Accepted Manuscript

Evaluating the key factors of green port policies in Taiwan through quantitative and qualitative approaches

Po-Hsing Tseng, Nick Pilcher

PII: S0967-070X(17)30809-0

DOI: https://doi.org/10.1016/j.tranpol.2018.12.014

Reference: JTRP 2124

To appear in: *Transport Policy*

Received Date: 18 November 2017

Revised Date: 13 October 2018

Accepted Date: 28 December 2018

Please cite this article as: Tseng, P.-H., Pilcher, N., Evaluating the key factors of green port policies in Taiwan through quantitative and qualitative approaches, *Transport Policy* (2019), doi: https://doi.org/10.1016/j.tranpol.2018.12.014.

Evaluating the key factors of green port policies in Taiwan through quantitative and qualitative approaches

Po-Hsing Tseng[a*] Nick Pilcher[b]

a. Department of Transportation and Logistics, Feng Chia University, No. 100, Wenhwa Rd., Taichung, 40724, Taiwan.

b. The Business School, Edinburgh Napier University, Edinburgh, EH14 1DJ, UK.

Abstract

This paper presents a holistic picture of the factors that affect green port policies through the use of both quantitative and qualitative approaches. Quantitatively, fuzzy analytic hierarchy process (FAHP) method with 25 questionnaires was used to identify key factors. Questionnaire participants included 13 ocean carriers and 12 governmental officials, all of whom were senior port experts with a minimum of 10 years working experience. Qualitatively, in-depth interviews based on grounded theory with ocean carriers (5) and governmental officials (4) in three ports were conducted in Taiwan. The quantitative FAHP analysis found the key factors to be environmental policy and regulation, followed by economic leverage, human and technical leverage. The qualitative interviews contextualise and enhance these FAHP results by illustrating the complexities and subtleties of these key factors for different stakeholders. Theoretical and practical implications are considered and suggestions are made for future policy approaches and to help develop green port approaches.

Keywords: Green port, Grounded theory, Fuzzy Analytic Hierarchy Process, Interview, Taiwan

1. Introduction

Ports produce air pollutants, oil pollution, excessive noise, health risks, and ecological threats that affect a nation's sustainable port development policy and are a critical and even life-threatening concern for port stakeholders. To date, much research has been undertaken in the area of port sustainability, but there is a need for more research into sustainability issues (Yap and Lam, 2013; Dulebenets, 2016; Lu et al., 2016; Yang, 2016; Bouman et al., 2017; Pruyn, 2017) and in investigating how ports respond to climate change (Ng et al., 2013). Yet, few studies on Asian ports exist (e.g. Lam and Notteboom, 2014) despite European ports being much studied (e.g. the fisheries sector port of Vigo in Spain (Lopes et al., 2013) and also ports in

* Corresponding author. Tel: +886-4-2451-7250; fax: +886-4-2452-0678
E-mail address: phtseng@fcu.edu.tw

Sweden (Mellin and Rydhed, 2011)). The field is, however, beginning to redress this; Vietnamese and Cambodian ports have recently been the focus of port sustainability studies (Le et al., 2014) as has Tianjin in China (Ying and Yijun, 2011). In addition, studies in Taiwan have also focused on sustainability issues such as SO_2 emissions and the Green Flag Incentive Program in Kaohsiung (Liu et al., 2014; Chang and Jhang, 2016).

This paper complements such research through a study that combines quantitative and qualitative methods to investigate green port issues. It thus adds to past related studies focused on particular pollution problems (e.g. emissions) in green port or potential (or particular) mitigation strategies to reduce pollution problems. For example, atmospheric emissions problem and regulation in shipping (Cullinane and Cullinane, 2013; Lindstad and Eskeland, 2016; Sys et al., 2016), emissions reduction in maritime intermodal container chain (Kontovas and Pasraftis, 2011), climate change and the adaptation strategies of ports in Australia (Ng et al., 2013), or the restructuring of environmental management in Polish ports (Klopott, 2013). The approach taken in this paper helps identify key overall factors (through quantitative approaches) and explores their complexities (through qualitative approaches) to help develop green port policies.

The remainder of the paper is structured as follows. First, the literature is reviewed regarding the major elements, solutions, and complexities of developing a green port. Following this, in section 3, the methodology and the approach to gathering and analyzing data from the ocean carriers and government officials using the FAHP and in-depth interviews is outlined. Section 4 presents and analyses the results. These results are then discussed in section 5, and section 6 concludes the article by drawing together the key elements and outlines some suggestions for stakeholders and policy makers in developing green port and considers the theoretical and practical implications of the study.

2. Literature Review

Shipping throughput is expected to see huge expansion over the next 15 years, with many implications for the environment and sustainability (Yap and Lam, 2013). Such expansion potentially contributes to climate change through the production of Greenhouse Gases (GHGs) (Lashof and Ahuja, 1990). Also, climate change will mean ports need to deal with sea level rises and extreme weather conditions, for example extreme hot temperatures (Ng et al., 2013).

Port sustainability is a key issue, and port activities have been shown to have a high Ecological Footprint (EF) (Rees, 1992; Wackernagel and Rees, 1996),for example in the case of the port of Vigo, Spain (Lopes et al., 2013)). The importance of collecting data is also much emphasized (Peris-Mora et al., 2005; Darbra et al., 2009) and in relation to this, a range of port indicators have been suggested, with suggested qualities ranging from ‘representativeness’, to ‘clarity’ and

'cost-effectiveness' (Peris-Mora et al., 2005). There is a need for studies into the green port concept, and the extent of its coverage and degree of implementation. For example, although Taiwan has enacted the 'Air Pollution Control Act', no rules are specified for gaseous pollutants such as SO_2, "which accounts for the large volume of the pollutants emitted" (Liu et al., 2014, p.420). Moreover, much research notes that the effectiveness and feasibility of port sustainability revolves very much around "the various green port policies and tools adopted by port/public authorities" (Lam and Notteboom, 2014, p. 175) and that different ports, "may adopt different policies considering the local regulatory, geographical, economic and political background" (ibid, p.175). Further, although some studies note that in a European context more headway is being made with port sustainability compared to Asia (for example in the cases of Antwerp and Rotterdam compared to Shanghai and Singapore (Lam and Notteboom, 2014)), these issues remain global. Notably, not all European ports implement environmental approaches similarly or with equal effectiveness (Darbra et al., 2009) and in other parts of the world conflicting rules exist, for example regarding how solid waste is disposed of in a port context (in Brazil (Jaccoud and Magrini, 2014)).

Shipping can negatively affect the environment through water pollution and GHG emissions. Water pollution issues include ballast water, fuel oil residue and waste disposal (Ng and Song, 2010). Ballast water can carry non-indigenous aquatic species, and there has been a call for management strategies regarding how such water is handled and disposed of (David and Gollasch, 2008). Indeed, in a case study of the port of Kaohsiung, Taiwan, many ships were found to have visited the ports without any records regarding ballast water, thus representing a risk of introducing non-indigenous aquatic species, particularly as many of these ships had sailed from toxic algae infested areas (Liu and Tsai, 2011).

In terms of GHG emissions, the release of CO_2, SO_2, NOx, PM_{10}, $PM_{2.5}$, HC, CO and VOC can be highly damaging to health and is linked to asthma, other respiratory diseases, cardiovascular disease, lung cancer and premature mortality (Bailey and Solomon, 2004). Some research shows that container ships are the second largest group of ships emitting such pollutants (Berechman and Tseng, 2012), although other ships also produce pollutants, such as coastal passenger shipping (Tzannatos, 2010) or car carrying ships (Villalba and Gemechu, 2011). Notably, the type of diesel that ships use differs from that of cars, is of a lower quality, and is "nicknamed Dirty Fuel" (Cullinane and Cullinane, 2013, p. 380). Such fuel produces more emissions and, significantly, more damaging emissions than on-road diesel engines, even from recently developed marine engines (Corbett and Farrell, 2002). One study of Kaohsiung shows that SO_2 emissions from port activities could constitute up to 10.2% of the total SO_2 emissions for the city (Liu et al., 2014).

Many other port activities besides shipping also involve numerous pollutative sources; activities ranging from land traffic to construction and repair of vessels and dredging, as well as the standard loading and unloading of container vessels; indeed, a total of 63 forms "of potential environmental impact in different port activities" (Peris Mora et al., 2005, p.1659) have been said to exist. There are also other negative impacts on the port area, given that urban expansion in many areas means that those living near the port increase in number (Borriello, 2013) and are exposed to both emissions and to noise pollution from ships' engines and from traffic near the port (Bailey and Solomon, 2004; Borriello, 2013).

Understandably, a number of solutions to these issues have been suggested. In a case study of Kaohsiung port, the combined dual approach of an incentive discount scheme and 'cold ironing', or shore-side power (Liu et al., 2014), has been suggested to help reduce SO_2 emissions. Such a dual approach of 'push and pull' approaches is often suggested; what Wang et al. (2007) refer to as a combination of command and control and market based mechanisms.

