Volume 5, Issue 6

Malaysia Journal of Invention and Innovation

https://journal.academicapress.org/aps/index.php/mjii

Research Article

VERTEX: An Automated Modular Container Storage System for Optimising Port Space Utilisation

Hamzah Jaafar[1], Antasya Raedah Md Azlan[2], Nur Dina Arifah Hazrilizam[3], Nurul Nazurah Samsudin[4], Putri Humairaa Rushdin[5], Siti Nur Syazwani Yusop[6], Adriana Kamelia Ahmad Kamal[7] and Mohd Isham Abidin[*]

1 Faculty Business and Management, Universiti Teknologi Mara (UiTM), Kampus Bandaraya Melaka, Malaysia; 2025234258@student.uitm.edu.my

2 Faculty Business and Management, Universiti Teknologi Mara (UiTM), Kampus Bandaraya Melaka, Malaysia; 2025484566@student.uitm.edu.my

3 Faculty Business and Management, Universiti Teknologi Mara (UiTM), Kampus Bandaraya Melaka, Malaysia; 2025429932@student.uitm.edu.my

4 Faculty Business and Management, Universiti Teknologi Mara (UiTM), Kampus Bandaraya Melaka, Malaysia; 2025225788@student.uitm.edu.my

5 Faculty Business and Management, Universiti Teknologi Mara (UiTM), Kampus Bandaraya Melaka, Malaysia; 2025481748@student.uitm.edu.my

6 Faculty Business and Management, Universiti Teknologi Mara (UiTM), Kampus Bandaraya Melaka, Malaysia; 2025240602@student.uitm.edu.my

7 Faculty Business and Management, Universiti Teknologi Mara (UiTM), Kampus Bandaraya Melaka, Malaysia; 2025430974@student.uitm.edu.my

* Correspondence: ishamabidin@uitm.edu.my; 011-39029198/06-2857145.

Keywords:
VERTEX
Container storage
Port operations
Space utilisation
Vertical storage system

Abstract: *Limited capacity is one of the major problems in warehouses and ports. Jalil (2026) states that cargo increase creates high pressure on the ports and the whole logistic network. A vertical storage system called VERTEX is developed by our team to solve the problem. The system is developed to help make the best use of space by loading containers on a base that has an elevator system that allows dropping them in the fixed compartments. With the help of the system, workers will get the ability to access containers whenever needed. The aim of the new system is to optimise processes in the warehouse, make fewer unnecessary moves, and use less land. The system needs more engineering solutions, financial estimation, and safety testing before applying it commercially.*

Copyright: © 2026 by the authors. Submitted for open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

The limited space for storage is one of the major problems in contemporary port operation particularly for the growing volume of containers and logistics requirements. Space on the yard is a critical factor in conventional container storage and can result in congestion if space becomes a limiting

factor. Westports had congestion in the yards up to 90% with average waiting times of two to three days, Star (2025) said. These conditions highlight the need to make existing storage facilities more effective and utilise existing space more efficiently. To solve the problem, our team is proposing vertex, a vertical container storage system that will be able to organise the containers in specific storage compartments. The system is designed to make best use of vertical space to enhance the storage system. This innovation is centered on the support of more efficient handling of containers, better use of space and in the future, possibly less need for more land at the port.

2. LITERATURE REVIEW

According to Star (2025), Westports Holdings Bhd experienced difficulties in increasing its container volume due to inadequate spare capacity at Port Klang. It noted that the average waiting time of vessels at berths was two or three days while the congestion in the container yard was about 90%, implying that a lack of storage capacity can hinder efficiency of the port.

The problem stresses the significance of better using the current port area instead of just building ports. When container terminals reach their maximum capacity, the available space for incoming containers becomes smaller. This may lead to congestion and less efficient cargo processing. For this reason, improved solutions for physical storage can assist ports in placing containers on their current premises.

