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Improving the Sustainability for Container Ports

Shih-Liang Chao[1], Ming-Miin Yu[2] and Shih-Shiuan Huang[1]
National Taiwan Ocean University, Keelung, Taiwan, ROC

1. Introduction

With the trend of environment protection, the global awareness of sustainable development has become an important issue. Currently, most major shipping countries are developing ″Green Ports″ or ″Eco Ports″ actively. This study explores the requirements of ecological protection for container ports using the quality function deployment (QFD) method. The results based on the port of Keelung (Taiwan) can help terminal operators determine the priority to deal with of the requirement items.

Literature has provided evaluation indicators for green ports and the measures necessary for establishing green ports or terminals (Yang, 2015). Although each of these studies contributes significantly to port sustainability, none of them offers a comprehensive framework for prioritizing the implementation of sustainable OPs. Consequently, there is a gap in conducting a comprehensive survey of sustainable practices specifically focusing on operational management. Such a survey could provide more meaningful and comprehensive suggestions to terminal stakeholders. To address this gap, the QFD method is a useful tool applied in product development to translate customer requirements (CRs) into actionable design requirements (DRs) (Carnevalli and Miguel, 2008). Typically, QFD utilizes the house of quality (HOQ) to translate CRs into DRs. This study aims to take the Keelung Port in Taiwan as an example to determine the environmental protection requirements. Additionally, this study also reviews and prioritizes common sustainable operation practices (OPs) based on the needs of container port stakeholders.

2. Literature review

Some studies investigated strategies and technologies for developing sustainable terminals, considering both costly and operation management (OM) approaches. For costly strategies, onshore power supply (OPS), which is called “cold ironing”, automatic or semi-automatic equipment (Yang and Lin, 2013), as well as transfer of diesel equipment to electric power systems (Moya et al., 2019) are commonly used to reduce the impact on the environment. On the other hand, the OM practices focused on optimizing yard management, organizing the layout of the terminal to improve the flow of trucks and containers, and reducing the deadheading of cranes and tractors (Kuo and Lin, 2020). For instance, Geerlings and Duin (2011) found that changing the terminal layout can significantly decrease CO_2 emissions, as demonstrated by the Rotterdam Shortsea Terminal, which achieved around a 70% reduction in emissions.

While pursuing sustainable practices, different container terminals (CTs) face various barriers and challenges. Radwan (2019) identified critical barriers to deploying OPS at Djibouti’s CTs using a fuzzy cognitive map approach. The findings show that the main barriers preventing the use of OPS technology in Djibouti are the power requirement, investment cost, and electricity cost. Yang (2015) established 21 assessment criteria for green CTs across berth area, yard area, gate area, and integrated area, and ranked six East Asian mega-hub ports accordingly. The study showed that Kaohsiung should focus on

[1] Department of Shipping and Transportation Management
[2] Department of Transportation Science

increasing energy efficiency and CO_2 reduction by implementing sustainable practices such as OPS, automated handling equipment, and electric RTGs. Furthermore, Calcerano and Hilsdorf (2021) proposed 27 criteria to determine the sustainability practices used in Brazilian terminals, based on the assessment criteria proposed by Yang (2015). The study found that high investment costs and a lack of support from port authorities were the biggest barrier to implementing sustainable practices. Overall, the green CTs are driving the development of new practices and technologies. As CT operators continue to introduce sustainable practices, it is essential to investigate how to use these practices effectively.

