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Transformation of Green Digital Paradigm of Port Terminal Enterprises through Systematic Theoretical Approach: Organizational Change and Innovation Management Strategies

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[Abstract]

The global port terminal industry is undergoing a paradigm shift due to the demand to adopt eco-friendly and digitized operations. This study investigated the eco-friendly digital transformation of port terminal companies to explore the factors driving this change, related challenges, and strategies for successful implementation. Through related case studies, this study derives essential strategies to promote the eco-friendly digital transformation of port terminal companies, and derives the importance of leadership, organizational change, and collaboration with stakeholders. Through this, we proposed a framework based on valuable insights and system theory that can align the operation of domestic port terminals with global sustainability standards and increase resource efficiency. We found that technology plays an important role in optimizing port efficiency and reducing environmental impact, identified the importance of an integrated approach for eco-friendly digital transformation, and it is expected that it can be used as a basis for establishing policies for the eco-friendly paradigm shift of ports in the future.

▸ **Key words**: Port Terminal Industry, Green Digital Transformation, Sustainable Port Operations, Organizational Change

[요 약]

글로벌 항만 터미널 산업은 친환경적이고 디지털화된 운영을 도입하려는 수요로 인해 패러다임 전환이 이루어지고 있다. 본 연구는 항만 터미널 기업의 친환경 디지털 전환을 조사하여 이러한 변화를 주도하는 요인과 관련 도전과제, 성공적인 추진 전략을 모색하고자 하였다. 본 연구는 관련 사례 연구를 통해 항만 터미널 기업의 친환경 디지털 전환을 촉진하기 위한 필수 전략을 도출하고, 리더십, 조직 변화, 이해관계자와의 협업의 중요성을 도출하였다. 이를 통해 국내 항만 터미널 운영을 글로벌 지속가능성 기준과 일치시키고 자원 효율성을 높일 수 있는 귀중한 인사이트와 시스템 이론에 기반한 프레임워크를 제안하였다. 우리는 기술이 항만 효율성 최적화와 환경 영향 감소에 중요한 역할을 한다는 것을 발견하고, 친환경 디지털 전환을 위한 통합적 접근의 중요성을 확인하였으며, 향후 항만의 친환경 패러다임 전환을 위한 정책 수립의 기초자료로 활용될 수 있을 것으로 기대된다.

▸ **주제어**: 항만터미널 산업, 친환경 디지털 전환, 지속 가능한 항만 운영, 조직 변화

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I. Introduction

The transition to an eco-friendly digital paradigm is essential for building a sustainable environment in the modern global port terminal industry. This is achieved by reducing carbon emissions and improving resource efficiency through AI-based digital platforms [1].

Eco-friendly digitalization of ports began in the early 20th century, but interest has declined since the 2008 financial crisis. However, after the bankruptcy of Hanjin Shipping in 2017, a series of mergers and acquisitions among port terminal companies raised interest in productivity and efficiency again [2]. Figure 1 shows the results of text mining identifying key interconnections among digital ports, technology elements, the marine industry, and sustainable management.

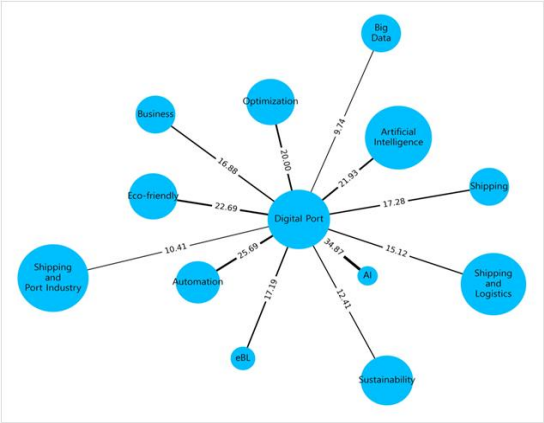

Fig. 1. Text network analysis on Digital Port

These changes have led to increased demand for comprehensive logistics process integration, standardization, and green digital platforms, which are closely related to goals such as optimizing energy use to reduce carbon footprint and minimizing latency. Port terminal companies are actively pursuing green digitalization and introduction of ammonia fuels as they adapt to changing global trends, such as rising expectations for ultra-personalized customers such as shippers and shipowners [3]. The main motivation for this transition is to optimize organizational efficiency and innovation capabilities essential for developing operational services that meet the needs of modern stakeholders.

Domestic port terminal companies are aware of the need for a paradigm shift, and we can see that they are aware of this need through Busan New Port Terminal 7 [4] which is the first fully automated port using eco-friendly battery-driven automated guidance vehicles (AGVs) and remote controlled cranes in Korea. This transition will take place in four dimensions. First, we will cultivate a mind to embrace new technologies among individuals in operational roles. Second, we will promote active collaboration to avoid the silo effect. Third, we will build an eco-friendly digital port logistics ecosystem. Fourth, we will strengthen community and policy support to systematize this transition.

The purpose of this study is to evaluate the feasibility of implementing the eco-friendly digital paradigm shift among domestic port terminal companies to align with global standards. Through an approach based on system theory, we will analyze the essentials, barriers, and challenges required for a successful implementation, providing valuable insights for practical application.

II. Previous Studies and Methodology

1. Theoretical Background

This work is initiated by considering the theoretical basis of the green digital paradigm shift. Specifically, the focus is on the transition process of port terminal companies as described in System Theory. To meet the expectations of, green work beyond mere cost savings must be established. Hub spoke strategies are constantly evolving, especially in the global supply chain [5]. This trend is establishing new operating standards based on environmental, social, and governance (ESG) management. Accordingly, the transition to green digital transformation strategies [6]. In order to promote environmental definition and sustainability,

which are essential for future competitiveness, the introduction of technologies for energy supply and resource relocation is essential [7].

