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Green Port Performance Indicators for Dry Bulk Terminal: A Case Study of Port Klang

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ABSTRACT

This study aims to develop green port performance indicators specifically for dry bulk terminals, using Port Klang as a case study. Handling approximately 4.5 billion tons of dry bulk cargo annually, this sector represents the largest volume of maritime trade and poses significant environmental challenges. Despite Malaysia's status as an important global shipping hub, there is a lack of comprehensive green policies in ports. The research employs the Fuzzy Delphi Method to achieve expert consensus on critical green port indicators. A purposive sampling technique selected 26 experts from various relevant sectors, including the Port Klang Authority, marine departments, and terminal operators. These experts provided their insights through structured surveys, and the data were analyzed using triangular fuzzy numbers to identify and prioritize key performance indicators. The findings highlight essential determinants for achieving sustainability in port operations, offering actionable insights for policy formulation and implementation. By adopting these indicators, Port Klang can enhance its environmental performance, contributing to the broader objective of sustainable maritime logistics.

1. Introduction

The transportation of about 4.5 billion tons of dry bulk cargo represents the biggest volume as compared to other types of cargo by ships worldwide annually [9]. The goods can be categorized into three main cargo groups: container, liquid bulk cargo and dry or solid bulk cargo such as coal, iron ore, grains, sugar, and fertilizers. Therefore, port traffic continues to expand and the question of how to secure long-term sustainability of the port sector turns out to be a critical concern at global level. According to United Nation Conference on Trade and Development (UNCTAD), dry bulk cargoes represent the largest group (more than 50%) from all loaded goods in terms of volumes for seaborne transport [22]. Carrying solid bulk cargoes involves genuine risk, which must be managed carefully to preserve the safety of the crew and the ship. These exposures include ship stability and

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even capsizing due to cargo liquefaction, fire, or explosion due to chemical hazards and damage to ship structures due to poor loading procedures.

According to the United Nations Conference on Trade and Development (UNCTAD), Malaysia is the world's fifth best connected country in terms of shipping line connectivity, ahead of the Netherlands and the United States [22]. The cornerstone for long-term development is a balance of social, economic, and environmental issues. The value of each region is the same. In the case of the port, the social scope frequently refers to components such as direct and indirect employment, contact and link between the port and the city, contribution to knowledge and education growth, and the "liveability" of the area surrounding the port. Return on investment is critical in evaluating any development project from an economic standpoint [15].

2. Literature Review

2.1 Green Port Problem

Although the Malaysian government has emphasized on the requirements of ports to become environmentally friendly and commercially viable, not many ports have come out with their own green policy or strategy and identify the necessary actions that would help them achieve a green port status. Only Johor Port Authority (JPA) has come up with the Green Port Policy that will act as a general guide for all port operators in moving towards a green port environment. The Green Port Policy has been identified as one of the Key Performance Indicators (KPI) for creating a safe and healthy port working environment under JPA's Strategic Plan 2013 - 2020. Additionally, despite the Malaysian government pledging its support to the United Nations Economics and Social Commission for Asia and the Pacific (UNESCAP) 2030 Agenda for sustainable development no study has been carried out on the types of enforcement and levels of compliance of Malaysian ports in support of the government green port agenda. Port Klang has been opened since 1901, however there are limited research conducted on development of the green port policy in Port Klang. Earlier research has mainly prioritised on green performance in container ports or evaluation of green port performance in general [7,15,21]. A research to identify green performance indicators on dry bulk ports or terminals is difficult to trace albeit handling of dry bulk cargo is potentially more dangerous to the surrounding environment as compared to other types of cargo. Generally, in dry bulk cargo handling, the risk of spillage and dust production are high. Beside this risk, other issues such as disposal of port waste or garbage, bunkering of ships, ship's waste, noise, air quality, energy consumption, water quality and habitat loss have been the concern of many [17].

