Examining sustainability performance at ports: Port managers' perspectives on developing sustainable supply chains

Chin-Shan Lu*

Professor, Department of Logistics and Maritime Studies,

Director, C.Y. Tung International Centre for Maritime Studies,

The Hong Kong Polytechnic University,

Hung Hom, Kowloon, Hong Kong

Tel: +852 2766 4066

Fax: +852 2330 2704

Email: chin-shan.lu@polyu.edu.hk;

Kuo-Chung Shang

Professor, Department of Transportation Science, National Taiwan Ocean University,

2 Pei-Ning Road, Keelung 20224, Taiwan, ROC

Tel: +886-2-24622191 ext. 7011

Email: gordon@mail.ntou.edu.tw

Chi-Chang Lin

Assistant Professor, Department of Marketing and Logistics Management, Chihlee Institute of Technology, Sec. 1, Wunhua Rd., Banciao District, New Taipei City 22050 Taiwan, R.O.C

Tel:+886-2-2257-6167 ext.1789

Email: josephlin@mail.chihlee.edu.tw; joseph5473@gmail.com

ABSTRACT

This research examined the effects of sustainable supply chain management (i.e. internal sustainable management and external sustainable collaboration) on sustainability performance in the port context. Structural equation modeling was employed in this study using survey data collected from 135 respondents holding the position of supervisor or above in three major international port corporations in Taiwan (i.e. Keelung, Taichung and Kaohsiung). Results indicated that external sustainable collaboration is positively associated with internal sustainable management, and internal sustainable management positively influences sustainability performance. This research also found that internal sustainable management mediates the effects of external sustainable collaboration on sustainability performance. The theoretical implications from the research findings are that the relationships between supply chains and sustainability performance, an empirical result that has not been found in current port literature. The practical implications are that port managers need to develop sustainable management strategies that incorporate the development of specific internal sustainable management such as resources, competences, capabilities, and supply chain collaboration with external stakeholders (i.e. carriers and service suppliers), in order to improve sustainability performance.

Keywords: port; sustainable supply chain; sustainability performance; structural equation modeling

1. Introduction

Ports are key nodes in the supply chain and transportation network. While efficient ports are vital to the economic development of a particular country or area, their development should be balanced against environmental protection and social issues. In recent decades, port sustainability has become an increasing focus of attention for port policy makers (The Port of Los Angeles, 2013), maritime reports (UNCTAD, 2014), and journals in various management fields (Darbra et al. 2009; Acciaro et al., 2014). For example, the Port of Los Angeles has highlighted major goals to increase sustainability in port operations and has emphasized five major sustainability areas, namely, community investment, land use and infrastructure, public health, energy and resource conservation and financial strength (The Port of Los Angeles, 2013). Increases in container throughput and trade volume intensify noise, air and oil pollution. Such pollution threatens public health and safety, so port sustainability is increasingly being advocated by ocean carriers, terminal operators, stevedores,

government, communities, and the general public.

Sustainability was defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" by the World Commission on Environment and Development (WCED, p. 43) in 1987, and this definition is widely used in several articles (Brundtland, 1987). Sustainability refers to the right of human beings to enjoy health and wealth and live harmoniously together in a way that meets the development needs of the present while protecting the environment for the generations to come (UNCSD, 1993). Sustainability also can be defined as increasing the welfare of the present generation while simultaneously not decreasing the welfare of the next generation (Pearce and Warford, 1993). Pronk and Haq (1992) explained sustainability as a fair opportunity for all human beings, not only particular interest groups, to achieve economic growth without further depleting natural resources and environmental capacity. These definitions of sustainability highlight three principal components of sustainability, namely: environmental sustainability, economic sustainability, and social sustainability (Glavic and Lukman, 2007; Quak and Koster, 2007). They also explore the widespread perception that negative influences on environment and society are trade-offs with economic development (Behrends et al., 2008).

A growing body of previous studies has discussed sustainability measures and green policy in the port sector (Gilman, 2003; Peris-Mora et al., 2005; Darbra et al., 2009). Peris-Mora et al. (2005) developed a system of sustainable environmental management for use by port authorities. Shiau and Chuang (2015) proposed a variety of port sustainability indicators including environmental, economic, and social aspects using social construction of technology based on a case study of Keelung Port. Thirty-six port sustainability indicators were suggested for port operators. Acciaro et al. (2014) developed an innovative conceptual framework for evaluating the environmental sustainability of ports. They found that objectives of sustainability linked to regulatory and landlord port functions seem to prevail. Lam (2015) discussed a sustainable maritime supply chain based on the Quality Function Deployment and Analytical Network Process approaches. The use of green-designed ships, engines and machinery was found to be the most important design requirement in major container shipping lines. Notably, the difference between the terms *sustainability* and *green* is significant. Sustainability consists of the issues of economy, environment and society, whereas green is only based on the exploitation of the environment. That is, green does not include the prosperity or welfare of a society (Zervas, 2012).

In particular, several studies have found that port sustainability should be implemented within an organization and in collaboration with port partners across key members of the supply chain, such as ocean carriers, terminal operators, truck companies, stevedoring companies, and depot operators (Gul and Cimen, 2012; Linton et al., 2007; Lu et al., 2010). Linton et al. (2007) stated that sustainability should be implemented by integrating all production functions throughout the manufacturing process. Port corporations are major operators at ports; however, the major sources of pollutants are their users or suppliers such as ocean-going vessels, harbor craft, cargo handling equipment, and trailers. Therefore, effective implementation of sustainability in ports needs to take into account sustainable management both within organizations and in partnership with external members, including terminal operators, stevedoring companies and trucking and warehousing operators (Lu et al., 2010).

While several researchers and port operators recognize the need to measure sustainable management across the supply chain, it seems that there are relatively few empirical studies which discuss the impact of sustainable port supply chains on sustainability performance (Peris-Mora et al., 2005). To fill this gap, this study aims to examine the relationships between sustainable supply chains (i.e. internal sustainable management and external sustainable collaboration) and sustainability performance in the context of port operations in Taiwan. Taiwan is an island-economy which is highly dependent on foreign trade. According to the Ministry of Transportation and Communications (Ministry of Transportation and Communications, 2014), more than 99 % of annual trade in Taiwan is carried by maritime transport and handled through sea ports. There are three major container ports in Taiwan: Kaohsiung, Keelung and Taichung. Container traffic in Taiwan slightly increased from 10,427,714 TEUs (twenty foot equivalent units) to 14,046,868 TEUs in the period from 2001 through 2013 (Ministry of Transportation and Communications, 2014). Among these ports, the Port of Kaohsiung is the largest container port in Taiwan, accounting for 70.7% of total container traffic in 2013, and ranked in the top 14 container ports in the world (Breet, 2014). With this significant growth of cargo volume, the issue of sustainability in ports has become increasingly important and of concern to port corporations and agencies in Taiwan.

There are five sections in this paper. Following this introduction is a review of previous literature as a theoretical basis to evaluate the effects of internal operations and external collaboration on sustainability performance. Several research hypotheses are formulated in this section. Section 3 discusses the research methodology, including the survey questionnaire, sampling techniques, and data analysis methods.

Section 4 presents the analytical results of factor analysis and structural equation modeling. The discussion and conclusion drawn from the research findings and their implications for port policy-makers are discussed in Section 5 and Section 6.

Literature review and hypotheses

As mentioned earlier, there are a number of reports and articles that have discussed sustainable management in the port sector (Gilman, 2003; Peris-Mora et al., 2005; Darbra et al., 2009). However, the techniques and measures described in the literature focus on developing sustainable management for an organization and do not capture the key concerns of the supply chain in total or how each organization affects overall sustainable management performance. Some researchers recognize the need to measure sustainability across the supply chain and provide a framework for developing sustainable supply chains to drive sustainable management performance (Gul and Cimen, 2012; Lu et al., 2010).