The shift in the eco-friendly digital paradigm is driven by the rapid development of digital technology and the increasing demand for environmental sustainability, including the introduction of AI and big data [8]. Companies must be integrated with environmentally friendly technologies to analyze marine data and enhance their competitiveness [9]. Business managers are getting information from data, which enables them to actively respond to trends in the marine logistics market [10], which can optimize energy management and reduce carbon emissions, which allows port companies to provide customized digital services to meet the unique needs of stakeholders. Flexible organizational principles and commitment to continuous digital innovation are also important.

As external factors such as COVID-19 worsen labor shortages and increase pressure on logistics digitization, the urgent need for a green digital paradigm shift is increasing [11]. In addition, the need to comply with stringent environmental regulations and the expectations of stakeholders are further strengthening the urgency of this transition. Major challenges include shifting existing port operations to an eco-friendly digital model and promoting cooperation among multiple stakeholders to optimize network effects. In addition, the labor process within the industry is gradually being replaced by eco-friendly technologies, requiring adaptation of port terminal companies [12].

System theory serves as an important framework for understanding green digital paradigm shifts [14]. It helps to interpret the complexity of changes that occur in the course of change. System theory provides the basis for various analytical approaches to examine in-depth the interrelationships between technical and organizational factors within port terminal enterprises [17][18]. Hierarchical interaction analysis can be used by organizations to understand how strategic objectives are communicated and executed [19]. This approach, combined with Gestalt theory, optimizes integration and alignment within organizations [20]. Finally, a comparative analysis of case studies highlights challenges and opportunities in the process of digital transformation, helping to develop strategies that are effective for the domestic port terminal industry [21][22].

Table 1. Methodology and Implications of Previous Studies

Ref.	Methodology	Implications
[5]	- Analysis of the paradigm (Utilizing Kuhn's theory)	- Emphasizes the increasing necessity for eco-friendly operations.
[6]	- Analysis of the eco-friendly digital transformation process	- Highlights the need for operational changes reflecting sustainability and societal demands.
[8]	- Relationship analysis between digital technologies and ESG management	- Indicates the establishment of a new standard for port operations.
[9]	- Data analysis and platform integration	- Emphasizes the need to utilize data as a basis for efficient decision-making.
[10]	- Analysis of maritime logistics market trends	- Highlights the necessity for swift responses to market changes.
[11]	- Literature review regarding COVID-19 and environmental regulations	- Discusses the impact of external factors on the transition to eco-friendly digital platforms.
[12]	- Application of Innovation Diffusion Theory	- Stresses the importance of early adoption and dissemination of innovative technologies.
[14]	- Application of systems theory	- Indicates the usefulness of systems theory for understanding complex interactions of change.
[19]	- Analysis of management goals through a cascading model	- Highlights the importance of feedback loops and communication for effective implementation of goals and strategies.
[21]	- Comparative system analysis through case studies	- Necessitates the development of optimal strategies by analyzing successful and failed transformation cases.
[22]	- Strategic direction through theoretical framework	- Offers critical insights on how the interaction between digital transformation and organizational culture can secure long-term sustainable competitiveness.

2. Methodology

This study effectively guides the eco-friendly digital transformation of domestic port terminal companies by utilizing the analysis framework that integrates system theory with the eco-friendly digital paradigm shift mechanism model. It enables systematic understanding and analysis of complex interactions and dynamic changes occurring in the internal environment-friendly digital conversion process.

The research methodology consists of the following steps. The first step in the research process involves a comprehensive literature review. It is done to do this. It aims to establish a theoretical background that emphasizes the necessity and importance of environmentally friendly digital transformation in the port terminal industry. Second, this study analyzes the cases of eco-friendly digital transformation of domestic and foreign port terminal companies and specifically focuses on the success and failure cases of the transition. It is done to identify the main factors that can influence the domestic situation.

Instead of surveys and interviews, a review of the comparative literature gathers insights from different studies on the challenges and opportunities faced in the green digital transformation process. It helps us to better understand the need for change.

Furthermore, the green digital paradigm shift process is validated through the lens of system theory by integrated system analysis combining enumeration factor system analysis, macro and microsystem analysis, and top-down and top-down approaches. It helps us understand the dynamics of complex interactions and changes that occur.

In conclusion, this study combines the results of literature review, case study, and comparative literature analysis along with the application of system theory to present strategic improvement measures to promote the successful environmentally friendly digital transformation of domestic port terminal companies. This comprehensive research methodology is expected to present valuable insights and specific strategies that can effectively lead the transition to eco-friendly digital practice within the industry.

III. Multiple Impact Factors and Scope of Environmentally Friendly Digital Transformation of Port Terminal Operators

1. Multiple Impact Factors

From the standpoint of port terminal companies, AI-led digital revolution is being applied not only to logistics and cargo processing within ports, but also to terminal management and operation as a whole. This is happening rapidly, with various digital technologies such as Things, blockchain, big data, AI, VR/AR, autonomous vehicles, 3D printers, and smart factories being introduced into the port terminal industry. These technologies are increasing operational efficiency and environmental sustainability [23]. In a report released in 2018, the Boston Consulting Group (BCG) identified several technologies that it believes play an important role in transforming the business of global port terminal companies. The report, titled "Digital Essentials of Container Transportation," highlighted the possibilities of electronic platforms, advanced analysis, IoT, artificial intelligence (AI), port automation and robotics, blockchain, and cybersecurity. It is expected that existing IoT, AI, automation, robots, and blockchain technologies will be integrated with AI-based logistics and processing pattern analysis, bringing about significant innovation in port terminal operation.