To achieve green CT operations without resorting to expensive measures like implementing OPS or using automated equipment, there are some low-cost practices rooted in OM that can be adopted. A CT is composed of three parts: the gate, container yard, and the shipside (Yang, 2015). For gate operations, it is crucial to reduce the time that trucks spend passing through the gate in order to decrease truck queues and, thereby minimizing emissions and noise. One effective measure is the implementation of a truck appointment system (TAS), which has been adopted in several countries. For example, the Port of Los Angeles (POLA) developed a TAS to address traffic issues and has successfully shortened truck queues at terminal gates to mitigate truck emissions. Punitive measures, such as fines, have been put in place in several ports to ensure comprehensive deployment of TAS. Additionally, many terminal operators have implemented optical character recognition (OCR) systems to increase the operational effectiveness of their gates in order to handle the growing container traffic (Moszyk et al., 2021). Using radio-frequency identification (RFID) in conjunction with OCR to recognize license plate numbers and container numbers to establish a gate automation system (GAS) can also reduce operation time and truck turnaround time. For yard operations, two main practices to reduce operation time are moving export containers upwards in advance and enlarging yard capacity by using taller yard cranes. Pre-marshalling is the process of organizing export containers in advance in the yard, so that they can be loaded with few or no re-handles while the loading process starts. By using this strategy, it is possible to shorten the actual operating time required for picking containers, which can result in significant decreases in ship loading time, leading to quicker berthing times and help terminals operate more efficiently. For shipside operations, the focus is on reducing the ship berthing time for handling containers. The yard truck pooling strategy is an effective approach that maximizes the utilization of yard trucks and reduces the empty trip of yard trucks as much as possible. This strategy involves a yard truck finishing working for a quay crane (QC) and then going to support another QC, rather than returning to the yard with an empty chassis. Zeng et al. (2009) created a model to demonstrate how the yard truck pooling approach can minimize the travel distance of yard trucks, reduce the disequilibrium of different working lines, and ultimately increase the efficiency of operations in container ports. Another useful strategy is adopting a twin-lift spreader. With a twin lift spreader, two 20-foot containers are allowed to be lifted at the same time. This strategy can increase productivity, accordingly, saving operation time at the shipside and efficiently mitigating noise and air pollution of trucks and cranes. The dual cycling system allows a QC to continuously load and discharge containers, which reduces empty movements of spreaders and trucks and significantly increases the use of QCs. Moreover, using the double-cycling strategy for yard trucks resulted in up to a 62% productivity improvement and a 38% reduction in ship turnaround time according to the evaluations of Ahmed et al. (2021). In conclusion, by implementing these OPs for gate, yard, and shipside operations, CTs can achieve green CT operations, thereby reducing environmental impacts and improve operation efficiency.

3. Methodology

In this study, we built an HOQ with five steps HOQ are detailed described as follows：

- Step 1: The initial step of HOQ involves determining the customer needs (WHATs) and converting them into CRs for the specific product or service under consideration. In this study, we collect from the literature the most crucial criteria that would satisfy customers about the sustainability of container ports.

- Step 2: Technical measures (HOWs) are then translated into DRs, which are directly linked to and measure the customer needs (WHATs). Technical measures are the solutions selected by the terminal stakeholders to meet the needs of the customers.

- Step 3: This step entails identifying the CRs and assessing their degree of importance and satisfaction. This ranking can be performed through questionnaires utilizing a 5-point Likert scale that ranges from "Strongly Disagree" to "Strongly Agree," with "Neither Agree nor Disagree" in the middle.

- Step 4: The relationship matrix between WHATs and HOWs is an important tool for assessing the degree of relationship between each customer need and each technical measure. This step is crucial for understanding the contribution of each technical measure to overall customer satisfaction and evaluating how these measures help fulfill each customer expectation. Experts provide input on the relationships between and , using a rating scale ranging from 0-1-3-9, representing no, weak, medium, and strong relationships, respectively.

- Step5: The technical rating for each DRs is a comprehensive measure indicating the extent to which the technical measures (HOWs) are related to all customer needs (WHATs).

4. Results

Figure 1 shows the HOQ built for the port of Keelung. The initial weights of each CR item were investigated and given importance level from terminal stakeholders. It is crucial for the port of Keelung to focus on the top three CR items, which are 'reduce the noise from CFS operations', 'reduce emissions from container lifting equipment' and 'reduce traffic congestion in the city area adjacent to the port'. Additionally, the experts have reached a consensus that the most effective OP to tackle environmental pollution in the port of Keelung is through the implementation of OP1, OP7, and OP8. In terms of the category composite score, the shipside operation obtained the highest score. Besides, the composite scores were also obtained for improvements in air pollution, noise pollution, and traffic. In the port of Keelung, the top priorities for addressing air pollution are OP8, OP7, and OP9.