Another possible solution is to improve fuel efficiency to help reduce a port's EF (Lopes et al., 2013). Cullinane and Cullinane (2013) describe a number of approaches to improving fuel efficiency, such as greater engine efficiency, waste heat recovery, improved hull design and performance, more efficient propellers and rudders, reductions in vessel speed, improved routing and scheduling, and enhanced fleet management. Further, journey slow steaming has been shown to greatly help fuel efficiency, as "according to Maersk Line, when voyage speed is reduced by 20%, fuel consumption and CO_2 emissions can be reduced by more than 40% and 20%, respectively" (Moon and Woo, 2014, p. 445). Chang and Jhang (2016, p. 6) found that capesize and post-panamax ships in a 20 nm reduced speed zone near Kaohsiung Port can achieve CO_2 emissions reduction of 4,719.60 tons and 80.40 tons, respectively. Regarding SO_2, this can be reduced by 133,079.12 tons and 2,266.96 tons, respectively. When combined with other approaches to improve port sustainability, such solutions can work synergistically to improve conditions. For example, research from a case study of Kaohsiung notes that reducing ship speed and adopting shore power could reduce emissions by up to 91% (Chang and Wang, 2012). Fuel efficiency can also be achieved by reducing the amount of time a ship spends in port. To reduce port time means less fuel is used and lower amounts of emissions are produced, and that reducing a ship's time in port by 30% can reduce CO2 emissions by a huge 36.8% (Moon and Woo, 2014). Also, improving port efficiency and productivity can reduce any negative environmental impact on the port environment (Chang and Tovar, 2014; Serebrisky et al., 2016). Based on a data envelopment analysis approach, Lee et al. (2014) showed that the Singapore, Busan, Rotterdam, Kaohsiung, Antwerp, and New York are the most environmentally efficient port cities.

Regarding implementation, some research suggests the need for greater guidelines from key bodies, in particular through dialogue and cooperation between countries and the International Maritime Organization (IMO) (Cullinane and Cullinane, 2013, p. 397). However, although interactions on climate change management have taken place, they have not yet translated into international policy and guidelines (Ng et al., 2013). Notably, given the immense cost involved in the implementation of such policies, it is arguable that such implementation is a community, rather than an industry, issue (Bateman, 1996), and that, "encouragement to go beyond the minimum environmental standard requires incentives and support from the government" (Lam and Notteboom, 2014, p.186). Such an idea of a balance of market forces and regulation is also suggested, for example in Tianjin, China (Ying and Yijun, 2011).

A number of researchers comment on the need for an appropriate and integrated approach to coastal management, "which incorporates various aspects including cross-sectorial management, strategic environmental assessment, systematic scientific research and public involvement" (Yap and Lam, 2013, p. 21). Elsewhere it is suggested a climate change manager be employed, (Ng et al., 2013), or multi-disciplinary teams of environmental managers, energy managers, operators and maintenance staff are recommended, alongside the need to provide initially achievable targets to help encourage motivation and drive for port greenification (Pavlic et al., 2014).

Success in any change arguably requires all stakeholders to be involved (Clarkson, 1995; Le et al., 2014), and for companies to report information and progress to all groups for whom they are responsible (Alkhafaji, 1989). This is, however, complex, and there are very different groups of stakeholders involved in port activities, with potentially different public or private motivations (Bergqvist and Egels-Zandén 2012). Furthermore, governments may disagree with stakeholders' desires to enforce CO2 emission reductions if this affects economic competitiveness (Mellin and Rydhed, 2011).

Coordination is considered essential for any green port policy to succeed. This coordination can be wider regional coordination and the commitment of all ports to reducing pollution. A lack of countrywide coordination can mean some ports pollute more than others (Homsombat et al., 2013), whereas coordination has been shown to improve water quality, for example in Taiwan (Ko and Chang, 2010). Regarding the wider port area environment, integrating environmental accounting with management (Borriello, 2013) can improve the environment and livability of the port. Such environmental accounting involves, "monitoring, measuring and evaluating the state of the natural environment subjected to the impacts of human actions; assessing the monetary costs related to environmental protection and governance; programming and reporting the use/consumption of natural resources" (Borriello, 2013, p. 4302). This has happened with Valencia, which adopted a "specific self-regulation" (Borriello, 2013, p. 4300)

based on a number of measures such as the C40 World Ports Climate Declaration. International guidelines can also be effective, for example the hugely positive reduction in oil spillage in the North Sea following the IMO-designation of the North Sea as an International Convention for the Prevention of Pollution from Ships (MARPOL) special area in 1999, and adoption of the EU directive on port reception facilities in 2000 (Lagring et al., 2012).

Data collection is emphasized by many (see above, Peris-Mora et al., 2005; Dabra et al., 2009) and such data can also help with solutions to environmental issues. For example, traffic pattern analysis of ships can be very useful to help identify ships at risk of introducing non-indigenous aquatic species through ballast water (Liu and Tsai, 2011).

Thus, the literature highlights the underlying need for more research, and the importance of port sustainability for the future. Yet, there are a number of tensions inherent in many of the areas highlighted. For example, in terms of the urgency for implementation, there is a tension between market costs and needs, and the need for environmental sustainability. Further, the related tension to how such areas should be implemented, and who by. In other words, who should introduce and manage such initiatives is unclear, as is the issue of who should bear the cost of such initiatives.

3. Methodology

Using both quantitative and qualitative approaches, this paper takes three ports in Taiwan as cases to evaluate key factors that affect the implementation of green port policies

3.1 FAHP analysis

AHP is a multiple criteria decision-making tool to assign weights to a group of elements through a systematic hierarchy structure (Satty, 1980). However, classical AHP may not accurately represent the decision makers' ideas as successfully as fuzzy AHP. Zadeh (1965) defined a fuzzy set as a class of objects with a continuum of grades of membership ranging between zero and one. Based on Zadeh (1965), fuzzy linguistic variables and corresponding fuzzy triangular numbers can be used for comparison among the elements included, and help solve vague and uncertain problems in decision making. It uses triangular membership functions to express interval judgments. Therefore, fuzzy logic, using fuzzy pairwise comparison matrices, is introduced to mitigate the uncertainness of AHP method (Chang, 1996; Kabir and Hasin, 2011). Such an analysis process is widely applied in many green transportation issues (e.g. Wang et al., 2014; Ahmed et al., 2017). In this paper, an integration of fuzzy set theory and AHP is used to identify the key factors and sub-factors that have a bearing on the key factors of green port policies. We use a column geometric mean method (Buckley, 1985) and the extent analysis method (Chang, 1996) to calculate the weights. A triangular fuzzy number used as the member

function is expressed in Fig. 1. Its membership function is defined by the triplet (l, m, u) as in Eq. (1) (Zadeh, 1975).

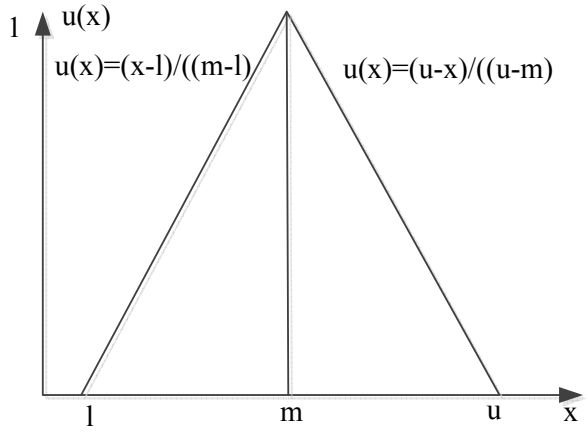

Fig. 1 A triangular fuzzy number.

$$U(x)=\begin{cases}\frac{(x-l)}{(m-l)}, l \le x \le m \\ \frac{(u-x)}{(u-m)}, m \le x \le u \\ 0, others\end{cases} \quad (1)$$

Where m is the most possible value of the fuzzy number U(x), l and u are the lower and upper bounds, respectively.

Given that the research in this paper is a multiple case study of ports in Taiwan, and is integrated with interviews in a multi-method approach, the Fuzzy AHP (FAHP) is arguably ideal in generating the key salient issues for comparison and consideration in greater depth in the interviews. The main processes of FAHP are followed as: constructing the hierarchic model, designing a questionnaire, constructing the pair-wise comparison matrix, calculating the fuzzy number, building the fuzzy positive reciprocal matrix, calculating the fuzzy weights, defuzzification, and normalisation and synthetic analysis (calculating the global weights of all sub-factors). In a quantitative approach, a FAHP with a nine point rating scale was designed to measure the respondents' perceptions of what was relatively important. Based on the questionnaire responses from experts and through an iterative process of analysis, FAHP can help identify the extent to which such factors affect the implementation of the green port concept.