The digitization of the port terminal industry is environmentally friendly from a micro and macro perspective and improves the efficiency of individual port terminals. It improves. For example, the emergence of self-driving vehicles such as AGVs could degrade the role of truckers in ports

and is currently being discussed as one of the social impacts of digital transformation. In addition, Long Beach Port in the United States is implementing emission reduction measures at ports, including implementation of clean fuel standards through the San Pedro Bay Port Clean Air Action Plan (CAAP), introduction of electrical equipment, and advancement of ship and port environmentally friendly technologies. Through the use of AI-powered LiDARs, automatic processing systems, and smart sensor technologies, it has been proven to contribute to optimizing the operation of port terminals and reducing carbon emissions from an environmentally friendly perspective. However, the introduction of these technologies can lead to changes in the labor market and privacy issues, which can negatively impact the human rights of port workers [24]. From an organizational hierarchical perspective, the introduction of eco-friendly digital technologies to port terminals has the effect of changing the structure and nature of the various internal and external organizations connecting ships and ports. Thus, to increase logistics efficiency on land and at sea, port terminal enterprises should adopt an approach that flexibly coordinates the structures and systems of these internal and external organizations [25]. This is because continuous agile decision-making and execution are required around port terminal companies. The introduction of automation systems requires a shift from traditional organizational class decision-making to alternative forms such as value-based decision-making instead of cost- and revenue-based decision-making. To achieve eco-friendly digitalization, it is essential that middle managers, sub-managers, and various internal and external stakeholders, as well as the top management of port terminal companies, internalize their willingness to make intentional and gradual changes [26]. For domestic port terminal companies to thrive in the context of eco-friendly digital paradigm shift, it is of paramount importance to establish mutually beneficial psychological contractual relationships based on long-term employment contracts with organizations and port workers facing change. This includes recruitment, job switching training, performance evaluation, compensation, etc. from the viewpoint of safety and efficiency of cargo handling. Traditional tasks such as port terminal operation, logistics management, and cargo processing can be transformed into eco-friendly digital tools and AI-based processes. This involves shifting away from past experience-based decision-making to data-based decisions based on long-term accumulated metadata analysis. Therefore, it is imperative that port terminal companies provide training programs to improve their employees' environmental digital capabilities (EDCs) to successfully achieve green digital transformation in the future [27].

2. Applicable Coverage

By analyzing the factors influencing the change in the green digital paradigm in the port terminal industry from a system theoretical perspective to specific applications, focusing on the case of individual port terminal companies, the following can be observed:

First, Singapore's PSA International, one of the global port terminal operators, adopted environmentally friendly IoT and AI technologies with the goal of optimizing port operation efficiency. The introduction of autonomous trucks and autonomous cranes has automated driving operations, reducing the port's overall energy consumption and minimizing carbon emissions. In addition, the construction of a smart port system has facilitated the analysis of real-time maritime data related to the port, allowing it to establish an optimal port logistics supply strategy [28].

Second, Rotterdam Port is promoting an eco-friendly 'smart port' project that entails the establishment of a blockchain technology platform based on maritime data for integrated sharing of maritime land logistics information. Through this,

we are supporting efficient cargo handling operations by increasing transparency in logistics flow between ships and ports and improving communication between ports and ships. In addition, Rotterdam Port utilizes maritime data and AI technology to monitor all stages of port operation and manages carbon emissions by linking digital platforms with eco-friendly energy sources such as solar and wind power [29].

Third, the Hong Kong International Terminal (HIT) has introduced electric self-driving trucks to automate transportation operations within its ports. These vehicles are monitored in real time through smart sensors that provide information about their location and status. HIT has built a cloud-based operating system to enable centralized management of all marine data related to port operations, increasing operational efficiency. To pursue environmentally-considered digital transformation, HIT has installed solar panels on cranes and other facilities to reduce carbon emissions and conform to Hong Kong's 2050 Climate Action Plan and Port Policy [30].

Finally, DP World in Dubai implemented automated port processing systems and intelligent sensors as part of its smart port initiative to optimize operational efficiency in the port. DP World has established a digital information sharing platform for maritime land logistics using blockchain technology, creating new added value through real-time sharing of logistics information between shippers and ship owners. In addition, DP World has reduced carbon emissions at its UAE operations by approximately 50% utilizing 100% eco-friendly energy provided by the Dubai Electric Water Authority (DEWA). The company has set a target of 50% reduction by 2028 through the introduction of 100% renewable energy [31].

Domestic port terminal companies are facing significant challenges to drive both eco-friendly and digital innovation at the same time. Looking at examples of major overseas ports, insights can be drawn:

First, domestic port terminal companies should introduce both eco-friendly technologies and digital innovations in parallel. Likewise, PSA and Rotterdam ports in Singapore are optimizing operational efficiency and reducing carbon emissions through the integration of IoT, AI, and blockchain technologies. Therefore, domestic companies should also integrate digital technologies with environmental goals. This can increase both eco-friendliness and operational efficiency.

Second, it is essential that these efforts be supported by clear regulations and policies. In addition, domestic port terminal companies should establish a transparent regulatory framework consistent with international agreements and address challenges related to the transition process through policy support for digital transformation and eco-friendliness.

Third, we must acknowledge the interdependence between digitalization and eco-friendliness. As demonstrated by DP World, which reduced carbon emissions using blockchain technology and a real-time logistics information sharing system with 100% renewable energy, domestic port terminals can simultaneously pursue digital innovation and eco-friendly goals.

Fourth, decarbonization funds and digital infrastructure development must be promoted together. It is important to focus on digital infrastructure development as well as securing funds for the introduction of eco-friendly technologies. To this end, consider actively utilizing green loans and public-private partnerships.

3. Obstacles to the Transformation of Green Digital Paradigm

There are concerns that domestic port terminal companies risk losing their future competitiveness if they fail to respond quickly to the global transition to eco-friendly digital technologies. In particular, the digitization and decarbonization of ports are emerging as essential elements of modern port operations. Failure to effectively address these

challenges during the transition period risks further reducing the competitiveness and sustainability of domestic port terminals. Therefore, it is essential to analyze the major obstacles to the eco-friendly digital transformation of ports from two perspectives.

