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Evaluating and Managing Tramp Shipping Lines Performances: A New Methodology Combining Balanced Scorecard and Network DEA

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Abstract—The shipping industry is essential for the economic development of nations like Taiwan as a means delivering and receiving cargo. Shipping has been depressed since 2008 as a result of the financial crisis increasing pressure for the shipping lines to operate more efficiently. This paper aims to contribute to the existing literature by proposing a novel model to identify and understand paths to improve shipping services by integrating network Data Envelopment Analysis (DEA) and the Balanced Scorecard (BSC). The proposed model treats the four perspectives of BSC (financial, customer, internal business processes, and learning and growth) as four interconnected stages and calculates overall efficiency of each shipping company as well as the individual efficiency of BSC each stage. We present proposed model to advance the analysis of the shipping industry and to suggest an approach that benefits from DEA and BSC. Applying our proposed model to a limited sample of shipping line data, our test results show the ranking and the differences in performance between peer-evaluation and self-evaluation of each company and provide examples of potential insights into specific operations where modification can improve shipping line performance. Our results suggest the way the proposed combined use of DEA and BSC applied to a complete set of operating data has the potential to assist shipping companies improve operations and focus efforts and investments on areas that have potential to generate improved performance.

Keywords Network Data Envelopment Analysis, Balanced Scorecard, Shipping line, Performance evaluation, Centralized approach, Cross-efficiency.

1. INTRODUCTION

The shipping industry supports over 90% of world trade, and is consequently affected by the global economy. Much of the shipping demand emanates from Asia and particularly China. Economic prosperity prior to the financial crisis of 2008 expanded the global shipping market to a record level of volume. However, since 2008, the shipping industry has been operating in a more difficult environment with stronger competition and reduced profitability. For many countries, shipping is a vital component of the economy, supporting growth in commerce. (Meera, 2005). Taiwan is a sea island and is heavily dependent on

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sea transportation to import bulk cargos because of a lack of raw materials and the need for a method to export finished or semi-finished goods. The dependence on shipping and the need to provide economically advantageous shipping costs has put pressure on Taiwanese shipping companies to seek methods to reduce operating expenses along with other methods of improving profitability to provide competitive transportation prices and protect their survival.

There are two shipping sectors distinguished based on the operational characteristics: freight liner shipping, which involves regularly scheduled ships with all or part devoted to repeated cargo delivery, and tramp shipping, which handles smaller diverse cargos that are scheduled for pickup or delivery to meet the needs of individual customers.

This paper focuses on evaluating performance of tramp shipping companies characterized by unfixed routes and schedules. Performance will be evaluated through integrated use of network Data Envelopment Analysis (DEA) and the Balanced Scorecard (BSC). The objective is to provide insights on performance that will help managers understand which aspect of the shipping operations can and should be improved and which aspects of the operations are performing well and should be maintained.

Prior studies that integrated DEA with BSC have included BSC dimensions as the outputs of DEA. For instance, Eilat et al. (2008) developed an extended DEA model to evaluate research and development (R&D) projects and Chiang and Lin (Chiang and Lin, 2009) developed an integrated framework for measuring management performance. Amado et al. (2012) proposed a conceptual framework combining these two approaches by using four models. However, these studies do not consider the interconnection among those models. Studies evaluating performance in the shipping industry, such as Cullinane et al. (2006) and Sharma and Yu (2009) focus on ports where ships are docked or container terminals. We have found very few studies on shipping lines performance evaluation. Panayides et al. (2011) examined the relative efficiency of firms in container shipping (where products are shipped in truck size containers) with no distinction between tramp and liner shipping, which we believe represent two different sets of operational challenges and may require different methods to locate paths to improve performance.

Existing studies that we have located do not offer specific directions and methods that when implemented can improve shipping practices. Thus, the main purpose of this study is to fill the research gap and develop an integrated framework to encompass the basic concepts of BSC and DEA to measure tramp shipping lines performances. We propose a framework and provide an introductory example of how this framework might be applied to tramp shipping and how the results may potentially be used to analyze and improve the performance of tramp shipping. Ultimately, we hope this framework will provide a foundation for further development, refinement and testing to generate a method that can be used and adopted by shipping lines to improve their operations, enhance the resource allocation decision process, and assist in identifying likely areas where further investments can help improve shipping line performance.

In this paper, we propose a model combining network DEA with BSC, and apply it to real public data from the Taiwan Stock Exchange Corporation (TWSE) analyzing seven competing tramp shipping lines. Moreover, assess the efficiency of each BSC stage as well as the overall efficiency of each shipping line, the decision-making units (DMU). The remainder of the paper is organized as follows. Section 2 provides a historical review of related references. Section 3 explains the proposed research framework integrating network DEA and BSC. In Section 4, the performance evaluation model is constructed, analyzed, and discussed. The findings and recommendations are the focus of Section 5.

2. LITERATURE REVIEW

2.1. Data Envelopment Analysis

DEA, first proposed by Charnes et al. (1978), is a non-parametric linear programming based technique used to measure the efficiency of operating units, referred to as decision making units (DMUs) by comparing their use of multiple inputs to produce multiple outputs. DEA provides information about the most efficient DMUs and the less efficient or inefficient DMUs (Mostafa, 2007). In a DEA approach, DMUs can be any entities engaged in many different activities in many different contexts, e.g., hospitals, US Air Force wings, universities, cities, courts, business firms, and others (Cook et al., 2010). These examples are largely public and private service organizations, applications areas where DEA has proven to be particularly effective. Tramp shipping represents an interesting new potential service area to determine if DEA can provide benefits in managing these DMUs. Another attribute of DEA is the internal production process of how, for example, resources are converted to produce multiple outputs need not be specified or known to benefit from DEA. This represents another reason DEA has the potential to be valuable in analyzing tramp shipping.

Traditional DEA models deal with measurements of relative efficiency of DMUs regarding multiple-inputs vs. multiple-outputs. A DEA Model is output-oriented if it seeks to increase outputs without increasing inputs. Similarly, a DEA model is input-oriented if it seeks to decrease inputs without decreasing outputs. However, these models do not address the set of internal activities or linking activities that result in the overall efficiency or inefficiency in a DMU. The discrimination power might be low by its nature. Super efficiency is a method to increase its discrimination power (Fang et al., 2013; Lee et al., 2011; Lee and Zhu, 2012). Applications of DEA in marine safety can be found in Wang and Lee (2012a, 2012b). Hwang et al. (2013) and Hwang et al. (2014) consider applications where

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undesirable outputs exist. Systems where exist ripple effects can be effectively modeled as indicated by Lee et al. (2013).

Network DEA introduced by Färe and Grosskopf (2000), explicitly considers the interrelationship of the processes within the system, to measure the efficiency of the system and those of the processes at the same time. Fukuyama and Mirdehghan (2012) indicated that, in such a network DEA approach, the production process of the DMU is divided into sub-processes, so that intermediate products are outputs of one sub-process and become the inputs of another sub-process. Therefore, the approach is able to open the "black box"and allows DEA to examine these sub-processes and identify sources of inefficiency in parts of the organizational processes. The general concept is that overall efficiency is affected by the efficiency of activities within the DMU, a concept that has been covered in various studies. One frequently cited example is health care (Chilingerian and Sherman, 2011; Sherman and Zhu, 2006) where there are multiple sets of activities contribute the overall efficiency of providing care to a patient. Hospital services such as housekeeping, medical records, and laundry support other services such as laboratories, radiology, inpatient bed care etc. Each needs to be efficiently operated, each provides an output that is then used as input for other services and ultimately the care of a patient. The efficiency of the patient care is dependent on both the amount of each of these internal services used as well as the efficiency with which the internal services are provided.

