ports are not merely centers for managing technological processes; they also serve as hubs where digitization is harnessed to enhance operational efficiency. Furthermore, smart container seaports are envisioned as spaces for integration with adjacent cities and for sourcing energy from sustainable alternatives such as wind, seawater, and solar power. In this context, a digitally controlled intelligent seaport can be envisioned as more than just a transshipment point for goods between waterways, railways, and road networks. It emerges as a dynamic entity, self-sustaining and self-improving, drawing from the inherent resources of the seaport itself and forming close ties with the smart city it's affiliated with.

Consequently, smart container seaports have garnered substantial attention as a global trend, drawing interest and efforts from various countries. While they have made significant technological and resource advancements to boost labor productivity and performance, there remains an urgent need to explore new directions for further enhancing economic efficiency and labor productivity.

Digitally controlled intelligent container seaports contend with a host of internal and external challenges, including congestion issues with ships and trucks, connectivity problems in container transportation between waterways, roads, and railways, container yard management, logistics delays, and power supply inadequacies.

Given the existing limitations and weaknesses in today's smart container seaports, it is imperative to seek improved solutions to overcome these challenges. The researcher's approach centers on adopting numerical control technology to address these issues, exploring alternative operational methods, and redefining the production models used in seaports. The goal is to identify strengths and weaknesses and propose constructive measures to enhance the situation, thereby fostering regional economic growth and stimulating consumer demand.

As of now, there is a scarcity of scientific literature that comprehensively addresses these conditions. The researcher's work promises to unveil fresh perspectives on the application of digital control technology within contemporary smart container seaports, and to outline the necessary and sufficient factors and conditions required for the development of this field.

III. Result

After Numerous research endeavors worldwide have explored the realm of digital control within container seaports. This article aims to showcase several illustrative instances of digital control implementations in container seaports across all five continents.

Numerical control at container seaports in Europe

Douaioui et al. (2020) have contended that a pivotal model involves the integration of smart seaports with their corresponding smart cities, representing a crucial stride towards harmonizing digitally controlled container seaports with the smart city concept. This symbiotic relationship lays a robust foundation for digital control, paving the way for a sustainable future. In parallel, Donepudi (2022) has presented an encompassing model of a smart port, replete with automated components. Furthermore, two distinct models elucidate the intricate interplay among equipment and machinery utilized in container seaports, all orchestrated on a shared IoT platform designed specifically for seaports.

Across Europe, nations with seaports have been diligently advancing digital control initiatives within their container seaports, a testament to their commitment to digital transformation. The unifying theme across

Europe lies in their steadfast dedication to research and development in the realm of digitally controlled container seaports, recognizing this as a pivotal path towards future progress. However, a divergence emerges in the form of tangible models that elucidate the cohesive integration of technologies and equipment employed in container seaports. In this regard, Europe has embarked on the initial steps of transitioning container seaports into digitally controlled intelligent entities. Despite this momentum, uncertainty looms as they grapple with finding the precise direction for fostering the evolution of digital control within their container seaports.

Numerical control at container seaports in Asia

The University of Rijeka (2022) emphasizes that achieving sustainable development in container ports hinges on innovation, particularly in the realm of digital control technology. The implementation of innovative solutions at seaports profoundly impacts the efficacy of container port activities, leading to cost reductions and bolstering their competitive standing in the market, thereby influencing the broader regional economy. These innovations, particularly those related to digital control technology, yield significant environmental benefits and enhance the quality of life for surrounding communities.

According to Jović et al. (2022), the sphere of digital control in shipping and container ports is evolving rapidly. Recent advancements in digital control technology, both within the maritime industry and specifically within container seaports, have propelled society closer to a transformative digital era encompassing all aspects of life. The primary objective is to address the critical questions arising during the process of digital control at container seaports. However, amidst this rapid technological development, specific risks like data tampering and manipulation require careful and thorough analysis. In contrast, the development of digital control in this sphere is still in its infancy, marked by fragmentation and a lack of a cohesive, official direction, as observed in European container seaports. In Asia, the implementation of numerical control applications primarily aims to simplify and expedite container entry and exit processes at a later stage. They also introduce novel, streamlined administrative procedures for customers involved in importing and exporting containers.

