e-Navi

Available online at http://www.e-navigation.kr/
e-Navigation Journal

Original article

EMPLOYING THE DELPHI METHOD TO SELECT THE SUSTAINABILITY ASSESSMENT INDICATORS: CASE OF HAI PHONG SEAPORT☆

Thanh-Trung VU[a], Thi-Thu-Hang DOAN[b*]

[a] Dept. of Economics, Vietnam Maritime University, Vietnam, trungvt@vimaru.edu.vn

[b*] Dept. of Economics, Vietnam Maritime University, Vietnam, hangdtt.ktnt@vimaru.edu.vn, Corresponding Author

Abstract

The concept of sustainability was first introduced a few decades ago, and it has gradually become the primary concern of many nations and firms around the world. Sustainability is a broad concept that encompasses three pillars, namely, economic, social, and environmental, represented as profit, people, and nature. It implies that firms can only sustainably develop if they grow without compromising the benefits of their stakeholders. Thus, this study aims to identify, through the participatory approach and the Delphi method, an appropriate set of sustainability indicators to strategically evaluate Hai Phong port's sustainable development achievements. The paper will critically review past studies on port sustainable development to find the most frequently used indicators for assessing port sustainability. These indicators vary because of the availability of data and the researcher's perceived level of importance given to each indicator. Finally, we employ the Delphi method to narrow down the initial set of sustainability indicators based on consensus on the importance of indicators and availability of data among experts. Some indicators that are not important and statistical data unavailable are eliminated. Therefore, the final set includes all crucial indicators for evaluating the sustainability of Hai Phong seaports with collected data.

Keywords: Seaport, sustainability evaluation indicators, Delphi method, Hai Phong.

https://doi.org/10.52820/j.enavi.2022.18.010

1. Introduction

The port sustainable development measurement is proved to be very important for managers and policymakers. This is an essential tool for managers to evaluate the port performance and improve management strategies if the port performance is poor. Furthermore, they can also assess ports' achievements in sustainable development that are clear evidence of the effectiveness of sustainable development strategies. It is a reason why there have been many studies conducted to find a set of port sustainability assessment indicators. Researchers have proposed many indicators for assessing port sustainability based on its importance and availability.

The past studies show that there is no consensus among researchers on the importance of a particular sustainability indicator. Researchers seem to assess the significance of these indicators differently according to their knowledge, interests, and experiences. For instance, if a researcher's expertise is related to finance, they seem to evaluate indicators concerning the financial performance of ports higher than the rest. Additionally, data availability is also needed to be taken into consideration while proposing a set of indicators for assessing sustainable development achievement of seaports. Consequently, various sustainable development assessment indicators have been introduced for sustainability evaluation purposes. We cannot decide which indicators are right or wrong because they are recommended to assess the port's sustainability achievements in different contexts. Therefore, this paper will select an appropriate set of sustainability indicators for the case of Hai Phong seaport using the Delphi method.

2. Port sustainable development

There are many different perspectives on sustainable development, varying from each other in terms of viewpoints. According to the summit on environment and development in Rio De Janeiro, Brazil, 1992, and the World Summit on sustainable development in Johannesburg - South Africa, 2002, sustainable development consists of three components: economic development (mainly economic growth), social development, and environmental protection.

In the realm of port development, there are also various definitions of port sustainable development. Ports have the characteristics of a complex organization that can be seen from many different perspectives: economic, social, cultural, and managerial perspectives; because there are many stakeholders involved in the operations of a seaport. (Puig et al., 2014a) A port can achieve sustainability through a series of improvements in sustainable development, including economic sustainability, environmental quality, and social responsibility. (Panayides, 2006)

On the other hand, there are also perspectives stating that port sustainable development strategies not only have to solve port's internal issues such as labor safety and port environment management but also to develop the actual capacity of the port and the training capacity of the region, to develop the port and the areas around the seaport through systematic solutions that can promote development and resolutions of the current needs of the port (Lu, Shang, et al., 2016; Sislian et al., 2016)

3. Seaport sustainability assessment indicators

In recent years, sustainable development has been proved to be an inevitable development trend, affecting countries' economic development strategies and those of enterprises. Therefore, the assessment of sustainable development - or the sustainability of the business has also become an urgent need, requiring researchers to develop specific sets of indicators to do this.