2.1 Sustainable Supply Chains in the Port Sector

The term "supply chain" has a number of definitions. The Council of Supply Chain Management Professionals (CSCMP) (2010) defines supply chain management as encompassing the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies. Mentzer et al. (2001) defined supply chain management as the systemic, strategic coordination of traditional business functions and tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole. In their view, supply chain management includes: (1) a systematic approach to reviewing the supply chain as a whole, and to managing the total flow of goods inventory from the supplier to the ultimate customer; (2) a strategic orientation toward cooperative efforts to synchronize and converge intra firm and inter firm operational and strategic capabilities into a unified whole; and (3) a customer focus aiming to create unique and individualized sources of customer value, leading to customer satisfaction.

Supply chain management has also been seen as the integration of key business processes from the end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders (Lambert and Cooper, 2000). Over the past two decades, the focus on optimizing operations has

moved from a specific organization to the entire supply chain. A focus on the supply chain is a step towards the broader adoption and development of sustainability, since the supply chain considers the product from the initial processing of raw materials to delivery to the customer. However, sustainability must also integrate issues and flows that extend beyond the core of supply chain management (Linton et al., 2007). Supply chain management should consider the effect of functions other than logistics on business processes spanning multiple organizations. Thus, research on sustainable or environmental management needs to view a whole supply chain as one entity and any management systems should span the entire supply chain.

Lambert et al. (2006) defined a sustainable supply chain as one that integrates the business flow from initial suppliers to end customers, and provides stakeholders with valued-added products and services by employing a sustainable operating concept. A sustainable supply chain has also been defined as one that strategically integrates external supply chain members and undertakes internal organizational reform in order to increase long-term profits and achieve the goal of environmental, economic and social development (Linton et al., 2007).

A number of previous studies have demonstrated the importance of suppliers, focal companies, customers, the government and stakeholders when exploring the impact of sustainable supply chain management on firm performance (Seuring and Muller, 2008). Various types of collaboration have been proposed in the extant literature, such as internal collaboration, customer collaboration, and supplier collaboration (Lambert et al. 2006). Consideration of the dimensionality of sustainable supply chains is important to understand the way that the individual dimension influence sustainable performance, as well as how they influence each other. While some studies propose sustainable supply chain as a unidimensional construct (e.g. Carter and Rogers, 2008; Linton et al., 2007; Pagell and Wu, 2009), others divide sustainable supply chain into internal collaboration and external collaboration (Flynn et al., 2010; Stank et al., 2001). While each of these dimensions reflect an important attribute of sustainable supply chain, there is a great deal of similarities between them. Sustainable port supply chains in this study can be defined as those which integrate external port supply chain members (e.g. shipping companies, port services providers) and undertake internal sustainable management in order to achieve the goal of sustainability in three major aspects: environmental, economic and social (Gul and Cimen, 2012; Lu et al., 2010; Seuring and Muller, 2008; Shang et al, 2010; Zhu et al, 2007). As a result, we focus specifically on internal sustainable management, customer/carrier collaboration, and supplier collaboration in this study.

2.2 Sustainability performance

Previous studies on sustainable supply chains have usually emphasised green supply chain management, and have therefore mostly focused on social and environmental aspects. (Seuring and Muller, 2008; Marlow, 2008). With the increasingly awareness of public participation, the stakeholders' attitude has been notable issue in the development of a port (Shiau and Chuang, 2015). Hence, all three areas of sustainability (including environmental, economic, and social aspects) need to be considered simultaneously when evaluating sustainability performance (Larson et al., 2011; Rohács and Simongáti, 2007; Seuring and Muller, 2008; Shiau and Chuang, 2015). Environmental dimensions consisted of air quality, greenhouse gas emissions, soil and land resources, debris, light and noise problems, water and climate change, all of which need to be taken into consideration. Economic dimensions included benefits to port users, fair competition, employment, local area economic development, tourism, and port investment (Ryan and Throgmorton, 2003; The Port of Long Beach Green Port, 2005; Sydney Ports, 2007; Department of Transport, 2010). Social dimensions consisted of population growth, port area availability, security and safety, and neighboring relationships (Abbott and Monsen, 1979; Holmes, 1978; Peris-Mora et al., 2005; Shiau and Chuang, 2015). Based on previous studies, nine performance items were selected in this study to measure sustainability performance (see Table 4).

2.3 Sustainable Supply Chain and Sustainability Performance

Several studies have examined sustainability in ports from a supply chain perspective (Acciaro et al., 2014; Lam, 2015; Lam and Notteboom, 2014; Leone and Iris, 2015; Shiau and Chung, 2015; Zhang et al., 2014). For example, Lam and Notteboom (2014) studied management tools related to sustainable management activities in ports including pricing, monitoring and measuring, market access control and environmental standard regulation. Acciaro et al. (2015) found that several sustainable management attributes were linked to green objectives for the function of a landlord port. These attributes included: protection of port ecosystems, ensuring environmental sustainability of economic activities linked to the port, optimal space allocation and creation of green recreational areas, provision of adequate waste reception facilities, attention to sustainable construction methods when building infrastructure, monitoring of pollution, etc. Accordingly, this study hypothesizes the following:

Hypothesis 1 : Internal sustainable management will be positively related to sustainability performance in the port context

In addition, previous studies have suggested that partner relationships among supply chain system members can increase environmental protection performance (Handfield et al., 1997; Sarkis, 2001). Koufterous et al. (2007) used the dimensions of internal

integration, and supplier integration to examine the effects of product innovation on firm profits. Flynn et al. (2010) analyzed the effects of supply chain integration on firm performance by classifying supply chain dimensions as customer integration, supplier integration and internal integration. Testa and Iraldo (2010) indicated that external members of a firm had a positive effect on environmental performance when a firm adopted a green supply chain management strategy. Hence, to achieve sustainable development, ports need to collaborate with external members in the supply chain system.

Collaboration is the process of decision-making among supply chain members. It involves joint ownership of decisions and collective responsibility for sustainable development (Stank et al., 2001). A port that seeks to attain effective sustainable supply chain management through external collaboration with service suppliers and customers should focus on internal sustainable management, so that it may better respond to environmental management requirements and achieve the objective of sustainable development. An effective implementation of a sustainable supply chain will be developed when port partners are willing to work together, understand other points of view, share information and resources, and achieve collective goals (Stank et al., 2001). Prior research has indicated that collaboration leads to improved environmental performance in small-and medium-sized suppliers (Lee and Klassen, 2008). With regard to previous studies on sustainable collaboration in ports, Parola et al. (2014) indicated that service supplier collaboration and customer collaboration are important factors in enhancing port sustainability performance. Acciaro et al. (2015) showed the importance of certain sustainable activities related to external sustainable collaboration with port partners including rewarding or punishing port operators for reaching or failing to reach environmental goals, sharing information with delegated agencies or the public, considering environmental factors in the selection and management of subcontractors, and so on. Gul and Cimen (2012) and Lu et al. (2010) also studied the influence of supply chain stakeholders on sustainability in ports. Accordingly, this study hypothesizes the following:

Hypothesis 2: External sustainable collaboration will be positively related to sustainability performance in the port context

A majority of previous studies have discussed collaboration or integration among members in the supply chain (Handfield et al., 1997; Mentzer et al., 2001; Kleindorfer et al., 2005; Seuring and Muller, 2008; Lam, 2015). Gyöngyi (2005) stated that firms should collaborate with their suppliers, customers and stakeholders to achieve the goal of sustainable development among supply chain members when facing a fast changing operating environment. Stank et al. (2001) found that internal collaboration

and external collaboration are positively related. Interviews we conducted in preparation for this research raise concerns regarding this relationship. The shipping industry is an international industry. Shipping operations should comply with the international shipping conventions or regulation from the International Maritime Organization, International Labor Organization and governments. These shipping conventions include international Convention for the Prevention of Pollution from Ships (MARPOL), International Safety Management Code (ISM Code), International Convention for the Safety of Life at Sea (SOLAS), Maritime Labour Convention (MLC), Port State Control, and so on. However, port corporations in Taiwan are a government owned organization. Therefore, the updated information or implementation of international conventions related to sustainability for ocean carriers will be earlier than port corporations. Although there is a lack of findings on the relationships between external collaboration and internal sustainable management in the literature, we argue that external collaboration with ocean carriers could positively influence internal sustainable management. Thus, this research postulates that:

Hypothesis 3: External sustainable collaboration will be positively related to internal sustainable management in the international port context

3. Methodology

3.1 Sample

Data for the study were collected from a survey questionnaire according to the stages outlined by Iacobucci and Churchill (2010), which include the type of questionnaire, its method of administration, content of individual questions, form of response to, and wording of, each question, question sequence, and physical characteristics of the questionnaire. The sample comprised those who had the position of supervisor or above in three major international port corporations in Taiwan (i.e. Keelung, Taichung, and Kaohsiung). A four-page questionnaire was sent to them in June 2012. A follow-up mailing was sent in July after the initial mailing. The potential effective sample size of 300 was reduced to 294 as six supervisors had left their position. The total number of usable completed questionnaires was 135, of which 62 were from Kaohsiung Port and 37 and 36 from Keelung Port and Taichung Port, respectively. The overall response rate for this study was therefore 45.91%.