Regarding this issue, VERTEX has come up with a different way of storing containers that maximises the vertical space. The concept is based on storing the containers in a special storage unit that will help to increase the storage capacity and cut down the need for land at the same time. The proposed solution can help to relieve overloaded container terminals and improve the land usage efficiency in ports. However, its real-time usefulness will depend on structural safety, accessibility of containers, needed equipment and costs of setting it up.

In general, the article by Star (2025) provides a real-life example of size constraints in port activities in Malaysia. It contributes to the rationale of developing VERTEX as a prospective equipment for physical storage. Unlike being a substitute for huge port expansion, VERTEX can be an addition to the present facilities that improves the efficiency of space utilization and helps ports cope with container storage demands.

3. METHODOLOGY



Figure 1

The proposed VERTEX system is designed around a controlled lifting mechanism that moves containers between a loading area and designated storage compartments.

3.1 Materials and Components

High strength structural steel is the major material for constructing the suggested VERTEX system that is meant to accommodate bulky shipping containers. In this regard, while the containers are transferred from one place to another horizontally through the use of a powerful transfer platform, the lifting and lowering of the containers will be done through the use of a hydraulic lifting system. A control panel to regulate container movement and storage locations, guide rails, mechanical locking mechanisms and sensors are additional parts.

3.2 Existing Container Storage Method

Traditionally, shipping containers are often piled on top of one another using container-handling machinery after being positioned in certain container yard areas. This method requires sufficient ground area, especially when the number of containers increases. According to Jalil (2026), growth in global business and cargo volume is adding pressure on Malaysia's ports. Low port capacity, container congestion, shortage of drivers and insufficient investments in the logistics industry are the problems that can influence port performance and cause delays in the transportation of cargo. Therefore, VERTEX introduces a vertical storage concept with individual compartments for container placement.

3.3 System Workflow

The operation of VERTEX involves five main stages: (1) Container Placement, where the container is positioned on the loading platform using suitable handling equipment; (2) Selection of Compartment, where the operator selects a suitable compartment to store the container taking into account the size and weight of the container via control panel; (3) Vertical Lifting, where the container is raised to a desirable level with the help of hydraulic platform; (4) Container Storage, where the transfer platform loads the container to its assigned compartment and locks it there; and (5) Container Unloading, where the required container is unloaded from the selected compartment and lowered to the exit platform.

4. FINDINGS

The survey and analysis of the sample that contained 33 responses giving an opinion of VERTEX. The survey was conducted to evaluate the current container storage challenges and gauge industry demand for VERTEX.

4.1.1 Gender

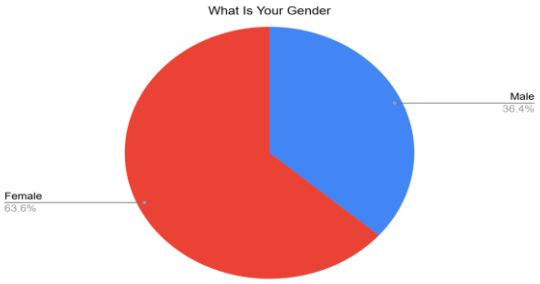


Figure 2

The analysis of the sample in figure 1, which included 33 responses revealed that 63.6% are female respondents while the remaining, 36.4% of the respondents are male respondents. The female respondents are more reaching to the distribution of awareness among the respondents compared to the male respondents.

4.1.2 The Frequency of Problem with Containers

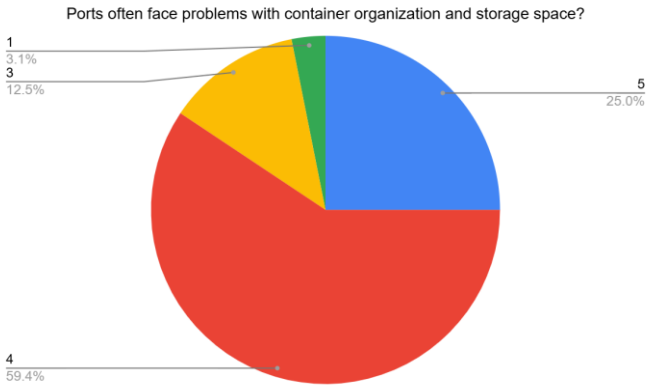


Figure 3

In the matter of awareness by the respondents about the frequency of problem with containers, 59.4% of the respondents are on the scale of 4 over 5. This shows that they agree that the statement is true about problems faced in port sites. 25% of respondents are on the scale of 5 where they strongly agree about the statement. The balance of the respondents of 12.5% on scale of 3 where they are neutral about it and meanwhile 3.1% of respondents are on scale 1 which strongly disagree. Some of them might not know any information about what is happening.