In recent years, the multi-process network DEA model has been applied to many studies. For example, Yu and Lin (2008) estimated efficiency and effectiveness for 20 selected railways, Yu and Fan (2009) estimated the performances of multimode transit firms, and Hsieh and Lin (2010) analyzed the efficiency and effectiveness of international tourist hotels. Subsequently, Lozano (2011) computed technical, scale, cost and allocative efficiency scores for homogeneous networks of processes, Zhao et al. (2011) measured the performance of a transportation network, and Chen and Yan (2011) focused on the supply chain performance evaluation. Examples of latest studies related to network DEA are: Matthews (2013) assessed managerial efficiency for banks, Lozano et al. (2013) assessed airports performances, Yang and Liu (2012) measured performances of bank branches, Xie et al. (2012) evaluated the environmental efficiency performance of power system, and Chen et al. (2012) evaluated sustainable product design performance.

2.2. Balanced Scorecard

The Balanced Scorecard, developed by Kaplan and Norton (1992), is a conceptual framework for translating an organization's strategic objectives into a set of performance measures distributed among four perspectives or dimensions: financial, customer, internal business processes, and learning and growth (Amado et al., 2012). It combines financial and operational measures, focuses on both short- and long-term objectives of the organization and emphasizes the need to identify and include future oriented measures that will suggest future performance as distinct from measure that reflect past performance (Eilat et al., 2008). (For example, new patents measure actual patents received but have the potential to spawn new products and is an example of a future oriented performance measure related to the learning and growth dimension of the BSC.) Advantages of BSC are its focusing on the four key dimensions and challenging the organization to develop key measures and targets related to each of these dimensions. When applied, it identifies areas where the organization is meeting these targets and where there is need for management attention. Meeting the BSC targets, if they are developed as prescribed in the framework, will advance the organization toward achieving its goals and implementing its preferred strategy. BSC also attempts to prevent sub-optimization by considering all the important measures together, while providing the ability to see whether improvement in one area may have been achieved at the expense of another (Eilat et al., 2006). By the middle 1990s, BSC became the hallmark of a well-run company (Asosheh et al., 2010).

The BSC approach addresses the issues of divergent stakeholder goals and gauging managers' effectiveness (Chiang and Lin, 2009). It provides answers to the following questions: How do we regard our shareholders? (financial perspective); how do our customers see us? (customer perspective); what must we excel at? (internal business processes perspective); how can we continue to innovate and create value? (learning and growth perspective) (Amado et al., 2012). By contrast, traditional financial measures are inadequate in providing a complete and useful overview of organizational performance (Eilat et al., 2008). Good performance on financial measures such as profitability does not guarantee or even suggest the firm's future success, because it does not measure the processes and initiatives that will generate future sales, new products, and effective personnel (Michalska, 2005). Therefore, BSC have been widely applied to organizations to accomplish critical management processes, clarify and translate their vision and strategy, communicate and link strategic objectives and measures, plan and align strategic initiatives, and enhance strategic feedback and learning (Eilat et al., 2008).

BSC has been the subject of much research in respect of its possibilities as a tool for strategic management (García-Valderrama et al., 2009). For instance, Michalska (2005) measured the Polish metallurgic enterprise's effectiveness, and Bhagwat and Sharma (2007) studied the performance measurement of supply chain management. Further, business performance evaluation of wealth management banks (Wu et al., 2010), assessing website performance for 967 U.S. Convention and Visitor Bureaus (Stepchenkova et al., 2010), evaluating performances of extension education centers in universities (Wu et al., 2011), assessing New Zealand's health system performance (Gauld et al., 2011), measuring the sustainable performance of the semiconductor industry (Hsu et al., 2011), and R&D performance measurement (Lazzaroti et al., 2011), are samples of using

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BSC in various areas. Recent research includes Houck et al. (2012) which assessed sustainable performance for forensic laboratories, and Grigoroudis et al. (2012) which measured strategic performance in a healthcare organization. We have not found any published BSC applications to shipping.

2.3. The integration of Data Envelopment Analysis and Balanced Scorecard

In today's complex competitive environment, firms need to be agile and flexible. As a result, availability of the right information at the right time for both decision making and performance evaluation has become critical (Banker et al., 2004). Performance measurement is a complex task since multiple inputs and multiple outputs are involved in the process (Chiang and Lin, 2009). Hence, it is important to select right inputs and outputs for DMUs which may affect the evaluation result. However, making such decisions is difficult because there are lots of quantitative and qualitative factors to be considered in evaluation process (Asosheh et al., 2010). Fortunately, Chiang and Lin (2009) indicated that BSC and DEA are different concepts but complementary to each other. On one hand, DEA is capable of improving the limitations of BSC and providing more useful information for managers. On the other hand, BSC can provide appropriate outputs for DEA. Therefore, managers must adopt the BSC to evaluate their performances from four perspectives. In addition, in order to evaluate the competitive position of the firm, managers need to apply DEA to identify the efficiency frontier, benchmarking partners and inefficient slacks for the firms (Chiang and Lin, 2009).

In recent years, many studies have developed the extended model integrating DEA with BSC and applied it in various research fields. For instance, Amado et al. (2012) assessed the performance of DMUs in a multinational company which operates in two business areas. Chiang and Lin (2009) evaluated the management performance in auto and commercial bank industries. Asosheh et al. (2010) proposed a new integrated model for finding the most efficient IT project. Eilat et al. (2008) evaluated R&D projects in different stages of their life cycles, during the selection, planning, execution, and termination phases. García-Valderrama et al. (2009) employed the method of DEA to develop various different models of efficiency for studying the relationships between the perspectives of the BSC for R&D activities. Thus we can say that both DEA and BSC approach and even the integrated conceptual framework are actively used. These methods, as Amado et al. (2012) indicated, help to identify where there is room for improving organizational performance and point out opportunities for reciprocal learning between DMUs.

3. RESEARCH FRAMEWORK

3.1. The conceptual framework

This study proposes and demonstrates a method to analyze tramp shipping businesses through an application to seven Taiwanese tramp shipping companies. Using publicly available shareholder reports we develop a BSC for these 7 shipping companies to be used with a network DEA model to assess their performance from multiple perspectives. The use of shareholder reports as the sole source of data does not allow us to provide a comprehensive BSC reflecting measures related to the four dimensions. A more comprehensive BSC would require access to internal corporate data on operations and strategy, and we expect that to be the focus of studies that follow this one.

Data used for the BSC and network DEA analysis from the shareholder reports are: fixed assets, current assets, operating costs, non-operating expenses, total assets turnover, cash flow ratio, operating revenue, non-operating revenue, earnings per share, and net income. These data are found in the financial statements submitted by businesses like these tramp shipping companies to the Taiwan Stock Exchange Corporation (2009). We have adapted these data elements to the four BSC components: Financial, Customer, Internal Business Processes and Learning and Growth Perspectives to evaluate the performances of tramp shipping companies. As Amado et al. (2012) indicated, the choice of indicators depends on the availability of the reliable data. In this respect, there are other indicators that would have been useful to include but were not available in these reports and some of data that would ultimately be required for a complete analysis of the tramp shipping performance would require additional internal data from the companies being evaluated. Consequently, this study should be viewed as a demonstration of the proposed methodology which may serve as the foundation for more detailed analyses and future development of this DEA-BSC methodology.