The questionnaire sought to obtain a profile of respondents by seeking information relating to their job title, work department, age and years of working experience. The importance of 33 internal sustainable management items and 16 external sustainable

collaboration items was elicited by asking respondents to indicate their level of agreement/disagreement with the items using a five-point Likert scale ranging from "1 = strongly disagree" to " 5 = strongly agree".

Although the response rate in this research was higher than 45%, it was necessary to conduct a non-response bias test as suggested by Armstrong and Overton (1977). Late respondents were assumed to be similar to non-respondents. The Chi-square statistics technique was used to examine differences in responses to questionnaire items between the first and second mailing based on respondents' job title, age, years of working experience, and work department. There were no statistically significant differences in response at the 0.05 level of significance. The information collected from the respondents could therefore be generalized to the target population.

3.2 Data analysis methods

Several research methods were used in this study, including descriptive statistics and exploratory factor analysis. The latter was conducted in order to identify and summarize a large number of internal sustainable management and external sustainable collaboration attributes into a smaller, manageable set of underlying factors or dimensions (Hair et al., 2010). A reliability test was conducted to assess whether these dimensions were adequate.

The assessment of content validity typically involves an organized review of a questionnaire's content to ensure it includes everything it should and does not include anything it should not. The content validity of the questionnaire used in this study was assessed through a review of the literature and interviews with practitioners; in other words, questionnaire questions were based on previous studies and judged to be relevant by 10 supervisors who worked at international port corporations in Taiwan. Confirmatory factor analysis was then conducted to verify measurement models. This involved the use of structural equation modeling software AMOS 6.0 to analyze the measurement models, assess psychometric proprieties, and to specify relationships among the latent variables and the proposed measures.

4. Results of Empirical Analyses

4.1 Characteristics of respondents

Table 1 shows the respondents' profile. More than half of respondents were directors (53.3%), while (29.6%) and (14.1%) were supervisors and senior directors, respectively. Few respondents (1.5%) were Presidents/ Vice presidents or Chief Secretaries or Chiefs. As regards respondents' age, more than half (54.9%) were aged between 31-40 years, and 24.1% and 21% were aged 30 or less and 41 or more,

respectively. Over 90% of respondents had worked in the port for more than 10 years. A much lower percentage (8.6%) had worked in the port for ten years or less. Specifically, the ports of Kaohsiung, Keelung and Taichung were successfully awarded a certification of EcoPort in November 2015 under the rules and regulations of the European Sea Ports Organization (ESPO). The Ecoport certification is an important, internationally recognized criteria of port sustainability (Taiwan International Ports Corporation, 2015). This suggesting that respondents had abundant practical experience of sustainability to answer questions. Table 1 also shows respondents' work departments. Nearly half of respondents (40.8%) worked in the operations department, 12.6% worked in the warehousing department, 11.1% worked in the secretarial department, and 9.6%, 8.9%, 6.7%, 4.4%, 3.7% and 2.2% worked in harbor affairs, information technology, harbor construction, human resource, navigation, and research and development departments, respectively.

< Insert Table 1 about here >

4.2 Factor analysis results

Factor analysis with VARIMAX rotation was employed to reduce 33 internal sustainable management items and 16 external sustainable collaboration items to smaller sets of underlying factors. This helped to detect the presence of meaningful patterns among the original variables and to extract the main internal and external factors as shown in Table 2 and Table 3.

< Insert Table 2 about here >

< Insert Table 3 about here >

To aid interpretation, only variables with a factor loading greater than 0.5 were extracted, which is a conservative criterion based on Kim and Muller (1978). Hence, variables with a factor loading less than 0.50 were eliminated. Four factors were found to underlie the internal sustainable management items in the international port context. They were labeled and are described below:

(1) Factor 1 consisted of 12 items related to sustainability participation. This factor was therefore labeled a sustainability participation dimension. It accounted for 24.53% of the total variance. The sustainable development goals setting had the highest factor loading on this factor.

(2) Factor 2 comprised 12 items which were practice related activities. This factor was therefore labeled a sustainability practice dimension. Mitigating emissions of CO_2 and noise from berthing ships had the highest factor loading on this factor.

Factor 2 accounted for 22.44% of the total variance.

(3) Factor 3 consisted of five items which were associated with policy activities. This factor was therefore designated a sustainability policy dimension. Publishing written sustainable development policies had the highest factor loading on this factor. Factor 3 accounted for 13.35% of the total variance.

(4) Factor 4 comprised four items relating to training activities. This factor was therefore designated a sustainability training dimension. Sustainable development courses being applied effectively in staff's work had the highest factor loading on this factor. Factor 4 accounted for 11.57% of the total variance.

A reliability test based on a Cronbach Alpha statistic was used to test whether these factors were consistent and reliable. Cronbach Alpha values for each dimension shown in Table 2 revealed that the reliability value of each dimension was greater than 0.80, which is considered adequate for a satisfactory level of reliability (Carmines, 1979; Iacobucci and Churchill, 2010; Litwin, 1995; Nunnally, 1978).

Furthermore, Table 3 shows the results of employing factor analysis to reduce the 16 external sustainable collaboration items to smaller sets of underlying factors. Two factors were found to underline the sustainable collaboration items in the international port context. They were labeled and are described below.

(1) Factor 1, a carrier collaboration dimension, comprised eight items. This factor accounted for 40.76% of the total variance. Carriers that were requested to acquire ISO 14001 or an equivalent certificate had the highest factor loadings on this factor.

(2) Factor 2 comprised eight items. These were supplier related activities. This factor was accordingly labeled a supplier collaboration dimension. Port service suppliers that are requested to undertake sustainable development evaluation of their contractors had the highest factor loading on this factor. Factor 2 accounted for 39.60% of the total variance.

The supplier collaboration dimension had the highest average mean scores (mean=3.62), while the carrier collaboration dimension’s average mean score was 3.50. A reliability test based on a Cronbach Alpha statistic was used to test whether these factors were consistent and reliable. The Cronbach Alpha value for each dimension was above 0.90, which is considered to represent a satisfactory level of reliability.

Factor analysis was also used to detect the presence of meaningful patterns in nine

self-reported sustainability performance items in the international port context (see Table 4). Results showed that two sustainability performance dimensions were found to underlie these items. These two dimensions (factors) accounted for 74.64% of the total variance. They were labeled and are described below.

< Insert Table 4 about here >

(1) Factor 1 was called the environmental performance dimension since it consisted of five items related to environmental performance. This factor accounted for 63.42% of the total variance. “I perceive that traffic accidents in port areas have significantly reduced” had the highest factor loading on this factor.

(2) Factor 2 consisted of four items. Since these items were social and economic related items, the factor was therefore called a social and economic performance dimension. “I perceive that port corporations’ service quality has improved” had the highest factor loading on this factor. Factor 2 accounted for 11.22% of the total variance.