3.2 Key factors

Based on the literature review in Table 1, a hierarchical structure of an FAHP scale with four factors (including environmental policy and regulation, technical leverage, economic leverage and human) and twelve sub-factors was created as discussed below.

3.2.1 Environment Policy and Regulation

Environment policy and regulation means implementing international conventions (e.g. MARPOL) and port environmental policies (including air pollution, water pollution, clear/alternative fuels, pollution tax, etc.) and regulation supervision in order to protect port environment and reduce potential pollutions (Knudsen and Hassler, 2011; Dooms et al., 2013; Cullinane and Cullinane, 2013; Jaccoud and Magrini, 2014; Lam and Notteboom, 2014; Pavlic et al., 2014; Zis et al., 2014; Sys et al., 2016; Lindstad and Eskeland, 2016). Besides compulsory environment policies, voluntary checking mechanism have gradually introduced for port operators in order to reduce work burden for officials of port authorities (Soylu and Dumville, 2011; Cullinane and Cullinane, 2013; Lam and Notteboom, 2014; Pavlic et al., 2014). Based on the aforementioned studies, three sub-factors were considered here, namely, international legislation, supervision and management, and voluntary checking mechanism.

3.2.2 Technical Leverage

Technical leverage means using innovative technologies in the green terminal equipment and ship facilities in order to construct well green port environment. Also, advanced monitoring systems have been introduced to identity potential pollution sources and provide real-time pollution prevention measures. Based on past studies (Ugboma et al., 2006; Chou, 2010; Heij et al., 2011; Chang and Wang, 2012; Cullinane and Cullinane, 2013; Klopott, 2013; Ng et al., 2013; Rohde et al., 2013; Blinge, 2014; Hollen et al., 2015; Liu and Lim, 2017), three sub-factors were considered here, namely, port infrastructure and terminal, ship structure and maintenance, and environmental monitoring technique.

3.2.3 Economic Leverage

Economic leverage means using operation cost reduction incentives to encourage port users adopt environmental friendly operation methods and reduce negative impacts on port environment. It can adopt carrot and stick methods to provide reward and punishment. The carrot can be a economic aid and punishment can be a fine or higher port operation costs. Based on past studies (Bergqvist and Egels-Zanden, 2012; Blinge, 2014; Kontovas and Psaraftis, 2011; Mellin and Rydhed, 2011; Chang and Tovar, 2014; Lam and Notteboom, 2014; Moon and Woo, 2014; Yang et al., 2014; Serebrisky et al., 2016; Chang and Jhang, 2016; Liu and Lim, 2017), three sub-factors were considered here, namely, port operation efficiency, penalty port pricing, and incentive port pricing.

3.2.4 Human

Human factors play a key role in green port promotion. Generally, green port operators must clearly understand potential environment risks, reduce pollution resources and also demonstrate corporate social responsibility with ethical behavior in the port environment (Petrosillo et al., 2009; Heij and Knapp, 2012). Also, any environment policies must obtain shipping operators' support in order to reduce barriers of policy implementation (Mellin and Rydhed, 2011). Finally, based on resource dependence theory, constructing congenial stakeholder relations with port communities is helpful in green port policy implementation (Bergqvist and Egels-Zanden, 2012; Cruz et al., 2013; Blinge, 2014; Lam and Notteboom, 2014; Le et al., 2014). Based on the aforementioned studies, three sub-factors were considered here: 'environmental risk perception', 'shipping operators' support' and 'stakeholder management'.

Table 1

Key factors influencing implementation of green port policies.

Layer 1: Factors	Layer 2: sub- factors	Sources
Environmental Policy and Regulation	International Legislation (F11)	Knudsen and Hassler (2011); Dooms et al. (2013); Cullinane and Cullinane (2013); Lam and Notteboom (2014); Pavlic et al. (2014); Zis et al. (2014); Sys et al. (2016); Lindstad and Eskeland (2016)
	Supervision and Management Framework (F12)	Ko and Chang (2010); Cullinane and Cullinane (2013); Jaccoud and Magrini (2014); Lam and Notteboom (2014); Pavlic et al. (2014)
	Voluntary Checking Mechanism (F13)	Soylu and Dumville (2011); Cullinane and Cullinane (2013); Lam and Notteboom (2014); Pavlic et al. (2014)
Technical Leverage	Port Infrastructure and Terminal	Ugboma et al. (2006); Chou (2010);

	(F21)	Ng et al. (2013); Blinge (2014); Hollen et al. (2015); Liu and Lim (2017)
	Ship Structure and Maintenance (F22)	Rohde et al. (2013); Cullinane and Cullinane (2013)
	Environmental Monitoring Technique (F23)	Heij et al. (2011); Chang and Wang (2012); Klopott (2013); Cullinane and Cullinane (2013)
Economic Leverage	Port Operation Efficiency (F31)	Kontovas and Psaraftis (2011); Moon and Woo (2014) ; Chang and Tovar (2014); Serebrisky et al. (2016); Liu and Lim (2017)
	Penalty Port Pricing Strategies (F32)	Mellin and Rydhed (2011); Bergqvist and Egels-Zanden (2012); Lam and Notteboom (2014)
	Incentive Port Pricing Strategies (F33)	Blinge (2014); Lam and Notteboom (2014); Yang et al. (2014); Chang and Jhang (2016)
Human	Environmental Risk Perception (F41)	Petrosillo et al. (2009); Heij and Knapp (2012)
	Shipping Operators' Support (F42)	Mellin and Rydhed (2011)
	Stakeholders Management (F43)	Bergqvist and Egels-Zanden (2012); Cruz et al. (2013); Blinge (2014); Lam and Notteboom (2014); Le et al. (2014)

To validate the scale, five senior managers (two ocean carriers and three governmental officials) were invited to pre-test the scale and verify the questionnaire's suitability.

3.3 Interview analysis

Regarding qualitative perspectives, in-depth interviews with key stakeholders (ocean carriers and governmental officials) were undertaken during June-July 2015. It is on the one hand a research limitation that our interviewees did not include other groups. Nevertheless, we argue the above two groups play key roles in the implementation of green port policies. Indeed, it is

generally the case that before the green port policies formally have been implemented, port authorities (e.g. governmental officials) must fully communicate these with port users (e.g. ocean carriers) in order to reduce the policy implementation barriers. Therefore, in this study, we try to understand the thinking from the governmental officials and ocean carriers and then present effective policies improvement suggestion or solutions to implement green port policies. We also hope other research in the future can compare these results with interviews with other stakeholder groups involved, and that the theory is therefore generalizable to other contexts (cf. Flyvbjerg, 2006). Le et al. (2014, p.173) identified eight groups of stakeholders in their study and further classified these "into internal/external and voluntary/involuntary categories." By voluntary, Le et al. (2014) mean those with investments (either human or capital) in the company, and involuntary to be those at risk from company activities. They further noted that, "their salience is then assessed based on their legitimacy, power, urgency, and proximity" (ibid, p.173). In the case of our study, a total of nine interviewees were interviewed, including five operators and four governmental officials in the port of Kaohsiung, Keelung and Taichung.[1] Each interview lasted on average 20-25 minutes. The interviewees were selected based on their background (e.g. senior manager with a strong reputation in the green port related field) and involvement in the topic being researched. The outlines for interviewees included: what were the key factors influencing implementation of green port policies? What kinds of strategies were available to mitigate port pollutions? As a method, interviews have been used elsewhere in the field successfully to gather data on similar issues (e.g. Dabra et al., 2009; Mellin and Rydhed, 2011; Ng et al., 2013; Le at al., 2014) but it is their use alongside the FAHP here that we argue strengthens and adds depth to the quantitative perspectives gathered. Interviews were conducted in the participants' own language (Cortazzi et al., 2011) anonymized, and transcribed by the researcher to aid analysis (Bird, 2005). They were then translated into English using a goal oriented 'skopos' approach (Vermeer, 2004) and verified for accuracy by a native English speaker. The interview data was coded using a constructivist grounded theory process whereby themes were allowed to emerge rather than being predetermined (Charmaz, 2011). This data was then compared with the quantitative FAHP data to give a multi-dimensional picture of the issues involved in green port and a holistic picture of recommendations for ports. We present and analyze these results below. As the FAHP sought to identify key elements from a quantitative basis of frequency and salience, these results are presented from shipping operatives and governmental officials combined. However, given that the interviews sought to explore the complexities and subjective elements of these salient areas, these results are presented first from

[1] *Five of the nine interviewees were invited to participate the research pretest.*

shipping operatives and then separately from government officials. Often, as shown below, although at times an element (for example economic leverage) is shown as salient to both groups of stakeholders in the FAHP analysis, the interviews show that in fact the underlying reasons for its salience subjectively differed in and within each group, and thus appreciation of its true importance can be more subtle than initially appears. Arguably, the combination of the quantitative and qualitative approaches used here that has allowed this more complex picture to emerge.