4.1.3 Container Retrieval Ease

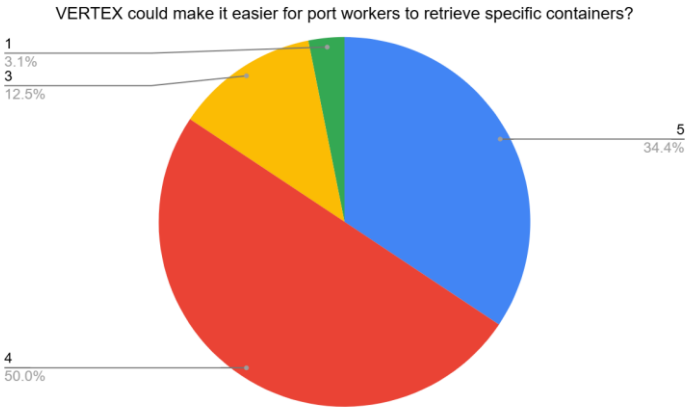


Figure 4

From figure 3, we can see that 50% of respondents are on the scale of 4 where they agree that VERTEX can help in terms of ease of retrieval of specific containers. The 34.4% of the respondents strongly agree by the scale of 5 with the statement saying VERTEX will be helpful for retrieval of containers. We can deny some of the respondents will be on the neutral thinking side with the statement

that only 12.5% of respondents and only 3.1% of respondents on scale 1 strongly disagree with this statement. They might still have some trust issue with this new product for some reason.

4.1.4 Ease of System Operation



Figure 5

According to the survey results, it indicates that vertex is expected to be easy for port workers to operate. Based on the chart, it shows 59.4% of respondents rated the 5 for this question and 28.1% respondents give a rating 4. these two highest ratings which are 87.5% indicating that positive response. However, 9.4% response rated it 3 and only 3.1% rated it as 1. These findings indicate that the majority of respondents believe that the system is easy to use. This supports the proposal to simplify container selection, storage and retrieval by using the control panel.

4.1.5 Vertical Space Utilisation

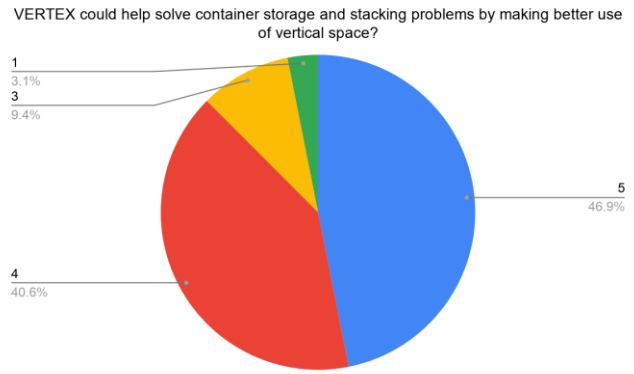


Figure 6

Figure 6 showing the respondent's perceptions of vertex about container storage and stacking problems through the better utilisation of vertical space. Based on the chart, it shows a positive rating because 46.9% rated it as 5 and 40.6% rated it 4. Meanwhile, 3.1% of respondents rating it 1 and in percentage is 3.1% and 9.4% give a rating of 3. These findings show us that most respondents believe vertex can increase the effectiveness of container storage by doing it vertically compared to horizontally. This could help our main goal which is to increase the storage capacity and lower requirement for land.

