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A performance evaluation model for supply chain of shipping company in Iran: an application of the relational network DEA

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A performance evaluation model for supply chain of shipping company in Iran: an application of the relational network DEA

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Shipping business is capital intensive and highly competitive. It necessitates for the shipping companies to constantly monitor their performance and measure relative efficiencies of their supply chains. Despite such importance, the studies devoted to this field have been surprisingly limited. This paper reviews the involved factors and proposes a relational network data envelopment analysis (DEA) model for measuring the efficiency of supply chain of an international shipping company in Iran with relevant sub-processes in the period 2008–2011. First, the supply chain network of the company is illustrated and then the input and output variables associated to each member are determined. The proposed model is suitable for shipping companies which usually use similar pattern in this business. Finally based on the results, recommendations are made for improvements and a new field of business is also proposed.

Keywords: shipping firm; supply chain; efficiency; relational network DEA; network structure

1. Introduction

International trade is the driving force of the world economic growth. Trade and economic growth have mutual and reciprocal interactions. Having a suitable means of moving the goods with reasonable costs from one country to another country is an essential requirement for trade, growth and development. Maritime transport is the backbone of international trade and a key engine driving globalization. It is important to note that around 80% of global trade in terms of volume and over 70% in terms of value is carried by sea and it is handled by ports worldwide; these shares are even higher in the case of most developing countries (UNCTAD 2012). No other method of transportation can connect the continents which are thousands of miles apart and separated by oceans, with such magnitudes of cargo and competitive prices.

The world seaborne merchandise trade has been 8747.7 million tons in the year 2011 and 8408.9 million tons in 2010 and the share of freight rate in the goods finished price at destination in a long-term trend in developed economies have been 7.5% in 1980s and 6.5% in 2000s (UNCTAD 2011). The given figures indicate how sea transportation reduces the carriage cost elements in finished price of the goods at destination and how shipping lines have been forced to reduce their tariff in the course of years. The nature of the shipping business is a service type and capital intensive venture and it calls for huge launching investment and heavy operational costs. Hence, there is a serious risk of heavy

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financial losses, collapse and bankruptcy if not watched and evaluated continuously and carefully. Nowadays, similar to many other firms, the supply chains of the shipping lines compete to one another. Therefore, continuous effort is required to evaluate the efficiencies of supply chains of shipping lines in order to ensure their optimum outputs.

Unfortunately, the studies devoted to performance assessment of shipping lines have been surprisingly limited (Panayides, Lambertides, and Savva 2011; Bang et al. 2012), whereas large number of studies in maritime field have been devoted to the measurement of relative efficiency in other sectors of shipping like ports and container terminals. Similar to many other modern industries, in order to have competitive advantages for the shipping lines, they must have a competitive supply chain. According to reports by Deloitte Consulting (1999), from now on the companies will compete together through their supply chains. This report is based on studies carried out over 200 producers and distributors in the USA and Canada. In today's highly competitive market, the lack of harmony among various elements within the operation of a shipping company will lead to severe damages and losses. Continuous and sustainable development of an organization is dependent on evaluation and measurement of key processes within an organization. A proper and effective functioning of supply chain within a shipping company has a key role in its success and gaining advantage toward competitors.

In fact, there is a distinct gap between the studies devoted to the measurement of relative efficiency in shipping firms and the limited studies devoted to the measurement of the relative efficiency of their supply chains. The limited attention given to relative efficiency evaluation of the supply chain of a shipping firm means that the structure of supply chain of shipping firm and the inputs and outputs variables used in the relative efficiency models have not been developed. By designing the structure of supply chain of a shipping company and determining the variables, this paper addresses an important gap in the existing literature. The structure designed and illustrated in this paper is a network of supply chain of an international shipping company in Iran. This network is compatible for most of shipping companies in the world because the members of supply chain used in this paper are usually existent in many shipping firms. Therefore, a great majority of the shipping companies can utilize the network and methodology of this paper for evaluating the efficiency of their supply chains.