The development of a set of indicators to measure the sustainable development of seaports is an essential task. A reliable set of indicators for assessing the sustainability of seaports will help a lot to evaluate the current state of seaports, the effectiveness of business development policies, and support policy makers to establish and monitor effective policies. A large number of sustainability assessment indicators have been used in past studies (Table 1). This is a reason why we will employ the Delphi method to select the best-suited indicators for measuring the sustainable development achievements of the Hai Phong seaport.

Table 1: Number of indicators for assessing sustainability

No	Researchers	Location	Numbers of indicators

1.	Ngô Đức Du (2017)	Vietnam	61
2.	Asgari (2015)	UK	9
3.	Laxe (2016)	Spain	33
4.	Puig (2014)	EU	19
5.	Kim and Chiang (2014)	Korea	26
6.	Lu (2012, 2016)	Taiwan	29
7.	Gallego (2006)	Spain	35
8.	Callens (1999)	Spain	32
9.	ROH (2016)	Korea	42
10.	Wooldridge (1999)	UK	6
11.	GRI	General firms	127
12.	Lu and Shang (2016)	Taiwan	31

4. The Delphi method

Delphi method is a quantitative analysis method first introduced by RAND cooperation – a nonprofit organization in 1950. Delphi method is used to support the decision-making process and forecast based on the information collected from experts. It is not a substitute for the statistical analysis method but is used for evaluation and prediction when data values are missing or not available. In such cases, the Delphi method uses experts' opinions instead of collected quantitative data.

Delphi method is used to solicit opinion from an expert panel in an iterative process. Typically, this process goes through three rounds. As a result, issues of concern will be addressed by the group of experts. This method is initially used to assess the particular subject based on the interaction between experts through the anonymous survey. The final result is the consensus among the expert panel after a discourse on the research subject. The number of experts involved in the research is flexible. According to past studies, the minimum number of experts is 8. If a group comprises experts with a wide variety of expertise, the number of experts should be between 20 to 60 (Geist, 2010), (Hasson & Keeney, 2011).

The Delphi method has been modified in various ways for different purposes. One of them is to find out an appropriate set of indicators for assessing sustainable development achievements. Accairo et al. (2014) used the Delphi method to select indicators to evaluate port environmental sustainability. The research is implemented in 7 large ports in Europe, namely, Antwerp, Ghent, Zeebrugge, Flushing, Rotterdam, Amsterdam, and Genoa (Acciaro et al., 2014).

Similarly, Puig et al. (2014) and Chen and Park (2017) also employed the Delphi method to find an appropriate set of environmental sustainability indicators. They review a considerable number of past research to list all previously used sustainability assessment indicators. Afterward, they gather a group of experts with deep knowledge about sustainable development for interviews. Puig et al. have the initial set of 304 indicators, but the number is significantly smaller after employing the Delphi method to select the most suitable indicators. Chen and Park applied the same procedure to choose applicable sustainability evaluation indicators. These indicators are chosen to assess the environmental sustainability of 3 ports in China, namely, Shanghai, Ningbo, and Qingdao ports (Chen & Pak, 2017). After three rounds, the final set includes 21 indicators that are more than half of the initial indicators set.

Furthermore, the application of the Delphi method is also found in many other studies. It is applied to find a proper set of indicators for evaluating the sustainability of the Latin American tourism sector (García-Melón et al., 2012), the sustainability of the rainforest in Taiwan (Kuo & Yu, 1999), and the sustainability of the Taiwan fishery sector (Liu, 2013). Besides, the Delphi method can be used to build the set of indicators for assessing dry port services quality in Spain(Awad Núñez et al., 2014) and the quality of the environment in urban areas in some cities in Malaysia(Musa et al., 2015).

5. The procedure of selecting sustainability evaluating indicators with the Delphi method

Based on the general evaluation procedure according to the Delphi method.