On the basis of Amado et al. (2012), we present the conceptual framework integrating DEA and BSC approaches as shown in Figure 1. Instead of treating four stages as four separate models (Amado et al., 2012), we regard these four stages as a whole in which the stages are interconnected following the cause and effect relationships. We are primarily suggesting that the overall efficiency of shipping company is dependent on the efficiency in each of the BSC components. If the efficiency of each component is measured in a manner that reflects the interconnetion among these components, then the combined efficiency will provide a relatively comprehensive measure of performance. In addition, the efficiency of each BSC component will be visible and can be used to identify the activities that explain the overall efficiency level and the areas that the shipping company may need to improve to increase its overall efficiency. While we are suggesting that there is a cause and effect relationship from stage 1 to stage 4, we also acknowledge that there are situations where, for example a stage 3 customer activity may have a direct or indirect effect on stage 2 internal business process. For example, customer input may trigger the need to change the way services are provided and revise the internal business processes to make this change.

In Figure 1, the learning and growth perspective identifies the infrastructure necessary to create long-term growth and development (Kaplan and Norton, 1996). For increasing ship capacity

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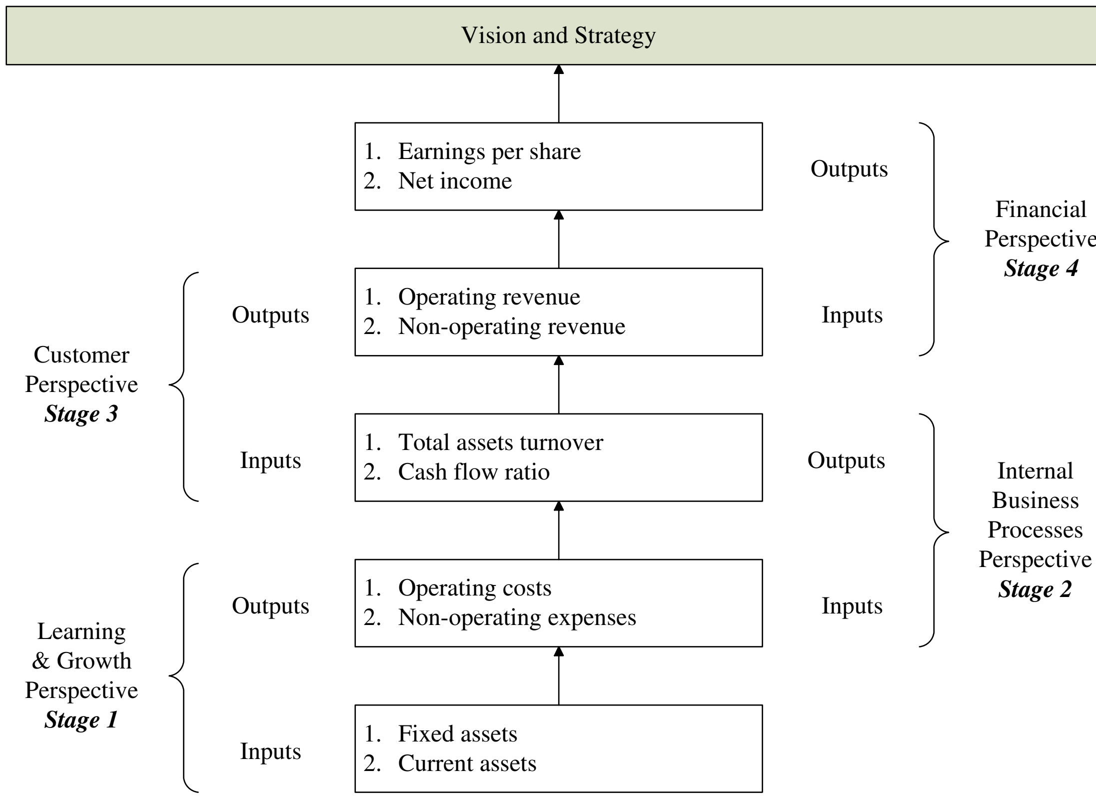

Figure 1. The conceptual framework integrating DEA and BSC approaches

and improving personnel capabilities, the first inputs include "fixed assets" which comprises property, plant and equipment, and "current assets", and outputs are "operating costs" and "non-operating expenses". The inputs chosen are fundamental elements which are indispensable and interdependent in production process. For shipping lines, the fixed assets reflect the primary assets used to provide the shipping services and while labor is not reflected as an asset on the balance sheet, the shipping assets here are relied on as a surrogate for labor as well. (We also assume that the shipping lines account for these assets in a similar method so that age of the shipping fleet and questions of whether they lease or own the ships do not skew the results.) The outputs chosen represent the costs resulting from utilization of the assets or in use of the assets in providing shipping services. Both of the costs, operating and non-operating expenses, "undesirable" outputs which should be minimized through learning and growth process to maximize the profitability of the business. To treat these "undesirable" outputs as normal outputs, we adopt a method in Scheel (2001), which transforms the undesirable output by adding to the additive inverse of the undesirable output a sufficiently large scalar constant such that the resulting output values are positive for each DMU. The scalar constant adopted here is the largest value plus the minimum value in each undesirable output. (Undesirable in this context solely reflects the direction of the output in that one would not want to incur more of these expenses than is needed. These outputs are critical to providing the shipping services and there is no expectation that these would ever be zero. This is in contrast to other outputs such as pollutants which are also undesirable where the objective might be to eliminate them.)

The internal business processes perspective should include indicators of the critical processes the company must excel at (Kaplan and Norton, 1996). Therefore, we considered the outputs of the stage 1 as inputs for the stage 2, and proposed "total assets turnover" and "cash flow ratio" as outputs. The "total assets turnover" represents the operational capability for total assets (revenues/assets). In other words, the higher ratio reflects the better capability for a company to generate revenues. The "cash flow ratio" represents the debt-paying ability that short-term creditors are concerned about. A company with higher ratio means that it has greater ability to pay debt and other vendor obligations. Thus, the outputs chosen are aimed at capturing the effectiveness of internal business processes.

In the third stage, we regard the outputs from the internal business processes perspective as inputs and propose "operating revenue" and "non-operating revenue" as outputs. The "operating revenue", resulted from shipping services, the primary result of business operation. The "non-operating revenue" includes other forms of revenue excluded from operating revenue. Since the higher the customer satisfaction and loyalty, the higher the amount of revenue would be generated, these two outputs are an attempt to capture the customers' appraisal of each shipping line.

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The financial perspective is intended to answer to the interests of shareholders (Amado et al., 2012). We propose "earnings per share" and "net income" as outputs in this stage to reflect the ability to generate profits from shipping and the ability to provide this benefit to shareholders through management of the commons shares outstanding. The "earnings per share"(EPS) is an important indicator to evaluate the value of stock investment to individual shareholders. While the absolute value of EPS is dependent on the common share structure, the share price and shareholder value may be higher for greater EPS if the price earnings multiple applied to the tramp shipping industry is similar and the EPS may reflect the way cash and financing are used by management to benefit shareholders distinct from the level of net income. The "net income" is a widely used profitability indicator and measure operational effectiveness. The two outputs used in this stage are also the outputs of the overall process.

3.2. The integrated model

On the basis of Charnes et al. (1978) and Chen et al. (2012), we propose a network DEA model for performance evaluation of tramp shipping lines includes four stages consistent with BSC approach: a "learning and growth perspective", an "internal business processes perspective", a "customer perspective" and a "financial perspective" as shown in Figure 2. Our model is input oriented as we assume that reducing inputs to improve profitability is a primary objective and we use the constant returns to scale (CRS). Other models may offer additional valuable perspectives which may be valuable alternatives to be considered in future studies.