Exploratory factor analysis (EFA) and estimations of reliability using Cronbach’s alpha were employed to develop and evaluate measurement scales in this study. While these traditional techniques are useful in the early stages of empirical analysis, where theoretical models do not exist and the basic purpose is exploration, they do not, however, assess unidimensionality (Segars, 1997; O’Leary-Kelly, 1998), nor can unidimensionality be demonstrated by either mathematical or practical examinations (Gerbing and Anderson, 1988; Koufteros, 1999). Several researchers have therefore suggested the use of confirmatory factor analysis (CFA) with multiple-indicator measurement models to assess unidimensionality (Anderson and Gerbing, 1988; Segars, 1997; Lu and Yang, 2010).

4.3 Confirmatory Factor Analysis

Before testing the hypotheses, confirmatory factor analysis, CFA, using AMOS, was performed to ensure the validity of the measurement scales (Anderson and Gerbing, 1988). A number of goodness-of-fit indices recommended by many researchers were used to assess the fit and unidimensionality of the measurement model (Bagozzi and Yi, 1988). The results, as shown in Table 5, revealed an adequate model fit (χ^2/df = 1.74; GFI = 0.95; AGFI = 0.88; TLI = 0.98; NFI=0.97; RMR = 0.01; RMSEA = 0.07), indicating that the proposed model was purified and credible (Bollen, 1989; Hair et al., 2010).

< Insert Table 5 about here >

Convergent validity can be tested by t-values that are all statistically significant on the factor loadings. The t-value in the AMOS output result indicates the critical ratio (C.R.), which represents the parameter estimate divided by its standard error. As a rule of thumb, the C.R. value needs to be greater than 2.00 or smaller than -2.00 for the estimate to be acceptable (Byrne, 2001). Results showed that all C.R. values were significant at the 0.05 level, confirming that all indicators measured the same construct and provided satisfactory evidence of the convergent validity and unidimensionality of each construct (Anderson and Gerbing, 1988). Item reliability (R^2) can be used to measure the reliability of a particular observed variable or item (Koufteros, 1999). Results revealed that all R^2 values were greater than 0.4, providing evidence of convergent validity (Car, 1999).

Discriminant validity was assessed by comparing the average variance extracted (AVE) with the squared correlation between constructs. Discriminant validity exists if items share more common variance with their respective construct than any variance that the construct shares with other constructs (Fornell and Larcker, 1981). As shown in Table 6, the results indicated that the highest squared correlation was 0.490, which was observed between carrier collaboration and supplier collaboration. This value was significantly lower than their individual AVE value of 0.619 and 0.661, respectively. The results therefore demonstrated evidence of discriminant validity for the study variables.

Composite reliability provides a measure of the internal consistency and homogeneity of the items comprising a scale (Iacobucci and Churchill, 2010). This means that a set of latent indicators of a construct are consistent in their measurement. The reliability of a construct can be estimated using AMOS output results. Such reliability is the degree to which a set of two or more indicators share the measurement of a construct. Highly reliable constructs are those in which the indicators are highly inter-correlated, indicating they are all measuring the same latent construct. The range of values for reliability is between 0 and 1. Results in this study revealed that the reliability of the sustainability participation, sustainability practices, sustainability policy, sustainability training, carrier collaboration, supplier collaboration, environmental performance and social and economic performance constructs was greater than 0.8. All constructs therefore exceeded the recommended level of 0.60 (Bagozzi and Yi, 1988; Sanchez-Rodriguez et al., 2005).

< Insert Table 6 about here >

4.4 Results of hypotheses testing

After confirming the fit of the measurement model, the study proceeded to assess the

proposed structural model and examine the hypothesized relationships. Figure 1 shows that the data adequately supported the estimated model. The Chi-Square statistic ($\chi 2$ =29.586, df =17) at 0.029 was slightly above the 0.05 level of significance. In addition, the goodness of fit index was calculated to be 0.945 and the adjusted goodness-of-fit index yielded 0.884 after adjustment was made for degrees of freedom relative to the number of variables. This indicated that 88.4% of the variance and covariance in the data observed were predicted by the estimated model. Moreover, the results of fitting the structural model to the data revealed that the model had a good fit as indicated by the normed fit index (NFI= 0.966), comparative fit index (CFI=0.985), root mean square residual (RMR= 0.013) and root-mean-square error of approximation (RMSEA =0.07).

< Insert Figure 1 about here >

Table 7 summarizes the hypotheses testing results which indicated that all hypothesized relationships were significant and in the expected direction, except for the path from external sustainable collaboration to sustainability performance, which was shown to be insignificant. As shown in Figure 1, internal sustainable management was found to have a significant relationship with sustainability performance (estimate = 0.81, C.R. = 3.23), and external sustainable collaboration was significantly associated with internal sustainable management (estimate = 0.91, C.R. = 11.68). Thus, hypotheses H1 and H3 were supported. As regards the relationship between external sustainable collaboration and sustainability performance, the results indicated that there was no direct impact of external sustainable collaboration on sustainability performance in this study. Hypothesis H2 was therefore not supported. Nevertheless, the results suggested that external sustainable collaboration had an influence on internal sustainable management and indirectly affected the port corporations' sustainability performance.

Hair et al. (2010) suggested that a mediating effect exists if the relationship between independent and dependent variables is reduced in magnitude and becomes insignificant. Accordingly, further analysis was conducted to examine whether internal sustainable management plays an intermediary role between external collaboration and sustainability performance.

< Insert Table 7 about here >

As shown in Figure 2, external sustainable collaboration was used as an independent variable in order to examine whether it had a positive influence on sustainability performance. While the study findings did not provide evidence that external sustainable collaboration had a positive influence on sustainability performance, they

suggested that it had an indirect influence via internal sustainable management and mediated the relationship between external sustainable collaboration and sustainability performance.

< Insert Figure 2 about here >

5. Discussions

While prior research has suggested that supply chain management has a positive influence on performance (Klassen and McLaughlin, 1996; Christopher and Ryals, 1999; Wolf, 2011), few studies have examined the relationship between a port's internal sustainable management and external sustainable collaboration with customers and suppliers (Pagell and Wu, 2009; Wolf, 2011) and the potential of such collaboration to make the supply chain more sustainable. Applying the notion of collaboration to sustainability may help us to better understand the practices which make the supply chain more sustainable and to assess the impact of such practices on sustainability performance (Wolf, 2011). To the best of the authors' knowledge, no earlier research has examined sustainable supply chain management in the port context.

Several implications can be drawn from the findings of this study for port decision-makers, corporations, managers and sustainable development. First, port-decision makers in sustainable management need to integrate external customers (i.e. carriers) and supply chain partners (i.e. terminal operators, truck companies, and stevedoring companies) with internal sustainable management to improve their sustainability performance. Second, with respect to internal sustainable management items, setting sustainable development goals and participating in sustainable development programs had the highest mean scores (see Table 2). This suggests that port corporations should pay attention to setting sustainable development goals, having regulations and a clear organization of responsibility, and encouraging staff participation in training programs, in order to implement sustainable development. Third, the study results indicated that internal sustainable management was positively associated with sustainability performance, including environmental, social and economic performance. These findings are consistent with those reported in prior studies (Mentzer et al., 2001; Zhu et al., 2008; Azevedo and Carvalho, 2011). Fourth, while the study findings did not provide evidence that external sustainable collaboration had a positive influence on sustainability performance, they did suggest that it had an indirect influence via internal sustainable management. Internal sustainable management plays a pivotal role in the international port operations context and is greatly improved by both carrier collaboration and collaboration with port service

suppliers. Finally, this study found external sustainable collaboration to be positively associated with international sustainable management. It should be noted that these two dimensions were significantly correlated. This implies that the establishment of effective sustainable management to improve sustainability performance requires a combination of these two dimensions (Stank et al., 2001; Wolf, 2011).