The initial challenge is related to the integration of eco-friendly digital platforms. The failure of 'TradeLens', a digital logistics platform involving port terminal companies, demonstrates the inherent difficulties of maritime data sharing and collaboration between port terminals and the challenge of uniformly applying eco-friendly regulations. TradeLens is a blockchain-based platform developed in collaboration with IBM and Musk. It aims to increase the transparency of maritime data and improve the efficiency of eco-friendly ports. However, several port terminal companies were reluctant to share and cooperate with maritime data, which in turn resulted in the failure to guarantee the long-term viability of eco-friendly digital platforms. This case study emphasizes the importance of stakeholder commitment and agreement on maritime data sharing and collaboration, and also highlights the standardization and consistent application of this data in the context of eco-friendly digital paradigm shift. Therefore, domestic port terminal companies need a strategic approach to solve various problems arising from pursuing the dual goals of eco-friendliness and digitalization [32].

Second, cybersecurity is another major challenge in the green digital paradigm shift. Port terminals should strengthen cybersecurity as well as physical security. Digitized port operations can be vulnerable to cyber threats such as hacking, marine data leakage, and malware attacks. As a key hub of the global supply chain, ports play an important role in timely logistics strategies [33]. Timely (JIT) is a strategy aimed at minimizing inventory costs and optimizing efficiency by supplying materials at the exact time of need. Nevertheless, cyberattacks on digital port systems can disrupt real-time supply chain operations, which can have a significant impact on global logistics flows. Therefore, domestic port terminal companies should strengthen their cybersecurity systems during the digital transformation process to ensure the continuous stability of their JIT strategy. Therefore, challenges related to integrating eco-friendly digital platforms and addressing cybersecurity issues are important obstacles for domestic port terminal companies to overcome in order to successfully lead the eco-friendly digital transformation. It is of utmost importance that port terminal companies carry out comprehensive analyses and implement effective measures to address the aforementioned challenges to maintain global competitiveness in the future.

In addition, from another perspective, there are concerns that the failure to respond quickly to environmental changes caused by the global eco-friendly digital paradigm shift could undermine the future competitiveness of domestic port terminal companies. The port terminal industry is currently facing two important challenges: digitalization and decarbonization. Digitization encompasses the use of digital technologies such as AI, IoT, and blockchain with the aim of improving operational efficiency, improving customer experience, and building new business models. On the other hand, decarbonization represents the international community's joint efforts to reduce greenhouse gas emissions in the face of the climate crisis. To help a comprehensive understanding of obstacles arising from this transition process, it is essential to look at them from the following two perspectives.

4. Economic Obstacles to Digitization and Decarbonization

Economic constraints are an important challenge for port terminal companies seeking an environmentally sustainable digital transformation.

Economic considerations can hinder the adoption of energy-efficient and decarbonization technologies [34]. For example, a lack of comprehensive data can hinder port terminals' willingness to adopt decarbonization technologies. In addition, unequal distribution of information to marine data can lead to adverse selection and moral hazard. Port terminal operators may not have access to accurate data on decarbonization technologies or may make incorrect decisions due to information asymmetry with technology providers. In addition, the issue of split incentives acts as a factor delaying the implementation of decarbonization measures. While port authorities bear the costs of various decarbonization measures, private port terminal companies are only enjoying the benefits, making it difficult to implement appropriate decarbonization measures smoothly [35]. In other words, high investment costs and capital access issues also act as important obstacles to the adoption of decarbonization technologies. The high costs associated with the adoption of these technologies can hinder the green digital paradigm shift for port terminal companies. In particular, technologies such as electrification of handling equipment or installation of alternative sea power (AMP) systems require significant initial investments, which can delay port decarbonization.

5. Non-economic Obstacles to Digitization and Decarbonization

Non-economic barriers include: In addition to the aforementioned economic constraints, a number of important factors hinder the digitization and decarbonization of port terminal enterprises. These include behavioral, organizational, institutional, and technical barriers.

Obstacles to behavior include a lack of accurate information formation and a lack of reliability of information regarding decarbonization. Port terminal managers can rely on irrational heuristics due to limited rationality when implementing decarbonization measures. In addition, cultural resistance and inertia within port terminal organizations related to the acceptance of eco-friendly digital devices act as important factors hindering the implementation of decarbonization [36].

The complexity of decision-making governance within port terminal enterprises presents organizational barriers. Failure to give sufficient authority to the environmental managers of port terminal enterprises can deprive them of decarbonization measures during the decision-making process [37]. The absence of strong government policies and regulations to promote the decarbonization of ports represents an important institutional barrier. To ensure the sustainability of ports, government-imposed decarbonization regulations must be strictly enforced, enabling port terminal enterprises to pursue sustainable investments at a faster rate [38]. Technical barriers include decarbonization technology and incompatibility between port types. For example, alternative maritime power (AMP) systems are suitable for relatively new vessels with proven compatibility between land and ship, but they are difficult to apply to older vessels [39]. Therefore, the eco-friendly digital transformation of ports faces challenges from economic and non-economic factors. Without effective strategies to overcome these obstacles, it will be difficult for port terminal enterprises to achieve sustainable development and secure competitiveness. Therefore, it is essential for domestic port terminal companies to devise a comprehensive approach to address the complexity and cybersecurity issues of integrating eco-friendly digital platforms, and to implement targeted measures to overcome economic and non-economic barriers.