Notably, digital control efforts in Asian container seaports are predominantly software-centric, concentrating on simplifying end-to-end operations in the container production cycle. They particularly target customers and container vessels as the audience, designing numerical control software applications to facilitate document-related procedures for container delivery and streamline ship docking through digital control platforms at the seaport. These efforts introduce models and directions to simplify specific steps in the customer's container delivery and shipboarding process. Key technologies and equipment in Asia primarily revolve around software solutions designed to expedite container delivery processes, such as the DigitalPort @SG one-stop digital portal, the maritime service system Just in Time, the Yest u-Port electronic gateway, and the u-IT gateway, which enhances user convenience in container forwarding. The I-Log platform addresses terminal operation issues at container seaports.

With a customer-oriented approach, container seaports build trust and allure more customers, thereby positioning themselves as preferred transshipment locations. Additionally, this strategy serves as an effective means to promote the container port business and confer a competitive advantage to small and medium-sized container seaport enterprises. Focusing on the needs and preferences of container ships fosters trust among shipowners and businesses, elevating a container seaport's desirability for vessel arrivals. Historically, Asian container seaports lagged behind the rest of the world, with a few exceptions like the cargo hubs of Singapore and the Shanghai ports in China. However, the advent of customer-centric digital control technologies, coupled with increased orders and customer preferences, has catapulted Asian container seaports into global significance. These seaports now serve as preferred destinations for cargo entering Asia from Europe and other continents. Nonetheless, Asian container seaports still grapple with infrastructure and superstructure deficiencies, limited technological capabilities, and restrictions on accommodating large-tonnage vessels. Many Asian countries remain in the development phase, lacking the financial means and budgets to mobilize capital for digital control development in container seaports. Asia's current imperative for container seaport development lies in enhancing human expertise in science and technology, while concurrently addressing the infrastructure inadequacies and challenges inherent to these seaports. Only after addressing these fundamental aspects can the region contemplate the establishment of a model for numerically controlled container ports, ultimately fostering heightened labor productivity, bolstered competitiveness, and enhanced goods production within the container seaports.

Numerical control at container seaports in Australia

Eric Smit (2022) has introduced several initiatives aimed at advancing numerical control in smart ports across Australia. The emphasis has been on the pivotal role of digital control, especially as North Queensland Bulk Ports (NQBP) seeks a comprehensive perspective on integrating numerical control into port operations. This drive aims to enhance efficiency and lay the groundwork for successful future endeavors. Ports Australia

(2022) has articulated the need for a division of roles, functions, and responsibilities between specific government agencies and seaports within Australia. These local government-managed seaports are envisioned as prime candidates for the incorporation of digital control technology into their operational processes. Various government agencies play critical roles in this endeavor, including:

Austrade: Responsible for deploying a commercial system, a vital component of the interactive production chain at container seaports, and overseeing tasks that require control.

Australian Border Force: Tasked with facilitating the one-stop shop approach for container-related issues.

Ministry of Agriculture and Environment: Engaged in enhancing the maritime warning system.

Department of Transport Infrastructure, Regional Development: Spearheading the construction of national data centers for vessels and trucks servicing container seaports.

Western Australia Transport and Logistics Council: Charged with implementing pilot projects to enhance transparency and monitor container transportation

Transport NSW-Transport for New South Wales: Responsible for developing a business system for the freight community at container ports.

Despite mentions of introducing digital control into production activities at container seaports, the seaports in Australia lack a concrete, unified direction for the development of smart ports. Their approach primarily involves offering several solutions to make the ports "smarter" and emphasizes the mandates of Australian government agencies and seaports in facilitating the integration of digital control into container ports.

The key commonality among the Australian container ports mentioned lies in their reference to various solutions for the development of smarter container ports, predominantly through the application of numerical control to port operations. What sets Australia apart from the global landscape is the establishment of close, purposeful connections between government agencies and seaports, fostering the deployment of digital control applications in container seaports. This collaborative approach underscores the vital role played by host country government agencies in the development of digital control at container seaports.