4.1.6 Operational Efficiency and Reduced Waiting TIme

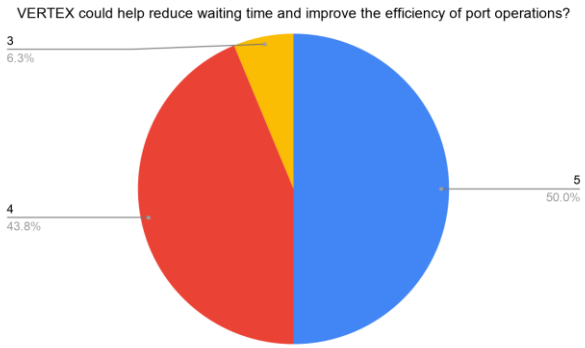


Figure 7

Figure 7 showing the respondent's opinion of vertex about port operations is efficient and can help reduce the time. Based on the chart, the result shows a strongly positive rating because 50%% rated it as 5 and 43.8% % rated it 4 which means they agree with the statement. Meanwhile, 6.3% give the rating as a 3 which means natural response. Overall, 93.8% of respondents give positive ratings and agree that vertex could help operational efficiency and reduce waiting time.

5.0 DISCUSSION

5.1 Problem Statement: Challenges of Conventional Container Storage Systems at Ports

5.1.1 Limited Storage Space

One of the major challenges faced by conventional container storage systems is limited storage space. Ports need plenty of land in order to provide adequate space for the arrangement of the shipping containers as the volume of international commerce and shipping cargo continues to grow. Traditional methods of storage mostly utilize ground storage, which demands extensive land spaces for the storage of containers. In other words, the rising levels of traffic in ports have basically led to an increase in demand for storage areas. The combination of rising levels of containers being moved and lack of space in storage areas has been quite challenging to the operations of port management (Carlo et al., 2014). The more containers there are, the less storage space remains and it becomes increasingly difficult for the port to provide accommodation for extra cargo. Additionally, expansion of the port demands additional land, which may be costly and difficult to obtain.

5.1.2 Container Congestion and Operational Delays

It can lead to delays in port operations and transportation activities. Ports must manage transport and deliver containers in a more efficient way due to increased cargo amounts. According to Jalil (2026), increased cargo amounts are adding extra burden to Malaysian ports, resulting in increased challenges of port activities and transport services. Increased waiting time and delay in delivering could happen because of traffic problems around the ports and trucking services, slowing down the process of delivering containers. Furthermore, in order to locate and transport certain containers, traditional methods of storing containers would require many processes.

5.1.3 High Operational Costs

In order to sustain daily operations, such as fuel, labor, machinery, equipment and container storage facilities, port operations need significant financial resources. Machines like cranes, forklifts and many others use fuel and will require regular maintenance in order to run effectively. Furthermore, the ports will require enough personnel for managing, organizing, handling and transporting containers. The operating costs will increase when there is an increase in the number of containers since the need for more labor, machines and storage facilities will be required (Xu et al., 2023).

5.2 Solution of Vertex

Based on the problem statement that has been discussed which are limited storage space, container congestion and delays and high operational costs, our group introduced vertex which is an automated modular container storage system that focuses on maximizing the storage space, improving congestion and delays and reducing the operational costs.

5.2.1 Maximise Storage Space

Vertex helps maximise storage space by using storage compartments instead of relying on only the area on the ground. The system is able to accommodate containers of different sizes, including 20-foot and 40-foot containers, in designated compartments. By utilising vertical space, vertex will be able to store more containers in a smaller area. This can help ports make better use of their available space and manage increasing container volumes more efficiently. According to Jiang et al. (2012), explained that container ports are encountering difficulties because the number of containers is increasing, but the land is limited. Their research proposed ways to improve storage management practices in a better manner. This works in favor of vertex's concept of vertical compartment storage in the ports.