Furthermore, in the restricted studies conducted in measuring relative efficiency of shipping industry, conventional data envelopment analysis (DEA) models have been used which treats the system as a black box by disregarding its internal structure. Whereas the supply chain of a shipping line is formed by a number of suppliers, producers and distributors which are inter-connected in a network, each member must have the highest possible efficiency in order to gain the highest efficiency in chain. Kao (2009) presented a relational network DEA model, taking into account the inter-relationship of the processes within the system, to measure the efficiency of the system and sub-processes at the same time. The relational network DEA is an appropriate model for measuring the efficiency of the supply chain because it measures the efficiency of the system and its internal processes at the same time.

Recognizing the gaps in the maritime transport literature, this paper is the first study which measures the relative efficiency of shipping firm's supply chain in which the efficiencies of system and sub-process are considered in a unified mathematical model. The study aims to provide a comparative analysis of shipping company's supply chains and its members at the same time. The paper makes a contribution to the measurement of relative efficiency in the maritime transportation literature by undertaking this assessment for the first time. In addition, the network and structure of shipping company is designed and its inputs and outputs are determined. In view of all above explanations, this paper evaluates the supply chain of a leading shipping company in Iran using relational network DEA model.

The rest of the paper is organized as follows. Next section provides literature review of relative efficiency studies in transportation. Section 3 describes the methodology utilized in this study and the relational model for supply chain of shipping firm in is shown. In Section 4, a case on the supply chain of shipping company of Iran is described. Section 5 provides the results and finally, conclusion is presented in Section 6.

2. Literature review of relative efficiency studies in transportation

The calculation of operational efficiency has been an important topic in the transportation studies and valuable efforts have so far been undertaken to measure the efficiencies in order to define a gauge for comparison (Markovits-Somogyi 2011). There are several methods to measure performance, out of which, DEA has been most used in order to evaluate the relative performance decision making units (DMUs) (Charnes, Cooper, and Rhodes 1978). DEA model has been extensively utilized in a range of transportation industries including airports (Martín and Román 2001; Gillen and Lall 1997), railway (Jitsuzumi and Nakamura 2010; Azadeh, Ghaderi, and Izadbakhsh 2008), public transportation (Sampaio, Neto, and Sampaio 2008) and sea ports (Cullinane et al. 2006).

Markovits-Somogyi (2011) studied the DEA assessments performed in transportation fields and showed that among the 64 transport researches using DEA, most of studies were on airports and seaports (23 and 21, respectively) and then railways (9), airlines (4), public field (10) and the rest (2). DEA was first used for seaport analysis by Roll and Hayuth (1993) and then many researchers used this method to measure the performance of terminal operating companies as of 2000 after seaport privatizations (Woo et al. 2012). In view of growing interests for applying DEA in the seaport researches, several review papers have been published about efficiencies of seaports (e.g. Panayides et al. 2009). Woo et al. (2012) also could reckon 32 papers which had used DEA in their studies of 840 seaports studies published as of 1980. However, through various published information, it is understood that the researches in marine fields have been mainly confined to seaports and the number of such studies concerning shipping company is very limited (Panayides, Lambertides, and Savva 2011; Bang et al. 2012).

Panayides, Lambertides, and Savva (2011) measured the efficiencies of 26 leading shipping lines including 15 container liners, 6 dry bulk tramps and 5 tanker companies by using both DEA and stochastic frontier analysis models. Bang et al. (2012) measured the relative efficiency of shipping liners in fields of financial and operational tasks and further reviewed the effects of strategic and operational management on performance efficiency. By using a two-stage DEA model (Tobit regression and DEA), they calculated the efficiency of 14 liner shipping companies out of the top 20 container lines.

With the outset of globalization and development of technologies, the competition among the firms changed its form to a new shape of battle among their supply chains (Xiao and Yang 2008). The performance of a supply chain is assessed and evaluated from its earliest elements of production up to the final point of delivering the products to consumers. In this process, all links must perform equally well, otherwise it will be of no use if some links work suitably and the others do not (Banomyong 2005).