Recently, Port Klang has been awarded the ASPN (APEC Port Services Network) Green Port 2020 unification for the second time since 2017 [23]. However, did not specifically cover on dry bulk cargoes. The Green Port Award System (GPAS) programme is a green evaluation system for ports in the APEC region developed by APSN with the endorsement of the APEC forum. The programme promotes the sustainable development of ports in the Asia-Pacific region. MPA noted this accolade affirms its efforts on decarbonization. Recently in June, 2021 Klang Municipal Council (MPK) has shut down an open air storage site at Jalan Kem following complaints of dust pollution by residents of Sri Berembang and Taman Kem flats in Port Klang. Almost 500 families living in the walk-up flats experienced discomfort for three weeks which they say resulted from the open-air site used to store coal and oil palm kernel. The residents also complained of dust that thinly coated the building's corridors and windows as well as clothes drying on their laundry lines and even caused breathing difficulties for some [24]. Hence, the identification of the important green port performance indicators for dry bulk terminals to observe is arguably very important. Comply with MARPOL Annex VI – Prevention of Air Pollution from Ships to reduce harmful air emission from port

activities and from vessels are essential to protect the community from harmful environmental impacts as a result of port operations.

2.2 Gap Analysis

Research has been done in the areas of green port indicators, Environmental indicator, Concept of green port, Factors contributing to the green ports etc. However, researcher unable to trace research involving bulk terminal. Similarly, research in Green Port was more focus in Northeast Asia and Europe. Research in Southeast Asia is arguably very limited. Research on Green Port had utilized AHP, Case study and Delphi, Entrophy, Survey, Cross case analysis, interview, and case study. So far, researcher has only traced two research using Delphi Method or combination or Delphi with other instruments.

Therefore, the researcher intends to utilize the Fuzzy-Delphi technique as it has not been regularly used in Green Port Research. The combination the techniques were strongly agreed by many researchers because it gain expert consensus on a problem. The rationale for uniting the Fuzzy technique with the Delphi technique is to enhance the performance, robustness, and flexibility of systems, especially in situations where traditional methods may fall short due to uncertainty, imprecision, or complexity in the problem domain. It also allows experts to consistently provide their views [11-13]. In addition, the combine of Fuzzy Delphi method is expected to strengthen the outcome and novelty of this research.

3. Research Design

This study used the Fuzzy Delphi technique. The selection of this technique is made to follow the study's purpose to obtain expert consensus on the elements used in designing module development. According to Mohd Jamil *et al.,* [13], this Fuzzy Delphi technique can be adopted to gain expert consensus on a problem. The rationale for applying the Fuzzy Delphi technique compared to the Delphi technique is that it saves time and cost in handling questionnaires. It also allows experts to consistently provide their views [14]. The minimum sample of experts in the Fuzzy Delphi studies is 10 to obtain high uniformity among experts [1]. Therefore, about 26 experts have been selected in this study using purposive sampling technique. They consisted of experts in Port Klang Authority, Marine Department, Ship agents, terminal operators and other academicians that are indirectly related with green port selected via purposive sampling technique. The experts had at least holding supervisory or managerial position and minimum of ten years of experience in the field. Expert selection criteria was in line with Berliner [5] who stated that an Asian Journal of University Education (AJUE) Volume 17, Number 1, January 2021 294 individual is considered skilled in a field if he has had more than five years of experience in that field; Gambatese *et al.,* [8] claimed experts must have high academic qualifications. However, according to Roldan *et al.,* [6], experts who do not have degree qualifications but already have more than 10 years experiences also been acceptable. To be summarize, criteria experts for this research as below:

i. at least holding supervisory or managerial position
ii. have high academic qualifications or
iii. do not have degree but already have more than 10 years experiences

Among the types of mixed method design, the Exploratory Sequential Mixed Method (ESMM) design is considered most suited and has been chosen for this research. ESMM design involves the

procedure of first gathering qualitative data to explore the phenomenon and then collecting quantitative data to explain the relationship found in the qualitative data. Hence, the utilisation of a combination of the Fuzzy-Delphi approach that requires the review of literature and a qualitative survey or interview with the relevant experts in order to formulate the problem hierarchically [18], is part of the ESMM.