5.2.2 Improve Container Congestion and Delays

Furthermore, it can improve container congestion and delays. This can be done through the lifting system and transfer platform. The operator would use the control panel to select the available compartment. The chosen container can be selected by the system when retrieval is needed without having to move other containers. According to Nadi et al. (2022), the issue that gains more attention is high waiting time for trucks at the terminal gates of seaports. There would be upstream and induce emissions, costs and delays if there are long queues of idling trucks at terminal gates which are waiting to pick up or deliver a container. In addition, lack of port hinterland alignment is the source of traffic jams, lengthy wait times and consequently bad truck turnaround times at the terminal.

5.2.3 Reduce Operational Costs

Lastly, operational costs can be reduced by minimising unnecessary container movements during storage and retrieval. In conventional container storage, equipment may need to move other containers before reaching the selected container. Through vertex, the operator can select the required container using the control panel, and the system will retrieve it from its assigned compartment. This can help reduce handling time and equipment usage, while improving storage efficiency. Based on Benghalia et al. (2025), who discussed how reducing empty trips and equipment waiting time can improve container terminal operations, they also found that optimising terminal operations can help reduce carbon emissions.

5.3 Impacts of Vertex

The proposed vertex automated modular container storage system may positively influence port operations, economic performance, environmental sustainability and technological development. The intent of the vertex is to maximize the efficient use of containers, container space and to reduce the problems caused by the lack of space and the increase in container traffic by combining vertical container storage with an automated lifting and retrieval system.

5.3.1 Operational Impact

By optimising the space carried in port facilities, vertex can enhance the efficiency of the port operation. Traditional container storage methods generally heavily rely on ground space for containers, which may be a constraint in a small port. The vertical storage design enables the stacking of containers in several levels and may bring an additional increase in the number of containers that can be stored in a specified space (Homayouni & Tang, 2016). Such a scheme might be advantageous for ports with a high volume of containers and little space for physical expansion.

Also, the automated lifting and conveyor systems can be used to assist in a more systematic storage and retrieval of containers. All containers can be moved to appropriate storage areas based on their size and storage needs. This can help minimise the extra movement of containers and help organise container handling activities. This can help alleviate congestion in storage areas and facilitate more efficient port operations, potentially improving overall efficiency and productivity (Knatz et al., 2022). But the efficiency gain would vary according to the design, capacity, and integration of the system at the port (Yu et al., 2025).

5.3.2 Economic Impact

Vertex can offer long term benefits to the port in terms of better utilization of port resources and reduction of some of the operational inefficiencies. This allows more containers to be stored in a restricted space, potentially enabling port operators to maximise the space they have without needing more immediately. This could be especially beneficial in the heavy traffic port system where land development is costly or challenging (Yu et al., 2025).

Furthermore, automatic handling of containers can help to minimize unnecessary movements of vehicles and increase labour efficiency. These enhancements may help reduce operations costs in the long term, based on the maintenance needs, energy usage and operations efficiency of the system. Improved container handling and retrieval systems may also contribute to more efficient cargo management and meet the growing demand for port operations (Knatz et al., 2022; ITF 2021).

However, the adoption of vertex would require significant investments in infrastructure, automated equipment, software and safety systems initially. On-going expenses would also include regular maintenance and technical support. Hence, port operators would have to consider the potential monetary savings in relation to the outlay and operating cost of the system before implementing it.

5.3.3 Environmental Impact

Vertex could make a positive contribution towards environmental sustainability by enabling more efficient handling of containers and minimising unnecessary movements within port facilities. In standard modes, vehicles and container handling equipment can be required to move from one storage area to another for the purpose of loading or unloading containers. With the incorporation of dedicated storage spaces and an automated retrieval system, vertex could help to reduce some of the unnecessary

movements, which can lead to a reduction in fuel consumption and associated carbon emissions (Gao et al., 2023).

Another possible environmental benefit is that more existing port land will be utilized. This will reduce the need for port operators to expand storage areas as much as possible, as it allows them to store more containers in a smaller space. This may help to minimise the need for further land development, however the environmental benefits will be dependent on the location, construction needs and size of implementation (Muhammad Arif Budiyanto et al., 2024).