6. Conclusions

Given the social pressures put on ports to be more environmentally responsive, knowledge of how to respond to these pressures more easily and effectively should be useful. This study's findings have important implications for port managers and the sustainable development sector. Port managers should develop sustainable management strategies that incorporate the development of specific internal resources, competences, and capabilities, that can be deployed in the introduction of sustainable management initiatives based on the supply chain management approach. Managers should also learn how to develop supply chain collaboration with external stakeholders, who include carriers and service suppliers, in order to facilitate the implementation of sustainable supply chain management and further improve sustainability performance.

This study provided empirical evidence on the influence of sustainable supply chain management on sustainability performance in the international port context. However, a number of limitations of the study have to be noted, and these also suggest directions for future research. First, this study specifically focused on international ports in Taiwan. Different port supply chain members may have different levels of port sustainability concerns. This may affect the generation of the conceptual model. Future research would profit from more diverse viewpoints, such as the perspective of carriers, stevedoring companies, truck companies, terminal operators, and other groups (Bell et al., 2012). If port partners (i.e. carriers and terminal operators) could collaborate with port corporations or agencies to improve sustainability at ports, they could obtain benefits such as a potential increase in business due to green reputation, cost savings (on fines, lawsuits, clean-up costs, claims, and increased premiums), efficient use of raw materials (fuel oil consumption/ engine), fewer inspections, and faster turnaround in ports.

Second, this study found that internal sustainable management mediated the relationship between external sustainable collaboration and sustainability performance. Therefore, if port operators want to improve sustainability performance through collaboration with external customers and suppliers, they need to enhance internal collaboration. Future research is needed to understand how port managers can

accomplish this and to identify what factors contribute to meaningful relationships with external port partners, suppliers, and customers. Notably, this research views sustainable port supply chains as being specifically based on the integration of external customers and supply chain partners. This can become very complex as many different supply chains (e.g. information flows and physical flows) tend to resemble a network rather than a linear supply chain through a port (Bichou and Gray, 2004). The findings may vary significantly if the supply has partial vertical integration as this would enable the sustainability issue to be 'pushed' through a supply chain. Third, this study was based only on a cross-sectional survey in 2012 and sought to develop a model of sustainable port supply chains in explaining sustainability performance. However, sustainability performance may have improved or changed in the last three years. Future research could conduct a longitudinal study to assess sustainable supply chain management and sustainability performance at different time points and therefore more accurately determine their efficacy within an organization. Finally, the collected data obtained from respondents' perceptions of sustainability performance in international port operation may have been subject to bias due to respondents' reluctance to report actual performance because of potential repercussions and an interest in avoiding lawsuits being brought against them by their employing department. Therefore, further research might measure port sustainability performance by actual observation or quantitative methods.

References

Abbott, W. F., and R. J. Monsen. 1979. "On the measurement of corporate social responsibility: self-reported disclosures as a method of measuring corporate social involvement." *Academy of Management Journal* 22: 501-515.

Acciaro, M., T. Vanelslander, C. Sys, Claudio. Ferrari, A. Roumboutsos, G. Giuliano, J. S. L. Lam, and S. Kapros. 2014. "Environmental sustainability in seaports: a framework for successful innovation." *Maritime Policy and Management* 41:5 480-500. DOI: 10.1080/03088839.2014.932926.

Anderson, J. C., and D. W. Gerbing. 1988. "Structural equation modeling in practice: a review and recommended two-step approach." *Psychological Bulletin* 103: 411–423.

Armstrong, S. J., and T. S. Overton. 1977. "Estimating nonresponse bias in mail survey." *Journal of Marketing Research* 14: 396-402.

Azevedo, S. G., H. Carvalho and V. C. Machado. 2011. "The influence of green practices on supply chain performance: a case study approach." *Transportation Research Part E: Logistics and Transportation Review* 47: 850-871.

Bagozzi, R.P., and Y. Yi. 1988. “On the evaluation of structural equation models.” *Academy of Marketing Science* 16: 74–93.

Behrends, S., Lindholm, M. and J. Woxenius. “The impact of urban freight transport: A definition of sustainability from an actor's perspective.” *Transportation Planning and Technology* 131(6): 693-713.

Bell, S., S. Morse, and R. A. Shah. 2012. “Understanding stakeholder participation in research as part of sustainable development.” *Journal of Environmental Management* 101: 13-22.

Bichou, K., and R. Gray. 2004. “A logistics and supply chain management approach to port performance measurement.” *Maritime Policy and Management* 31(1): 47-67.

Bollen, K. A. 1989. *Structural Equations with Latent Variables*. New York: John Wiley & Sons Inc.

Brundtland, G.H. 1987. *Our Common Future: The World Commission on Environment and Development*, Oxford: Oxford University Press.

Byrne, B. M. 2001. *Structural Equation Modeling with AMOS: Basic Concepts, Applications, and Programming.* New Jersey, Hillsdale: Lawrence Erlbaum.

Carmines, E. G., and A. Z. Richard. 1979. *Reliability and Validity Assessment*, Newbury Park: Sage Publications.

Carr, A. S., and J. N. Pearson. 1999. “Strategically managed buyer–supplier relationships and performance outcomes.” *Journal of Operations Management* 17: 497–519.

Carter, C. R., and D. S. Rogers. 2008. “A framework of sustainable supply chain management: moving toward new theory.” *International Journal of Physical Distribution* 38:5 360-387.

Christopher, M., and L. Ryals. 1999. “Supply chain strategy: its impact on shareholder value.” *International Journal of Logistics Management* 10(1): 1–10.

Council of Supply Chain Management Professionals (CSCMP). 2010. *Supply Chain Management Definitions*, Available at: http://cscmp.org/aboutcscmp/ definitions.asp

Darbra, R. M., N. Pittam, K. A. Royston, J. P. Dabra, and H. Journee. 2009. “Survey on environmental monitoring requirements of European ports.” *Journal of Environmental Management* 90: 1396-1403.

Department of Transport (UK). 2009. *Ports: National Policy Statement for England & Wales-Appraisal of Sustainability (AoS) Report*. Available at: http://www.dft.gov.uk/ consultations/closed/portsnps/. Retrieved on: 17 March 2013.

Feitelson, E. 2002. “Introducing environmental equity dimensions into the sustainable transport discourse: issues and pitfalls.” *Transportation Research Part D: Transport and Environmen*t 7: 88-118.

Flynn, B. B., B. Huo, and X. Zhao. 2010. “The impact of supply chain integration on performance: a contingency and configuration approach.” *Journal of Operations Management* 28: 58-71.

Fornell, C., and D. F. Larcker. 1981. “Evaluating structural equation models with unobservable variables and measurement error.” *Journal of Marketing Research* 18: 186–192.

Gerbing, D. W., and J. C. Anderson. 1988. “An updated paradigm for scale development incorporating unidimensionality and its assessment.” *Journal of Marketing Research* 25: 186-192.

Gilman, S. 2003. “Sustainability and national policy in UK port.” *Maritime Policy and Management* 30: 275-291.

Glavic, P. and Lukman, R. 2007. "Review of sustainability terms and their definitions." *Journal of Cleaner Production* 15: 1875-1885.

Gul, D. S., and Cimen, K. C. 2012. "Port sustainability and stakeholder management in supply chains: A framework on resource dependence theory." *The Asian Journal of Shipping and Logistics* 28(3): 301-320.

Gyöngyi, K. 2005. “Supply chain collaboration for sustainability.” Proceedings of the Business Strategy and the Environment Conference, Available at: http://www.bseconference.org/downloads/gyoengyi.pdf.

Hair, J. F., W. C. Black, B. J. Babin, and R. E. Anderson. 2010. *Multivariate Data Analysis, 7th ed*. Upper Saddle River, New Jersey: Prentice-Hall.

Handfield, R. B., S. V. Walton, L. K. Seegers, and S. A. Melnyk. 1997. “Green value chain practices in the furniture industry.” *Journal of Operations Management* 15: 293-315.

Hartman, B. C., and C. B. Clott. 2012. “An economic model for sustainable harbor trucking.” *Transportation Research Part D: Transport and Environment* 17: 354-360.

Holmes, S. L. 1978. “Adapting corporate structure for social responsiveness.” *California Management Review* 21: 47-54.