Despite the importance of relative efficiency measurement for the supply chain of shipping firms, the studies devoted to this matter have been surprisingly limited. In fact, there is no study for calculating the supply chain performance of a shipping firm with network DEA. In the meantime, no studies have been performed in supply chain sectors of shipping in order to develop indicators to compare and evaluate important aspects of their performance. The limited attention given to relative efficiency estimation of shipping firms indicates that gauges and measures that may be used as inputs and outputs in the relative efficiency models have not been developed.

3. Methodology

3.1. *Overview of DEA and network DEA*

DEA was initially presented by Charnes, Cooper, and Rhodes (1978). It is a non-parametric method for analysing and evaluating the relative efficiency of similar DMUs based on multiple inputs and outputs. The constant returns to scale (CCR) efficiency score of DMU k is as follows:

$$
\begin{aligned}
E_k = {} & \max \sum_{r=1}^{s} u_r Y_{rk} \\
& s.t.\ \sum_{i=1}^{m} v_i X_{ik} = 1, \\
& \sum_{r=1}^{s} u_r Y_{rj} - \sum_{i=1}^{m} v_i X_{ij} \leq 0, \qquad j = 1, \ldots, n \\
& u_r, v_i \geq \varepsilon,\ r = 1, \ldots,\ i = 1, \ldots, m,
\end{aligned}
\tag{1}
$$

where X_{ij} and Y_{rj} are the ith input, (i = 1,. . .,m) and rth output (r = 1,. . ., s) for the jth DMU (j = 1,. . .,n). Also, ε is a small non-Archimedean number.

Traditional DEA models considered a DMU as "black box" which takes the first inputs to create the final output without surveying the internal processes (Lewis and Sexton 2004). On the other hand, no assumptions are made regarding the processes occurring inside a DMU in the traditional DEA.

The problems and deficiencies associated with classical DEA system caused the researchers to have more attention on the internal processes and structure of DMUs. Kao and Hwang (2010) have classified these researches into three groups of "independent", "connected" and "relational". In the independent methodology, the efficiency of the system and sub-processes are calculated independently, in which there is no relationship between the two mentioned efficiencies. These models were first studied by Seiford and Zhu (1999). They utilized this approach to evaluate the efficiency of the top commercial banks in the USA.

In the connected approach, for measuring the system efficiency, the interactions between the two processes are also considered. There after system efficiency is obtained using above-mentioned method. The efficiencies of the two processes are also worked out separately and independently. In this methodology, the calculated efficiency is closer to the facts of the system but again, no direct relationship between the system and process efficiencies exists. This approach is introduced by the network DEA model of Färe and Grosskopf (2000).

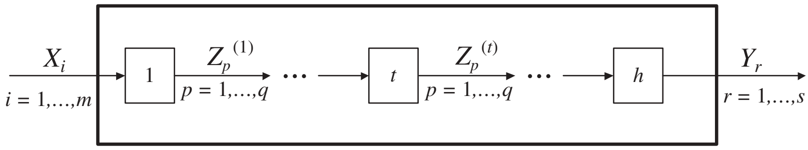

Figure 1. Series system discussed in Kao (2009).

In the relational methodology, a single mathematical program is used to calculate the efficiencies of system and processes. Then, through the constraints of the mathematical program the relationship between the system efficiency and processes efficiencies is obtained. The relational approach and methodology was first introduced by Kao and Hwang (2008) for evaluation of a system which had two sub-processes connected in series. Kao (2009) then further extended the above-mentioned two-stage model by adding more sub-processes in series and parallel.

To introduce the relational DEA model for a system with series structure, Kao (2009) considered a series system of h processes which is shown in Figure 1. In Figure 1, X_{ij} and Y_{rj} are ith input and rth output of the system, respectively, and $Z_{pj}^{(t)}$ is the pth intermediate product, $p = 1,\ldots,q$, of process t, $t = 1,\ldots,h\text{–}1$, for DMU j.