Vertex would also require energy to function its lifting mechanisms, conveyors, automated systems and controls. Overall environmental impact would thus be a function of the energy efficiency of the system and the source of energy. The use of energy efficient machinery, renewable electricity when possible, would further enhance its potential contribution to sustainable port operations (Gao et al., 2023).

5.3.4 Technological and Workforce Impact

Vertex is a technological leap that takes the concept of container storage to the next level, adding automation to the processes of moving, storing and retrieving containers. It has a control unit that enables the operator to choose between different sizes of containers and storage compartments, considerably making the management of container placing more systematic. This method might help ports to invest in more sophisticated technologies and enhance the implementation of automated equipment within current port systems (Knatz et al., 2022).

The new "vertex" may also have an impact on the number of workers needed at port installations. While automation might alleviate some of the repetitive aspects of manual work, human operators would still be essential for tasks such as keeping an eye on the system, maintaining equipment, conducting safety checks, troubleshooting, and managing operations. This means that employees may require further training in technical skills to be able to effectively handle automated storage systems (Gattuso & Pellicanò, 2023).

In addition, the use of vertex could provide opportunities for technical training and professional development in such fields as automation, equipment maintenance, and digital system management. The port operators, however, would have to ensure that employees are appropriately trained to operate the system safely and effectively in case of technical issues. Automation plus workforce development could help to gradually modernise port operations and be a part of vertex (Tsagkaris & Moschovou, 2025).

5.4 Commercialization Potential

The commercialization potential of vertex is the future of the target market of this product innovation for any core of business in the world that specifically focuses on seaport container terminals companies. This is because there are a good example we have which is Malaysia Mining Companies Berhad (MMC) as an example.

5.4.1 Massive Target Market

A massive target market meaning vertex wants the product to be reached with various of container ports terminals in the world. A research of operations had been done by Weerasinghe et al. (2023) showing that the container terminals had faced huge demand daily. By this happening, vertex can makes the terminals become a scalable management tools as for a global competitiveness. The

example of the specific target markets are container terminals, global port operators, and regional maritime logistics leaders such as at MMC port.

5.4.2 High Return Of Investment (ROI)

A company that owns this product innovation of vertex in their port terminal can easily reduce or eliminate the heavy financial burden because it can convert to the efficiency for the operations. For example, a burden of acquiring, leasing, or even developing high-cost coastal land for any extra storage. As we know, one of the largest capital-intensive in a port's capacity is land expansion. Other than that, maximizing the existing asset productivity provides a big return on capital too (Jiang et al., 2012).

5.4.3 High Physical Space & Density Optimization

Vertex can enhance the spatial utilization and stacking density and enable the high-volume operators to handle thousands of containers daily. The expansion can be through without a physical footprint expansion. According to Zhen et al. (2022), under uncertainty of maximizing yard space utilization where it coordinates berth arrivals with yard space allocation. When it dramatically increases in stacking capacity. It is confirmed that port operators can scale throughput without the physical land expansion. Vertex can protect ports from purchasing an expensive new land during the increases of cargo volume.

6. CONCLUSION

To conclude, the proposed VERTEX an Automated Modular Container Storage System (AMCS) is an innovative solution that promises to overcome the key challenges facing traditional containers storage systems including space constraints, congestion, delays and high operational cost. The VERTEX introduces a vertical storage concept with an automated lifting and retrieval mechanism to maximise the usage of the available space and to optimise the handling and storing of containers. The overall response from the survey with 33 respondents shows that the proposed system is accepted. Most respondents felt that VERTEX has a potential to improve container retrieval space utilization and to enhance the operational efficiency. Specifically, 93.8% of the participants rated it positively in terms of its ability to enhance the operations of ports and shorten waiting times. In addition, VERTEX can offer long term economic gains, environmental benefits and technological progress as it decreases the number of unnecessary container movements, cuts the need for further expansion of port land and promotes the use of automation in port operations. Overall, VERTEX can enable the modernisation of port operations and assist container terminals in coping with the growing volumes of cargo more efficiently l. However, to be successful this would require further development such as structural safety testing, technical improvements, cost estimation, energy efficiency assessments and proper training of the workforce. While more research and development is required to enable commercialization, VERTEX is certainly a promising development towards intelligent space efficient and sustainable containers storage management in the future.