We consider a set of n different companies in tramp shipping as the DMUs. Assume that for each company, denoted by $DMU_j (j = 1, \ldots, n)$, there are m inputs, denoted by $x_{ij} (i = 1, \ldots, m)$, to Stage 1 (learning and growth perspective) and D_1 outputs, denoted by $z^1_{dj} (d = 1, \ldots, D_1)$, from that stage. These D_1 outputs are also the inputs to Stage 2 (internal business processes perspective) and will be referred to as intermediate measures. The rest may be deduced by analogy. The D_2 intermediate as outputs, denoted by $z^2_{dj} (d = 1, \ldots, D_2)$, from Stage 2 are the inputs to Stage 3 (customer perspective). Further, the D_3 intermediate as outputs, denoted by $z^3_{dj} (d = 1, \ldots, D_3)$, from that stage are also the inputs to Stage 4 (financial perspective). Finally, the outputs from Stage 4, denoted by $y_{rj} (r = 1, \ldots, s)$, are the levels of tramp shipping lines financial outputs.

In this paper, we propose a four-stage network DEA model with the "centralized" approach which does not require conducting each stage separately. As Chen et al. (2012) indicated, the centralized approach allows the simultaneous and joint decision-making concurrently. Thus, the efficiency in these four stages are optimized simultaneously. The efficiency of each stage for $DMU_j (j = 1, \ldots, n)$ can be calculated as:

$$
\begin{aligned}
\max e^1_k &= \frac{\sum_{d_1=1}^{D_1} w^{1k}_{d_1} z^1_{d_1 k}}{\sum_{i=1}^{m} v^k_i x_{ik}} \\
s.t. \quad & \frac{\sum_{d_1=1}^{D_1} w^{1k}_{d_1} z^1_{d_1 j}}{\sum_{i=1}^{m} v^k_i x_{ij}} \leq 1, \; j = 1, \ldots, n \\
& v^k_i \geq 0, \; i = 1, \ldots, m \\
& w^{1k}_{d_1} \geq 0, \; d_1 = 1, \ldots, D_1
\end{aligned} \tag{1}
$$

$$
\begin{aligned}
\max e^2_k &= \frac{\sum_{d_2=1}^{D_2} w^{2k}_{d_2} z^2_{d_2 k}}{\sum_{d_1=1}^{D_1} w^{1k}_{d_1} z^1_{d_1 k}} \\
s.t. \quad & \frac{\sum_{d_2=1}^{D_2} w^{2k}_{d_2} z^2_{d_2 j}}{\sum_{d_1=1}^{D_1} w^{1k}_{d_1} z^1_{d_1 j}} \leq 1, \; j = 1, \ldots, n \\
& w^{1k}_{d_1} \geq 0, \; d_1 = 1, \ldots, D_1 \\
& w^{2k}_{d_2} \geq 0, \; d_2 = 1, \ldots, D_2
\end{aligned} \tag{2}
$$

$$
\begin{aligned}
\max e^3_k &= \frac{\sum_{d_3=1}^{D_3} w^{3k}_{d_3} z^3_{d_3 k}}{\sum_{d_2=1}^{D_2} w^{2k}_{d_2} z^2_{d_2 k}} \\
s.t. \quad & \frac{\sum_{d_3=1}^{D_3} w^{3k}_{d_3} z^3_{d_3 j}}{\sum_{d_2=1}^{D_2} w^{2k}_{d_2} z^2_{d_2 j}} \leq 1, \; j = 1, \ldots, n \\
& w^{2k}_{d_2} \geq 0, \; d_2 = 1, \ldots, D_2 \\
& w^{3k}_{d_3} \geq 0, \; d_3 = 1, \ldots, D_3
\end{aligned} \tag{3}
$$

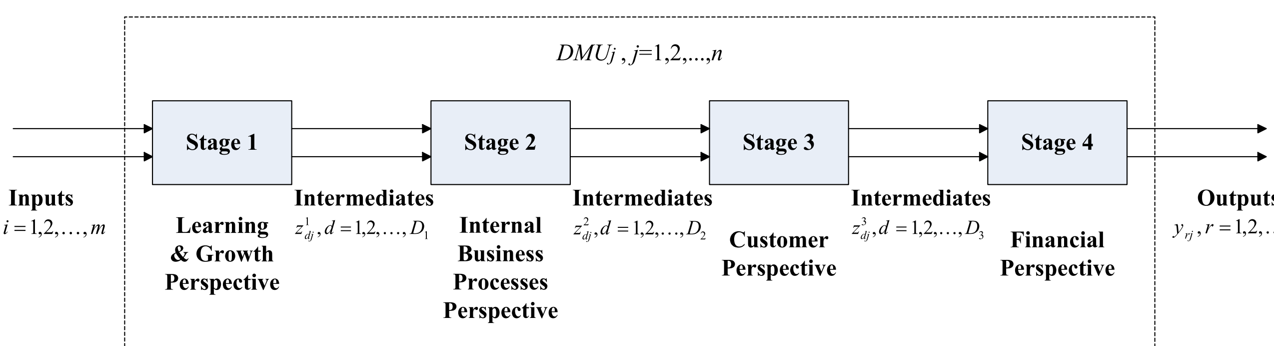

Figure 2. The network DEA model for evaluating tramp shipping lines performances

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$$\max e_k^4 = \frac{\sum_{r=1}^{s} u_r^k y_{rk}}{\sum_{d_3=1}^{D_3} w_{d_3}^{3\,k} z_{d_3 k}^3}$$
$$s.t. \quad \frac{\sum_{r=1}^{s} u_r^k y_{rj}}{\sum_{d_3=1}^{D_3} w_{d_3}^{3\,k} z_{d_3 j}^3} \le 1,\ j = 1, \ldots, n$$
$$w_{d_3}^{3\,k} \ge 0,\ d_3 = 1, \ldots, D_3$$
$$u_r^k \ge 0,\ r = 1, \ldots, s \qquad (4)$$

To optimize the efficiencies of the four stages simultaneously, we have the following model:

$$\max e_k^1 e_k^2 e_k^3 e_k^4 = \frac{\sum_{d_1=1}^{D_1} w_{d_1}^{1\,k} z_{d_1 k}^1}{\sum_{i=1}^{m} v_i^k x_{ik}} \times \frac{\sum_{d_2=1}^{D_2} w_{d_2}^{2\,k} z_{d_2 k}^2}{\sum_{d_1=1}^{D_1} w_{d_1}^{1\,k} z_{d_1 k}^1} \times \frac{\sum_{d_3=1}^{D_3} w_{d_3}^{3\,k} z_{d_3 k}^3}{\sum_{d_2=1}^{D_2} w_{d_2}^{2\,k} z_{d_2 k}^2} \times \frac{\sum_{r=1}^{s} u_r^k y_{rk}}{\sum_{d_3=1}^{D_3} w_{d_3}^{3\,k} z_{d_3 k}^3}$$
$$s.t. \quad \frac{\sum_{d_1=1}^{D_1} w_{d_1}^{1\,k} z_{d_1 j}^1}{\sum_{i=1}^{m} v_i^k x_{ij}} \le 1,\ j = 1, \ldots, n$$
$$v_i^k \ge 0,\ i = 1, \ldots, m$$
$$w_{d_1}^{1\,k} \ge 0,\ d_1 = 1, \ldots, D_1$$
$$\frac{\sum_{d_2=1}^{D_2} w_{d_2}^{2\,k} z_{d_2 j}^2}{\sum_{d_1=1}^{D_1} w_{d_1}^{1\,k} z_{d_1 j}^1} \le 1,\ j = 1, \ldots, n$$
$$w_{d_1}^{1\,k} \ge 0,\ d_1 = 1, \ldots, D_1$$
$$w_{d_2}^{2\,k} \ge 0,\ d_2 = 1, \ldots, D_2$$
$$\frac{\sum_{d_3=1}^{D_3} w_{d_3}^{3\,k} z_{d_3 j}^3}{\sum_{d_2=1}^{D_2} w_{d_2}^{2\,k} z_{d_2 j}^2} \le 1,\ j = 1, \ldots, n$$
$$w_{d_2}^{2\,k} \ge 0,\ d_2 = 1, \ldots, D_2$$
$$w_{d_3}^{3\,k} \ge 0,\ d_3 = 1, \ldots, D_3$$
$$\frac{\sum_{r=1}^{s} u_r^k y_{rj}}{\sum_{d_3=1}^{D_3} w_{d_3}^{3\,k} z_{d_3 j}^3} \le 1,\ j = 1, \ldots, n$$
$$w_{d_3}^{3\,k} \ge 0,\ d_3 = 1, \ldots, D_3$$
$$u_r^k \ge 0,\ r = 1, \ldots, s \qquad (5)$$

