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SUSTAINABLE CONTAINER TERMINAL OPERATIONS: THE CASE OF THE PORT OF LITHUANIA

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Abstract. This paper analyses the activities of a marine container terminal to assess the integration of sustainability principles in container storage, handling and service processes. This study aims to identify measures that would facilitate more sustainable operations in container terminals, to minimise their adverse impact on the environment. The empirical data were obtained through semi-structured interviews, document analysis and internal company operational documents. The results of the study showed that sustainable operations at the terminal include pollution abatement measures, infrastructure improvements, efficient use of storage areas, and the management of hazardous and temperature-sensitive cargoes per environmental standards. The main operational challenges were found to be related to the lack of storage space, ageing machinery and limited staff training to work with upgraded systems. The paper makes recommendations to improve the sustainability and competitiveness of the terminal's operations by applying innovative technologies and enhancing staff skills.

Keywords: sustainability; seaport; terminal; terminal operations

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JEL Classifications: Q56, L90, O19

1. Introduction

Container terminals play a vital role in the global trade system, and their operational efficiency and sustainability are emerging as key challenges in implementing the green port concept. According to Svetikaitė (2021), a container terminal is an infrastructural complex designed to load and distribute maritime containers. To ensure sustainable and responsible logistics operations, all terminal processes - from loading to storage - must focus not only on efficiency but also on minimising negative environmental impacts (Moros-Daza et al., 2024; Santos, 2025; Lu & Lu, 2025).

Roy, De Koster, and Bekker (2020) emphasise that analysing terminal operations not only enhances operational efficiency but also facilitates the integration of sustainability measures. Continuous modernisation, adopting digital solutions, and implementing smart control systems are becoming essential to reduce energy consumption and emissions, thereby contributing to green logistics goals (Budiyanto & Shinoda, 2020; Saleh et al., 2024).

Loading processes remain among the most critical activities at container terminals (Wang et al., 2019). Their organisation must prioritise efficiency and safety, aligning with broader environmental objectives. Kuo and Lin (2020) point out that, to reduce the risk of accidents and container damage, it is necessary to implement advanced safety systems and ensure a transparent process for weighing and reloading operations.

Budiyanto (2020) noted that high-quality terminal operations are unattainable without consistent evaluation and updating of existing equipment and infrastructure. Batarlienè (2020) highlights that container wear monitoring and the development of technical maintenance systems play a crucial role in ensuring operational reliability and sustainability, both within and beyond the terminal premises.

To successfully implement the principles of a green port, container terminal operations must be guided by logistical efficiency and environmental stewardship, safety standards, and social responsibility.

This study aims to identify measures that would facilitate more sustainable operations in container terminals, to minimise their adverse impact on the environment.

2. Theoretical background

Modern container terminals play a strategic role in global supply chains, with their operational efficiency directly linked to the achievement of sustainability goals (Hu et al., 2025; Wang, Jin & Luo, 2025; Duan, Xiong & Li, 2025).

Given the increasing volume of freight and the environmental impact of logistics, growing attention is being paid to how terminal storage and related processes can contribute to reducing emissions, conserving energy, and optimising resource use (Gao, Chang, & Chen, 2022; Yang et al., 2023; Mahmud, Chowdhury & Shaheen, 2024)

According to Martin, Martin, and Lai (2019), container storage at terminals requires specialised infrastructure and solutions that enable efficient flow management while ensuring the sustainable use of resources. Sustainable storage practices begin with assessing the technical condition of containers and implementing continuous monitoring (Hu et al., 2021; Jakovlev et al., 2025).

Further distribution should be based on spatial optimisation and reduced energy consumption (Abu, Ouhimmou, & Paquet, 2020), and efficiency of operation (Hsu et al., 2024; Li et al., 2024).

Cargo with special requirements, such as excise goods or temperature-sensitive items, demands heightened attention to environmental protection and safety (Roy et al., 2020; Kusrini & Parmasari, 2020). These goods must be maintained at stable temperatures, undergo regular technical maintenance, and be subject to effective risk management to prevent spoilage and food waste (He & Tan, 2018; Wang et al., 2019).