Table 2. Types of Barriers to Digitalization and Decarbonization

Barrier Type	Main Factors	Implications
Behavioral Barriers	- Lack of accurate information and reliability concerning decarbonization. - Managers may rely on irrational heuristics due to bounded rationality. - Cultural resistance and inertia in accepting eco-friendly digital devices.	- Enhance training and education on decarbonization to improve decision-making processes. - Foster a culture of acceptance for eco-friendly technologies within organizations.
Organizational Barriers	- Complexity of decision-making governance. - Insufficient authority of environmental managers can lead to deprioritization of decarbonization measures.	- Ensure that environmental managers have adequate authority in decision-making processes. - Streamline governance structures to facilitate effective implementation of decarbonization strategies.
Institutional Barriers	- Lack of strong government regulations or policies to promote decarbonization. - Need for strict enforcement of regulations to ensure port sustainability.	- Advocate for stronger government policies that support sustainable investments in port terminals. - Actively engage with policymakers to promote a regulatory environment conducive to decarbonization.
Technical Barriers	- Incompatibility of decarbonization technologies with certain port types, particularly older ships. - Challenges in applying technologies like AMP systems.	- Invest in research and development to improve compatibility of decarbonization technologies with diverse port types. - Develop tailored solutions for older ships to facilitate their integration into eco-friendly systems.
Overall Implications	- Challenges stem from both economic and non-economic factors, affecting sustainable development and competitiveness.	- Domestic port terminal companies must develop strategic approaches to integrate eco-friendly digital platforms and address cybersecurity issues. - Establish specific measures to overcome both economic and non-economic barriers to successful decarbonization.

IV. Improvements for Transformation of Double axis Paradigm based on Green Digital of Korean Port Terminal Company at Global Level

1. Prerequisites for the Success of Green Digital Paradigm Transformation

Just because the CEO of a port terminal company has declared the need for a "green digital paradigm shift" does not mean that all members of the organization can share this view or effectively implement it. A major obstacle to this shift is the limited understanding of the CEO, which is perceived as a simple technical issue related to flaws and costs. This perspective emphasizes that simply adopting technology is not enough to address the complexities associated with a green digital paradigm shift across organizations.

The composition of professional teams or outsourcing of work alone is not enough to achieve true success. From the perspective of system theory, this transition requires not only the establishment of a digital infrastructure, but also the promotion of intra-organizational consensus led by the CEO. All members must internalize the importance of this transition and recognize their role in the transition to an AI-driven, greener digital platform [40].

In order to ensure the success of domestic port terminal companies in these changes, it is necessary to cultivate problem-solving capabilities through knowledge sharing rather than relying on individual talents [41]. It is essential to cultivate talented people with the capacity to implement both digital and eco-friendly transitions. This requires the integration of advanced digital capabilities and technical training. Formal training has proven beneficial for land companies, but port terminal companies must be highly dependent on field experience and apprenticeship learning [42].

In addition, functional myopia occurs frequently within port terminals, requiring departments to

focus narrowly on specific tasks without adequate cooperation. This lack of holistic view reduces operational efficiency. Knowledge accumulation can lead to loss of trust and loss of fragmentation and communication due to the inability to share critical marine data among departments [43].

To address these challenges, businesses need to leverage AI-driven, eco-friendly digital technologies to improve data exchange between land and sea. This will facilitate knowledge sharing and learning culture, increase efficiency, achieve dual goals of digitization and decarbonization, and ultimately enhance global competitiveness..

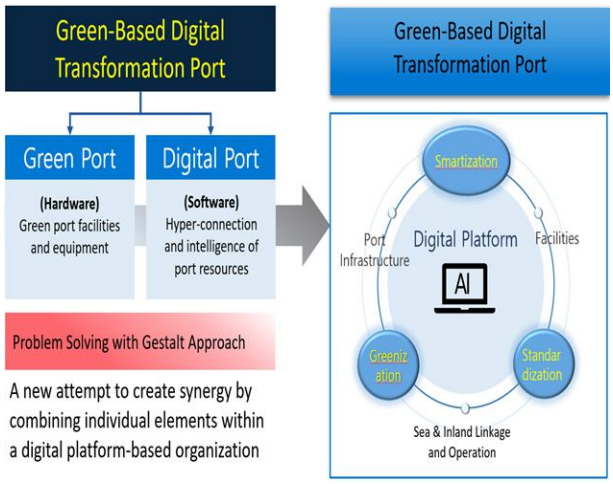

Fig. 2. Gestalt approach to achive green-based digital transformation port

2. Change of Port Terminal Company's Position for Transformation of Green Digital Paradigm

The green digital paradigm shift is a major challenge for port terminal companies seeking to strengthen their sustainability and competitiveness. Given the inherent complexity of this transition, implementing it across all units in a short period of time is not easy [44]. Successfully facilitating the green digital paradigm shift requires port terminal companies to adopt a gradual and detailed approach rather than relying on a single strategy. Therefore, a multi-level strategy should be implemented with particular emphasis on designing processes tailored to the specific characteristics of each company. The 'agile transformation' approach can be a more effective way to facilitate the green digital paradigm shift for port terminal companies than the traditional 'bottom-up' approach [45]. Unlike the traditional bottom-up approach, which delivers modifications from top to bottom of an organization, this approach implements agile and iterative processes of change across port terminal companies, enabling a gradual and adaptive transition.

In particular, the utilization of Agile frameworks such as Scrums and Canvans is highly effective because they enable unit organizations within port terminal enterprises to autonomously test and acquire new technologies and procedures, helping to achieve practical and sustainable results [46]. Change management theory is particularly suited to this approach in the context of port terminal enterprises, as it provides a strong theoretical framework that can help organizations adapt across the enterprise when introducing new systems or procedures such as eco-friendly and AI-driven technologies. For example, Prosci's ADKAR model (including awareness, needs, knowledge, capabilities, and enhancement) can be used as a representative change management framework to help each organization unit effectively adapt to the eco-friendly digital transformation [47].

In addition, port terminal enterprises should implement organizational structures that facilitate self-organization and cross-functional teaming to enable rapid feedback generation and agile response. This team structure improves organizational agility, providing a foundation for rapid implementation of eco-friendly digital technologies. It also plays an important role in addressing internal information asymmetry within port terminal enterprises and facilitating cooperation and knowledge sharing among departments.