3.4 Sample description

A total of 30 questionnaires were administered by mail with postage-paid return envelopes to 30 respondents (including 15 ocean carriers and 15 governmental officials) in Taipei, Keelung, Taichung and Kaohsiung city on 1 June, 2015.[2] Before sending the questionnaire, we reviewed each individual's working background (e.g. professional training or working experiences, etc.) to ensure they were suitably qualified questionnaire participants. Then we contacted these experts by email or phone call to obtain agreement to participate in o ur study. By the cut-off date (15 June, 2015), 27 questionnaires had been received. For each sample, the consistency index (CI) and consistency ratio (CR) were tested to confirm the consistency of its pairwise comparison matrix. The results indicated two questionnaires with CI>0.1 and CR>0.1 were highly inconsistent (Satty, 1980) and were consequently discarded. Therefore, the overall response rate was 83.3% (=25/30). The profiles of the 25 valid respondents' characteristics[3] (including 13 ocean carriers and 12 governmental officials) were then used in the FAHP analysis.

4. Results*4.1 FAHP result and analysis*

Table 2 shows most of the respondents were senior experts with at least 10 years working experience in shipping (port) industries, thus supporting the reliability of the survey findings.

Table 2

Profiles of the respondents.

Characteristics	Range	Frequency	Percentage (%)
Job title	President/Director	3	12%
	Senior deputy director	4	16%

[2] It is a research limitation that our questionnaire participants just include ocean carriers and governmental officials and other stakeholders are not included in our research scope. These groups are nevertheless important stakeholders in implementing green port policy and we also hope these results can be compared with the views of other stakeholders in future research.

[3] Here a valid respondent is one whereby the questionnaire answers of the respondent must pass the Consistency Index (CI) and the Consistency Ratio (CR). In our study, 30 questionnaires were administered. Therefore, there were five invalid questionnaire (including three non-reply respondents and two non-consistency answer respondents) and 25 valid respondents.

	Division director	8	32%
	Supervisor	5	20%
	Senior engineer	5	20%
Age (years)	Under 40	2	8%
	41~50	5	20%
	51~60	15	60%
	Above 60	3	12%
Educational Level	Bachelor	20	80%
	Master	5	20%
Seniority	10~15	3	12%
	16~20	10	40%
	21~25	7	28%
	Above 26	5	20%

The local weights of each construct and influencing factor are shown in Table 3. All consistency ratio (CR) values are less than 0.1, and thus fit the consistency test. The results indicate that environment policy and regulation (0.274) is the most important factor influencing the implementation of green port, followed by economic leverage (0.273), human (0.267), and technical leverage (0.185). With regard to attributes, supervision and management framework (0.350), port infrastructure and terminal (0.414), port operation efficiency/incentive port pricing (0.372), and ocean carriers' support (0.399) were perceived to be the most important attributes with respect to each factor in relation to environmental policy and regulation, technical leverage, economic leverage, and human, respectively.

In a subsequent stage of analysis, the global weights were synthesized from the second level drawn by multiplying the local weights and the corresponding criteria in the level above, and adding them to each element in a level according to the criteria affected. The results reveal that the top three important criteria influencing the implementation of green port are shipping operators' support (0.1066), port operation efficiency (0.1018) and incentive port pricing (0.1016), respectively.

Table 3

FAHP analysis results of all participants.

Factor	Local weights	Consistency ratio (CR)	Attributes	Local weights	Global weights	Rank

Environmental Policy and Regulation	0.274	0.00184	International legislation	0.311	0.0854	6
			Supervision and management framework	0.350	0.0960	4
			Voluntary checking mechanism	0.338	0.0928	5
Technical Leverage	0.185	0.00442	Port infrastructure and terminal	0.414	0.0767	9
			Ship structure and maintenance	0.223	0.0414	12
			Environmental monitoring technique	0.363	0.0673	11
Economic Leverage	0.273	0.07000	Port operation efficiency	0.372	0.1018	2
			Penalty port pricing	0.256	0.0700	10
			Incentive port pricing	0.372	0.1016	3
Human	0.267	0.00209	Environmental risk perception	0.296	0.0792	8
			Shipping operators' support	0.399	0.1066	1
			Stakeholders management	0.304	0.0813	7

Notes: * Local weight is derived from judgment with respect to a single criterion; ** Global weight is derived from multiplication by the weight of the criteria.

In order to compare to perception comparisons between ocean carriers and government officials, we conducted the following weight analysis in Table 4. Regarding factor weights, results showed that ocean carriers were concerned about economic leverage, whereas government officials were concerned more with environmental policy and regulations. Such a result revealed that operation cost or economic incentives still play a key role for ocean carriers when they evaluate a port's pollution regulation policies. For government officials, they pay more attention to understanding if port users' can fit the threshold of environmental rules. In term

of attributes, these two groups are concerned with the port operation efficiency and view it as being first priority. Other attributes, by comparison, show some differences between ocean carriers and government officials.

Table 4

FAHP analysis results of between ocean carriers and government officials.

Factor	Local weights	Attributes	Local weights	Global weights	Rank
Environmental Policy and Regulation	0.272 (o) 0.280 (g)	International legislation	0.317(o) 0.329 (g)	0.0863 (o) 0.0922 (g)	6 (o) 6 (g)
		Supervision and management framework	0.361(o) 0.307 (g)	0.0984 (o) 0.0860 (g)	4 (o) 7 (g)
		Voluntary checking mechanism	0.322(o) 0.364 (g)	0.0878 (o) 0.1018 (g)	5 (o) 2 (g)
Technical Leverage	0.189 (o) 0.177 (g)	Port infrastructure and terminal	0.394(o) 0.477 (g)	0.0744 (o) 0.0845 (g)	9 (o) 8 (g)
		Ship structure and maintenance	0.214(o) 0.225 (g)	0.0405 (o) 0.0399 (g)	12 (o) 12 (g)
		Environmental monitoring technique	0.392(o) 0.297 (g)	0.0741 (o) 0.0527 (g)	10 (o) 11 (g)
Economic Leverage	0.277 (o) 0.271 (g)	Port operation efficiency	0.368(o) 0.407 (g)	0.1019 (o) 0.1104 (g)	1 (o) 1 (g)
		Penalty port pricing	0.263(o) 0.223 (g)	0.0727 (o) 0.0604 (g)	11 (o) 10 (g)
		Incentive port pricing	0.369(o) 0.370 (g)	0.1022 (o) 0.1003 (g)	3 (o) 3 (g)
Human	0.262 (o) 0.272 (g)	Environmental risk perception	0.287(o) 0.340 (g)	0.0751 (o) 0.0924 (g)	8 (o) 5 (g)
		Shipping operators' support	0.408(o) 0.356 (g)	0.1068 (o) 0.0967 (g)	2 (o) 4 (g)
		Stakeholders management	0.305 (o) 0.305 (g)	0.0798 (o) 0.0828 (g)	7 (o) 9 (g)

Note: (o) means ocean carriers; (g) means governemt officials

4.2.1. Ocean carrier

For ocean carrier, a key area of pollution concerned water, with the issue that a general shipyard *"will not use water recycling or rainwater collection systems so it will produce waste water, especially in old water pipelines"* (cf. Ng and Song, 2010). Further, other sources of pollution existed, such as noise pollution, waste steel, dust, waste water, and garbage, but that *"it is difficult to regulate these random pollution sources"*.

With regard to promoting port sustainability, ocean carriers made many comments. In terms of making ships greener, one operative mentioned the Energy Efficiency Design Index (EEDI) and the huge range of elements this addressed ranging from environmental coolants to shore power systems. Another carrier suggested such indices could be used for fee discounts and in the second hand ship market (e.g. in the case of the Environmental Ship Index). Limiting ship age was suggested, as was the management of rules for *"when terminals are rented to private companies", and* to *"reduce the frequency of sailing and waiting time and subsequently reduce the working hours of engines."* In both cases, it was implied that authority intervention would be needed. Another solution involved replacing the potentially highly polluting rubber tire gantry unloading cranes with electric rail-mounted gantry cranes. Another ocean carrier suggested adding bio-diesel to super diesel, but that regionally this was not done in all ports, and would also require strategic governmental intervention. Other carriers also felt that green policies *should have consistent check standards for any countries' ships. In other words, that no individual differences exist between Taiwanese Flag of Convenience (FOC) and other countries' Flag of Convenience (FOC).*" Thus, both regional (cf. Homsombat et al., 2013) and coordinated (cf. Ko and Change, 2010) action was required.