In the context of international logistics, maintaining container hygiene is also critical. Vicrihadi, Sembiring, and Ayutia (2021) highlight the geometric versatility of containers as a factor necessitating strict hygiene control. As noted by Walker et al. (2021), containers are cleaned and disinfected to eliminate hazardous residues, while Rasulov, Masharipov, and Ismatullaev (2021) emphasise that the intensity of cleaning depends on the container type, the nature of the cargo, and the geographic region in which the container is used.

Accurate container weighing is another essential component of sustainability. Youssef and Aly (2020) argue that incorrect weight determination can result in equipment damage and financial losses. Belova and Krochina (2019) assert that precise weighing is vital for compliance with safety and legal standards. Data logging and digitisation (Luo & Wu, 2020) support operational transparency and efficiency, while, as highlighted by Huang et al. (2019), they also help avoid errors and improve service quality.

Digital solutions - such as internal accounting systems and load monitoring technologies - are equally important in promoting sustainability.

Li et al. (2022) emphasise that these systems facilitate more accurate operational forecasting, reduce error probability, and contribute to CO₂ emissions reductions. Moreover, adherence to safety protocols (El Mahi, 2021), routine technical maintenance (Svetikaitė & Plačienė, 2021), and precise container identification (Ilesaliev, Makhmatkulov, & Abduvakhitov, 2020; Ilesaliev et al., 2019) are all critical components of sustainable terminal operations.

Implementing modern technologies and infrastructure upgrades enhances the ability to detect defects efficiently, save time, and prevent the unnecessary use of resources. As Puzinavičius and Vaitiekus (2021) observe, rapid fault detection ensures the continuity of terminal operations. Zhao et al. (2020) further emphasise that regular technical inspections reduce downtime and promote modernisation and resource conservation.

In summary, container terminal operations, particularly in seaports, are intrinsically tied to sustainability principles. The integration of maintenance, weighing, hygiene procedures, and efficient loading processes not only optimises performance but also significantly contributes to environmental objectives by reducing emissions, conserving energy and resources, and enhancing the long-term resilience of the logistics system.

The growing flow of containers is increasing cargo volumes and, along with it, environmental pollution, noise, and energy consumption. Such activities inevitably have a negative impact on the environment, so every terminal should look for ways to reduce this impact.

3. Research objective and methodology

A Lithuanian seaport terminal specialising in maritime container services was selected for the study. This terminal is distinguished by its wide range of services, which include cargo storage, weighing, container loading and transshipment (including CFS - Container Freight Station operations), handling of all types of containers, and their repair and cleaning. The terminal also manages the loading of various types of railway wagons and provides technical maintenance for reefer containers.

A mixed qualitative research strategy was employed, incorporating the analysis of scientific literature, content analysis of documents, and semi-structured interviews. A semi-structured interview method was chosen because it allows for the integration of pre-formulated questions and their flexible adaptation to the participants' responses. The interview questions were formulated logically and coherently, maintaining clarity and specificity, and were designed to support an in-depth analysis of container terminal operations.

Informants were selected using a criterion-based sampling method, which facilitated the identification of experts who met the research criteria and possessed relevant experience. Selection was based on participants' positions at the terminal, professional experience, and specialised knowledge, which enabled them to provide diverse and in-depth perspectives on the research subject. A key selection criterion was the participants' openness-their ability to reflect on organisational strengths and challenges and problem areas encountered in practice. This approach ensured both the depth and analytical value of the data collected.

The qualitative data gathered through interviews were processed using a verbatim transcription method. To ensure the anonymity of the participants, all personal information was anonymised, and the informants were coded (e.g., I1, I2, I3). Transcripts included participants' professional profiles, interview location, date, duration, and complete responses to the research questions.

The textual data were analysed thematically by creating structured categories, sub-categories, and tables of supporting statements. This analytical approach made it possible to identify the most significant research themes, examine their interrelationships, and ground the conclusions in empirical evidence.

Additionally, primary documents were used as one of the main sources of information to explore container terminal operations in greater detail. The content analysis focused on a defined area of the research topic and utilised both paper-based and digital documents. According to Tidiki (2003), the use of such sources ensured the reliability, validity, and relevance of the data. Following Kudinovienė (2008), a classical content analysis method was applied, enabling the collected information to be systematised and the research findings to be logically structured and illustrated using tables and other visual tools. This approach enhanced both the informativeness of the results and the scientific rigour of the study.