In conclusion, port terminal companies should effectively facilitate a green digital paradigm shift by integrating agile transformation and change

management models, allowing each organization unit to gradually embrace change and the entire organization to successfully achieve its dual-axis goals of digitalization and decarbonization in the long run [48].

3. Changing the roles of each member of the organization of the port terminal enterprise

An important factor in the eco-friendly digital transformation of port terminal companies is the evolution of organizational roles and the formation of new organizational identities. The success of this transformation depends on the commitment of chief executives, middle managers, and frontline employees. Along with the digital transformation, it is of utmost importance to prioritize responding to environmental regulations and sustainability needs. Instead of relying solely on past experiences, CEOs should make data-driven decisions using marine data. This requires the synthesis of data from logistics processes and insights from external experts. In the face of challenges such as economic uncertainty and strict regulation, CEOs should assess an organization's digital capabilities and provide integrated training programs focused on eco-friendly strategies to promote understanding and achievement of each department's digitalization and sustainability goals [49].

Middle managers play an important role in this transition, shifting from traditional management tasks to the role of change agents. Based on field experience, they must promote innovation while maintaining stability while developing strategies to meet eco-friendly demand [50]. To succeed in the eco-friendly digital transformation, port terminal companies must adopt creative system thinking, enabling departments to function as integrated systems. This approach encourages a comprehensive transition across the organization, rather than adopting new technologies in isolation. It promotes rapid response to external changes and improves the organization's sustainable competitiveness [51]. In conclusion, successful implementation of the green digital paradigm shift in port terminal enterprises requires an integrated approach in which all members take on new roles, share the organization's vision, and collaborate effectively. These partnerships enable us to achieve our greenness and digitization goals, which will drive sustainable growth.

The Green Digital Paradigm Transformation requires not only the implementation of new technologies, but also structural changes and role redefining across organizations. The CEO emphasizes the importance of Green Transformation by setting strategic directions and implementing data-driven practices to integrate these goals. The Environment, Social, and Governance (ESG) department is responsible for setting environmental and governance goals and working with all departments to achieve social responsibility and compliance. The Business Support Office works with the Strategic Planning and Operations Planning Team to develop and execute strategies for the transition. The Operations Planning Office and the Smart Lab Team focus on the practical implementation of these strategies that leverage digital twin technologies to increase operational eco-friendliness. Finally, a successful transition requires strong leadership, effective planning, and execution capabilities to achieve the Green Digital Paradigm Transformation through hierarchical collaboration.

V. Conclusion

It is essential that ports recognize the importance of a green digital paradigm shift in order to effectively respond to multi-faceted changes occurring economically and environmentally at the global level. This study uses system theory to analyze role changes occurring within organizations and reallocate resources through a Gestalt approach to support this digital transformation.

According to the study, green innovation needs more than just technology introduction, and the use of marine data to improve operational efficiency and environmental sustainability requires role redefining and structural change. For effective innovation across the company, it is essential that CEOs provide effective leadership, middle managers drive processes, and frontline employees execute plans. Implementing the latest processes, such as Agile Transformation, can help organizations quickly adapt to external needs.

The study also highlights the importance of integrating digitization and decarbonization for the success of port terminal companies for sustainable growth and competitiveness. However, challenges such as difficulties in digital platform integration and cybersecurity issues must be addressed with targeted strategies. Improving collaboration and data sharing, and taking strong technical action can lead to more effective data-driven decision-making. In addition, addressing technical challenges and cultural resistance is essential for the green digital transformation. State-of-the-art technologies such as AI, blockchain, and IoT can improve operational efficiency, and training programs can help employees adapt to these changes, ultimately enhancing the long-term competitiveness of port terminal companies.

This study provides a theoretical framework for understanding organizational change in the context of eco-friendly digital innovation, and suggests actionable strategies to improve agility and competitiveness in rapidly changing industries. One limitation is that it relies on specific case studies that may not capture global diversity. Future studies should examine success and failure cases more broadly to identify key success factors and challenges.

In conclusion, port terminal companies are urged to adopt a systematic and multi-layered strategy for sustainable growth by integrating leadership, convenience of middle managers, and execution capabilities of frontline workers. Embracing cultural changes and the latest digital technologies will help us secure a competitive advantage and achieve long-term sustainability.

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REFERENCES

[1] Basulo-Ribeiro, Juliana, Carina Pimentel, and Leonor Teixeira, Digital Transformation in Maritime Ports: Defining Smart Gates through Process Improvement in a Portuguese Container Terminal, Future Internet, Vol.16, No. 10, 2024. https://doi.org/10.3390/fi16100350

[2] Barakat, Hala, and Heather Elaydi. "Global Food Crisis: Updates from the MENA Region." in "Global Food Crisis and the Responses: A Comprehensive Update and Discussion", co-organized by WCC and the Civil Society and Indigenous Peoples' Mechanism for relationswith the UN Committee on World Food Security , 2022. Available Online: https://www.hlrn.org/img/documents/Food%20Crises%20MENA%20Region%202022.pdf

[3] Olakunle Oloruntobi, Kasypi Mokhtar, Adel Gohari, Saira Asif, Lai Fatt Chuah, Sustainable transition towards greener and cleaner seaborne shipping industry: Challenges and opportunities, Cleaner Engineering and Technology, Vol. 13, 2023. https://doi.org/10.1016/j.clet.2023.100628.

[4] https://www.chosun.com/special/special_section/2024/04/09/ARLEAOHKCNHBDLCD5RGZHO2GY4/ (Access date: 2024.10.02.)

[5] Idriss Jamil Aberkane. Mind Ergonomy for the Knowledge Economy: software Neuroergonomics and Biomimetics for the Knowledge Economy. Why? How? What?. Cognitive Sciences. Université Paris Saclay (COmUE), 2016.