5. Conclusions

According to the empirical survey carried out is this study, some conclusions and suggestions are given as follows. Based on the results, the respondents identified CR items N3, A2 and T4 were the top three CRs at the port of Keelung. This finding aligns with the environmental report from TIPC in 2021, which indicated that certain noise monitoring stations in the port of Keelung exceeded the standard during nighttime in both 2019 and 2020 (TIPC, 2021). Given the port's location is in the downtown area, the noise generated by container handling and transportation activities has become more noticeable to locals. In addition, the overall composite score in the port of Keelung suggests that implementing TAS emerges as a promising solution. This OP is reasonable because the hinterland of the port of Keelung is relatively small, and the CT's capacity for container storage is limited. As a result, many containers end up being stored in nearby inland CTs, often leading to traffic congestion around the container port. Therefore, implementing TAS would be a suitable strategy to address this issue. For port of Keelung, it is crucial to prioritize noise reduction measures due to its downtown location and intensive noise from container handling activities. Implementing OPs like TAS can significantly improve the port's environmental impact and address concerns raised by locals.

	WHATs / HOWs	Gate			Yard			Shipside		
		OP1	OP2	OP3	OP4	OP5	OP6	OP7	OP8	OP9
	CUSTOMER REQUIREMENTS	TECHNICAL MEASURES								
Air Pollution improvement	A1. Reduce emissions from container trailers	6.27	4.82	4.64	4.59	3.68	4.23	5.05	3.23	3.27
	A2. Reduce emissions from container lifting equipment	2.45	0.86	2.59	1.18	3.45	3.05	4.73	5.05	4.91
	A3. Reduce NOx emissions	2.91	2.18	2.86	1.77	2.64	3.82	4.45	5.18	4.45
	A4. Reduce SOx emissions	2.50	1.91	2.59	2.05	2.18	2.91	3.91	4.50	3.77
	A5. Reduce the proportion of VOCs emitted from liquid chemical vessels	1.82	1.55	2.45	1.36	2.14	2.05	1.82	2.45	1.95
	A6. Reduce emissions from CFS internal operations	3.45	1.73	2.36	2.09	3.50	2.36	2.95	2.73	2.73
Noise Pollution improvement	N1. Reduce the noise generated by trailers	5.09	3.09	2.95	3.27	3.55	2.86	4.59	2.23	2.50
	N2. Reduce the noise generated by container lifting equipment	2.73	0.68	2.55	0.59	2.82	2.41	3.55	3.95	3.73
	N3. Reduce the noise from container freight stations (CFS)	3.73	1.50	2.55	1.50	2.86	1.55	1.77	1.95	2.09
	N4. Reduce the noise generated from ships at berths	0.95	0.41	1.00	0.73	0.95	0.77	1.82	1.82	1.73
Traffic flow improvement	T1. Reduce congestion on the apron during loading and unloading operations	8.00	4.73	4.45	2.73	5.50	5.23	6.82	5.86	5.41
	T2. Reduce congestion in the yard area operations	8.05	4.82	4.68	2.82	6.14	4.86	4.32	4.05	3.82
	T3. Improve the congestion of trailers at container port gates	8.59	5.77	5.09	3.09	4.45	5.36	6.05	4.09	3.86
	T4. Reduce traffic congestion in the city area adjacent to the port	7.09	5.23	5.86	2.41	3.73	5.55	4.23	2.86	2.50
	T5. Reduce waiting time for container ships at anchorage	3.27	2.41	3.14	1.41	2.95	2.41	4.50	4.73	4.55
	score	4.830	3.019	3.498	2.202	3.564	3.497	4.278	3.736	3.516
	Normalized score	0.150	0.094	0.109	0.069	0.111	0.109	0.133	0.116	0.109
	Rank	1	8	6	9	4	7	2	3	5

Figure 1 The HOQ built for Port of Keelung

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