The procedure of selecting indicators to assess the sustainability of seaports is done in the order as shown in Figure 1 in Appendix. This procedure has been built

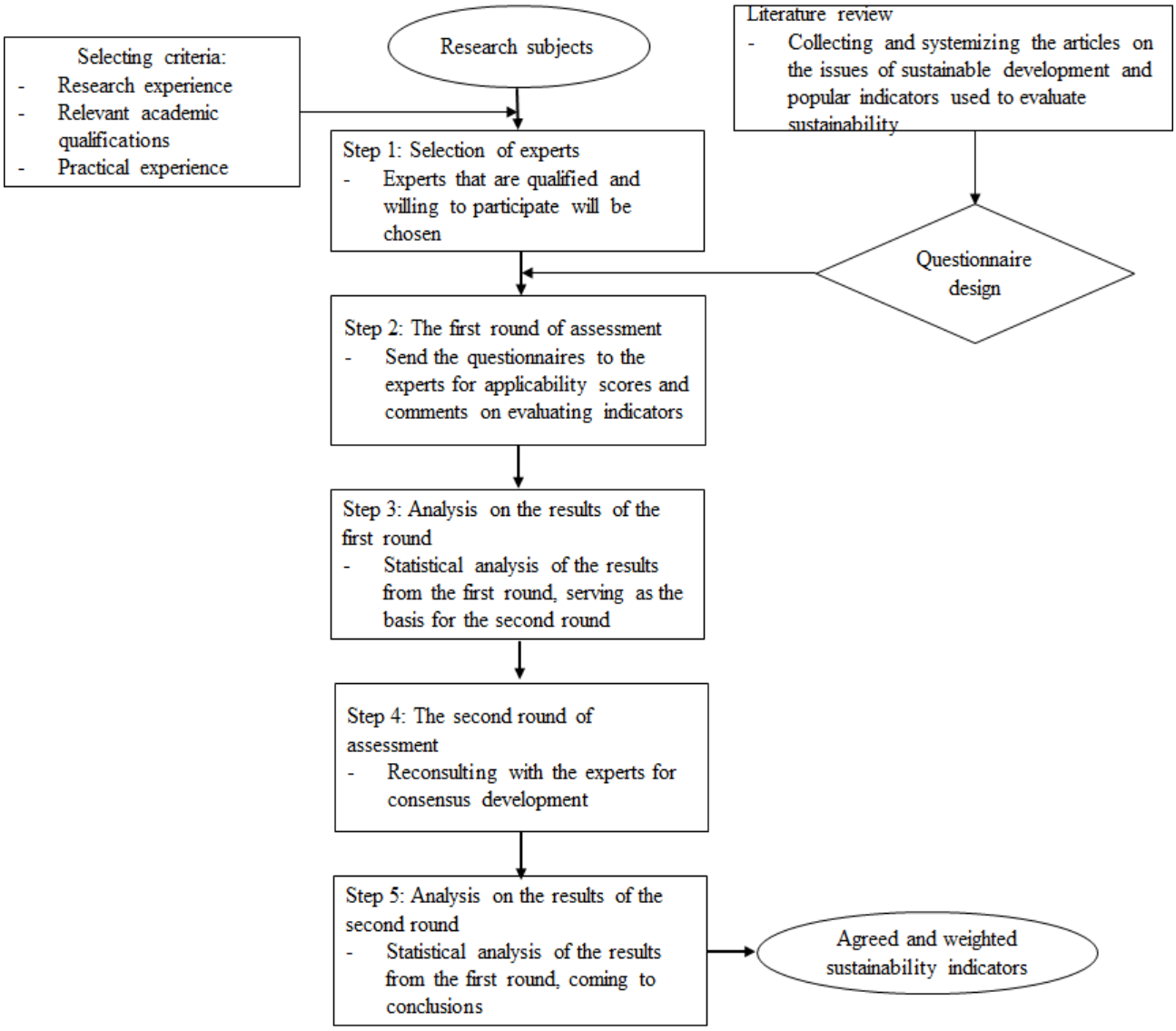

Figure 1: Selection procedure using the Delphi method

Source: Ahmad and Wong (2019) (Ahmad & Wong, 2019)