Model (5) can be converted into the following linear program.

$$\text{Max} \sum_{r=1}^{s} u_r^k y_{rk}$$
$$\text{s.t.} \quad \sum_{r=1}^{s} u_r^k y_{rj} - \sum_{d_3=1}^{D_3} w_{d_3}^{3\,k} z_{d_3 j}^3 \le 0, \quad j = 1, \ldots, n$$
$$\sum_{d_3=1}^{D_3} w_{d_3}^{3\,k} z_{d_3 j}^3 - \sum_{d_2=1}^{D_2} w_{d_2}^{2\,k} z_{d_2 j}^2 \le 0, \quad j = 1, \ldots, n$$
$$\sum_{d_2=1}^{D_2} w_{d_2}^{2\,k} z_{d_2 j}^2 - \sum_{d_1=1}^{D_1} w_{d_1}^{1\,k} z_{d_1 j}^1 \le 0, \quad j = 1, \ldots, n$$
$$\sum_{d_1=1}^{D_1} w_{d_1}^{1\,k} z_{d_1 j}^1 - \sum_{i=1}^{m} v_i^k x_{ij} \le 0, \quad j = 1, \ldots, n$$
$$\sum_{i=1}^{m} v_i^k x_{ik} = 1$$
$$v_i^k \ge 0, i = 1, \ldots, m;$$
$$w_{d_1}^{1\,k} \ge 0,\ d_1 = 1, \ldots, D_1;\ \ w_{d_2}^{2\,k} \ge 0,\ d_2 = 1, \ldots, D_2;$$
$$w_{d_3}^{3\,k} \ge 0,\ d_3 = 1, \ldots, D_3;\ \ u_r^k \ge 0,\ r = 1, \ldots, s. \qquad (6)$$

With the proposed model (6), we will be able to compare and evaluate the performances of different DMUs and identify the bottlenecks for each DMU, which deteriorate the overall performance of a DMU.

4. RESEARCH RESULTS

4.1. Data description

By using the data of 7 tramp shipping lines, we perform the four-stage network DEA model (6) to obtain the overall efficiency of each company as well as the individual efficiency of each stage. The descriptive statistics for the variables used in the DEA model we proposed is shown in Table 1. There is substantial differences between the means and the range of values across each of the dimensions. The variability may be due to differences in performance and suggest opportunities to improve performance, but also may reflect structural differences among these seven tramp shipping lines that may suggest other extensions for this research.

4.2. Simple efficiency

Based on the input oriented model (6), the relative performance scores for each of the 7 tramp shipping lines are shown in Table 2. The detailed results are presented in this table with disguised names as Tramp Shipping Line 1 (TL1) to Tramp Shipping Line 7 (TL7). Ultimately, this type of analysis would provide specific insights into the relative performance of these organizations, however, this study is focused on developing the framework for this analysis with available data and we believed that the specific names of the lines would not be critical to this objective. The table shows the individual efficiency of each BSC component and the overall efficiency of the seven companies.

In Table 2, TL1 is calculated to be efficient on the “customer perspective” and “financial perspective”, but is inefficient on the “learning and growth perspective” and particularly inefficient on the “internal business processes perspective”. In respect of TL2 and TL5, they are both considered as good performers on the “learning and growth perspective” as well as the “financial perspective”. However, they have low efficiency scores on the

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TABLE 1.
Descriptive statistics of data for 7 tramp shipping lines

Variable	Average	Std. dev.	Max.	Min.
Fixed assets	10,723,801	5,180,867	19,649,228	3,420,784
Current assets	9,194,701	9,182,297	30,599,830	1,520,032
Operating costs	4,944,971	3,996,250	14,025,289	2,175,483
Non-operating expenses	454,905	369,287	1,172,425	70,061
Total assets turnover	0.38	0.21	0.89	0.22
Cash flow ratio	86.70	68.74	223.94	5.47
Operating revenue	7,532,552	5,129,290	18,012,524	3,887,945
Non-operating revenue	870,926	695,702	2,358,444	139,224
Earnings per share	5.54	3.33	11.20	0.08
Net income	2,060,300	1,662,252	5,663,831	131,710

TABLE 2.
Performance scores for tramp shipping lines

Tramp Shipping Line (DMU)	Learning & growth	Internal Business Processes	Customer	Financial	Overall efficiency
TL1	0.440507	0.306741	1.000000	1.000000	0.135121
TL2	1.000000	0.317685	0.454961	1.000000	0.144534
TL3	0.325697	1.000000	1.000000	0.569525	0.185492
TL4	0.638227	0.177041	0.487440	0.700537	0.038583
TL5	1.000000	0.279630	0.254180	1.000000	0.071076
TL6	0.452230	1.000000	0.148850	0.847638	0.057058
TL7	1.000000	0.441912	0.443847	0.055467	0.010879
Maximum	1.000000	1.000000	1.000000	1.000000	0.185492
Minimum	0.325697	0.177041	0.148850	0.055467	0.010879

"internal business processes perspective" and "customer perspective". TL3 is efficient both on the "internal business process perspective" and "customer perspective". Its performance on the "learning and growth perspective" is the lowest among seven companies. However, it is the best performer in terms of the overall efficiency. As for TL4, it not only presents inefficiency on each perspective, but also shows the lowest performance score on the "internal business process perspective". For TL6, it performs well only on the "internal business process perspective", but particularly badly on "customer perspective". TL7 simply shows efficiency on the "learning and growth perspective". Even though, it performs as the last one on the "financial perspective" as well as the overall efficiency. TL3 has the highest overall efficiency, and TL2, TL1, TL5, TL6, TL4 and TL7 are ranked in descending order.

Here the analysis suggests for each of the shipping lines, which aspect of their operations appears to be efficient and therefore is being well-managed based on the inputs and outputs used for this assessment. It also suggests areas where there are inefficiencies and these are likely areas where management effort and investment of additional resources may be needed as a means to improve the performance of that dimension and the overall performance of the shipping line. In this way, this BSC-DEA methodology analysis has the potential to identify paths to improve overall performance of the shipping line.