4. Results and discussion

The Container Terminal pays significant attention to storage activities, recognising their importance for operational efficiency and achieving sustainability objectives. Container terminal storage is part of the logistics chain and a key activity with high requirements for responsibility and diligence. Depending on the type of containers, they are placed in specially adapted areas in accordance with the company's internal storage rules: full containers are stacked up to five floors, and empty containers are stacked up to six floors. This system not only helps to rationalise the use of space, but also contributes to optimising energy consumption and working time, reducing the intensity of the movement of technical equipment and thus indirectly contributing to the reduction of CO₂ emissions.

The terminal's storage model, based on the AUTOSTORE programme's container layout scheme, ensures that each type of container is stored according to its specific requirements, guaranteeing individual supervision and control. This approach is in line with the principles of sustainable development, aiming to maximise the use of available resources, minimise the logistical impact on the environment and ensure a safe and efficient operating environment.

To analyse the measures taken to improve storage efficiency and their impact on sustainability, the study used a semi-structured interview method, the data collected from which is presented in Table 1.

Table 1. Warehousing activities

Category	Sub-category	Supporting statements
Optimal use of storage areas	Planning	I1, “<...> Containers are stored in the terminal at the highest possible capacity to accommodate incoming ships <...>, planned use of the area”. I2, “<...> Arriving ships are further planned to fill the terminal area accordingly <...>”.
	Responsible persons	I1, “The persons responsible for the optimal use of <...> shall be the Chief Executive Officer. KDO, Head of Planning and Site Planner”. I2, “The Head of Planning, the Site Planners and the Chief Planning Officer shall be responsible for the management of the site. KDO are responsible for <...>”. I3, “<...> the site planners, the head of the unit and other staff are responsible”.
Operational efficiency Improving efficiency	Optimal use of storage areas	I2, “This storage method allows for optimal use of storage areas”. I3, “<...> Placing one container on top of another <...> helps to make more efficient use of available storage space”.
	Measures to increase productivity	I1, “The efficiency of storage operations is ensured by planning the placement of containers/cargo in storage areas”. I3, “Operational efficiency is improved by the proper adaptation of the terminal area for container storage”.

The results of the study showed that container storage planning is an essential process to ensure the smooth running of operations and to solve problems related to limited storage capacity. Informants highlighted that optimal use of areas would not be possible without coordination between responsible staff and effective information dissemination.

Storage activities at a container terminal start when the sea containers arrive at the terminal by different modes of transport. The largest volume of containers arrives by ship and is unloaded using STS cranes. Containers are then transported to the storage yards, where they are assigned to storage areas by RTG or RS forklifts and the

AUTOSTORE software, according to the following criteria: completeness, size, nature of contents (excise, hazardous, refrigerated) and export direction.

Efficient warehousing contributes to logistics sustainability by reducing the intensity of machinery movements, fuel consumption and emissions. "The AUTOSTORE system ensures transparent container accounting, allowing rational distribution of cargo and reducing the need for excess movements. In addition, dispatchers and planners play an important role in ensuring that information flows quickly. The centralised accounting system allows the movement and storage of containers to be controlled, thus contributing to the organisation of efficient, safe and environmentally friendly operations.

The terminal stores different types of containers, which require different levels of maintenance depending on their technical characteristics, the nature of the cargo and safety requirements. The storage of particular groups of containers - for example, dangerous, temperature-controlled or excise containers - requires tailor-made infrastructural solutions and increased control.

In order to identify the main problems encountered during the warehousing process, the study carried out semi-structured interviews with terminal staff. The results obtained were summarised and presented in Table 2 to highlight the main categories of challenges and their impact on the sustainability and efficiency of operations.