Carriers also commented on the complexities of sustainability. The practical difficulties of introducing shore power were highlighted, such as *"each country's voltage and socket are different"* (cf. Tseng and Pilcher, 2015), that the *"establishment costs of shore power are quite high"*, and that *"it relies on a ship owner's inclination"* as to whether it is used or not. Indeed, in Taiwan different voltages, sockets, contract volumes and also the issue of subsidies for ship refitting (where necessary) were highlighted as being obstacles to introducing shore power that would need to be addressed. Importantly, *"these problems must be discussed among Taiwan international Ports Corporation, Environmental Protection Administration and Economic Affairs Administration"*. Indeed, one operative stated that they had the capability to introduce shore power in Taiwan, but that *"currently, the related laws and rules are not clear"*.

Fuel types and emissions were also commented on. In Taiwan, traditionally ships used *"heavy oil since it is cheaper"* (cf. Cullinane and Cullinane, 2013). Further, and in contrast to the US

(e.g. Seattle and Los Angeles) where ship speed reduction (cf. Moon and Woo, 2014) is adopted, *"in Taiwan, ship speed reduction is not formally conducted since there are some technical and management problems that need to be resolved. It is currently in a testing stage"*. Vessel speed reduction was often noted to be key, one operative saying *"the most urgent factor is to conduct vessel speed reduction within 20 miles as ships approach the port"* and another that the most urgent need to reduce pollution was currently *"reducing the sulfur content of fuel"*. The exemplary approach of the US was often commented on, for example Long Beach port as *"providing a good experience for our ports"*, given that such policies significantly reduce *"air pollution and the probability of breathlessness for children and adults near the port area"* (cf. Bailey and Solomon, 2014).

One unexpected element commented on by carriers was the importance of marketing port approaches to green port policies. One carrier spoke of how they had used *"networks to disseminate policies and information"* and how they sometimes *"invite government officials or ocean carriers from other international ports to visit our ports"*. Further, that *"holding international conferences"* was also a policy to market what companies were doing, as was the establishment of *"sister"* or 'twin' ports in other countries.

The financial implications of any solutions were also highlighted, as *"in order to reduce these pollutants requires the involvement of technical and policy problems and the need to spend a large amount of money"*. Critically, *"when conducting green port policies, most shipping companies will consider their benefits and revenues. That is the barrier"*. Financial elements were also noted in relation to how the EU was in the future going to have a *"bunker tax for international shipping in the future"*, which was important as *"Labor Unions will become involved and it will increase the cost burden for ocean carriers"*. Cost was considered key to any implementations, for example the need to have all employees involved (cf. Le et al., 2014), and the cost of specific training, as in *"emission treatment facilities as [an] example, operation and maintenance are significantly challenging"*. Notably, in times of an economic boom, *"shipping companies will request their ships to speed up sailing"* but that this *"will add fuel consumption and emissions"*, and thus *"operation and environmental protection can not balance very well"*.

The importance of gathering and recording data was also emphasized, and that *"a port environment database should be established to monitor port pollution including noise pollution, air pollution, water quality, ecology, sludge, and so on"* (cf Peris-Mora et al., 2005; Borriello, 2013). Yet, the complexities of doing this were also commented on, as many *"strategies are tested in the laboratory"* and that *"the real effects are difficult to confirm and verify due to complicated sea situation, ocean current, and so on"*. Thus, here again the need for governmental leadership and direction was highlighted.

Such a need for governmental and international leadership was often directly stated. For example, that the *"IMO should formulate or establish international standards for different countries to follow, such as shore power facilities and with standards for the ESI (Environmental Ship Index)"*. Further, that there should be schedules and implementation targets, and that subsidies must be formulated when green policies are introduced, such as *"rent or fee discounts"* for ocean carriers replacing old facilities and components with new ones, as if these are not provided there will be a *"backlash"*. One carrier spoke very frankly that *"currently, the rules of green port policies are not well formed in Taiwan…* [and that]*… if the incentives of reward can not balance shipping companies' cost, it will reduce shipping companies inclination to call at the port or they may not cooperate at all"*. This carrier suggested a reward-based implementation of green policies. Another carrier hoped that *"real incentives should be provided for shipping companies…[to]…attract more operators to develop green supply chain"* and that *"I hope Taiwan International Ports Corporation does not set making money as the priority purpose."*

Nevertheless, one carrier felt that with IMO regulations, although *"trade barriers would exist at an early stage, in the long term, green port policies would have positive impacts on the global marine environment"*. Indeed, carriers also said they followed IMO measures: *"our oil regulation and treatment for ship facilities follows international conventions (e.g. IMO)"*. A general feeling was the desire for help from the port authorities in meeting regulations, for example, *"if the port could provide a retrieval service on board and help with treatment that this would reduce the possibilities of the discarding of waste in to the sea"*. Similarly, that *"if the port could provide waste treatment services, this would be a benefit for conducting green port policies"*.

4.2.2. Government officials

Perhaps understandably, Government Officials' knowledge pertained to wider elements than those of the shipping operatives: the national port image, the natural environment (e.g. how pollutants would carry upstream), port resident relationships, and port policies. Also, wider hinterland aspects such as airborne pollution from sand and *"dust and asbestos fibers from the mineral yard"* were mentioned. Further, the importance of the *"road transfer system"* and the *"port hinterland"* and *"supplementary measures"* were highlighted as being necessary to help support a green port environment. It was felt that currently *"the hinterland of Taiwan's ports is not quite sufficient."*

Government officials often commented on Taiwan's initiatives regarding green ports, for example *"port authorities have spent lots of time and money to build eco-port programs and established a green and technologically advanced container terminal"*. Indeed, Kaohsiung port

did receive the certificate of Eco-port in Europe in 2014.[4] The Taiwan International Ports Corporation was said to focus on the four areas of passenger transport, cargo transport, port environment, and community development, and was said to have *"spent lots of money on infrastructure and software resources, green economics planning and stakeholder relationship"*. Further, much cooperation between national and local governmental bodies and units was highlighted with units that *"regularly patrol and check the port areas and conduct pollution record checks; illegal activities will be penalized and fined"*. Other green initiatives were *"low carbon/green building materials and planted many trees"* and *"energy-saving lamps in the port streets and also used solar powered energy systems"*. Nevertheless, opportunity for improvement was noted, as *"there is no single unit service center to develop green port policies in Taiwan. Therefore, doubt about the legitimacy of port operations has existed. For example, ballast water treatment, water pollution regulation law, waste treatment, toxin management law and environmental impact assessment law"*.

In financial terms, interestingly, officials felt green regulations would actually encourage ship calls at the port, to *"enhance environmental protection visions for port development and also help attract the ocean carriers…. increase the volume of cargo transshipment and port operation performance"*. Indeed, in the words of another official: *"once it brings significant effects for group cooperation and cargo as well, it would further attract the shipper's interests to call at these green ports"*. Put succinctly: *"if profit exists, then the shipping companies will actively pursue it"*. Such views contrasted with those of the ocean carriers.

Regarding international laws, government officials also commented on the fact that shipping companies had to follow international laws, such as those from MARPOL, regarding how they disposed of and treated waste oil, waste water and approached air pollution. Also similarly, the complexity of this was noted: *"in general, garbage and living waste water and ballast water are not easily found compared to other pollutants"*. Officials also felt the US and Europe were advanced in green ports compared to Taiwan. In order to improve Taiwan's current green port policies, other countries' implementation experiences were mentioned as being those worth learning from. For example, one official commented that *"there are some benchmarking green ports, such as Long Beach Port, Los Angeles Port, Singapore Port and Rotterdam Port. The main strategies of these ports are reducing air pollution; the second is water pollution improvement"*. Therefore, in addition to understanding various green port policies, how to effectively utilize the port resources and funds is another important issue.

[4] Port of Kaohsiung, Taiwan International Ports Corporation. http://kh.twport.com.tw/en/

Regarding the role of finance in promoting green ports, some saw finance as an incentive, others as a punitive. For example, in an *"order command system"… [whereby]… illegal activities will be punished or fined"* or as a *""levy system"…[to]…levy pollution tax"* or even as a *"guarantee money system"…[that]…asks ocean carriers to pay the money in advance, then after polluters provide evidence regarding pollutant treatment…they could take the money back"*. As a reward, one official suggested *"we could copy the mechanism of Singapore to provide financial reward"*, and that *"the government should adopt rewards to replace punishments, and adopt group power to create significant effect"*. In terms of subsidies, one official felt there *"must be enough funding to support the various green port policies, and if the funding is provided by central government, that would bring significant benefit when conducting green port policies"*. At present though, this was considered insufficient: *"currently, the effect of green port policies is not significant since low sulfur fuel increases the high operation costs…. [and that]… compared to these costs, subsidies from the port are not enough to pay the extra expenses due to the regulation of green port policies"*. Occasionally, the specific department that could provide subsidies was alluded to: *"port water and electricity are provided by Taiwan Water Corporation and Taiwan Power Corporation; they should provide rate discount and facilities planning programs"*.