Aknowledgements: We would like to express our sincere gratitude to everyone who contributed to the successful completion of our innovation project named VERTEX. We would like to thank our advisor, Sir Isham Abidin for his valuable guidance and advice. The research was supported by Universiti Teknologi Mara (UiTM) and this support gratefully acknowledged.

REFERENCES

Benghalia, A., Ferdjallah, A., Oudani, M., & Boukachour, J. (2025). Machine learning

and simulation for efficiency and sustainability in container terminals. *Sustainability*, *17*(7), 2927. https://doi.org/10.3390/su17072927

Carlo, H. J., Vis, I. F. A., & Kees Jan, R. (2014). Storage yard operations in container terminals: Literature overview, trends, and research directions. *Maritime Logistics*, *235*(2), 412–430. https://doi.org/10.1016/j.ejor.2013.10.054

Gao, Y., Chang, D., & Chen, C.-H. (2023). A digital twin-based approach for optimizing operation energy consumption at automated container terminals. *Journal of Cleaner Production*, *385*, 135782. https://doi.org/10.1016/j.jclepro.2022.135782

Gattuso, D., & Pellicanò, D. S. (2023). Perspectives for ports development, based on automated container handling technologies. *Transportation Research Procedia*, *69*, 360–367. https://doi.org/10.1016/j.trpro.2023.02.183

Homayouni, S. M., & Tang, S. H. (2015). Optimization of integrated scheduling of handling and storage operations at automated container terminals. *WMU Journal of Maritime Affairs*, *15*(1), 17–39. https://doi.org/10.1007/s13437-015-0089-x

Jalil, A. (2026, August 20). *Ports at tipping point*. NST Online; New Straits Times.

https://www.nst.com.my/business/economy/2026/08/1514892/ports-tipping-point-watch

Jiang, X., Lee, L. H., Chew, E. P., Han, Y., & Tan, K. C. (2012). A container yard storage strategy for improving land utilization and operation efficiency in a transshipment hub port. *European Journal of Operational Research*, *221*(1), 64–73. https://doi.org/10.1016/j.ejor.2012.03.011

Knatz, G., Notteboom, T., & Pallis, A. A. (2022). Container terminal automation: Revealing distinctive terminal characteristics and operating parameters. *Maritime Economics & Logistics*, *24*(3), 537–565. https://doi.org/10.1057/s41278-022-00240-y

ITF (2021). Container Port Automation: Impacts and Implications. *International Transport Forum Policy Papers,* No. 96, OECD Publishing, Paris. https://doi.org/10.1787/8db18610-en

Muhammad Arif Budiyanto, Faril Ichfari, & Shinoda, T. (2024). Modest method for estimating CO2 emissions from container handling equipment at ports. *Sustainability*, *16*(23), 10293–10293. https://doi.org/10.3390/su162310293

Nadi, A., Nugteren, A., Snelder, M., Van Lint, J., & Rezaei, J. (2022). Advisory-Based

time slot management system to mitigate waiting time at container terminal gates. *Transportation Research Record Journal of the Transportation Research Board*, *2676*(10), 656–669. https://doi.org/10.1177/03611981221090940

Star, T. (2025, June 10). *Lack of capacity choking westports push for container volume growth*. The Star. https://www.thestar.com.my/business/business-news/2025/06/11/lack-of-capacity-choking-westports-push-for-container-volume-growth

Tsagkaris, P., & Moschovou, T. P. (2025). The impact of automation on the efficiency of port container terminals. *Future Transportation*, *5*(4), 155. https://doi.org/10.3390/futuretransp5040155

Weerasinghe, B. A., Perera, H. N., & Bai, X. (2023). Optimizing container terminal operations: A systematic review of Operations Research Applications. *Maritime Economics & Logistics*. https://doi.org/10.1057/s41278-023-00254-0