Table 2. Challenges identified

Category	Sub-category	Supporting statements
Fixed problems	FIFO process malfunction	I1, "<...> normal FIFO process is disrupted". I2, "<...> adversely affects the FIFO principle used in the terminal". I3, "<...> freight flows affect the FIFO process".
	Lack of storage space	I2, "Lack of storage space in the terminal is the most important problem". I3, "Lack of space in the terminal is a problem which affects the pace of work".
Container control	Inaccuracies occurring	I1, "<...> there are many inaccuracies in container control". I2, "<...> Makes it difficult to control containers in storage". I3, "There are many inaccuracies <...> in the control of containers".
Measures to avoid problems	Adaptation of the site	I1, "More space <..> or better use of existing space". I2, "Expansion of the terminal area or better use of the existing area <..>". I3, "<...> development opportunities or redevelopment of the currently managed area".

The interviews revealed that one of the main challenges for sustainable container storage is the limited amount of storage space. The lack of space hampers smooth operations, slows down work rates and threatens the quality of service. To make more efficient use of resources and to reduce environmental impacts, it is proposed that the storage strategy be reviewed, infrastructure be optimised, and the possibility of expansion or redevelopment of the site be considered.

The terminal has an exclusive service for temperature and excise containers. Refrigerated containers are connected to the electricity supply in accordance with the instructions in the digital documents and are regularly checked to ensure the quality of the cargo and to reduce energy waste. Excise containers are stored in secure areas, in compliance with legal and security requirements, and their condition is checked daily.

As container volumes increase, there is a noticeable increase in the capacity of the handling equipment and a decrease in working speeds, especially when cars are placed in the terminal area. This leads to storage disruptions, and it is therefore proposed that the less active activities be relocated to the peripheral areas and that the road markings be updated for better traffic management.

Sustainable operations are not only ensured by an advanced container management system, but also by the entire service infrastructure, such as repair workshops, scales and cleaning facilities. The terminal uses dust-reducing measures and regularly cleans containers, machinery and grounds. These measures contribute to reducing emissions and maintaining a clean working environment. Repair work is carried out at the terminal, saving customers' time and reducing logistics costs.

The terminal operates in an integrated and sustainable manner, focusing on efficient use of infrastructure, providing safe and quality services and reducing environmental impact.

All relevant container information is available in the container dashboard of the AUTOSTORE application. During loading, container sealing is carried out in accordance with the specified requirements, taking into account the AUTOSTORE data, the transshipment acts and the customer's requests. Unless the presence of an authorised representative is specified in the notes, containers shall be sealed in accordance with the internal standards of shipping lines such as Hapag-Lloyd, Maersk Line, COSCO Shipping, CMA CGM, etc. The seals differ in numbering and colour identification according to the owner and the type of container. Excise containers are sealed in accordance with customs requirements, on the basis of information from the KIPIS system or in the presence of a customs officer. In order to analyse the organisation of the sealing processes in more detail, interviews were carried out, and the results are presented in Table 3.

Table 3. Container sealing (table of categories, sub-categories, supporting statements)

Category	Sub-category	Supporting statements
Provision of seals	The terminal does not have seals	I2, "The terminal does not have its own seals <..>". I3, "The terminal does not produce seals and does not have assigned seals".
Shipping lines	Transfer of seals	I2, "<...> are delivered by the line representatives to the control room, where they are handed over to the Talmans <..>". I3, "Each shipping line shall hand over the seals to the forwarders".
Incorrectly selected seals	Inspection of seals	I1, "<...> only an "eye test" is used to check whether a seal is present". I2, "<...> carries out a visual inspection of the seals". I3, "<...> inspection and control<...> is carried out".
Activities carried out	Responsibilities	I1, "The terminal is not currently responsible for any liability <..>". I3 '<...> arrives already sealed and is therefore not the responsibility of the terminal'>
Problems to be solved	Liability of lines/carriers	I1, "It is the responsibility of the lines/carriers". I2, "Sealing of export containers is the responsibility of the lines/carriers <..>".

Based on the interview data, it can be said that the sealing of export containers is not the responsibility of the terminal, as these containers arrive at the terminal already loaded and sealed by the consignor or customer. Only containers that are loaded on site, in accordance with the loading documents, customer requests or the provisions of the internal operational strategy 'Restrictions', are sealed at the terminal. The sealing process is based on a precise allocation of resources and division of responsibilities, and the seals themselves are provided to the terminal by the shipping lines' agents or forwarders. As the terminal does not have individual seals, their logistics are optimised by centralising their distribution through a control room, thus reducing excess seal storage and associated waste. Responsible staff - the cargo accountants - ensure that seals are used precisely as intended and that potential errors are minimised through systematic seal checks.