4.3. Cross-efficiency

The cross-efficiency was suggested by Sexton et al. (1986) and Doyle and Green (1994), which assesses each unit with the DEA weights of all the DMUs instead of with only its own weights (Ruiz and Sirvent, 2012). Each unit is evaluated with reference to the range of weights chosen by all the DMUs, which provides a peer-evaluation of the unit under assessment, as opposed to the conventional DEA self-evaluation (Ramón et al., 2010). The cross-efficiency for $DMU_j (j = 1, \ldots, n)$ can be calculated as followed. Let e_j^k denote the cross-efficiency accorded DMU_j using DMU_k's weights where $e_j^k = e_j^{1\,k} \cdot e_j^{2\,k} \cdot e_j^{3\,k} \cdot e_j^{4\,k}$

and

$$e_j^{1\,k} = \frac{\sum_{d_1=1}^{D_1} w_{d_1}^{1\,k} z_{d_1 j}^1}{\sum_{i=1}^{m} v_i^k x_{ij}}, \qquad e_j^{2\,k} = \frac{\sum_{d_2=1}^{D_2} w_{d_2}^{2\,k} z_{d_2 j}^2}{\sum_{d_1=1}^{D_1} w_{d_1}^{1\,k} z_{d_1 j}^1}$$

$$e_j^{3\,k} = \frac{\sum_{d_3=1}^{D_3} w_{d_3}^{3\,k} z_{d_3 j}^3}{\sum_{d_2=1}^{D_2} w_{d_2}^{2\,k} z_{d_2 j}^2} \quad \text{and} \quad e_j^{4\,k} = \frac{\sum_{r=1}^{s} u_r^k y_{rj}}{\sum_{d_3=1}^{D_3} w_{d_3}^{3\,k} z_{d_3 j}^3}.$$

We have $e_j^k = \frac{\sum_{r=1}^{s} u_r^k y_{rj}}{\sum_{i=1}^{m} v_i^k x_{ij}}$. Since the weights of DMU_k obtained from (6) is not unique, we use the following aggressive formulation, in which we use $\sum_{r=1}^{s} u_r^k y_{rj} - \sum_{i=1}^{m} v_i^k x_{ij}$ as the surrogate

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of the cross-efficiency of DMU_j using DMU_k'j weights, to determine the weights of DMU_k:

$$\text{Min} \sum_{j\neq k}^{n}\left(\sum_{r=1}^{s} u_r^k y_{rj} - \sum_{i=1}^{m} v_i^k x_{ij}\right)$$

$$\text{s.t.} \quad \sum_{r=1}^{s} u_r^k y_{rk} - e_k^k \sum_{i=1}^{m} v_i^k x_{ik} = 0$$

$$\sum_{r=1}^{s} u_r^k y_{rj} - \sum_{d_3=1}^{D_3} w_{d_3}^{3\,k} z_{d_3 j}^3 \le 0, \quad j = 1, \ldots, n$$

$$\sum_{d_3=1}^{D_3} w_{d_3}^{3\,k} z_{d_3 j}^3 - \sum_{d_2=1}^{D_2} w_{d_2}^{2\,k} z_{d_2 j}^2 \le 0, \quad j = 1, \ldots, n$$

$$\sum_{d_2=1}^{D_2} w_{d_2}^{2\,k} z_{d_2 j}^2 - \sum_{d_1=1}^{D_1} w_{d_1}^{1\,k} z_{d_1 j}^1 \le 0, \quad j = 1, \ldots, n$$

$$\sum_{d_1=1}^{D_1} w_{d_1}^{1\,k} z_{d_1 j}^1 - \sum_{i=1}^{m} v_i^k x_{ij} \le 0, \quad j = 1, \ldots, n$$

$$\sum_{i=1}^{m} v_i^k x_{ik} = 1$$

$$v_i^k \ge 0,\ i = 1, \ldots, m;$$

$$w_{d_1}^{1\,k} \ge 0,\ d_1 = 1, \ldots, D_1; \quad w_{d_2}^{2\,k} \ge 0,\ d_2 = 1, \ldots, D_2;$$

$$w_{d_3}^{3\,k} \ge 0,\ d_3 = 1, \ldots, D_3; \quad u_r^k \ge 0, r = 1, \ldots, s. \quad (7)$$

Let $w_{d_1}^{1\,k*}$, $w_{d_2}^{2\,k*}$, $w_{d_3}^{3\,k*}$, v_i^{k*}, u_r^{k*} be the optimal solution of (7). The cross-efficiency for DMU_j using the weights of DMU_k is given by

$$E_{jk} = \frac{\sum_{d_1=1}^{D_1} w_{d_1}^{1\,k*} z_{d_1 j}^1}{\sum_{i=1}^{m} v_i^{k*} x_{ij}} \times \frac{\sum_{d_2=1}^{D_2} w_{d_2}^{2k*} z_{d_2 j}^2}{\sum_{d_1=1}^{D_1} w_{d_1}^{1\,k*} z_{d_1 j}^1} \times \frac{\sum_{d_3=1}^{D_3} w_{d_3}^{3k*} z_{d_3 j}^3}{\sum_{d_2=1}^{D_2} w_{d_2}^{2k*} z_{d_2 j}^2} \times \frac{\sum_{r=1}^{s} u_r^{k*} y_{rj}}{\sum_{d_3=1}^{D_3} w_{d_3}^{3k*} z_{d_3 j}^3} \quad (8)$$

The averaged appraisal by peers for DMU_j is

$$\frac{\sum_{k=1, k\neq j}^{n} E_{jk}}{n-1}. \quad (9)$$

Here we present the results of averaged cross-efficiency in Figure 3.

Model (8) assesses each unit with the DEA weights of other DMU instead of with only its own weights and model (9) averages the appraisals by peers. Figure 3 provides a peer-evaluation of the unit under assessment in contrast to DEA self-evaluation in Table 2. For example, TL3 has the highest value of averaged cross-efficiency, which means it is the highest performance score among these 7 shipping companies from the perspectives of the peers. Model (9) provides appraisals from a more objective view, i.e., the peer view, as oppose to model (6), which provides the appraisals from a subjective view, i.e., the self-evaluation. From the peer view, the shipping companies are ranked in descending order as TL3, TL1, TL5, TL2, TL6, TL4 and TL7.

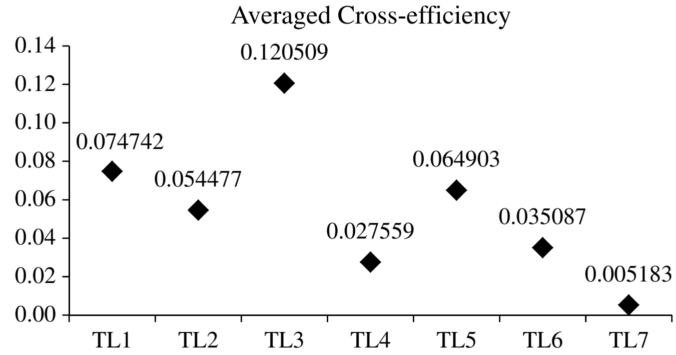

Figure 3. Averaged cross-efficiency for 7 tramp shipping lines

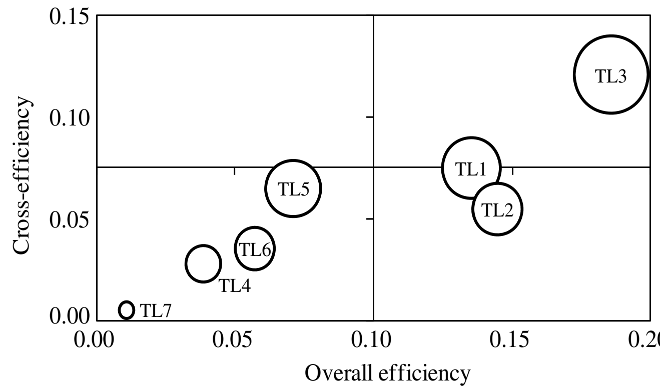

Figure 4. Efficiency comparisons for 7 tramp shipping lines

Figure 4 provides comparison of all DMUs from both views of the self-evaluation and peer-evaluation. The x-axis presents the self-evaluation and the y-axis presents the peer-evaluation. DMUs are divided into four quadrants. DMUs in quadrant 1 represent they perform well in both self-evaluation and peer-evaluation. DMUs in quadrant 2 represent they perform well in peer-evaluation but not in self-evaluation. DMUs in quadrant 3 represent they perform badly in both self-evaluation and peer-evaluation. DMUs in quadrant 4 represent they perform well in self-evaluation but not in peer-evaluation. As shown in Figure 4, TL3 lies in quadrant 1, which means it performs well in both peer-evaluation and self-evaluation. TL4, TL5, TL6 and TL7 lie in quadrant 3, which means they perform badly in both self-evaluation and peer-evaluation. TL1 and TL2 lie in quadrant 4, which means they perform well in self-evaluation but not in peer-evaluation.