Iacobucci, D., and G. A. Churchill. 2010. *Marketing Research: Methodological Foundation, 10th ed*. New York: The Dryden Press.

Kim, J. O., and C. W. Muller. 1978. *Introduction to factor analysis: what it is and how to do it. Series: Quantitative Applications in the Social Sciences*, Newbury Park,

California: Sage Publications, Inc.

Kleindorfer, P. R., K. Singhal, and L. N. van Wassenhove. 2005. “Sustainable operations management.” *Production and Operations Management* 14: 482–492.

Koufteros, X. A. 1999. “Testing a model of pull production: a paradigm for manufacturing research using structural equation modeling.” *Journal of Operations Management* 17: 467–488.

Lam, J.S.L. 2015. “Designing a sustainable maritime supply chain: a hybrid QFD-ANP approach.” *Transportation Research Part E: Logistics and Transportation Review* 78: 70-81.

Lam, J.S.L., and T. Notteboom. 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.

Lambert, D. M., K. L. Croxton, S. J. García-Dastugue, M. Knemeyer, and D. S. Rogers. 2006. *Supply Chain Management Processes, Partnerships, Performance, 2nd ed*. Jacksonville, Florida: Hartley Press.

Lambert, D. M., M. C. Cooper. 2000. “Issues in supply chain management.” *Industrial Marketing Management* 29: 65-83.

Lee, C.K.M., and J.S.L. Lam. 2012. “Managing reverse logistics to enhance sustainability of industrial marketing.” *Industrial Marketing Management* 41:4 589-598.

Lee, S. Y., and R. D. Klassen. 2008. “Drivers and enablers that foster environmental management capabilities in small-and medium-sized suppliers in supply chains.” *Production and Operations Management* 17: 573-586.

Leone, C.E. S., and F.A. Iris, V., 2015. "Port supply chain integration: Analyzing biofuel supply chains." *Maritime Policy and Management*. Published online: 08 Jun 2015, http://dx.doi.org/10.1080/03088839.2015.1050078.

Linton, J.D., R. Klassen, and V. Jayaraman. 2007. Sustainable supply chains: an introduction. *Journal of Operations Management* 25: 1075-1082.

Litwin, M. S. 1995. *How to Measure Survey Reliability and Validity*. Thousand Oaks, California: Sage Publications.

Lu, C. S., and C. S. Yang. 2010. “Safety leadership and safety behavior in container terminal operations.” *Safety Science* 48: 123-134.

Lu, C. S., P. B. Marlow, and P. L. Lai. 2010. “Sustainable supply chain management for ports.” Proceedings of The 6th International Gwangyang Port Forum and The 3rd

International Conference of the Asian Journal of Shipping and Logistics, 189-213, Gwangyang, Korea.

Marlow, P. B. 2008. “Sustainability and corporate social responsibility in shipping.” IAME 2008 Annual Conference, International Association of Maritime Economists, CD file, Dalian, China.

Mentzer, J. T., D. J. Flint, and G. T. M. Hult. 2001. “Logistics service quality as a segment customized process.” *Journal of Marketing* 65: 82-104.

Nunnally, J. C. 1978. *Psychometric Theory, 2nd ed*. New York: McGraw-Hill.

O’Leary-Kelly, S. W., and R. J. Vokurka. 1998. “The empirical assessment of construct validity.” *Journal of Operations Management* 16: 387-405.

Pagell, M., and Wu, Z. 2009. “Building a more complete theory of sustainable supply chain management using case studies of 10 exemplars.” *Journal of Supply Chain Management* 45:2 37-56.

Parola, F., G. Satta, and S. Caschili, 2014. “Unveiling co-operative networks and ‘hidden families’ in the container port industry.” *Maritime Policy and Management* 41:4 384-404.

Pearce, D. W., and J. J. Warford. 1993. *The Concepts of Sustainable Development: World Without End: Economics, Environment, and Sustainable Development*. Oxford: Oxford University Press.

Peris-Mora, E., J. M. D. Orejas, A. Subirats, S. Ibanez, and P. Alvarez. 2005. “Development of a system of indicators for sustainable port management.” *Marine Pollution Bulletin* 50: 1649-1660.

Pronk, J., and M. Haq. 1992. *Sustainable Development: From Concept to Action*. New York: UNDP.

Quak, H.J. de Koster, M.B.M. 2007. "Exploring retailers' sensitivity to local sustainability policies." *Journal of Operations Management* 25: 1103-1122.

Rohács, J., and G. Simongáti. 2007. “The Role of Inland Waterway Navigation in a Sustainable Transport System.” *Transport* 22:3 148–153.

Ryan, S., J. A.Throgmorton. 2003. “Sustainable transportation and land development on the periphery: a case study of Freiburg, Germany and Chula Vista, California.” *Transportation Research Part D: Transport and Environment* 8: 37-52.

Sanchez-Rodriguez, C., D. Hemsworth, and A. R. Martinez-Lorente. 2005. “The effect of supplier development initiatives on purchasing performance: A structural model.” *Supply Chain Management: An International Journal* 10: 289–301.

Sarkis, J. 2001. “Manufacturing’s role in corporate environmental sustainability: concerns for the new millennium.” *International Journal of Operations & Production Management* 21: 666-85.

Segars, A. 1997. “Assessing the unidimensionality of measurement: a paradigm and illustration within the context of information systems research.” *Omega International Journal of Management Science* 25: 107-121.

Seuring, S. 2004. “Integrated chain management and supply chain management comparative analysis and illustrative cases.” *Journal of Cleaner Production* 12: 1059-1071.

Seuring, S., M. Muller. 2008. “From a literature review to a conceptual framework for sustainable supply chain management.” *Journal of Cleaner Production* 16: 1699-1710.

Shang, K. C., C. S. Lu, and S. Li. 2010. “A taxonomy of green supply chain management capability among electronics-related manufacturing Firms in Taiwan.” *Journal of Environmental Management* 91:5 1218-1226.

Shiau, T. A., and C. C. Chuang. 2014. “Social construction of port sustainability indicators: a case study of Keelung port.” *Maritime Policy and Management* 42:1 26-42.

Stank, T. P., S. B. Keller, and P. J. Daugherty. 2001. “Supply chain collaboration and logistic service performance.” *Journal of Business Logistics* 22: 29-48.

Sydney Ports. 2007. *Sustainability Report*. Available at: http://www.sydneyports.com.au/ environment/green_port_guidelines

Testa, F., and F. Iraldo. 2010. “Shadows and lights of GSCM (Green Supply Chain Management): determinants and effects of these practices based on a multi-national study.” *Journal of Cleaner Production* 18: 953-962.

The port of Long Beach. 2005. *Green Port*. Available at http://www.polb.com/

The Port of Los Angeles, 2013. Port of Los Angeles Sustainability Report July 2011-June 2013. Available at: http://www.portoflosangeles.org/Publications/ Sustainability_Report_2013.pdf.

The Port of Los Angeles. 2008. *Port of Los Angeles Sustainability Assessment and Plan Formulation*. Retrieved from http://www.portoflosangeles.org/.

Taiwan International Ports corporation, Ltd. Retrieved from http://www.twport.com.tw/en/News.aspx?n=94628666D12B6144&sms=AB20696A04F7E563.

U.S. Environmental Protection Agency. 2007. *An Environmental Management System*

Primer for Ports: Advancing Port Sustainability, Interim Final Draft. Available at: http://www.epa.gov/otaq/diesel/documents/ems_primer.pdf. Retrieved on: 17 March 2010.

United Nations Conference on Trade and Development (UNCTAD). 2014. "*Review of Maritime Transport*." United Nations Publication.

United Nations General Assembly. 2005. *2005 World Summit Outcome, Resolution A/60/1*. Adopted by the General Assembly on 15 September 2005. Retrieved on: 2012-10-21.

Walton, S. V., R. B. Handfield, S. A. Melnyk. 1998. "The green supply chain: integrating suppliers into environmental management processes." *Journal of Supply Chain Management* 34: 2-11.