Regarding the green potential of shore power, this was often commented on in the context of the financial ideas of reward or punishment. Some felt ship owners could be taxed if they did not install the equipment, others felt they could be subsidized to do so. Government officials also commented on the challenges involved with introducing shore power, noting, *"there is no clear standard and planning direction for voltage, electric current or electric frequency"*. Another commented on the fact that if Taiwan did not have the infrastructure to support shore power, only a few ships that could use it would use these ports. Similarly, the challenges of introducing LNG were also noted. Although LNG was felt to be a natural future source of energy, its uptake *"will depend on LNG supply methods of ports and related policies"*.

Management was, understandably, considered key, one official saying *"port authorities should regularly conduct emergency response and disaster management plans to reduce pollution due to ship collision and accidents in the port area"*. It was also highlighted that the success of such measures would depend on coordination and cooperation through local and national bodies (cf. Cullinane and Cullinane, 2013). Not all officials were optimistic this could be achieved. For example, one official said that when attempting to implement green port strategies, central government will *"sometime…have barriers from local government"*, for example in resistance to the construction of wind turbines or in asking for a high percentage of port land returned. Barriers were also arguably raised by the need for many different bodies to discuss any green

policy before its implementation. For example, shore power was currently being discussed by the *"Ministry of Transportation and Communication, Environmental Protection Administration (to discuss policies and economic incentives), Ministry of Economic Affairs (to discuss discount for electricity rate) and port operators"*. Government officials also felt some policies may be counterproductive if not managed correctly. For example, one official commented on the fact that shipping companies were unhappy at how waste oil was outsourced by the port authorities to licensed environmental operators, some of which charged *"high fees"*. This official felt *"port authorities should further understand their facilities and their treatment process and regularly record it"*.

Other green port elements Government Officials noted related to marketing and data collection. Regarding Marketing, one official commented that these strategies included *"network dissemination, inviting foreign port authorities and shipping companies to visit Taiwan's ports, assigning employees to take education training in the advanced ports, making sister ports, holding international conferences…"* In terms of compiling data, this was felt very important, but that ocean carriers must supply this data: *"basically, ships must submit the necessary data to port authorities 24 hours before calling at the port, port authorities will conduct a risk assessment and then decide whether the ship can call at the port."* Such data would be checked against a number of criteria ranging from those in the International Oil Pollution Prevention Certificate to the International Energy Efficiency Certificate. Other officials commented on the challenges involved with collecting data, for example that *"it is difficult to check carriers' green performance"*.

5. Discussion

The above academic literature, FAHP analysis, and in-depth interviews, all show the importance accorded to the green port concept. Furthermore, considered together, they show that achieving a green port is a highly complex issue that requires careful coordination and in which economic leverage, the human factor, and policy and regulations play a key role. Yet, as our results and analysis show, the situation is far more subtle and multi-layered than simply stating that these three elements are vital and should be followed. We do not claim that such complexities have not been highlighted in the literature before, but what we do argue our results show, is the different underlying tensions that exist, and that by showing these tensions, we argue that the results provide a useful discussion focus to help resolve these tensions with the overall aim of improving the success of green port initiatives.

Firstly, in terms of environmental policy and regulation (it is noted that economic leverage plays a similar important role since their local weights are very close which are 0.274 and 0.273, respectively), much of the literature underlines the importance of profit for the ocean carriers

being of fundamental importance (e.g. Cullinane and Cullinane, 2013). Further, our FAHP analysis shows this to be the most important element in achieving green port as well. However, our in-depth interviews show differing perspectives on the role of such profit. For many ocean carriers, any adverse effect on profit was considered to be so important that they often talked of needing government subsidies. Government officials, however, whilst often talking of the need for such subsidies, also championed the notion of the threat to profit that could be imposed on those ships and shipping companies that did not meet environmental requirements. There were thus contrasting views of the role of money in the attainment of green port from ocean carriers and government officials. Clearly, such issues would need to be carefully discussed before implementation of any policies. In addition, such results could be utilized in future research with other stakeholder groups such as the public or city councilors for comparison (cf. Flyvbjerg, 2006).

With regard to the role of international guidelines and regulations to develop green port, much of the literature calls for greater intervention from international organizations. Similarly, our FAHP analysis underlines the importance of the need for policy and regulation. Nevertheless, in our interviews, many of the ocean carriers we spoke to here said they were already following these measures, such as IMO stipulations for the treatment of oil. Yet, when the issue of who should be responsible for helping implement these guidelines, there were once again differing views. Ocean carriers felt that the government should take responsibility, whereas often the government felt that it was ocean carriers who should take responsibility. Further whilst ocean carriers commented on, for example, the urgent need for the government to ensure uniformity in voltage supplies for shore power, government officials claimed this was being done. There was thus at times a difference between the understanding of what was in reality happening between the different stakeholder groups..

In addition, the academic literature notes the need for coordination and uniformity (e.g. Homsombat et al., 2013), to promote green port, and so does our FAHP analysis. However, our interviews showed that ocean carrier experience was that different ports in Taiwan approached adding bio-diesel to super diesel differently, and a desire was expressed for ports to take more control over certain processes such as water treatment. Even government officials commented on how it would be more effective for ports to take more control over treatment procedures that had been outsourced to private companies. There were also comments highlighting the large number of departments involved in needing to coordinate certain policies, and of resistance from certain local government bodies to port sustainability initiatives such as the construction of wind turbines in the port area. Thus, from the literature, from the FAHP analysis, and from the interviews there was an urgent sense of a need for someone to take control, and of the need for

umbrella organizations to help coordinate port sustainability. This is despite the fact that such an umbrella organization in Taiwan, in the form of the MOTC (see below) purportedly exists to undertake such control. What is more, there was confusion as to actually who should take control and how this should be done: who should take responsibility therefore remains a key question, even though there is ostensibly already an organization that does this in Taiwan. The literature and the FAHP analysis both showed the importance of this, but the interviews showed precisely how complex this was to introduce and enforce. . Given that many interviewees spoke of the advanced state of US ports, perhaps such ports could be visited to note how they have introduced sustainable procedures and policies and to emulate what they have done. Through consultation and through developing strategic networks through sister ports may enable ports in Taiwan to learn from the advice and experience of such ports and implement sustainability more effectively themselves.

We would argue that the initiative for such a process has to be implemented at a central government level by an umbrella organization. This argument is supported through the literature but also through our FAHP analysis and our interviews. Our FAHP analysis highlighted the importance of these human and policy implementation elements, and our interview data also showed that participants advocated this. Based on these, we argue that the Ministry of Transportation and Communication in Taiwan [5] coordinate initiatives to implement and disseminate information about existing and ongoing green port policies in Taiwan.

6. Conclusion and policy implications

To investigate the key factors influencing the implementation of green port policies, in this paper we undertook a mixed methods research study that drew on both quantitative and qualitative approaches and methods. Quantitatively, we used an FAHP analysis with 25 ocean carriers and government officials. This FAHP analysis identified the most important factor was considered to be environmental policy and regulation, followed by economic leverage, human factors and then technical leverage. Regarding the weight analysis between ocean carriers and government officials, Table 4 showed that economic leverage and environmental policy and regulation are most important factors for ocean carriers and government officials, respectively. Qualitatively, we explored port sustainability around these issues and this confirmed these factors are key, but that a number of complexities and subjectivities exist which need to be considered to successfully implement green port. For example, although economic leverage is indeed key, government officials' and ocean carriers perspectives often differed regarding how to achieve

[5] Ministry of Transportation and Communication (MOTC). http://www.motc.gov.tw/en/
In Taiwan, MOTC is the principle control and supervision unit regarding port policy management and can deal with potential conflicts when conducting green port policies between governmental units (e.g. Maritime Port Bureau and Taiwan International Port Corporation).

this. Ocean carriers emphasized maintaining profitability, whereas government officials voiced ideas of making profit themselves through punitive measures for ocean carriers who did not meet certain environmental criteria. Related to this was the importance of how such measures should be implemented. On the one hand, a number of ocean carriers commented on how they were following existing global measures (for example IMO guidelines for the treatment of oil). On the other hand they also commented on the fact that not all policies were implemented uniformly throughout ports in Taiwan (for example that bio-fuel was added to diesel in some ports but not others). Government officials on the one hand talked about the existence of numerous bodies to help with the implementation of any policies (for example the Ministry of Transportation and Communication, the Environmental Protection Administration, the Ministry of Economic Affairs and so on) but on the other hand of resistance from certain government organizations to post sustainability initiatives (e.g. local government's opposition to the construction of wind turbines). Thus, although our FAHP analysis shows the salience of economic leverage, it is often through a consideration of policy implementation that such leverage can be achieved, and consideration to the different views of all stakeholders involved is critical. Without this, companies may use other ports.