Step 1: The research subject must be clearly defined, which is the sustainability of seaports in this case. The next step is the selection of experts to participate in this process. The selection criteria must also be clearly defined, including expertise (demonstrated by relevant academic qualifications), or research experience related to the research field (the sustainability of the seaports), and willingness to participate in the assessment process (Musa et al., 2015). In addition to the above necessary conditions, experts participating in the assessment process need to agree to participate in assessment rounds and agree to respond responsibly to questions related to the research content.

After selecting a sample, it is necessary to review previous scientific works to determine the sustainability assessment indicators that previous researchers have used. A list of indicators or groups of indicators to be used for the evaluation should be formulated. The clearer and more specific the questions are, the easier the information is to collect and the more accurate the results. Once the questionnaire has been developed, these questions will be sent to experts in the first assessment round.

Step 2 and Step 3: After the research team has collected the scorings and comments of the experts from the first assessment round, the results will be evaluated based on several statistical indicators such as mean value, standard deviation, etc.

Step 4: The research team continues to conduct the second round of assessments based on the first round results. The aim of the second round is to clarify the issues that the majority of the experts has not agreed

in the first round and, if possible, to limit the list of indicators for assessing the sustainability of seaports. This can be done by reassessing the scorings that have significant differences between experts (based on the results of statistical analysis), in which the experts will be contacted for consultation again. If the scorings are similar after reassessment, the indicator can be retained. The research team can also consider omitting the indicators in the case that it is impossible to get the consensus from the experts or the matter causes controversy, and it is unable to reach the consent of the majority of experts.

Step 5: The second assessment round's results are evaluated with the Delphi method. The evaluation and variable omitting procedures are the same as those in Step 3. After the above evaluation steps are performed, the final results will be used as a basis for decision-making. The final list consists of important factors that are agreed upon by the majority of the experts. Meanwhile, the factors that are not important or do not get the consent of the majority of experts will be removed. The final shortlist will be used to assess the sustainability of seaports in the Hai Phong city area as well as seaports in other regions throughout the country.

As presented above, the list of indicators to evaluate port sustainability is built based on the two criteria: the importance of assessing each aspect of sustainability and the availability of information – ease of collecting data. These two criteria must be simultaneously considered when gathering information and data. Therefore, in order to make the assessment easier, a synthetic index including the two above can be built in which the experts determine the values of the component variables.

$$z_i = w_1 x_{1i} + w_2 x_{2i} \quad (1)$$

In which:

z_i: Synthetic index

w_1: Weight of the importance

w_2: Weight of the availability of information

x_{1i}: The importance of the indicator

x_{2i}: The availability of the information

w_1 and $w_2 \leq 1$; $w_1 + w_2 = 1$

However, some indicators that have inconsistency in the level of assessment among the experts will be re-evaluated. There are indicators that some experts believe to be easy to collect information, but others may think that the data is not easy to collect due to businesses' information confidentiality. There are also indicators that some experts consider important, but that's not necessarily the case from the viewpoints of other experts. These indicators will serve as the basis for designing the questionnaires in the second round.

The following criterion to be used to remove the non-conforming indicators based on the experts' opinions is the Sum Square of Deviation of expert evaluation (SSD) - the square difference between the evaluation of each expert and the mean of evaluation of each indicator (SSD_i). This is also an important index to evaluate the consistency in the evaluation of indicators among experts.

$$SSD_i = \sum_{j=1}^{m} (x_{ij} - \bar{X}_i)^2 \quad (2)$$

In which:

SSD_{ij}: The sum of the square of the evaluation deviation of indicator i

x_{ij}: Evaluation of expert j on indicator i

$\bar{X}_i$: The mean of evaluation of experts on indicator i

The smaller this index, the greater consensus in the experts' evaluation. This means that the indicator has a higher degree of confidence. If all ratings are the same, $SSD_i = 0$. Using this index to eliminate indicators with low consensus will help remove indicators that are not necessary or cause disagreements among experts in the evaluation process.