It is important to note that effective management of sealing processes contributes to sustainable operations by optimising time, reducing paperwork and avoiding unnecessary re-work. In this context, moving away from physical (paper) excise documents towards digital documentation is recommended, thereby reducing paper consumption, speeding up data processing and reducing the carbon footprint associated with the physical movement of documents. This step would meet both efficiency and sustainability objectives for the container terminal operations.

The terminal carries out complex cargo handling activities, including loading different types of cargo into different types of vehicles. Based on emission permits and digital applications (AUTOSTORE, KIPIS), the handling processes are organised in such a way as to ensure efficiency and minimum environmental impact. In Q1 2024, the terminal recorded a 16.5% growth in cargo through the use of modern, energy-efficient machinery and automated management systems. For bulk cargo (e.g., sulphur, grain), specialised forklifts and rotainers are used to reduce the risk of dispersion and speed up operations. The MANTSINEN 70 crane, with up to 35% less energy consumption, ensures efficient handling of grain loads. Loading activities are planned using digital systems - ship planners optimise container loading according to the capacity of the STS cranes, with real-time information.

Loading complies with the requirements of the pollution permits: controlling the height and speed of the embankment, and ensuring that the cargo is loaded with the minimum level of pollution. Warehouses in the terminal area are designed for the storage and handling of bulk cargo, and the load is distributed among transport modes (cars, ships, rail wagons) according to an agreed schedule. The terminal's handling technologies and organisational solutions are geared towards sustainable logistics - minimising environmental impact, optimising the use of resources and ensuring safe and efficient processes. Cargo is delivered to the loading bays according to a pre-defined schedule and arrives at the terminal by different modes of transport. The breakdown of the results of the interviews by mode of transport is shown in Table 4.

Table 4. Transport of containers.

Category	Sub-category	Supporting statements
Container transport	Type of transport	I1 , “<...> The modes of transport bringing containers to the terminal are container ships, road transport, trucks and rail transport”. I2 , “<...> containers are transported by <...> road transport, namely trucks”. I3 , “Containers are mainly brought to the terminal by trucks, rail and container ships”.
Advantages	Well-developed roads	I1 , “<...> ship routes as well as land routes are the best developed <...>”. I3 , “<...> Extensively developed network of land and water roads <...>”.

Based on the interview data, it can be assumed that efficient container logistics at the terminal is closely linked to a favourable geographical location and a well-developed transport infrastructure. Most of the containers arrive at or depart from the terminal by container vessels, which ensures the simultaneous transport of large volumes of cargo, contributing to lower emissions per unit. Road transport remains popular due to its flexibility, mobility and responsiveness to logistics needs, while rail, with its four sidings within the terminal area, provides an environmentally friendly means of transporting bulk cargo. There is a convergence of views among informants on the dominant modes of transport, which provides a reliable assessment of the current situation. To strengthen sustainable logistics and ensure smoother management of handling processes, it is recommended to invest in upgrading the terminal's road infrastructure. Improved road conditions would improve transport safety and reduce the need for maintenance, contributing to a long-term reduction in environmental impact. It is proposed that the smart gates, which currently cause congestion in and out of the terminal, be upgraded. Introducing smart solutions would contribute to more efficient flow management, reduce pollution from parked vehicles and increase the overall sustainability of operations.

The warehousing strategy also reinforces the sustainability principles: to reduce the dwell time of empty containers, handling is carried out on a FIFO basis. This allows for a smooth logistics flow and efficient use of resources. The most common load in containers is used tyres, which are diverted from storage areas to containers, semi-trailers or rail wagons. Once loaded, the containers are then transported by land or sea in accordance with the AUTOSTORE system. To further analyse how the load planning process works at the terminal, the results of the interviews are presented in Table 5.