The system efficiency of DMU k is calculated as follows (Kao 2009):

$$\begin{aligned}
E_k = \max & \sum_{r=1}^{s} u_r Y_{rk} \\
s.t.: & \\
& \sum_{i=1}^{m} \gamma_i X_{ik} = 1 \\
& \sum_{r=1}^{s} u_r Y_{rj} - \sum_{i=1}^{m} \gamma_i X_{ij} \le 0, \qquad j = 1,\ldots,n \\
& \sum_{p=1}^{q} w_p^{(1)} Z_{pj}^{(1)} - \sum_{i=1}^{m} \gamma_i X_{ij} \le 0, \qquad j = 1,\ldots,n \\
& \sum_{p=1}^{q} w_p^{(t)} Z_{pj}^{(t)} - \sum_{p=1}^{q} w_p^{(t-1)} Z_{pj}^{(t-1)} \le 0, \qquad j = 1,\ldots,n, \quad t = 2,\ldots,h-1 \\
& \sum_{r=1}^{s} u_r Y_{rj} - \sum_{p=1}^{q} w_p^{(h-1)} Z_{pj}^{(h-1)} \le 0, \qquad j = 1,\ldots,n \\
& u_r, \gamma_i, w_p^{(t)} \ge \varepsilon, \ r = 1,\ldots,s, \ i = 1,\ldots,m, \ p = 1,\ldots,q, \ t = 1,\ldots,h-1,
\end{aligned} \tag{2}$$

where $w_p^{(t)}$ is the multiplier associated with the pth intermediate product of process t.

For a system composed of h processes connected in parallel form which is shown in Figure 2, Kao (2009) developed the relational DEA model to calculate the efficiency of the parallel system as follows:

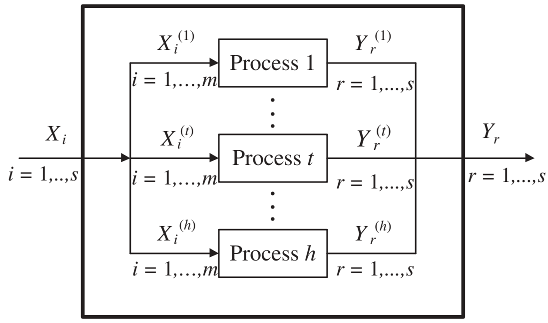

Figure 2. Parallel system discussed in Kao (2009).

$$
\begin{aligned}
E_k = \max & \sum_{r=1}^{s} u_r Y_{rk} \\
s.t.: & \\
& \sum_{i=1}^{m} \gamma_i X_{ik} = 1 \\
& \sum_{r=1}^{s} u_r Y_{rk} - \sum_{i=1}^{m} \gamma_i X_{ik} + s_k = 0, \\
& \sum_{r=1}^{s} u_r Y_{rk}^{(t)} - \sum_{i=1}^{m} \gamma_i X_{ik}^{(t)} + s_k^{(t)} = 0, \qquad t = 1, \ldots, h \\
& \sum_{r=1}^{s} u_r Y_{rj} - \sum_{i=1}^{m} \gamma_i X_{ij} \le 0, \qquad j = 1, \ldots, n,\ j \neq k \\
& \sum_{r=1}^{s} u_r Y_{rk}^{(t)} - \sum_{i=1}^{m} \gamma_i X_{ik}^{(t)} \le 0, \qquad j = 1, \ldots, n,\ j \neq k, \quad t = 1, \ldots, h \\
& u_r, \gamma_i \ge \varepsilon, \quad r = 1, \ldots, s, \quad i = 1, \ldots, m,
\end{aligned}
\tag{3}
$$

where ${X_{ij}}^{(t)}$ and ${Y_{rj}}^{(t)}$ are the ith input and the rth output of process t, respectively.

After introducing the relational DEA in series and parallel form, Kao (2009) presented relational network DEA and pointed out that by utilizing dummy processes, any network system can be transformed into a series system where each stage in the series has a parallel structure. He used the case discussed in Färe and Grosskopf (2000) to represent the idea.