The following index to be used to analyze the results and omit the indicators that cannot get consensus from the experts is the Kendall coefficient – the index that measures the degree of uniformity of experts' assessment. In the statistical analysis, this index must be at least 0.5 to conclude that the assessments have a high degree of uniformity. The Kendall coefficient is measured as in the following equation.

$$W = \frac{12S}{m^2(k^3 - k)} \quad (3)$$

And

$$S = \sum_{i=1}^{k} (R_i - \bar{R})^2 \quad (4)$$

In which:

W: The Kendall coefficient

m: The number of experts

k: The number of indicators

R_i: Score of indicator i

$\bar{R}$: Mean of the values of R_i

The Kendall coefficient will help researchers evaluate the conformity of the experts' scorings. A lower Kendall coefficient means a greater difference in the experts' assessment of the indicators. Conversely, if the experts are entirely in agreement on the scoring of the indicators, the Kendall index will be equal to 1. The elimination of variables with significant differences in scorings is also a basis for improving the Kendall coefficient, in which eliminating the indicators with a high SSD_i to optimize the Kendall coefficient.

6. Result discussion

A group of experts with port-related experience and knowledge is selected, including 32 members, and most of them are researchers with Ph.D. qualifications, and the rest are port managers. There are 32 questionnaires delivered directly and electronically and 28 valid responses received.

There are several indicators eliminated based on the synthetic index, SSD, and Kendall coefficient. In the first round, some indicators with small synthetic indexes small will be removed. Synthetics index is the mean value of the importance of indicator and data availability given by experts because weights of the two facets of the synthetic index are distributed evenly.

Specifically, indicators with a synthetic index (z_i) smaller than 3 will be eliminated. z_i smaller than 3 implies the value of Importance and Availability of Data is smaller than 3. This means either the indicators are not important or very hard to collect this type of data. Unimportant indicators with unavailable data should not be included in the final set of sustainability assessment indicators. In the case of Hai Phong ports, it is very tough to collect some environmental variables because it seems no one is in charge of monitoring and reporting the ecological condition of port terminals. Therefore, even though some indicators are considered critical, they should not be included in the final set because the data is unavailable—for example, the amount of greenhouse gas emission, amount of liquid and solid waste discharge. After the first round, only 52 indicators are remaining.

In the second round, all experts are asked to re-evaluate the importance and data availability of 52 remaining indicators. The result is consistent with the first round. We keep eliminating the indicators that their importance and the ease of collecting data ratings by experts are significantly varying based on SSD and Kendall coefficient. Results of the elimination process are shown in Table 2.

Table 2: Size of the final set of indicators and their Kendall coefficient

Number of remaining indicators	Criteria	Kendall coefficient	
		Importance	Data availability
52	$z_i < 3$	0.37835 (p – value =0.000)	0.34281 (p – value =0.000)
41	$SSD_i > 10$	0.39930 (p – value =0.000)	0.40626 (p – value =0.000)
36	$SSD_i > 9$	0.43350 (p – value =0.000)	0.44811 (p – value =0.000)
29	$SSD_i > 8$	0.47289 (p – value =0.000)	0.51043 (p – value =0.000)
25	$SSD_i > 6$	0.51415 (p – value =0.000)	0.50854 (p – value =0.000)
24	$SSD_i > 5$	0.50989 (p – value =0.000)	0.51930 (p – value =0.000)
10	$SSD_i > 4$	0.35889 (p – value =0.000)	0.76008 (p – value =0.000)