The technologies and equipment offered in Australia primarily encompass small-scale software solutions for loading and unloading operations and information modeling at container seaports (BIM). While container seaports in Australia have taken practical measures to implement both hardware and software for digital equipment and machinery in their operations, there is a notable absence of a consolidated cyber platform uniting these technologies across the continent.

Despite the modest scale, the improvements achieved in terms of labor productivity and production efficiency in Australian container seaports are laudable, especially when compared to their historical performance, which trailed many other continents.

Australia's geographical advantage of being surrounded by the sea on all sides and the prevalence of coastlines in all Australian states provide substantial potential for equitable and distributed growth in the maritime sector. This stands in contrast to regions concentrated around specific areas. Additionally, Australia boasts a higher level of expertise in marine science and technology, particularly in container seaports, compared to many other maritime nations, furnishing a solid foundation for the development of digital control in container ports.

In line with Europe, Australia possesses economic potential, investment capital, and a digitally skilled workforce. However, the country still awaits a definitive direction for the advancement of digital control in container seaports. A crucial initial step is to formulate a comprehensive model for digitally controlled container ports, which can guide and unify their digital control efforts.

Numerical control at container seaports in Africa

The United Nations Conference (2022) has advocated a project aimed at concurrently developing digital control for intelligent container seaports and fostering sustainable development across African nations, including the development of small islands as a future target. Huawei (2022) has underscored the substantial benefits that African container seaports can derive from the implementation of smart container port systems with digital control capabilities. Specifically, the control of container port operations through digital means can facilitate the supply chain in Africa. While African governments are investing in expanding container port infrastructure to mitigate congestion and container loading/unloading delays, such expansion incurs additional commercial costs. Consequently, there is a pressing need to consider the control of container seaport operations alongside the current port conditions. Trade volume through container seaports in Africa is considerable, yet only a few container ports operate optimally due to the lack of fully integrated rail and road systems that enable operational elements to communicate and allow customers to monitor the progress of their containers.

At present, seaports in Africa, including conventional container seaports, exhibit numerous shortcomings and deficiencies, spanning from port infrastructure to auxiliary facilities for production activities. Developing smart ports demands a substantial investment, which poses a significant financial burden on

economically challenged African nations. As such, the development of digital control in Africa remains a distant prospect. While discussions about it have taken place, no substantial progress has been made toward transforming a container seaport into a digitally controlled container seaport. Therefore, the development of digitally controlled intelligent container seaports still faces an uncertain future in African countries with seaports.

Africa, despite having some preliminary plans for developing smart containers, grapples with challenges stemming from conflict and poverty that have impeded the continent's progress. To date, equipment and machinery systems for loading, unloading, and production activities in African seaports remain underdeveloped, outdated, lack significant upgrades, and exhibit a lack of synchronous connectivity. Common characteristics among container seaports in Africa include their antiquated and underdeveloped status, often trailing behind many Asian countries. Furthermore, due to economic weaknesses and limited technological advancements, there are numerous areas for potential local economic development, including within the container seaport sector. The distinguishing feature in Africa's approach is the integration of digitally controlled intelligent container ports with sustainable development, a critical focus that sets it apart from many countries in other continents. Although Africa has set the right development course, container seaports in Africa have yet to implement a specific process or adopt digitally controlled equipment and technology for production tasks.

In its pursuit of sustainable development with the goal of digitally controlled intelligent seaports, Africa is embarking on a commendable and forward-thinking journey, aiming to leave a positive legacy for future generations. This endeavor is not limited to African container ports but extends to container ports worldwide. The mere contemplation of research aspects related to digitally controlled intelligent seaports reveals a stark contrast in awareness and the level of human understanding within the African region. Despite being the world's poorest and most underprivileged continent, African nations have shown their resilience, proving that they are "handicapped but not incapacitated." This has manifested through significant contributions to global science and technology, including the development of digitally controlled intelligent container seaports.