4. The Fuzzy Delphi Survey

A systematic literature review was conducted to determine the indicators and follow with Delphi survey using a Likert scale between 1 (least important) to 7 (very important). A seven-point Likert scale has been selected in order to better discriminate between the "important determinants" where most of the identified determinants should belong and the "very important determinants" [19,20]. In a five-point Likert scale, it may not be easy to discriminate between these two categories. In their review on earlier literature on the utilisation of Likert scale, Gullone, Tessa and Robert [10], summarise that expanding the number of Likert scale beyond 5 points does not systematically damage the scale reliability. However, it increases scale sensitivity [10], which is considered important in this exercise.

Besides the determining factors identified through the literature review process, expert respondents have also been encouraged to identify other important determinants that could influence the success of indicator of the green port for bulk terminal. The main channel for the transmission of the survey questionnaire was through the email with follow-up phone calls or short messaging service (SMS) where necessary in order to minimize the survey cost.

Since the first part of the data collection involved a Delphi survey with selected experts from among government officials, academicians, and researchers as well as maritime transport practitioners, a guideline for the Delphi session have been prepared and incorporated into the first round of the Delphi questionnaire. This is meant to enable the standardization of the survey process among all respondents irrespective whether the survey is conducted through email, phone call or face-to-face interview. Among the points highlighted in the guideline are the objective of the study which is to identify the determining factors that are required to ensure for a successful of indicator of the green port for bulk terminal; a brief background of the study and the sequence of Delphi survey which may continue until at least two rounds. This has enabled the respondents to estimate the duration they would be required to participate in the survey as well as to develop certain expectations that have guided their response when they were required to participate in the subsequent rounds [16].

The Round 1 (R1) Delphi questionnaire have been divided into three parts. Part I deals with their personal detail involving name, present position, present company, and the years of experience in the maritime industry or maritime research. This is to ensure that the respondents that participated fulfilled the criteria required. It would also allow the researcher to segregate them into the respective sectors particularly the government, industry, and academia to enable a collection of a balance perspective from different categories of stakeholders. Part II involves the provision of the determinants that have been analyzed through the content analysis to enable the researcher to be aware of the determinants that have been discussed in contemporary literature. Part III is the survey questions and is further divided into three sections. Sections IIIA deals with qualitative questions involving the likely additional indicator that respondents want to add. Additionally, the opinions given in this section have also allowed the researcher to cross-check with the answers provided in the other sections. Section IIIB is meant to identify the main determinants that may affect the indicator, where the respondents were requested to rate the importance of the

determinants listed Part II on a 7-point Likert scale ranging from Least Important to Most Important. In addition, the respondents were also requested to list other additional determinants that have not been listed and rate their importance accordingly. The purpose of the questions in this section is to identify the important determinants that may affect the indicator of the green port of bulk terminal. Finally, the questions developed in Section IIIC requires the respondents to group the various determinants into suitable clusters. This will enable a systematic arrangement of the determinants.

Furthermore, the Round 2 (R2) was drafted with the objective to gain a consensus among the respondents before to employ a fuzzy-Delphi approach. Therefore, all the determining factors that were rated in Round 1 were listed again together with the median score from the aggregate result and the respondent's personal score for each determining factors in Round 1. They were then requested to reconsider their earlier judgments based on the aggregate result provided. This Round 2 has enabled the researcher to determine the key determinants for a green dry bulk terminal based on a fuzzy-Delphi.

The next step is converts all linguistic variables into fuzzy triangle numbering. Assume that the fuzzy rij number is the variable for each criterion for expert K for i = 1, ..., m, j = 1, ...n, k = 1 ... .., k and rij = 1 / K (r1ij ± r2ij ± rKij). Table 1 shows the linguistic variables for seven (7) scales where it displays the measurement statement for an item and the fuzzy scale value it represents [2].