After the first round, the number of remaining sustainability measuring indicators is 52. We continue to reduce this set in the second round by ignoring some indicators with the inconsistent assessment based on SSD and Kendall coefficient. The higher SSD of the indicator scorings, the more varying expert scorings are observed. Therefore, we start to remove the indicators with high SSD. Furthermore, the Kendall

coefficient is important statistical evidence to determine a level of agreement on the ratings among experts. This number smaller than 0.5 mean they do not reach the consensus, and it is from 0.5 is acceptable. The number of indicators in the final set gradually decreases from 41 to 39 and 25. The decreasing number of indictors makes the Kendall coefficient steadily increase. It starts from around 0.4 for both Importance and Data availability evaluations when the number of indicators is 41. Afterward, it reaches a peak of about 0.51 when the remaining number of indicators are 24 and 25 before reducing if the size of the set is getting smaller. When the size of the final set of indicators is 10, the Kendall coefficient measuring the consensus of experts on evaluating the importance of each indicator is approximately 0.36. It does not meet the minimum level of 0.5 even though this number for Data availability is very high – 0.76. In addition, all the P-value of the Kendall coefficient is almost zero. This indicates that they are all statistically significant. Comparing two sets of sustainability assessment indicators, including 25 and 24 indicators, respectively, we favor a slightly smaller set with 24 indicators. The set of 24 indicators will be selected and used to assess the sustainability of Hai Phong seaports. These indicators are listed in Table 3.

Table 3: List of selected indicators

No	Indicators
1.	Port throughput
2.	Revenue
3.	Customer satisfaction
4.	Revenue/worker
5.	Inventory turnover ratio
6.	Handling equipment productivity
7.	Enhancing cargo handling process
8.	Improving the port planning efficiency
9.	Energy consumption
10.	Recycled water consumption
11.	Greenhouse gases emission/output
12.	Solutions addressing climate change
13.	Encouraging shipping lines to use environment-friendly materials
14.	Cooperating on the environment-friendly projects
15.	Percentage of labor suffering occupational disease
16.	Spending on personal protective equipment
17.	Regular health check activity
18.	Employee total income
19.	Employee total income
20.	Financial support for training activities
21.	Working condition and safety
22.	The proportion of female managers
23.	The proportion of female employees
24.	Tax payment

7. Conclusion

Using the Delphi method to design a system of indicators for assessing the sustainability of Hai Phong seaports is of great importance to policymakers and managers. Firstly, these indicators are the basis for managers to determine the sustainability of seaports, serving as a basis for making appropriate and practically effective policies. Secondly, the assessment of each aspect of sustainability is the premise for assessing the overall sustainability of seaports that can help ports acknowledge their own limitations and recognize the existing issues that need to be solved. Moreover, this assessment also serves as a tool for policymakers and port managers to evaluate whether a development policy is effective and comprehensive or not, hence help them to plan to distribute resources to achieve the established sustainability goals effectively. Finally, this method has gathered experts' opinions with extensive experience and professional knowledge related to seaports, especially the seaports in Hai Phong City, based on which to select the indicators to evaluate sustainability in the most practical and effective way. The assessment results are highly reliable and precisely reflect the development status of seaports in Hai Phong.

Reference

Acciaro, M., Vanelslander, T., Sys, C., Ferrari, C., Roumboutsos, A., Giuliano, G., Lam, J. S. L., & Kapros, S. (2014). Environmental sustainability in seaports: A framework for successful innovation. Maritime Policy & Management, 41(5), 480–500.

Ahmad, S., & Wong, K. Y. (2019). Development of weighted triple-bottom line sustainability indicators for the Malaysian food manufacturing industry using the Delphi method. Journal of Cleaner Production, 229, 1167–1182.

Asgari, N., Hassani, A., Jones, D., & Nguye, H. H. (2015). Sustainability ranking of the UK major ports: Methodology and case study. Transportation Research Part E: Logistics and Transportation Review, 78, 19–39.

Awad-Núñez, S., González-Cancelas, N., & Camarero-Orive, A. (2014). Application of a model based on the use of DELPHI methodology and Multicriteria Analysis for the assessment of the quality of the Spanish Dry Ports location. Procedia-Social and Behavior Science, 162, 42–50.

Callens, I., & Tyteca, D. (1999). Towards indicators of sustainable development for firms: A productive efficiency perspective. Ecological Economics, 28(1), 41–53.