Currently, Africa grapples not only with financial constraints and development challenges but also lags behind in terms of scientific and technological advancements. Therefore, Africa's foremost priority is to address issues related to hunger and underdevelopment within its nations. Subsequently, the continent can shift its focus toward economic development, including the establishment of digitally controlled intelligent seaports, by introducing a model for digital control in container seaports.

Numerical control at container seaports in Americas

The United States Environmental Protection Agency (2022) has stressed the significance of evaluating energy technology within coastal regions of container ports in the United States through the application of digital control. These container ports prioritize the meticulous surveillance of goods entering the U.S., ensuring safety measures to enhance business competitiveness and create employment opportunities for Americans. Aisha et al. (2021) have argued that the terminal operations in container seaports play a pivotal role as heating elements within a multimodal transport system. Control over terminal operations within the port significantly contributes to improving container loading and unloading processes, thereby enhancing operational efficiency at container seaports.

The information above provides a more lucid perspective on the development of digital control in the Americas. The region aligns its efforts with sustainable development, particularly focused on environmental protection, and delineates specific directions and methods for integrating digital control into container seaports.

What sets the Americas apart from other continents is their emphasis on deploying technology to safeguard the marine environment, resulting in solutions for reducing air pollution in container seaport areas. Their approach is methodical and highly controlled: they first identify challenges or impacts affecting container seaports, break down complex problems into manageable components, and meticulously plan stages for numerical control to address each specific issue in a systematic manner. Subsequently, the container ports in the Americas leverage their development opportunities to extend their influence to other potential markets, such as Asia and Australia. The Americas have introduced digital control technology and advanced technological equipment for production activities at seaports, with a simultaneous focus on environmental protection. This includes innovations like coastal electric energy technology.

Seaports in the Americas exhibit a clear and strategic direction toward smart port development. Their substantial financial resources give them a distinct advantage in constructing smart container seaports. Consequently, their digitally controlled equipment and machinery are among the most cutting-edge and modern in the world. These technologies are integrated on a shared management platform within the cyberspace of seaports, ensuring seamless operation across the entire continent.

As the Americas embark on their plans to implement digital control in container seaports, they have adopted a pragmatic, efficient, and forward-looking approach. They anticipate the manifold benefits that digital

control will bring to America's container ports and the broader continental economy. Additionally, the development of coastal infrastructure to serve container seaports and their adjacent cities represents a long-term solution that guarantees both environmental safety and hygiene. This encompasses the well-being of air and water quality, as well as safety standards.

The Americas consistently lead the way in developing new scientific and technological applications, including digital control at container seaports. This competitive edge is leveraged to the fullest, not only for research but also for the practical application of digital control concepts within container seaports. This endeavor requires significant financial, human, and political resources, along with various other contributing factors, and few regions can match the Americas in this regard. The critical point to note about container ports in the Americas, as in other continents, is the absence of a clear strategy for future development – a model for intelligently controlled numerical container ports. Once the Americas define a path for their container seaports, the transformation will be rapid, ushering in a significant shift in the global seaport economy. It will also serve as a magnet to attract foreign investors and visitors from other continents, eager to learn and share experiences and elevate the Americas to the position of a pioneering elder in the field.

General comments on the situation of digital control in container seaports in the world

In various regions across Asia, Australia, the Americas, and Africa, digital control technology is being gradually integrated into seaport operations to enhance productivity and transition from standard ports to smart ports. Discussions about digital control in the context of container seaports have primarily occurred in seaport research forums and international conferences, often focusing on the convergence of digital control with sustainable development. European seaports have shown remarkable vision and pace in developing intelligently controlled container seaports. They have not only emphasized the imperative of digital control technology but have also introduced innovative concepts in line with societal evolution. Moreover, they've presented comprehensive models, ranging from high-level overviews to intricate details, facilitating a more intuitive understanding of the steps required to implement digital control in container seaports.

Many seaports across the world, excluding those in Africa, have advanced processes and modern, high-tech equipment and technologies. These advancements have led to significant enhancements in labor productivity, yielding a host of positive results.