These issues and perspectives are intended to help focus for discussion to implement green port. Such discussion could be led at a higher, central government (e.g. Ministry of Transportation and Communication) level by an umbrella organization. On the basis of the results here, and even though Taiwan has received accolades such as the certification of Eco-port in Europe (see 4.2.2), one approach is for the Taiwanese government at a higher central government level to develop further and study how exemplary ports (e.g. Seattle[6]) have introduced green port and seek to emulate this in Taiwan, and that further research be conducted to help facilitate this. For example, port authorities in Taiwan could survey and prioritize the main pollution sources of port operations (including ship, terminal facilities, truck, warehouse, building, etc.) in each port. It is suggested a flexible port pricing and "carrot and stick" strategy could encourage port operators to adopt greener operation methods (e.g. low sulfur fuel, shore power, clear truck, clear ballast, water recycle, solar energy, etc.) and a pollution tax could reduce the burden of port environment. Effective pricing strategies based on demand management could reduce the phenomenon of peak and non-peak hour and consequently reduce fuel waste and air pollutions. In addition, port authorities could use an annual environmental

[6] Seattle has joined Northwest Ports Clean Air Strategy which is a collaborative project and has linked with Port of Tacoma (U.S.), and Port Metro Vancouver (Canada). They mutually develop clear air strategies in collaboration with government, industry and commuter stakeholders. They set up clear pollution reduction targets in various pollution sources, such as ocearn going vessels, harbor vessels, cargo handling equipment, trucks, rail, administration during the base year (2007) to target year (2020). https://www.portseattle.org/page/northwest-ports-clean-air-strategy.

excellence awards program[7] to select best green operators in various operation fields and provide a bonus or port fee reduction. Finally, having an automatic terminal (intelligent port or smart port) is an important development trend for enhancing operation efficiency and reducing pollution. In Europe, Hamburg and Rotterdam are examples of such ports, and decision makers in port authorities/operators in Taiwan could learn these successful experiences to apply developments in their port operations. Regarding ocean carriers, since the regulation rules will become stricter in the future, it is suggested to invest and develop efficient/greener ships with Environment Ship Index (ESI).[8] From the perspective of long term sustainable development, ocean carriers should actively strengthen the collaboration relations with ship manufacturers, port authorities, central/local government, and other stakeholders in order to understand green port issues research (e.g. clear fuel, facilities electrification, etc.) and development trends and adopt mitigation strategies.

At present, some feasible green strategies can be conducted in Taiwan's port, such as covered warehousing facilities, automatic gate lane, vehicle washing lane, noise/water/sediment quality monitoring system, water treatment facilities, habitat conservation, green building (with rooftop photovoltaic system). Nevertheless, some barriers to green strategies still exist. Taking shore power system as example, although most of Taiwan's international ports have planned these facilities, most ocean carriers do not invest in shore power system in their old ships due to there being no compulsory rule in Taiwan. Also, a fair charge rate of shore power system has been under discussion. Therefore, Taiwan's government units (e.g. Ministry of Transportation and Communication, Ministry of Economic Affairs, Environmental Protection Administration, etc.) should conduct budget planning and provide financial incentives to encourage and assist ocean carriers to invest new capital equipment and replace old ones through effective environmental legislation implementation. Such policies will inevitably require key, and perhaps hard, decisions to be made on budget allocation and financing of such approaches. What needs to be considered in this context is what specific green port policies are really necessary and important for Taiwan. We hope the above results can help inform considerations and provide theory and data both for such decisions and for further research in the area.

Acknowledgements

This work was supported by Ministry of Science and Technology, Taiwan (grant numbers MOST 105-2410-H-035-030).

[7] https://www.portseattle.org/programs/environmental-excellence-awards-program
[8] http://www.environmentalshipindex.org/Public/Home

References

Ahmed, S., Ahmed, S., Shumon, M.R.H., Falatoonitoosi, E., Quader, M.E., 2017. A comparative decision-making model for sustainable end-of-life vehicle management alternative selection using AHP and extent analysis method on fuzzy AHP, International Journal of Sustainable Development & World Ecology 23(1), 83-97.Alkhafaji, A.F., 1989. A stakeholder approach to corporate governance. Managing in a Dynamic Environment. Quorum Books, Westport, CT.

Bailey, D., Solomon, G., 2004. Pollution prevention at ports: Clearing the air. Environmental Impact Assessment Review 24(7-8), 749-774.

Bateman, S., 1996. Environmental issues with Australian ports. Ocean & Coastal Management 33(1-3), 229-247.

Berechman, J., Tseng, P.H., 2012. Estimating the environmental costs of port related emissions: The case of Kaohsiung. Transportation Research Part D: Transport and Environment 17(1), 35-38.

Bergqvist, R., Egels-Zandén, N., 2012. Green port dues-The case of hinterland transport. Research in Transportation Business & Management 5, 85-91.

Bird, C.M. 2005. How I stopped dreading and learned to love transcription. Qualitative Inquiry 11(2), 226-248.

Blinge, M., 2014. Policy measures to realize green corridors-A stakeholder perspective. Research in Transportation Business & Management 12, 55-62.

Borriello, F., 2013. The sustainability of Mediterranean port areas: environmental management for local regeneration in Valencia. Sustainability 5(10), 4288-4311.

Bouman, E.A., Lindstad, E., Rialland, A.I., Strømman, A.H., 2017. State-of-the-art technologies, measures, and potential for reducing GHG emissions from shipping - A review, Transportation Research Part D: Transport and Environment 52, 408-421.

Buckley, J.J., 1985. Fuzzy hierarchical analysis, Fuzzy Sets and System 17(3), 233-247.

Chang, D.Y., 1996. Application of the extent analysis method on fuzzy AHP, European Journal of Operational Research 95(3), 649-655.

Chang, C.C., Jhang, C.W. 2016. Reducing speed and fuel transfer of the Green Flag Incentive Program in Kaohsiung Port Taiwan, Transportation Research Part D: Transport and Environment 46, 1-10.

Chang, V., Tovar, B., 2014. Efficiency and productivity changes for Peruvian and Chilean ports terminals: a parametric distance functions approach, Transport Policy 31, 83-94.

Chang, C.C., Wang, C.M., 2012. Evaluating the effects of green port policy: Case study of Kaohsiung harbor in Taiwan. Transportation Research Part D: Transport and Environment 17(3), 185-189.

Charmaz, K. 2011. Grounded Theory Methods in Social Justice Research. In Denzin, N.K., & Lincoln, Y.S. (Eds). The Sage Handbook of Qualitative Research. (359-380) Thousand Oaks, Calif: Sage.

Chou, C.C., 2010. AHP model for the container port choice in the multiple-ports region. Journal of Marine Science and Technology 18(2), 221-232.

Clarkson, M.B.E., 1995. A stakeholder framework for analyzing and evaluating corporate social performance. Academy of Management Review 20(1), 92-117.

Corbett, J.J., Farrell, A., 2002. Mitigating air pollution impacts of passenger ferries. Transportation Research Part D: Transport and Environment 7(3), 197-211.

Cortazzi, M., Pilcher, N., Jin, L., 2011. Language choices and 'blind shadows': investigating interviews with Chinese participants. Qualitative Research 11(5), 505-535.

Cruz, M.R.P., Ferreira, J. J., Azevedo, S. G., 2013. Key factors of seaport competitiveness based on the stakeholder perspective: An Analytic Hierarchy Process (AHP) model. Maritime Economics & Logistics 15(4), 416-443.

Cullinane, K., Cullinane, S., 2013. Atmospheric emissions from shipping: The need for regulation and approaches to compliance. Transport Reviews 33(4), 377-401.

Darbra, R.M., Pittam, N., Royston, K.A., Darbra, J.P., Journee, H., 2009. Survey on environmental monitoring requirements of European ports. Journal of Environmental management 90(3), 1396-1403.

David, M., Gollasch, S., 2008. EU shipping in the dawn of managing the ballast water issue. Marine Pollution Bulletin 56, 1966-1972.

Dooms, M., Lugt, L., Langen, P.W., 2013. International strategies of port authorities: The case of the port of Rotterdam authority, Research in Transportation Business & Management 8, 148-157.

Dulebenets, M.A. 2016. Advantages and disadvantages from enforcing emission restrictions within emission control areas, Maritime Business Review 1(2), 107-132.

Flyvbjerg, B. 2006. Five misunderstandings about case-study research. *Qualitative inquiry*, *12*(2), 219-245.

Heij, C., Bijwaard, G. E., Knapp, S., 2011. Ship inspection strategies: Effects on maritime safety and environmental protection, Transportation Research Part D: Transport and Environment 16(1), 42-48.

Heij, C., Knapp, S., 2012. Evaluation of safety and environmental risk at individual ship and company level, Transportation Research Part D: Transport and Environment 17(3), 228-236.

Hollen, R.M.A., Bosch, F.A.J., Volberda, H.W., 2015. Strategic levers of port authorities for industrial ecosystem development, Maritime Economic & Logistics 17(1), 79-96.