Chen, Z., & Pak, M. (2017). A Delphi analysis on green performance evaluation indices for ports in China. Maritime Policy & Management, 44(5), 537–550. https://doi.org/10.1080/03088839.2017.1327726

Gallego, I. (2006). The use of economic, social and environmental indicators as a measure of sustainable development in Spain. Corporate Social Responsibility and Environmental Management, 13(2), 78–97.

García-Melón, M., Gómez-Navarro, T., & Acuña-Dutra, S. (2012). A combined ANP-delphi approach to evaluate sustainable tourism. Environmental Impact Assessment Review, 34, 41–50.

Geist, M. R. (2010). Using the Delphi method to engage stakeholders: A comparison of two studies. Evaluation and Program Planning, 33(2), 147–154. https://doi.org/10.1016/j.evalprogplan.2009.06.006

Hasson, F., & Keeney, S. (2011). Enhancing rigour in the Delphi technique research. Technological Forecasting and Social Change, 78(9), 1695–1704. https://doi.org/10.1016/j.techfore.2011.04.005

Kim, S., & Chiang, B. (2014). Sustainability practices to achieve sustainability in international port operations. 한국항만경제학회지, 30(3), 15–37.

Kuo, N.-W., & Yu, Y.-H. (1999). An evaluation system for national park selection in Taiwan. Journal of Environmental Planning and Management, 42(5), 735–745.

Laxe, F. G., Bermúdez, F. M., Palmero, F. M., & Novo-Corti, I. (2016). Sustainability and the Spanish port system. Analysis of the relationship between economic and environmental indicators. Marine Pollution Bulletin, 113(1), 232–239.

Lu, C.-S., Shang, K.-C., & Lin, C.-C. (2012). Identifying crucial sustainability assessment criteria for international ports. International Forum on Shipping, Ports and Airports, Hong Kong,27–30.

Lu, C.-S., Lu, C.-S., Shang, K.-C., Shang, K.-C., Lin, C.-C., & Lin, C.-C. (2016). Identifying crucial sustainability assessment criteria for container seaports. Maritime Business Review, 1(2), 90–106.

Musa, H. D., Yacob, M. R., Abdullah, A. M., & Ishak, M. Y. (2015). Delphi method of developing environmental well-being indicators for the evaluation of urban sustainability in Malaysia. Procedia Environmental Sciences, 30, 244–249.

Liu, W.-H. (2013). Managing the offshore and coastal fisheries in Taiwan to achieve sustainable development using policy indicators. Marine Policy, 39, 162–171.

Ngô, Đ. D. (2017). Đề xuất giải pháp phát triển bền vững cảng biển Hải Phòng [Luận Án, Đại học Hàng hải Việt Nam]. http://tailieuso.vimaru.edu.vn/doc/sdh-ts-00045-de-xuat-giai-phap-phat-trien-ben-vung-cang-bien-hai-phong-416197.html

Panayides, P. M. (2006). Maritime logistics and global supply chains: Towards a research agenda. Maritime Economics & Logistics, 8(1), 3–18.

Puig, M., Wooldridge, C., & Darbra, R. M. (2014a). Identification and selection of environmental performance indicators for sustainable port development. Marine pollution bulletin, 81(1), 124–130.

Puig, M., Wooldridge, C., & Darbra, R. M. (2014b). Identification and selection of environmental performance indicators for sustainable port development. Marine Pollution Bulletin, 81(1), 124–130.

Roh, S., Thai, V. V., & Wong, Y. D. (2016). Towards Sustainable ASEAN Port Development: Challenges and Opportunities for Vietnamese Ports. The Asian Journal of Shipping and Logistics, 32(2), 107–118.

Sislian, L., Jaegler, A., & Cariou, P. (2016). A literature review on port sustainability and ocean's carrier network problem. Research in transportation business & management, 19, 19–26.

Wooldridge, C. F., McMullen, C., & Howe, V. (1999). Environmental management of ports and harbours—Implementation of policy through scientific monitoring. Marine Policy, 23(4), 413–425.

Received **10 May 2021**

Accepted **26 May 2021**