[6] Chengying Hua, Jihong Chen, Zheng Wan, Lang Xu, Yun Bai, Tianxiao Zheng, Yijie Fei, Evaluation and governance of green development practice of port: A sea port case of China, Journal of Cleaner Production, Vol. 249, 2020. https://doi.org/10.1016/j.jclepro.2019.119434.

[7] Jihong Chen, Tianxiao Zheng, Akhil Garg, Lang Xu, Sifan Li, Yijie Fei, Alternative Maritime Power application as a green port strategy: Barriers in China, Journal of Cleaner Production, Vol.

213, pp. 825-837, 2019. https://doi.org/10.1016/j.jclepro.2018.12.177.

[8] Sigrid Damman, Markus Steen, A socio-technical perspective on the scope for ports to enable energy transition, Transportation Research Part D: Transport and Environment, Vol. 91, 2021, https://doi.org/10.1016/j.trd.2020.102691.

[9] Sangseop Lim, So-Hyun Jo, Changhee Lee, Development of Business Models using Maritime, Journal of The Korea Society of Computer and Information, Vol. 27, No. 6, pp. 175-180, 2022. https://doi.org/10.9708/jksci.2022.27.06.175

[10] Chul-hwan Han, Assessing the impacts of port supply chain integration on port performance, The Asian Journal of Shipping and Logistics, Vol. 34, No. 2, pp. 129-135, 2018. https://doi.org/10.1016/j.ajsl.2018.06.009.

[11] Chinonyerem Nwokedi, T. (2022). Harnessing the Environment of Maritime Transport and Port Logistics Sector in the Management of Covid-19 Pandemic. IntechOpen. doi: 10.5772/intechopen.101587

[12] Dearing JW. Applying Diffusion of Innovation Theory to Intervention Development. Res Soc Work Pract. 2009 Sep 1;19(5):503-518. doi: 10.1177/1049731509335569. PMID: 20976022; PMCID: PMC2957672.

[13] Mohd Javaid, Abid Haleem, Ravi Pratap Singh, Anil Kumar Sinha, Digital economy to improve the culture of industry 4.0: A study on features, implementation and challenges, Green Technologies and Sustainability, Vol. 2, No.2, 2024. https://doi.org/10.1016/j.grets.2024.100083.

[14] Zeeshan Raza, Johan Woxenius, Ceren Altuntas Vural, Mikael Lind, Digital transformation of maritime logistics: Exploring trends in the liner shipping segment, Computers in Industry, Vol. 145, 2023. https://doi.org/10.1016/j.compind.2022.103811.

[15] Carmine Bianchi, System Dynamics. Theory and Applications - Edited by Brian Dangerfield" System Dynamics Review, System Dynamics Society, Vol. 37, pp. 241-244, 2021.

[16] Heikkilä, M., Saarni, J., & Saurama, A. Innovation in Smart Ports: Future Directions of Digitalization in Container Ports. Journal of Marine Science and Engineering, Vo.10, No.12, 2022. https://doi.org/10.3390/jmse10121925

[17] Almeida F. Challenges in the Digital Transformation of Ports. Businesses. Vol.3, No.4, pp. 548-568. 2023. https://doi.org/10.3390/businesses3040034

[18] Zang Y, E J, Fiondella L. A Network Reliability Analysis Method for Complex Real-Time Systems: Case Studies in Railway and Maritime Systems. Mathematics. Vol.12, No.19, 2024, https://doi.org/10.3390/math12193014

[19] Yi-Chih Yang, Yun-Hsin Hsieh, The critical success factors of smart port digitalization development in the post-COVID-19 era, Case Studies on Transport Policy, Vol. 17, 2024, https://doi.org/10.1016/j.cstp.2024.101231.

[20] Spoth, J., Toman, S., Leichtman, R., & Allan, J. Gestalt approach. In J. Passmore, D. B. Peterson, & T. Freire (Eds.), The Wiley-Blackwell handbook of the psychology of coaching and mentoring, pp. 385–406. 2013. Wiley Blackwell.

[21] Peter Čerin & Bojan Beškovnik, 2023. "Enhancing Sustainability through the Development of Port Communication Systems: A Case Study of the Port of Koper," Sustainability, MDPI, Vol. 16, No.1, pp. 1-17, 2023.

[22] Sakita, B.M., Helgheim, B.I., Bråthen, S. Drivers, Barriers, and Enablers of Digital Transformation in Maritime Ports Sector: A Review and Aggregate Conceptual Analysis. In: Martins, A.L., Ferreira, J.C., Kocian, A., Tokkozhina, U., Helgheim, B.I., Bråthen, S. (eds) Intelligent Transport Systems. INTSYS 2023. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, vol 540. Springer, Cham. 2024 https://doi.org/10.1007/978-3-031-49379-9_1

[23] Durlik I, Miller T, Kostecka E, Łobodzińska A, Kostecki T. Harnessing AI for Sustainable Shipping and Green Ports: Challenges and Opportunities. Applied Sciences. Vol.14, No.14, 2024. https://doi.org/10.3390/app14145994

[24] Nazmiye Guler, Samuel N. Kirshner, Richard Vidgen, A literature review of artificial intelligence research in business and management using machine learning and ChatGPT, Data and Information Management, Vo.8, No.3, 2024. https://doi.org/10.1016/j.dim.2024.100076.

[25] Inutsuka H, Ichimura K, Sugimura Y, Yoshie M, Shinoda T. Study on the Relationship between Port Governance and Terminal Operation System for Smart Port: Japan Case. Logistics. Vol.8, No.2, 2024. https://doi.org/10.3390/logistics8020059

[26] Heikkilä M, Saarni J, Saurama A. Innovation in Smart Ports: Future Directions of Digitalization in Container Ports. Journal of Marine Science and Engineering, Vol.10, No.12, 2022. https://doi.org/10.3390/jmse10121925

[27] Tiziana Campisi, Samuele Marinello, Giacomo Costantini, Luca Laghi, Sabrina Mascia, Francesco Matteucci, Davide Serrau, Locally integrated partnership as a tool to implement a Smart Port Management Strategy: The case of the port of Ravenna (Italy), Ocean & Coastal Management, Vo.224, 2022. https://doi.org/10.1016/j.ocecoaman.2022.106179.