5. CONCLUSIONS AND RECOMMENDATIONS

This paper proposes a new methodology for evaluating tramp shipping lines performances. By using data from Taiwan Stock

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Exchange Corporation, we integrate network DEA with BSC approach as a four-stage model to assess the efficiency of 7 companies. Our contributions are to extend the industry literature by focusing on tramp shipping lines performances, and improve the non-interconnected model presented in previous studies by embracing the centralized concept combining BSC and DEA. We also analyze the efficiency of each stage and DMU, and finally make the efficiency comparison from the self-evaluation and peer-evaluation viewpoints. The main results showed here are that TL3 and TL7 are respectively the best and the worst performer for overall efficiency as well as cross-efficiency. TL6 and TL4 are in the same order both for the overall efficiency and cross-efficiency. TL1, TL2 and TL5 show different orders between two kinds of efficiencies are resulted from the greater overestimation in self-evaluation of TL2. Briefly, we are capable of distinguishing the real efficient DMU from all units with the model proposed.

The management implications of the appraisals by model (6) are as follows. TL1 is inefficient because of the learning and growth perspective and internal business processes perspective, which are the bottlenecks of TL1. TL1 exhibits efficient in the customer and financial perspectives. To be efficient, T1 has to improve on the learning and growth perspective and internal business processes. TL2 is not efficient. Among the four stages, there are two stages which are efficient for TL2, namely, the learning and growth perspective and financial perspective. TL2 is not efficient on stage 2 (internal business processes) and stage 3 (customer). To be efficient, TL2 has to improve on the internal business processes and customer perspectives. TL3 is not efficient, though it outperforms other tramp shipping lines. TL3 is efficient on stage 2 (internal business process) and stage 3 (customer), but however, inefficient on stage 1 (learning and growth) and stage 4 (financial). To be efficient, TL3 has to improve its efficiency on stage 1 and stage 4. TL4 performs badly overall because none of the four stages is efficient. TL5 is inefficient because stage 2 and stage 3 are inefficient. To be efficient, it has to improve on stage 2 and stage 3. TL6 is not efficient because it is inefficient on stage 1, stage 3 and stage 4. To be efficient, TL6 has to improve on stage 1, stage 3 and stage 4. Finally, TL7 demonstrates the poorest performance among the seven tramp shipping lines though it is efficient on stage 1. It is ranked the last because the performance in stage 4(financial perspective) is very poor. To be efficient, it has to improve stage 4 first, then stage 2, and stage 3 finally.

Companies evaluated in the manner suggested in this paper would potentially gain insights into the problems or weaknesses in their operations compared with peers. Accordingly, they will be able to ameliorate the overall performance by improving one or more BSC dimensions identifies with this model. In other words, this paper proposes an informative model which not only examines the performances of each company, but also clarifies the direction for modification. The model proposed is, we believe, an enhancement to prior models and with the potential to be adopted in various research fields for better understanding of the relative performance of organizations. Some key factors as compensation of cargo claim, application rate of vessel or share of ship chartering are not included here because of the data unavailability.

One of the limitations of our model is that it can't deal with negative financial data directly. If negative data appears in the data set, some kind of preprocessing is needed. Therefore, one of the possible research directions in the future is to extend our model so that it can deal with negative data directly.

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REFERENCES

Amado, C.A.F., Santos, S.P., and Marques, P.M. (2012), “Integrating the data envelopment analysis and the balanced scorecard approaches for enhanced performance assessment”, *Omega-International Journal of Management Science,* 40(3): 390–403.

Asosheh, A., Nalchigar, S., and Jamporazmey, M. (2010), “Information technology project evaluation: an integrated data envelopment analysis and balanced scorecard approach”, *Expert Systems with Applications,* 37(8): 5931–5938.

Banker, R.D., Chang, H.H., Janakiraman, S.N., and Konstans, C. (2004), “A balanced scorecard analysis of performance metrics”, *European Journal of Operational Research,* 154(2): 423–436.

Bhagwat, B. and Sharma, M.K. (2007), “Performance measurement of supply chain management: A balanced scorecard approach”, *Computers & Industrial Engineering,* 53(1): 43–62.

Charnes, A., Cooper, W.W., and Rhodes, E. (1978), “Measuring the efficiency of decision making units”, *European Journal of Operational Research,* 2(6): 429–444.

Chen, C. and Yan, H. (2011), “Network DEA model for supply chain performance evaluation”, *Omega-International Journal of Management Science,* 213(1): 147–155.

Chen, C.L., Zhu, J., Yu, J.Y., and Noori, H. (2012), “A new methodology for evaluating sustainable product design performance with two-stage network data envelopment analysis”, *Omega-International Journal of Management Science,* 221(2): 348–359.

Chiang, C.Y. and Lin, B. (2009), “An integration of balanced scorecards and data envelopment analysis for firm's benchmarking management”, *Total Quality Management & Business Excellence,* 20(11): 1153–1172.

Chilingerian, J. and Sherman, H.D. (2011), “Health Care Applications - From hospitals to physicians, from productive efficiency to quality frontiers”. *In* Cooper, W.W., Seiford, L., and Zhu, J. (eds), Handbook of Data Envelopment Analysis (DEA)- 2nd Edition, chapter 16, Springer, pp.445–493.

Cook, W.D., Zhu, J., Bi, G.B., and Yang, F. (2010), “Network DEA: additive efficiency decomposition”, *European Journal of Operational Research,* 207(2): 1122–1129.

Cullinane, K., Wang, T.F., Song, D.W., and Ji, P. (2006), “The technical efficiency of container ports: comparing data envelopment analysis and stochastic frontier analysis”, *Transportation Research Part A: Policy and Practice,* 40(4): 354–374.

DOI 10.3138/infor.51.3.130

Doyle, J. and Green, R. (1994), "Efficiency and cross-efficiency in DEA: Derivations, meanings and uses", *Journal of the Operational Research Society,* 45(5): 567–578.

Eilat, H., Golany, B., and Shtub, A. (2006), "Constructing and evaluating balanced portfolios of R&D projects with interactions: A DEA based methodology", *European Journal of Operational Research,* 172(3): 1018–1039.

Eilat, H., Golany, B., and Shtub, A. (2008), "R&D project evaluation: an integrated DEA and balanced scorecard approach", *Omega-International Journal of Management Science,* 36(5): 895–912.

Färe, R. and Grosskopf, S. (2000), "Network DEA", *Socio-Economic Planning Sciences,* 34(1): 35–49.

Fang, H.H., Lee, H.S., Hwang, S.N., and Chung, C.C. (2013), "A slacks-based measure of super-efficiency in data envelopment analysis: An alternative approach", *OMEGA - The International Journal of Management Science,* 41(4): 731–734.

Fukuyama, H. and Mirdehghan, S.M. (2012), "Identifying the efficiency status in network DEA", *European Journal of Operational Research,* 220(1): 85–92.