The network used by Kao (2009) is a simple form of network structure. When the network is complex, transforming it to series and parallel structure is not easy. Kao and Hwang (2010) expanded the relational network DEA for evaluating network structures without transforming the network structure to series and parallel. Since the network system does not have a general structure, therefore, a single valid model for all types of network structures cannot be presented. This is the reason for the necessity of having different models for different types of networks although the general concept for all of

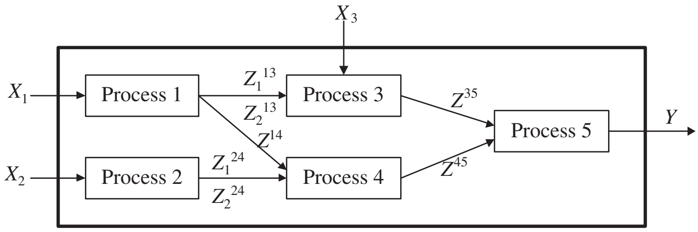

Figure 3. Network system discussed in Lewis and Sexton (2004).

them may be similar. Kao and Hwang (2010) used the network system of Lewis and Sexton (2004) to illustrate the relational network DEA model. Figure 3 shows the network system discussed in Lewis and Sexton (2004).

The relational network DEA of Kao and Hwang (2010) shown at Figure 3 is as follows:

$$
\begin{aligned}
E_k = \max\ & uY_k \\
s.t.:\ & \\
& \gamma_1 X_{1k} + \gamma_2 X_{2k} + \gamma_3 X_{3k} = 1 \\
& uY_j - (\gamma_1 X_{1j} + \gamma_2 X_{2j} + \gamma_3 X_{3j}) \le 0, && j = 1, \ldots, n \\
& w_1^{13} Z_{1j}^{13} + w_2^{13} Z_{2j}^{13} + w^{14} Z_j^{14} - \gamma_1 X_{1j} \le 0, && j = 1, \ldots, n \\
& w_1^{24} Z_{1j}^{24} + w_2^{24} Z_{2j}^{24} - \gamma_2 X_{2j} \le 0, && j = 1, \ldots, n \\
& w^{35} Z_j^{35} - (w_1^{13} Z_{1j}^{13} + w_2^{13} Z_{2j}^{13} + \gamma_3 X_{3j}) \le 0, && j = 1, \ldots, n \\
& w^{45} Z_j^{45} - (w^{14} Z_j^{14} + w_1^{24} Z_{1j}^{24} + w_2^{24} Z_{2j}^{24}) \le 0, && j = 1, \ldots, n \\
& uY_j - (w^{35} Z_j^{35} + w^{45} Z_j^{45}) \le 0, && j = 1, \ldots, n \\
& u_1, \gamma_1, \gamma_2, \gamma_3, w_1^{13}, w_2^{13}, w^{14}, w_1^{24}, w_2^{24}, w^{35}, w^{45} \ge \varepsilon.
\end{aligned}
\tag{4}
$$

Hsieh and Lin (2010) evaluated the efficiencies of Touristic hotels in Taiwan by utilizing Kao (2009) model. Chen and Yan (2011) used the network DEA to evaluate the efficiency of a supply chain consisting of one supplier and two manufacturers in three approaches of centralized, decentralized and mixed.

3.2. *Relational model for supply chain of a shipping firm*

This paper uses a relational network DEA method to measure the performance of the supply chain of a major shipping line in Iran. Figure 4 shows the structure of the supply chain. In stage 1, Processes 1–4 use inputs X_1, X_2, X_3 and X_4 to produce intermediate products Z_1, Z_2, Z_3 and Z_4, respectively. Process 5 uses intermediate products Z_1, Z_2, Z_3 and Z_4, produced by Processes 1–4, to produce intermediate products Z_{51} and Z_{52}. In stage 2, process 6 uses intermediate product Z_{51} and input X_5 to produce intermediate product Z_6. Process 7 uses intermediate product Z_{52} and input X_6 to produce intermediate product Z_7. Finally, in stage 3, process 8 uses intermediate products Z_6 and Z_7 to produce final output Y.