Table 5. Load planning process

Category	Sub-category	Supporting statements
Load planning process	Planning	I2 , “<...> The planning process at the terminal is carried out using smart technologies and applications”. I3 , “The load planning process at the terminal is carried out using <...> applications <...>”.
	Tracking	I1 , “<...> where the fast-tracking processes at the terminal can be monitored and controlled”. I2 , “<...> can monitor the handling activities with video cameras<...>”.
	Control	I2 , “The fast pace of work is ensured by monitoring and controlling the loading process <...>”.
	Systems used	I1 , “<...> processes are recorded in various systems (AUTOSTORE, VBS, VISY) where they can be monitored and controlled <...>”. I2 , “VBS system, AUTOSTORE internal program, KIPIS program (VISY)”. I3 , “<...> the digital applications used: AUTOSTORE terminal internal application, VBS timing system, VISY, KIPIS”.

The results of the interviews confirm that the freight planning activity is based on the use of smart digital technologies. Digital systems and skilled staff allow for efficient organisation of handling processes, optimisation of the use of resources and reduction of the risk of human error. This technological basis helps to

ensure the rapid and accurate distribution of cargo to the different modes of transport - sea, road and rail - thus contributing to sustainable logistics management.

The terminal's infrastructure, integrated with smart systems, enables detailed control of the handling process, which is essential for productivity and reducing environmental impact. Automated data management and operational planning reduce unnecessary manoeuvres, save energy and reduce emissions. For even more sustainable operations, it is recommended that the digital skills of staff be continuously improved, internal communication strengthened, and infrastructure upgraded, including traffic management measures in the terminal area. Such actions would enhance the terminal's international competitiveness and contribute to the green logistics objectives.

Conclusions

The study identified practical measures that, if implemented at container terminals, would support more sustainable operations and reduce environmental impact.

The digital systems used at the terminal allow efficient planning, monitoring and control of all handling and storage processes. This reduces the likelihood of errors, optimises the use of resources and saves time and energy, directly contributing to the organisation of sustainable operations.

The efficient arrangement of containers according to type, content and purpose reduces the movement of machinery and fuel consumption, thus indirectly contributing to the reduction of emissions.

Modern handling equipment increases the speed of work while reducing energy consumption by up to 35% and helps to avoid dust dispersion and environmental pollution.

Most containers arrive at the terminal by sea or rail, helping to reduce the carbon footprint compared to road transport alone.

The sealing of export containers is outsourced to the carriers, and only locally loaded containers are sealed at the terminal. This allows for a rational distribution of responsibilities, avoiding excessive use of seals and reducing the circulation of physical documents. Introducing digital solutions in this area would help reduce the use of paper and increase the transparency of processes.

The survey revealed that limited storage space and the state of the road infrastructure are major challenges. Investments in site development, upgrading smart gates and improving signage are proposed. This would help optimise traffic flows, reduce wear and tear on machinery, and reduce the long-term environmental impact.

During the study, limitations in data availability were encountered, as not all aspects of terminal operations were publicly documented or accessible due to commercial confidentiality. As a result, some parts of the analysis relied on secondary sources or aggregated data.

References

- Abu, M. A., Ouhipmou, M., & Paquet, M. (2020). Optimisation of container terminal layouts in the seaport—Case of port of Montreal. *Sustainability*, 12(3), 1165. <https://doi.org/10.3390/su12031165>
- Belova, J., & Krochina, J. (2019). Uosto krovos įmonės technologinių išteklių ir kuriamos ekonominės pridėtinės vertės sąsajos tyrimas: konteinerių krovos verslo atvejis. *Darnios aplinkos vystymas*, 16(1), 91-100. <https://ojs.kvk.lt/index.php/DAV/article/view/127>
- Budiyanto, M., Shinoda, T. (2020). Energy efficiency on the reefer container storage yard; an analysis of thermal performance of installation roof shade. *Energy Reports*, 6, 686-692. <https://doi.org/10.1016/j.egyr.2019.11.138>