[28] https://www.globalpsa.com/

[29] https://www.portofrotterdam.com/en

[30] https://www.hit.com.hk/

[31] https://www.dpworld.com/en/uae

[32] https://www.kaikosystems.com/blog/blockchain-in-the-maritime-industry-tradelens-case-analysis

[33] Leon Bremer, Sacha den Nijs, Henri L.F. de Groot, The energy efficiency gap and barriers to investments: Evidence from a firm survey in The Netherlands, Energy Economics, Vol. 133, 2024. https://doi.org/10.1016/j.eneco.2024.107498.

[34] Karaca, I., Soner, O.: An evaluation of students' cybersecurity awareness in the maritime industry. Int. J. 3D Print. Technol. Digit. Ind. 7. https://doi.org/10.46519/ij3dptdi.1236264

[35] Alamoush AS, Dalaklis D, Ballini F, Ölcer AI. Consolidating Port Decarbonisation Implementation: Concept, Pathways, Barriers, Solutions, and Opportunities. Sustainability. 2023; 15(19):14185. https://doi.org/10.3390/su151914185

[36] Anas S. Alamoush, Fabio Ballini, Aykut I. Ölçer, Investigating determinants of port decarbonisation implementation using the lens of Implementation Theory, Transport Economics and Management, Vol.2, pp. 90-111, 2024. https://doi.org/10.1016/j.team.2024.04.002.

[37] Baştuğ, S., Akgül, E.F., Haralambides, H. et al. A decision-making framework for the funding of shipping decarbonization initiatives in non-EU countries: insights from Türkiye. J. shipp. trd. Vol.9, No.12, 2024. https://doi.org/10.1186/s41072-024-00172-1

[38] Bakar A, Najihah N, Bazmohammadi N, Vasquez JC, Guerrero JM, Electrification of onshore power systems in maritime transportation towards decarbonization of ports: a review of the cold ironing technology. Renew Sustain Energy Rev, Vol.178, 2023. https://doi.org/10.1016/j.rser.2023.113243

[39] Lee J, Sim M, Kim Y, Lee C. Strategic Pathways to Alternative Marine Fuels: Empirical Evidence from Shipping Practices in South Korea. Sustainability, Vol.16, No.6, 2024. https://doi.org/10.3390/su16062412

[40] Xin Zhang & Felix Nutakor & Michael Kaku Minlah & Jinke Li, Can Digital Transformation Drive Green Transformation in Manufacturing Companies?—Based on Socio-Technical Systems Theory Perspective, Sustainability, MDPI, Vol.15, No.3, pp. 1-24, 2023.

[41] Parola, F.; Musso, E. Market Structures and Competitive Strategies: The Carrier–Stevedore Arm-Wrestling in Northern European Ports. Marit. Policy Manag. Vol.34, pp.259–278, 2007.

[42] Yeo, H. Participation of Private Investors in Container Terminal Operation: Influence of Global Terminal Operators. Asian J. Shipp. Logist. Vol.31, pp.363–383. 2015.

[43] Huang, H., Wang, Q. Within digital collaborative teams, how can leaders promote productive knowledge sharing among members with diverse settings?. DESD Vol.2, No.2, 2024. https://doi.org/10.1007/s44265-023-00027-w

[44] Kee-Hung Lai, Venus Y.H. Lun, Christina W.Y. Wong, T.C.E. Cheng, Green shipping practices in the shipping industry: Conceptualization, adoption, and implications, Resources, Conservation and Recycling, Vol.55, No.6, pp.631-638, 2011. https://doi.org/10.1016/j.resconrec.2010.12.004.

[45] Akim Berkani, Dominique Causse, Laurent Thomas, Triggers analysis of an agile transformation: the case of a central bank, Procedia Computer Science, Vol.164, pp.449-456, 2019. https://doi.org/10.1016/j.procs.2019.12.205.

[46] Mamanovna, S., & Ligay, T., Comparison of Kanban and Scrum methodologies. What is the best fit for your company?. Scientific Collection «InterConf», Vo.142, pp.58–61, 2023, https://archive.interconf.center/index.php/conference-proceeding/article/view/2337

[47] Balluck J, Asturi E, Brockman V. Use of the ADKAR® and CLARC ® Change Models to Navigate Staffing Model Changes During the COVID-19 Pandemic. Nurse Lead., Vol.18, No.6, pp.539-546, 2020. doi: 10.1016/j.mnl.2020.08.006.

[48] Jing Li, Yuejin Zhou, Experimental analysis of self-organizing team's behaviors, Expert Systems with Applications, Vol.37, No.1, pp.727-732, 2010. https://doi.org/10.1016/j.eswa.2009.05.084.

[49] Neugebauer, J., Heilig, L. & Voß, S. Digital Twins in the Context of Seaports and Terminal Facilities. Flex Serv Manuf J, 2024. https://doi.org/10.1007/s10696-023-09515-9

[50] Son, J.; Kim, D.-H.; Yun, S.-W.; Kim, H.-J.; Kim, S. The development of regional vessel traffic congestion forecasts using hybrid data from an automatic identification system and a port management information system. J. Mar. Sci. Eng. Vo.10, 2022. https://doi.org/10.3390/jmse10121956

[51] Eom J-O, Yoon J-H, Yeon J-H, Kim S-W. Port Digital Twin Development for Decarbonization: A Case Study Using the Pusan Newport International Terminal. Journal of Marine Science and Engineering., Vo.11, No.9, 2023. https://doi.org/10.3390/jmse11091777

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