Table 1
Linguistic variables for seven (7) scales

Scale	Level of Agreement	Fuzzy Scale
1	Extremely Strongly Agree	(0.9,1.0,1.0)
2	Strongly Agree	(0.7,0.9,1.0)
3	Agree	(0.5,0.7,0.9)
4	Moderately Agree	(0.3,0.5,0.7)
5	Disagree	(0.1,0.3,0.5)
6	Strongly Disagree	(0.0,0.1,0.3)
7	Extremely Strongly Disagree	(0.0,0.0,0.1)

The data analysis is based on the triangular fuzzy number where it aims to get threshold value (d). Therefore, the first requirement to be followed is threshold (d) value must be less or equal to 0.2 [3]. The use of vertex method was carried out to calculate the distance between the average rij. The threshold value (d) of the two (2) fuzzy numbers
m = (m1, m2, m3) and n = (m1, m2, m3) are calculated using the formula:

$$d(m\tilde{},n\tilde{})=\sqrt{1/3[(m1-n1)2+(m2-n2)2+(m3-n3)2]} \quad (1)$$

In this process, the determination of the second condition is done where determining the percentage value of the expert agreement is executed. The second condition that needs to be observed is that the percentage of experts' agreement must be equal to or greater than 75.0% [4].

The data analysis used average of fuzzy numbers @ average response (Defuzzification Process). In this analysis, it is aimed to get the score of fuzzy score (A). To ensure the third condition is followed, the value of the fuzzy score (A) must be greater than or equal to the median value (α - cut value) of 0.5. This indicates that the element is accepted by an expert agreement. Among other functions, the value of fuzzy scores (A) can be used as a determinant and a priority for an element according to experts' opinions. The formula involved in getting the score of fuzzy (A) is as follows:

$$A = (1/3) * (m1 + m2 + m3) \quad (2)$$

The fuzzy score value must in the range 0 to 1. This is important to meet the requirement of the fuzzy numbers which must be in the range 0 to 1. Additionally, value less than 0 is not a fuzzy number and value more than 1 also not a fuzzy number. As conclusion, the value for fuzzy number must be in the range 0 to 0.999999 or 1. Fuzzy logic is an approach to variable processing that allows for multiple possible truth values to be processed through the same variable. Fuzzy logic attempts to solve problems with an open, imprecise spectrum of data and heuristics that makes it possible to obtain an array of accurate conclusions [4].

5. Research Findings

5.1 Experts Demographics Information

According to Roldan *et al.,* [6], experts who do not have degree qualifications, but already have more than 10 years experiences also been acceptable. To be summarize, criteria experts for this research as below:

i. At least holding supervisory or managerial position
ii. Have high academic qualifications or
iii. Do not have degree but already have more than 10 years experiences

Hence, for expert who have degree qualification with at least 5 years of experiences also been acceptable. A brief profile of the 26 respondents is presented at Table 2 below.

Table 2
A brief profile of the 26 respondents

Organization	Management level	Supervisory level	Total
West Port	3	3	6
North Port	2	2	4
Port Klang Authority	4	2	6
Marine Department	2	1	3
Ship Agent	2	2	4
Others	2	1	3
Total			26

5.2 Analysis of Expert Consensus

Table 3 presents an expert analysis of key elements pertaining to environmental management within port operations, structured into distinct clusters. These clusters encompass a wide array of strategies and measures aimed at addressing various environmental concerns associated with port activities.

In Cluster I, the focus is on mitigating air pollution through measures such as controlling dust pollutants, reducing toxic gas emissions from ships, and promoting the use of environmentally friendly machinery and low-sulfur fuels. Cluster II centers on water pollution management, including enforcement of oil spill control measures, sewage management, and efforts to improve water quality and prevent waste dumping.

Cluster VI highlights the importance of recycling solid waste and garbage, emphasizing the need for effective management practices, recycling initiatives, and modernization of waste facilities. In Cluster VII, the emphasis is on utilizing green technology, with a focus on selecting environmentally friendly materials and harnessing renewable energy resources to reduce environmental impact.