- Duan, J.G., Xiong, Z.C., & Li, L.Z. (2025). Integrated Sustainable Scheduling in U-Shaped Automated Container Terminal Considering Collection-Distribution Operations and Adaptive Partitioning Strategies. *Transportation Research Record*, Early Access <http://doi.org/10.1177/03611981251327218>
- Gao, Y.P., Chang, D.F., Chen, C.H. (2022). A digital twin-based approach for optimising operation energy consumption at automated container terminals. *Journal of Cleaner Production*, 385, Article Number 135782 <http://doi.org/10.1016/j.jclepro.2022.135782>
- He, J., & Tan, C. (2019). Modelling a resilient yard template under storage demand fluctuations in a container terminal. *Engineering Optimisation*, 51(9), 1547-1566. <https://doi.org/10.1080/0305215X.2018.1525711>
- Hoffmann, N., Stahlbock, R., & Voß, S. (2020). A decision model on the repair and maintenance of shipping containers. *Journal of Shipping and trade*, 5, 1-21. <https://doi.org/10.1186/s41072-020-00070-2>
- Hsu, W.K.K., Huang, S.H.S., Huynh, N.T., & Huang, K.H. (2024). An evaluation model of sustainable efficiency for container terminals *Sustainable Development*, 32(1), 1170-1187. <http://doi.org/10.1002/sd.2707>
- Hu, X., Liang, C., Chang, D., & Zhang, Y. (2021). Container storage space assignment problem in two terminals with the consideration of yard sharing. *Advanced Engineering Informatics*, 47, 101224. <https://doi.org/10.1016/j.aei.2020.101224>
- Hu, Y.Z., Wang, M., Min, R., Liu, J.X., Lukinykh, V.F., Tang, S.L., Zhao, D. (2025). Coordinated scheduling optimisation of quay cranes and AGVs in automated container terminals. *Computers & Operations Research*, 182, Article Number 107147 <http://doi.org/10.1016/j.cor.2025.107147>
- Huang, X., Dai, X., Luo, Y., & Wang, Y. (2019). Design of container terminal handling system based on index forecast and economic evaluation. *Journal of Coastal Research*, 94(SI), 377-384. <https://doi.org/10.2112/SI94-077.1>
- Ilesaliev, D. I., Abduvakhitov, S. R., Ismatullaev, A. F., & Makhmatkulov, S. G. (2019). Research of the main storage area of the container terminal. *International Journal of Engineering and Advanced Technology (IJEAT)*, 9(1), 4625-4630. <https://doi.org/10.35940/ijeat.A2923.109119>
- Jachimowski, R., Zieliński, T., & Józwiak, A. (2022). The issue of transport documentation circulation between logistic processes participants. *WUT Journal of Transportation Engineering*, 2022, vol. 135. <http://doi.org/10.5604/01.3001.0018.8426>
- Jakovlev, S., Eglynas, T., Jusis, M., Jankunas, V., Voznak, M. (2025). Mitigating Container Damage and Enhancing Operational Efficiency in Global Containerisation. *Sensors*, 25(7), Article Number 2019 <http://doi.org/10.3390/s25072019>
- Kusrini, E., & Parmasari, A. N. (2020). Productivity improvement for unit terminal container using lean supply chain management and single minute exchange of dies (SMED): A case study at semarang port in Indonesia. *International Journal of Integrated Engineering*, 12(1), 122-131. <https://doi.org/10.30880/ijie.2020.12.01.013>
- Li, L.Y., Liu, J., Yang, J., Ma, X.Z., & Yuan, H.P. (2024). Investigating the efficiency of container terminals through a network DEA cross efficiency approach. *Research In Transportation Business and Management*, 53, Article Number 101107 <http://doi.org/10.1016/j.rtbm.2024.101107>
- Lu, H.J., & Lu, X. (2025). Joint Optimisation of Berths and Quay Cranes Considering Carbon Emissions: A Case Study of a Container Terminal in China. *Journal of Marine Science and Engineering*, 13(1), Article Number 148 <http://doi.org/10.3390/jmse13010148>
- Luo, J., & Wu, Y. (2020). Scheduling of container-handling equipment during the loading process at an automated container terminal. *Computers & Industrial Engineering*, 149, 106848. <https://doi.org/10.1016/j.cie.2020.106848>
- Mahmud, K.K., Chowdhury, M.M.H., & Shaheen, M.M.A. (2024). Green port management practices for sustainable port operations: a multi method study of Asian ports. *Maritime Policy & Management*, 51(8), 1902-1937. <http://doi.org/10.1080/03088839.2023.2258125>
- Moros-Daza, A., Castro, D., Bonifacio, J., Amaya-Mier, R., & Voss, S. (2024). Greening container terminals: An innovative and cost-effective solution for sustainable reefer container storage. *Journal of Cleaner Production*, 466, Article Number 142664 <http://doi.org/10.1016/j.jclepro.2024.142664>
- Puzinavičius, R., & Vaitiekus, A. (2021). Šiuolaikinių technologijų naudojimas įmonės sandėliavimo procese. Verslas, technologijos, biomedicina: inovacijų išvalgos 2021: straipsnių rinkinys, (1), 389-397. <https://talpykla.elaba.lt/elaba-fedora/objects/elaba:100981403/datastreams/MAIN/content>
- Rasulov, M., Masharipov, M., & Ismatullaev, A. (2021). Optimisation of the terminal operating mode during the formation of a container block train. *E3S Web of Conferences*, Vol. 264, p. 05025. EDP Sciences. <https://doi.org/10.1051/e3sconf/202126405025>
- Roy, D., De Koster, R., & Bekker, R. (2020). Modeling and design of container terminal operations. *Operations Research*, 68(3), 686-715. <https://doi.org/10.1287/opre.2019.1920>.