Wolf, J. 2011. "Sustainable supply chain management integration: a qualitative analysis of the German manufacturing industry." *Journal of Business Ethics* 102: 221-235.

World Commission on Environment and Development (WCED). 1987. *Report of the World Commission on Environment and Development: Our Common Future*. Available at: http://www.un-documents.net/wced-ocf.htm.

Zervas, E. 2012. "Green growth versus sustainable development. " Proceedings of teh 3rd International Conference on Development, Energy, Environment, Economics (DEEE), 399-404, Paris, France.

Zhu, Q., J. Sarkis, and K. H. Lai. 2008. "Green supply chain management implication for closing the loop." *Transportation Research Part E: Logistics and Transportation Review* 44: 1-18.

Zhu, Q., J. Sarkis, and K. Lai. 2007. "Initiatives and outcomes of green supply chain management implementation by Chinese manufacturers." *Journal of Environmental Management* 85: 179-189.

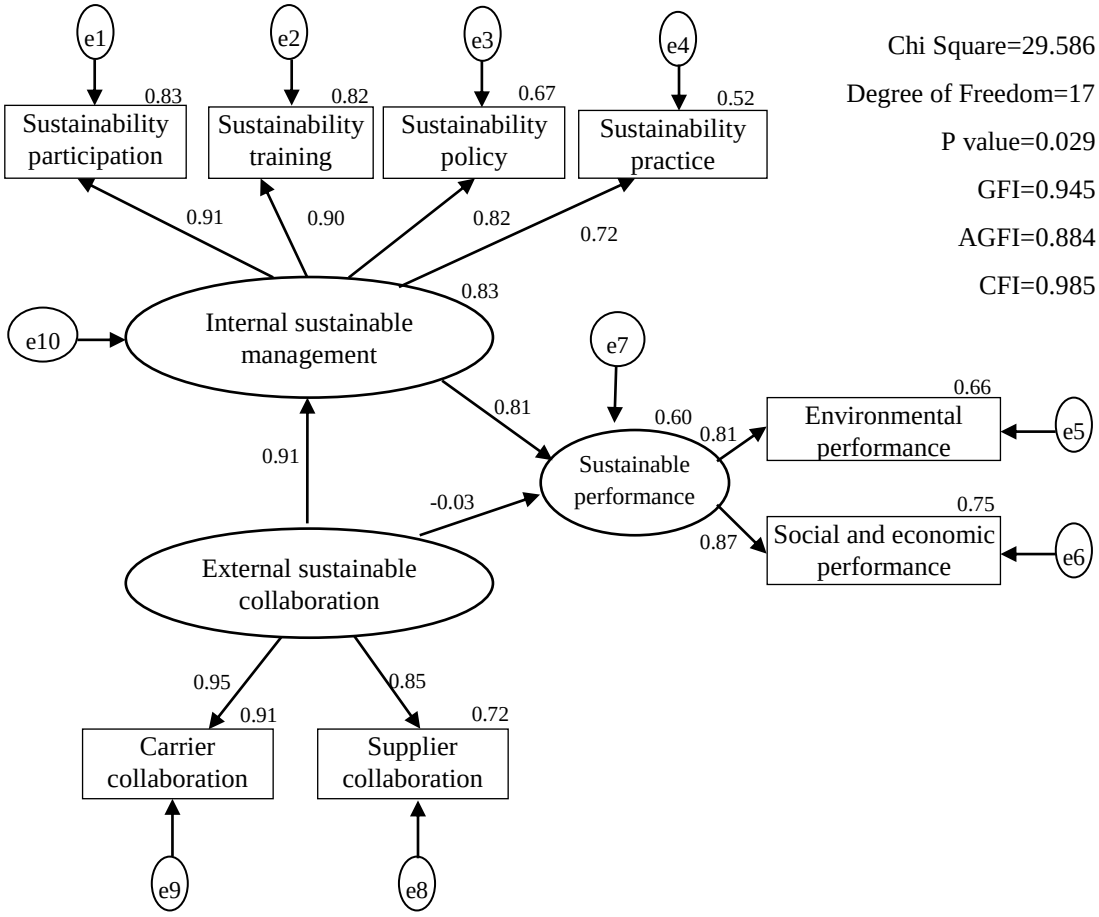

Fig. 1. Structural equation modeling results

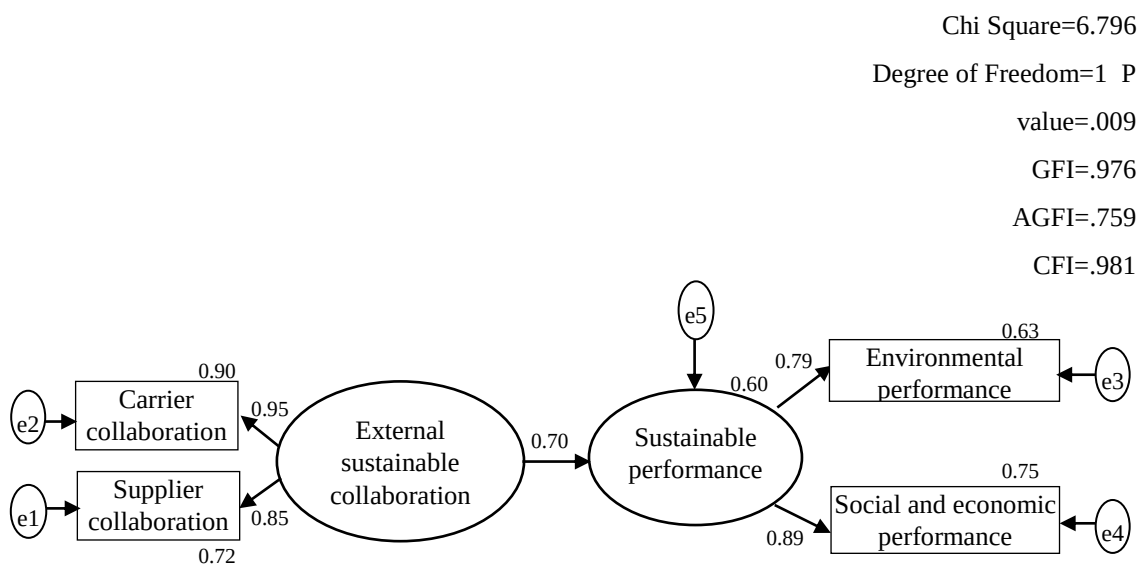

Fig. 2. Results of the effect of external sustainable collaboration on sustainable performance

Table 1 Profile of respondents

Characteristic	Number of respondents	Percentage of respondents
Job title		
President/Vice president	2	1.5
Chief secretary/Chief Engineer/Harbor master	2	1.5
Senior director	19	14.1
Director	72	53.3
Supervisor	40	29.6
Age		
30 years or less	33	24.1
31-40 years	74	54.9
40 years or more	28	21
Years of working experience		
10 years or less	12	8.6
11-20 years	43	31.9
20 years or less	80	59.5
Work Department		
Operations	55	40.8
Warehousing	17	12.6
Secretarial	15	11.1
Harbor Affairs	13	9.6
Information Technology	12	8.9
Harbor Construction	9	6.7
Human Resource	6	4.4
Navigation	5	3.7
Research and Development	3	2.2