Table 3
Analysis of Experts Consensus

Bil	Item / Element
C1A	Cluster I: Air Pollution Management [1. Dust pollutant control]
C1B	Cluster I: Air Pollution Management [2. Reduction of air pollution from toxic gas from ship]
C1C	Cluster I: Air Pollution Management [3. Use of environmentally friendly machineries and equipment]
C1D	Cluster I: Air Pollution Management [4. Encourage ships to use of low-sulphur fuel]
C2A	Cluster II: Water Pollution Management [5. Enforcement of oil spill control measures]
C2B	Cluster II: Water Pollution Management [6. Sewage management]
C2C	Cluster II: Water Pollution Management [7. Improvement in water quality]
C2D	Cluster II: Water Pollution Management [8. Prevention of waste dumping]
C2E	Cluster II: Water Pollution Management [9. Ballast water polluting control]
C6A	Cluster VI: Recycling of Solid Waste and Garbage [10. Solid waste management]
C6B	Cluster VI: Recycling of Solid Waste and Garbage [11. Recycling of waste, garbage, and resources]
C6C	Cluster VI: Recycling of Solid Waste and Garbage [12. Modernisation of waste management & facilities]
C7A	Cluster VII: Utilisation of Green Technology [13. Environmentally friendly materials selection]
C7B	Cluster VII: Utilisation of Green Technology [14. Using Renewable energy resource]
C9A	Cluster IX: Effective Coordination and Regulatory Measures [15. Provision of Incentives and fines]
C9B	Cluster IX: Effective Coordination and Regulatory Measures [16. Effective leadership]
C9C	Cluster IX: Effective Coordination and Regulatory Measures [17. Establish green port organisation]
C9D	Cluster IX: Effective Coordination and Regulatory Measures [18. Establishment of multi- disciplinary teams]
C10A	Cluster X: Efficient Port Development and Operations [19. Port greenery]
C10B	Cluster X: Efficient Port Development and Operations [20. Research on port development]
C10C	Cluster X: Efficient Port Development and Operations [21. Efficient planning of port development]
C10D	Cluster X: Efficient Port Development and Operations [22. Identification of key green projects]
C10E	Cluster X: Efficient Port Development and Operations [23. New measures to reduce port service time]
C10F	Cluster X: Efficient Port Development and Operations [24. *Develop green zones and buffers in the port area]
C11A	Cluster XI: Environmental Awareness and Training [25. Port staff training]
C11B	Cluster XI: Environmental Awareness and Training [26. Development of awareness among workers]
C11C	Cluster XI: Environmental Awareness and Training [27. Community awareness promotion and education]
C11D	Cluster XI: Environmental Awareness and Training [28. *Develop interactive environmental and energy information and management systems that enrich business processes]
C13A	Cluster XIII: Management of Hazardous Cargo [29. Hazardous cargo management]
C13B	Cluster XIII: Management of Hazardous Cargo [30. *Awareness for Marine pollutant DG cargo]

Effective coordination and regulatory measures are addressed in Cluster IX, with elements such as providing incentives and fines, promoting effective leadership, establishing green port organizations, and forming multidisciplinary teams to ensure regulatory compliance and enhance environmental governance.

Efficient port development and operations are the focal point of Cluster X, encompassing initiatives such as integrating greenery within ports, conducting research on sustainable development, efficiently planning expansions, identifying key green projects, and implementing measures to reduce service time and develop green zones within port areas.

Finally, Cluster XI underscores the importance of environmental awareness and training, with elements including staff training, raising awareness among workers and communities, and developing interactive environmental management systems to enhance business processes.

Overall, this analysis provides a comprehensive framework for addressing environmental challenges within port operations, highlighting the diverse strategies and measures required to

promote sustainability, regulatory compliance, and environmental stewardship in the maritime industry.

5.3 Analysis based on Fuzzy Number

The threshold value (d), expert consensus percentage, defuzzification and item position for the above items are shown in Table 4 below. Basically, this study adheres to the principles of triangular fuzzy numbers, emphasizing a threshold (d) of less than 0.2 for managing uncertainty, achieving consensus among experts of over 75%, and prioritizing fuzzy scores (A) of 0.5 or higher to ensure clarity in decision-making.