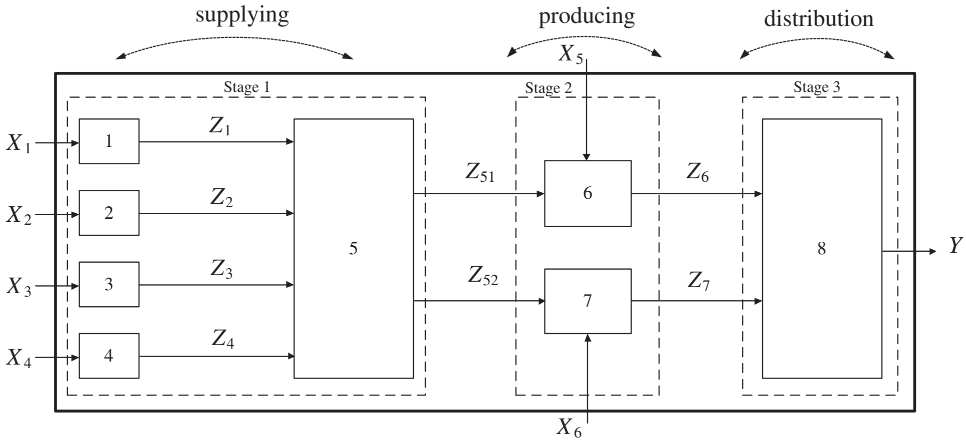

Figure 4. The structure of the supply chain.

Since the relational network DEA measures the overall organizational efficiency and the efficiencies of processes within the organization, so it has been regarded to be an efficient method for evaluating supply chains.

The supply chain network of a shipping line is more complex and complicated than the one discussed by Lewis and Sexton (2004). Therefore, the network model used in this paper is not the same model (4). The relational network model for calculating the supply chain of Figure 4 is as follows:

$$\begin{aligned}
& E_k = \max uY_k \\
& s.t. \\
& \quad v_1X_{1k} + v_2X_{2k} + v_3X_{3k} + v_4X_{4k} + v_5X_{5k} + v_6X_{6k} = 1, \\
& \quad uY_j - (v_1X_{1j} + v_2X_{2j} + v_3X_{3j} + v_4X_{4j} + v_5X_{5j} + v_6X_{6j}) \le 0, && j = 1,\ldots,n \\
& \quad w_1Z_{1j} - v_1X_{1j} \le 0, && j = 1,\ldots,n \\
& \quad w_2Z_{2j} - v_2X_{2j} \le 0, && j = 1,\ldots,n \\
& \quad w_3Z_{3j} - v_3X_{3j} \le 0, && j = 1,\ldots,n \\
& \quad w_4Z_{4j} - v_4X_{4j} \le 0, && j = 1,\ldots,n \\
& \quad w_{51}Z_{51j} + w_{52}Z_{52j} - (w_1Z_{1j} + w_2Z_{2j} + w_3Z_{3j} + w_4Z_{4j}) \le 0, && j = 1,\ldots,n \\
& \quad w_6Z_{6j} - (w_{51}Z_{51j} + v_5X_{5j}) \le 0, && j = 1,\ldots,n \\
& \quad w_7Z_{7j} - (w_{52}Z_{52j} + v_6X_{6j}) \le 0, && j = 1,\ldots,n \\
& \quad uY_j - (w_6Z_{6j} + w_7Z_{7j}) \le 0, && j = 1,\ldots,n \\
& \quad v_1, v_2, v_3, v_4, v_5, v_6, w_1, w_2, w_3, w_4, w_{51}, w_{52}, w_6, w_7, u \ge \varepsilon > 0,
\end{aligned} \tag{5}$$

where v_i (i = 1,…6) and w_p (p = 1,2,3,4,51,52,6,7) are the multipliers.