García-Valderrama, T., Mulero-Mendigorri, E., and Revuelta-Bordoy, D. (2009), "Relating the perspectives of the balanced scorecard for R&D by means of DEA", *European Journal of Operational Research,* 196(3): 1177–1189.

Gauld, R., Al-wahaibi, S., Chisholm, J., Crabbe, R., Kwon, B., Oh, T., Palepu, R., Rawcliffe, N., and Sohn, S. (2011), "Scorecards for health system performance assessment: The New Zealand example", *Health Policy,* 103(2–3): 200–208.

Grigoroudis, E., Orfanoudaki, E., and Zopounidis, C. (2012), "Strategic performance measurement in a healthcare organisation: A multiple criteria approach based on balanced scorecard", *Omega-International Journal of Management Science,* 40(1): 104–119.

Houck, M., Speaker, P.J., Fleming, A.S., and Riley, R.A. Jr. (2012), "The balanced scorecard: Sustainable performance assessment for forensic laboratories", *Science & Justice,* 52(4): 209–216.

Hsieh, L.F. and Lin, L.H. (2010), "A performance evaluation model for international tourist hotels in Taiwan-An application of the relational network DEA", *International Journal of Hospitality Management,* 29(1): 14–24.

Hsu, C.W., Hu, A.H., Chiou, C.Y., and Chen, T.C. (2011), "Using the FDM and ANP to construct a sustainability balanced scorecard for the semiconductor industry", *Expert Systems with Applications,* 38(10): 12891–12899.

Hwang, S.N., Chen, C., Chen, Y., Lee, H.S., and Shen, P.D. (2013), "Sustainable design performance evaluation with applications in the automobile industry: focusing on inefficiency by undesirable factors", *OMEGA - The International Journal of Management Science,* 41(3): 553–558.

Hwang, S.N., Lee, H.S., Tang, S.C., and Hsu, S.S. (2014), "Measuring quality of life using DEA-AR: focusing on undesirable factors", *INFOR,* 51(2): 84–91.

Kaplan, R.S. and Norton, D.P. (1992), "The balanced scorecard-Measures that drive performance", *Harvard Business Review,* 70(1): 71–79.

Kaplan, R.S. and Norton, D.P. (1996), *The Balanced Scorecard: Translating Strategy into Action,* Harvard Business School Press, Boston.

Lazzarotti, V., Manzini, R., and Mari, L. (2011), "A model for R&D performance measurement", *International Journal of Production Economics,* 134(1): 212–223.

Lee, H.S. and Zhu, J. (2012), "Super-efficiency Infeasibility and Zero Data in DEA", *European Journal of Operational Research,* 216(2): 429–433.

Lee, H.S., Chu, C.W., and Zhu, J. (2011), "Super-efficiency DEA in the presence of infeasibility", *European Journal of Operational Research,* 212(1): 141–147.

Lee, H.S., Tzeng, G.H., Yeih, W., Wang, Y.J., and Yang, S.C. (2013), "Revised DEMATEL: resolving the infeasibility of DEMATEL", *Applied Mathematical Modelling,* 37(10–11): 6746–6757.

Lozano, S. (2011), "Scale and cost efficiency analysis of networks of processes", *Expert Systems with Applications,* 38(6): 6612–6617.

Lozano, S., Gutiérrez, E., and Moreno, P. (2013), "Network DEA approach to airports performance assessment considering undesirable outputs", *Applied Mathematical Modelling,* 37(4): 1665–1676.

Matthews, K. (2013), "Risk management and managerial efficiency in Chinese banks: a network DEA framework", *Omega-International Journal of Management Science,* 41(2): 207–215.

Meera, S.N. (2005), "Development of Indian shipping during five year plans", *Finance India,* 19(4): 1337–1364.

Michalska, J. (2005), "The usage of the balanced scorecard for the estimation of the enterprise's effectiveness", *Journal of Materials Processing Technology,* 162–163: 751–758.

Mostafa, M. (2007), "Benchmarking top Arab banks' efficiency through efficient frontier analysis", *Industrial Management & Data Systems,* 107(6): 802–823.

Panayides, P.M., Lambertides, N., and Savva, C.S. (2011), "The relative efficiency of shipping companies", *Transportation Research Part E: Logistics and Transportation Review,* 47(5): 681–694.

Ramón, N., Ruiz, J.L., and Sirvent, I. (2010), "On the choice of weights profiles in cross-efficiency evaluations", *European Journal of Operational Research,* 207(3): 1564–1572.

Ruiz, J.L. and Sirvent, I. (2012), "On the DEA total weight flexibility and the aggregation in cross-efficiency evaluations", *European Journal of Operational Research,* 223(3): 732–738.

Scheel, H. (2001), "Undesirable outputs in efficiency valuations", *European Journal of Operational Research,* 132(2): 400–410.

Sexton, T.R., Silkman, R.H., and Hogan, A.J. (1986), "Data envelopment analysis: Critique and extensions", *New Directions for Program Evaluation,* 1986(32): 73–105.

Sharma, M.J. and Yu, S.J. (2009), "Performance based stratification and clustering for benchmarking of container terminals", *Expert Systems with Applications,* 36(3): 5016–5022.

Sherman, H.D. and Zhu, J. (2006), *Service Productivity Management: Improving Service Performance using Data Envelopment Analysis,* Springer, Boston.

Stepchenkova, S., Tang, L., Jang, S.C., Kirilenko, A.P., and Morrison, A.M. (2010), "Benchmarking CVB website performance: Spatial and structural patterns", *Tourism Management,* 31(5): 611–620.

Taiwan Stock Exchange Corporation, Market Observation Post System. http://newmopsov.twse.com.tw (2009), Accessed on 29 October 2012.

Wang, H.S. and Lee, H.S. (2012a), "The impact of navigation safety in Kaohsiung harbor", *Journal of Marine Engineering and Technology,* 11(1): 45–50.

Wang, H.S. and Lee, H.S. (2012b), "Evaluating navigation safety for harbours in Taiwan: An empirical study", *Journal of Marine Engineering and Technology,* 11(3): 31–37.

ISSN 0315-5986 | EISSN 1916-0615
DOI 10.3138/infor.51.3.130

Wu, C.R., Lin, C.T., and Tsai, P.H. (2010), "Evaluating business performance of wealth management banks", *European Journal of Operational Research,* 207(2): 971–979.

Wu, H.Y., Lin, Y.K., and Chang, C.H. (2011), "Performance evaluation of extension education centers in universities based on the balanced scorecard", *Evaluation and Program Planning,* 34(1): 37–50.

Xie, B.C., Fan, Y., and Qu, Q.Q. (2012), "Does generation form influence environmental efficiency performance? An analysis of China's power system", *Applied Energy,* 96: 261–271.

Yang, C. and Liu, H.M. (2012), "Managerial efficiency in Taiwan bank branches: a network DEA", *Economic Modelling,* 29(2): 450–461.

Yu, M.M. and Fan, C.K. (2009), "Measuring the performance of multimode bus transit: a mixed structure network DEA model", *Transportation Research Part E: Logistics and Transportation Review,* 45(3): 501–515.

Yu, M.M. and Lin, E.T. (2008), "Efficiency and effectiveness in railway performance using a multi-activity network DEA model", *Omega-International Journal of Management Science,* 36(6): 1005–1017.

Zhao, Y., Triantis, K., Murray-Tuite, P., and Edara, P. (2011), "Performance measurement of a transportation network with a downtown space reservation system: a network-DEA approach", *Transportation Research Part E: Logistics and Transportation Review,* 47(6): 1140–1159.

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