Table 2 Factor analysis of internal sustainable management items

Items	Factor			
	1	2	3	4
Sustainability participation				
Setting sustainable development goals	0.80	0.35	0.11	0.23
Participating in sustainable development programs	0.79	0.27	0.17	0.23
Attending relevant sustainable development conferences	0.79	0.32	0.28	0.17
Discussing sustainable development issues with staff	0.77	0.33	0.25	0.22
Following strict procedures to implement sustainable development	0.77	0.32	0.30	0.25
Responding to sustainable development questions promptly	0.74	0.36	0.25	0.24
Establishing sustainable development communication channel	0.71	0.38	0.21	0.30
Convening sustainable development conferences periodically	0.67	0.34	0.28	0.31
Encouraging green power operations (e.g. electric vehicles)	0.65	0.36	0.15	0.19
Providing sustainable development information to staff	0.63	0.34	0.38	0.34
Advising staff of relevant risk with regard to developing sustainability	0.60	0.40	0.37	0.30
Improving sustainable development through cross section coordination	0.56	0.44	0.25	0.29
Sustainability practices				
Mitigating emission of Co2 and noise from berthing ships	0.36	0.75	0.07	0.23
Collecting most recent information about sustainable development regulation	0.29	0.71	0.28	0.28
Mitigating emission of Co2 and noise from port operations	0.32	0.71	0.14	0.28
Establishing evaluation criteria for sustainable development	0.27	0.70	0.33	0.17
Employing a variety of plans for mitigating emission of Co2 from vehicles in port area	0.41	0.68	0.22	0.25
Sustainable development has the highest priority of all issues	0.23	0.68	0.43	0.23
Port operations strictly follow ISO14001	0.28	0.63	0.26	0.16
Beautifying port area and sea view	0.20	0.61	0.26	0.08
Expanding green space in port area	0.30	0.60	0.28	0.04
Using pipeline and warehousing operation for decreasing pollution from ore bulk cargo carriers	0.28	0.58	0.13	0.02
Efforts to achieve sustainable development exceed legal requirements	0.36	0.57	0.34	0.27
Using green materials in design and building of port construction	0.37	0.57	0.24	0.20
Sustainability policy				
Publishing a written sustainable development policy	0.31	0.33	0.78	0.08
Clear division of responsibility for implementing sustainable development	0.25	0.34	0.76	0.19
Advocacy of sustainable development regulations	0.36	0.29	0.69	0.31
Setting sustainable development codes of practice	0.36	0.33	0.67	0.31
Establishing evaluation indicators for recycling, greenhouse gas mitigation, and resources saving.	0.13	0.34	0.61	0.35
Sustainability training				
Sustainable development courses should be applied effectively in staff's work	0.29	0.22	0.16	0.77
Providing sufficient sustainable development training courses	0.24	0.14	0.19	0.76
Sustainable development programs should have excellent course design	0.34	0.20	0.14	0.74
Periodically holding port accident drills	0.22	0.16	0.29	0.58
Means	3.62	3.67	3.73	3.72
Standard Deviation	0.91	0.88	0.93	0.71
Eigenvalues	8.09	7.41	4.41	3.82
Percentage variance %	24.53	22.44	13.35	11.57

Accumulated Percentage variance%	24.53	46.97	60.32	71.89
Cronbach α	0.97	0.95	0.93	0.85

Table 3 Factor analysis of external sustainable collaboration items

Items	Factor	
	1	2
Carrier collaboration		
Carriers are requested to acquire ISO 14001 or equivalent certification	0.82	0.46
Carriers are requested to implement sustainable development programs	0.82	0.42
Sustainability indicators are used as crucial criteria for evaluating carriers' operational performance	0.82	0.41
Carriers are requested to provide written sustainable development specifications	0.81	0.43
Carriers are requested to undertake sustainable development evaluation of their contractors	0.80	0.44
Port corporations give assistance to carriers to set sustainable development policy	0.80	0.42
Carriers set sustainable development indicators with port authorities	0.79	0.37
Carriers work together with port authorities to reduce impacts on port areas	0.78	0.30
Supplier collaboration		
Port service suppliers are requested to undertake sustainable development evaluation of their contractors	0.34	0.81
Port corporations give assistance to suppliers to set sustainable development policy	0.37	0.81
Port service suppliers set sustainable development indicators with port authorities	0.38	0.81
Sustainability indicators are used as crucial criteria for evaluating port service suppliers' operational performance	0.38	0.80
Port service suppliers are requested to implement sustainable development programs	0.44	0.78
Port service suppliers are requested to acquire ISO 14001 or equivalent certification	0.43	0.76
Port service suppliers are requested to provide written sustainable development specifications	0.43	0.76
Port service suppliers work together with port authorities to reduce impacts on port areas	0.39	0.71
Mean	3.50	3.62
Standard Deviation	0.89	0.85
Eigenvalues	6.52	6.33
Percentage variance %	40.76	39.60
Accumulated Percentage variance%	40.76	80.37
Cronbach α	0.97	0.96

Table 4 Factor analysis of self-reported sustainable performance items

Items	Factor	
	1	2
Environmental performance		
I perceive that traffic accidents in port areas have significantly reduced	0.89	0.17
I perceive that industrial accidents in port areas have significantly reduced	0.82	0.26
I perceive that oil pollution in port areas has significantly reduced	0.75	0.47
I perceive that air quality in port areas has significantly improved	0.73	0.44
I perceive that noise in port areas has significantly reduced	0.71	0.45
Social and economic performance		
I perceive that port authorities' services quality has improved	0.28	0.84
I perceive that the relationship between neighboring residents and port authorities is getting better	0.24	0.79
I perceive that port authorities actively cooperate with industrial and economic development	0.30	0.78
I perceive that the economic development of the area surrounding the port is getting better	0.39	0.73
Mean	3.83	4.00
Standard Deviation	0.77	0.77
Eigenvalues	5.71	1.01
Percentage variance %	63.42	11.22
Accumulated Percentage variance%	63.42	74.64
Cronbach α	0.92	0.877

Table 5 Goodness of fit indicators

SEM indicators	Criteria	Results
χ^2(Chi-square)	-	29.57
χ^2/df	< 2	1.74
P value	> 0.05	0.03
GFI	> 0.9	0.95
AGFI	> 0.9	0.88
TLI	> 0.9	0.98
NFI	> 0.9	0.97
RMR	Close to 0	0.01
RMSEA	< 0.08	0.07

Note: GFI: goodness of fit index; AGFI: adjusted goodness-of-fit index; TLI: Tucker-Lewis index; NFI: normed fit index; RMR: root mean square residual; RMSEA: root mean square error of approximation。

Table 6 Assessment of discriminate validity

Dimensions	AVE[a]	Sustainability participation	Sustainability practices	Sustainability policy	Sustainability training	Carrier collaboration	Supplier collaboration	Environmental performance	Social and economic performance
Sustainability participation	0.51	1							
Sustainability practices	0.50	0.66** (0.33)[b]	1						
Sustainability policy	0.50	0.66** (0.38)	0.76** (0.43)	1					
Sustainability training	0.52	0.55** (0.23)	0.60** (0.24)	0.62** (0.29)	1				
Carrier collaboration	0.66	0.62** (0.36)	0.77** (0.43)	0.66** (0.44)	0.65** (0.30)	1			
Supplier collaboration	0.61	0.56** (0.30)	0.71** (0.37)	0.59** (0.36)	0.55** (0.24)	0.80** (0.49)	1		
Environmental performance	0.61	0.55** (0.26)	0.63** (0.29)	0.52** (0.28)	0.41** (0.6)	0.50** (0.27)	0.52** (0.26)	1	
Social and economic performance	0.62	0.65** (0.30)	0.62** (0.28)	0.56** (0.30)	0.45** (0.17)	0.59** (0.31)	0.50** (0.24)	0.70** (0.30)	1

a: Average variance extracted (AVE) = (sum of squared standardized loadings)/[(sum of squared standardized loadings) + (sum of indicator measurement error)];
b: Squared correlation
** Correlation is significant at the 0.01 level.

Table 7 Structural equation modeling results

	Paths	Estimates			
		Standardized β	S.E.[a]	C.R.[b]	P
H1	(Internal sustainable management) → （Sustainable performance）	0.81	0.19	3.23	**[c]
H2	(External sustainable collaboration) → （Sustainable performance）	-0.03	0.20	-0.14	0.89
H3	(External sustainable collaboration) → (Internal sustainable management)	0.91	0.68	11.68	**

Note: a. S.E. is an estimate of the standard error of the covariance.

b. C.R. is critical ratio which obtained by dividing the covariance estimate by its standard error.

c. ** P value is significant at the 0.05 level.