Table 4
Analysis based on fuzzy number

Item	Condition Triangular Fuzzy Numbers		Defuzzy Process	Experts Consensus	Rank
	Threshold Consensus Value, d	Percentage of Consensus, %	Skor Fuzzy (A)		
C1A	0.176	91.30%	0.868	Accepted	20
C1B	0.162	91.30%	0.875	Accepted	14
C1C	0.185	91.30%	0.842	Accepted	27
C1D	0.192	91.30%	0.857	Accepted	26
C2A	0.16	95.65%	0.89	Accepted	8
C2B	0.143	95.65%	0.901	Accepted	10
C2C	0.164	91.30%	0.884	Accepted	4
C2D	0.132	95.65%	0.9	Accepted	1
C2E	0.117	95.65%	0.907	Accepted	16
C6A	0.147	95.65%	0.87	Accepted	16
C6B	0.147	95.65%	0.87	Accepted	24
C6C	0.139	95.65%	0.861	Accepted	28
C7A	0.191	91.30%	0.841	Accepted	29
C7B	0.173	91.30%	0.839	Accepted	9
C9A	0.136	100.00%	0.887	Accepted	11
C9B	0.138	95.65%	0.881	Accepted	16
C9C	0.122	100.00%	0.87	Accepted	21
C9D	0.117	100.00%	0.865	Accepted	23
C10A	0.154	100.00%	0.864	Accepted	16
C10B	0.122	100.00%	0.87	Accepted	6
C10C	0.108	100.00%	0.893	Accepted	12
C10D	0.095	100.00%	0.88	Accepted	5
C10E	0.097	100.00%	0.9	Accepted	25
C10F	0.108	100.00%	0.857	Accepted	13
C11A	0.119	95.65%	0.88	Accepted	7
C11B	0.091	100.00%	0.891	Accepted	14
C11C	0.115	95.65%	0.875	Accepted	21
C11D	0.143	95.65%	0.865	Accepted	2
C13A	0.126	86.96%	0.906	Accepted	3
C13B	0.114	91.30%	0.904	Accepted	30

Based on the findings in the Table above, all items recorded a value of Threshold (d) ≤ 0.2. This result indicates that all these items have gained an expert consensus [3]. The expert agreement percentage shows that all items are above 75% and all defuzzification values for items also exceed the value of α - cut = 0.5.

6. Discussion

In summary, the Round 1 Delphi is about to assess the importance of one determinant over another within the 13 clusters, which has enabled the establishment of the hierarchy for all variables as an initial step before the Delphi decision making model process for identifying the main indicators for green port performance for dry bulk terminals in Port Klang. At this stage, the quantitative data have been analysed accordingly by using statistical analysis. Besides that, the qualitative data, which contained the precise recommendations made by experts, has been analysed by employing the content analysis and coding process for the purpose of hierarchy development. As analysed, the Round 1 Delphi had shortlisted 30 determinants and eight clusters that have been incorporated into the hierarchy for the purpose of the Round 2 Delphi.

In brief, the Round 2 Delphi can be viewed as successfully conducted although the time taken for all of the respective respondents to provide their response has taken about 5 months. This is unavoidable due to the Pandemic Covid 19, restriction schedule of the respondents, the complexity to manage the interviewed session due to location. Therefore, the Round 2 Delphi was done by email, online survey (google form), phone called interviewed and online interviews. In terms of Delphi criteria, the Round 2 Delphi is about to achieve the consensus of expert respondents for the determinants by utilized the mean value and standard deviation respectively. Next, based on the consensus agreement of the expert on the Round 2 Delphi, the weightage of all clusters and determinants have been carried out. Eventually, the fuzzy number have been included to advance the final consensus and to carry out the ranking of the clusters and determinants respectively.

7. Conclusions

In conclusion, this study contributes to the growing body of knowledge on green port performance indicators by focusing specifically on dry bulk terminals. By examining the case of Port Klang, valuable insights are gained into the challenges and opportunities associated with sustainability in this critical sector of port operations. Through the implementation of recommended strategies, Port Klang and other dry bulk terminals can move towards more environmentally friendly and efficient operations, contributing to the broader goal of sustainable maritime logistics.

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