Homsombat, W., Yip, T.L., Yang, H., Fu, X., 2013. Regional cooperation and management of port pollution. Maritime Policy & Management 40(5), 451-466.

Jaccoud, C., Magrini, A., 2014. Regulation of solid waste management at Brazilian ports: Analysis and proposals for Brazil in light of the European experience. Marine Pollution Bulletin 79(1), 245-253.

Kabir, G., Hasin, M.A.A., 2011. Comparative analysis of AHP and Fuzzy AHP models for multicriteria inventory classification, International Journal of Fuzzy Logic System 1(1), 1-16.

Klopott, M., 2013. Restructuring of environmental management in Baltic ports: Case of Poland. Maritime Policy & Management 40(5), 439-450.

Ko, T.T., Chang, Y.C., 2010. Integrated marine pollution management: A new model of marine pollution prevention and control in Kaohsiung, Taiwan. Ocean & Coastal Management 53(10), 624-635.

Kontovas, C., Psaraftis, H.N., 2011. Reduction of emissions along the maritime intermodal container chain: Operational modes and policies, Maritime Policy & Management 38(4), 451-469.

Knudsen, O.F., Hassler, B., 2011. IMO legislation and its implementation: Accident risk, vessel deficiencies and national administrative practices. Marine Policy 35, 201-207.

Lagring, R., Degraer, S., de Montpellier, G., Jacques, T., Van Roy, W., Schallier, R., 2012. Twenty years of Belgian North Sea aerial surveillance: A quantitative analysis of results confirms effectiveness of international oil pollution legislation. Marine Pollution Bulletin 64(3), 644-652.

Lam, J.S.L., Notteboom, T., 2014. The greening of ports: A comparison of port management tools used by leading ports in Asia and Europe. Transport Reviews 34(2), 169-189.

Lashof, D.A., Ahuja, D.R., 1990. Relative contributions of greenhouse gas emissions to global warming. Nature 344, 529-531.

Le, X.Q., Vu, V.H., Hens, L., Van Heur, B., 2014. Stakeholder perceptions and involvement in the implementation of EMS in ports in Vietnam and Cambodia. Journal of Cleaner Production 64, 173-193.

Lee, T., Yeo, G.T., Thai, V.V., 2014. Environmental efficiency analysis of port cities: slacks-based measure data envelopment analysis approach, Transport Policy 33, 82-88.

Lindstad, H., Eskeland, G., 2016. Environmental regulations in shipping: Policies leaning towards globalization of scrubbers deserve scrutiny, Transportation Research Part D: Transport and Environment 47, 67-76.

Liu, Q., Lim, S. H., 2017. Toxic air pollution and container port efficiency in the USA, Maritime Economics & Logistics 19(1), 94-105.

Liu, T.K., Tsai, T.K., 2011. Vessel traffic patterns in the Port of Kaohsiung and the management implications for preventing the introduction of non-indigenous aquatic species. Marine Pollution Bulletin 62(3), 602-608.

Liu, T.K., Sheu, H.Y., Tsai, J.Y., 2014. Sulfur dioxide emission estimates from merchant vessels in a port area and related control strategies. Aerosol and Air Quality Research 14(1), 413-421.

Lopes, C., Antelo, L.T., Franco-Uría, A., Botana, C., Alonso, A. A., 2013. Sustainability of port activities within the framework of the fisheries sector: Port of Vigo (NW Spain). Ecological Indicators 30, 45-51.

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

Mellin, A., & Rydhed, H., 2011. Swedish ports' attitudes towards regulations of the shipping sector's emissions of CO_2. Maritime Policy & Management 38(4), 437-450.

Moon, D.S.H., Woo, J.K., 2014. The impact of port operations on efficient ship operation from both economic and environmental perspectives. Maritime Policy & Management 41(5), 444-461.

Ng, A.K., Chen, S.L., Cahoon, S., Brooks, B., Yang, Z., 2013. Climate change and the adaptation strategies of ports: The Australian experiences. Research in Transportation Business & Management 8, 186-194.

Ng, A.K.Y., Song, S., 2010. The environmental impacts of pollutants generated by routine shipping operations on ports. Ocean & Coastal Management 53, 301-311.

Pavlic, B., Cepak, F., Sucic, B., Peckaj, M., Kandus, B., 2014. Sustainable port infrastructure, practical implementation of the green port concept. Thermal Science 18(3), 935-948.

Peris-Mora, E., Orejas, J.D., Subirats, A., Ibáñez, S., Alvarez, P., 2005. Development of a system of indicators for sustainable port management. Marine Pollution Bulletin 50(12), 1649-1660.

Petrosillo, I., Valente, D.V., Zaccarelli, N., Zurlini, G., 2009. Managing tourist harbors: Are managers aware of the real environmental risks? Marine Pollution Bulletin 58, 1454-1461.

Pruyn, J. 2017. Are the new fuel-efficient bulkers a threat to the old fleet? Maritime Business Review, 2(3), 224-246.

Rees, W.E., 1992. Ecological footprints and appropriated carrying capacity: What urban economics leaves out. Environmental Urban 4, 121-130.

Rohde, F., Pape, B., Nikolajsen, C. Zero-Emission Ferry Concept for Scandlines, STG International Conference on Ship Efficiency, 23-24, September, 2013, Hamburg.

Satty, T.L., 1980. The Analytic Hierarchy Process. McGaraw-Hill Companies, Inc., New York.

Serebrisky, T., Sarriera, J.M., Suárez-Alemán, A., Araya, G., Briceño-Garmendía, C., Schwartz, J., 2016. Exploring the drivers of port efficiency in Latin America and the Caribbean,

Soylu, K., Dumville, J.C., 2011. Design for environment: The greening of product and supply chain, Maritime Economics & Logistics 13(1), 29-43.

Sys, C., Vanelslander, T., Adriaenssens, M., Rillaer, I.V., 2016. International emission regulation in sea transport: Economic feasibility and impact, Transportation Research Part D: Transport and Environment 45, 139-151.

Tseng, P.H. Pilcher, N., 2015. A study of the potential of shore power for the port of Kaohsiung, Taiwan: to introduce or not to introduce? Research in Transportation Business & Management 17, 83-91.

Tzannatos, E., 2010. Ship emissions and their externalities for the port of Piraeus - Greece. Atmospheric Environment 44, 400-407.

Ugboma, C., Ugboma, O., Ogwude, I.C., 2006. An Analytic Hierarchy Process (AHP) Approach to Port Selection Decisions – Empirical Evidence from Nigerian Ports, Maritime Economics & Logistics 8(3), 251-266.

Vermeer, H.J., 2004. Skopos and commission in translational action. In: Venuti L (ed.) The Translation Studies Reader (2nd Edition). London: Routledge, 221-232.

Villalba, G., Gemechu, E.D., 2011. Estimating GHG emissions of marine ports-The case of Barcelona. Energy Policy 39, 1363-1368.

Wackernagel, M., Rees, W., 1996. Our ecological footprint: reducing human impact on the earth. New Society Publishers, Gabriola Island, BC.

Wang, C., Corbett, J.J. Winebrake, J.J., 2007. Cost-effectiveness of reducing sulfur emissions from ships. Environmental Science Technology 41, 8233-8239.

Wang, Y., Jung, K.A., Yeo, G.T., Chou, C.C., 2016. Selecting a cruise port of call location using the fuzzy-AHP method: A case study in East Asia, Tourism Management 42, 262-270.

Yap, W.Y., Lam, J.S.L., 2013. 80 million-twenty-foot-equivalent-unit container port? Sustainability issues in port and coastal development. Ocean & Coastal Management 71, 13-25.

Yang, C.S. 2016. Evaluating the use of alternative maritime power in Taiwan, Maritime Business Review 1(3), 208-224.

Yang, C.C., Tai, H.H., Chiu, W.H., 2014. Factors influencing container carriers' use of coastal shipping. Maritime Policy & Management 41(2), 192-208.

Ying, H., Yijun, J., 2011. Discussion on green port construction of Tianjin Port. Energy Procedia 11, 4059-4064.

Zadeh, L.A., 1965. Fuzzy Sets. Inform Control, 8(3), 338-353.

Zadeh, L.A., 1975. The concept of a linguistic variable and its application to approximate reasoning—I, Information Sciences 8(3), 199-249.

Zis, T., North, R.J., Angeloudis, P., Ochieng, W.Y., Bell, M.G.H., 2014. Evaluation of cold ironing and speed reduction policies to reduce ship emissions near and at ports, Maritime Economics & Logistics 16(4), 371-398.

Highlights

- This paper investigates factors affecting green port policies
- Quantitative fuzzy Analytic Hierarchy Process is used
- Qualitative in-depth interviews approaches are also used
- This combined approach reveals subtleties and complexities for policy makers
- Environmental regulation and economic leverage are the top two key factors