In summary, seaports worldwide have initiated specific actions to progress toward smart container seaports. However, there is a lack of a clearly defined and uniform direction for this development. To establish smart container seaports, it is crucial to collaborate between the public and private sectors. This partnership is essential since the private sector boasts substantial economic and technological potential, while the public sector provides the necessary regulatory framework. Thus, adopting a port owner model is a promising approach for developing intelligently controlled container seaports. Furthermore, it is crucial to research and develop a model for applying numerical control to production activities within the port. This includes equipping the container seaports with the requisite digitally controlled machinery for loading and unloading operations, offering a highly effective path toward realizing smart container seaports.

Nevertheless, the information mentioned above only represents a portion of the entire seaport system. While it offers a viable option, it may not be the most optimal one. The first step toward enhancing port processes involves a comprehensive overhaul of the port's internal infrastructure, followed by the incorporation of modern software technologies into the port's daily operations. This comprehensive transformation is essential for evolving an ordinary seaport into a smart seaport.

Numerical control has a widespread impact across various maritime sectors, including container ports. It enhances port productivity, thereby improving efficiency and competitiveness. However, the challenges related to interoperability and linkage between digital control systems in container seaports must be addressed promptly. This includes aspects like IoT data collection, network connections, data storage and restoration, data analysis, and factors influencing analysis outcomes. The ability to integrate digital control devices will drive transformative changes in the communication between technology and seaports.

Furthermore, issues persist regarding the development of seaport ecosystems into green seaports, a fundamental prerequisite for achieving contemporary sustainable development goals. These ecosystems are often affected by external factors or third parties conducting activities around the port. Achieving transparency in digitized data and digital control can also be a complex matter, as companies may be hesitant to share information with competitors.

However, blockchain technology presents an effective solution. It ensures transparency in document and information verification throughout the supply chain. Blockchain bolsters traceability and supports digital control processes in seaports. Numerical control necessitates substantial human and material resources. Information storage issues are prevalent in container seaports, especially in smaller ports where a single individual manages information. Infrastructure components, such as information systems, often operate disjointedly and asynchronously. Container seaports worldwide are continuously striving to adopt more

efficient, innovative, and user-centric operational models, guided by the concept of Smart Seaports, ensuring that port activities are sustainable. These efforts mainly revolve around four key areas: environmental sustainability, technological advancements, geopolitical stability, and demographic shifts in port areas.

The challenge lies in the disruption experienced while introducing numerical control to ports. As seaports, including container seaports, strive to integrate digital control into their operations, many are still in the early stages of this transition. Comprehensive adoption of digital control has been limited to a select few modern ports worldwide, such as the Dutch port of Rotterdam, the Port of Singapore, and the Port of Shanghai in China. In regions with underdeveloped economies and limited technological advancements, the application of digital control remains a complex and lengthy endeavor. To successfully implement digital control in container seaports, a flexible approach is needed. This model should cater to the unique needs of each specific area and port type, whether privately or publicly owned. It should address the processes, equipment, and technologies that suit the size and function of the seaport. The application of digital control technologies within container seaports will lead to optimized labor productivity and operational efficiency, unlocking the full potential of seaport production compared to traditional port operations today.

IV. Conclusion

The adoption of digital control technologies is an inevitable progression that all countries worldwide will eventually need to embrace to stay in step with the ever-advancing era. While larger nations have taken the lead in numerous sectors, including the maritime industry, smaller countries are gradually and cautiously embarking on their transformation journey. To emerge as a new powerhouse in the maritime economy and establish themselves as global Hub Ports, coastal nations must undergo substantial changes. Container ports, being a vital component, are of paramount importance and serve as a model for other nations to observe, study, and emulate.

To secure a promising future, there are two essential aspects that need to be addressed. Firstly, the deployment, enhancement, and implementation of contemporary management software for operational activities within container ports are imperative. Simultaneously, there is a pressing need to revamp the entire infrastructure and replace outdated hardware. As we are now in the era of Industry 5.0, a more adaptable framework is essential to accommodate advanced technological applications from across the globe.

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