Saleh, M.A.M., Hicham, A., Ben Maâti, M.L., Taha, H., & Mohammed, Y.M.A. (2024). Development of a sustainable strategy model for predicting optimal container stacking locations in container yards using artificial intelligence and cubic data. *Kuwait Journal of Science*, 51(2), Article Number 100174 <http://doi.org/10.1016/j.kjs.2023.100174>

Santos, T.A. (2025). Sustainable Port Operations: Pollution Prevention and Mitigation Strategies. *Sustainability*, 17(11), Article Number 4798 <http://doi.org/10.3390/su17114798>

Svetikaitė, P., & Plačienė, B. (2021). Šiuolaikinių inovacijų konteinerių terminaluose tyrimai. *Verslas, technologijos, biomedicina: inovacijų žvalgos 2021: straipsnių rinkinys*, (1), 464-474.

Vicrihadi, A., Sembiring, H. F. A., & Ayutia, Y. (2021). Analysis of The Operational Performance of Loading and Unloading Containers at Operating Terminal 3 Port of Tanjung Priok. *Advances in Transportation and Logistics Research*, 4, 352-362. <https://doi.org/10.25292/atlr.v4i0.401>

Walker, T., Smith, R., Taylor, L., & Evans, M. (2021). Hazard prevention through container disinfection. *Journal of Hazardous Materials Management*, 22(2), 133-142.

Wang, N., Chang, D., Shi, X., Yuan, J., & Gao, Y. (2019). Analysis and design of typical automated container terminals layout considering carbon emissions. *Sustainability*, 11(10), 2957. <https://doi.org/10.3390/su11102957>

Wang, X.H., Jin, Z.H., & Luo, J. (2025). Joint Allocation of Shared Yard Space and Internal Trucks in Sea-Rail Intermodal Container Terminals. *Journal of Marine Science and Engineering*, 13(5), Article Number 983 <http://doi.org/10.3390/jmse13050983>

Yang, D., Liao, S.G., Lun, Y.H.V., & Bai, X.W. (2023). Towards sustainable port management: Data-driven global container ports turnover rate assessment. *Transportation Research Part E-Logistics and Transportation Review*, 175, Article Number 103169 <http://doi.org/10.1016/j.tre.2023.103169>

Youssef, H., & Aly, M. (2020). Preventing overloading in port container terminals. *Journal of Transportation Safety & Security*, 12(1), 75-88.

Zhao, N., Liu, Y., Mi, W., Shen, Y., Xia, M., Zhao, N., ... & Xia, M. (2020). Operation Management in the Container Terminal. *Digital Management of Container Terminal Operations*, 47-73. https://doi.org/10.1007/978-981-15-2937-5_2

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