The second constrain is related to the efficiency of supply chain of given shipping firm, and the third to seventh constrains are related to its suppliers. The constrains eight and nine are related to producers and the tenth constrain is related to disturber. The efficiencies and effectiveness of supply chain members are calculated as follows:

$$
\begin{aligned}
E_k^{(1)} &= \frac{w_1^* Z_{1k}}{v_1^* X_{1k}} \qquad E_k^{(2)} = \frac{w_2^* Z_{2k}}{v_2^* X_{2k}} \\
E_k^{(3)} &= \frac{w_3^* Z_{3k}}{v_3^* X_{3k}} \qquad E_k^{(4)} = \frac{w_4^* Z_{4k}}{v_4^* X_{4k}} \\
E_k^{(5)} &= \frac{w_{51}^* Z_{51k} + w_{52}^* Z_{52k}}{w_1^* Z_{1k} + w_2^* Z_{2k} + w_3^* Z_{3k} + w_4^* Z_{4k}} \\
E_k^{(6)} &= \frac{w_6^* Z_{6k}}{w_{51}^* Z_{51k} + v_5^* X_{5k}} \\
E_k^{(7)} &= \frac{w_7^* Z_{7k}}{w_{52}^* Z_{52k} + v_6^* X_{6k}} \\
E_k^{(8)} &= \frac{u^* Y_k}{w_6^* Z_{6k} + w_7^* Z_{7k}},
\end{aligned}
\tag{6}
$$

where u_r^*, v_i^* and w_q^* represent the optimal multipliers of the mathematical model.

4. Supply chain of shipping in Iran and data

Doubtlessly shipping is by far dominating the transportation of goods from ports to ports and countries to countries and will probably remain so for many more years and decades. No other method of transportation can provide such capacities in terms of millions of tones to carry raw materials from places and countries. Nor any other means of transportation can connect continents which are thousands of miles apart with such competitive prices.

The movement and operation of ships in remote and varying locations, causes their supply chain also to be likewise mobile, volatile and diverse. The shipping company chosen for our studies is a leading shipping line in Iran. It has different fields of operation in terms of container feeders, passenger transportation and cars. The detail of the network supply chain of this company is shown in Figure 5.

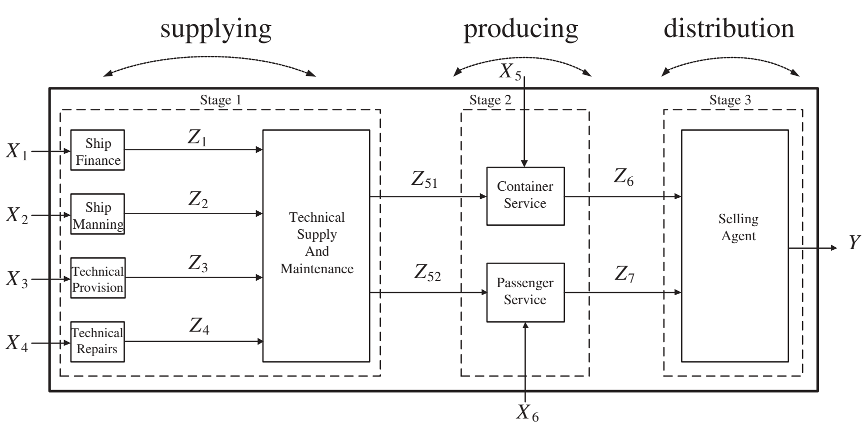

Figure 5. Supply chain network of shipping line in Iran.

As can be seen in above figure, our shipping company has three stages supplying, producing and distributing in its supply chain network. The supplying process is the provision of basic requirements to run and maintain the ships as main production tools of the company. The producing of services is the section which operates and makes use of the ships to make production and the distribution of service is effected by distributors such as agents, main office sales staff, branches and freight forwarders, indicated at above diagram.

4.1. *Stage I, supplying and maintenance of ship*

At this stage, there are a number of sub-processes which provide required capital to buy ships and make other required investments, for example, provision of containers and so on. The injected capital to the system is then depreciated annually by paying back three monthly instalments. Therefore, seeking and provision of funds is the input at this stage and annual depreciation is the output of the process.

The other sub-process at this stage is Manning. The function of ship manning process is to provide human resources and seafarers in order to operate the ships. The number of marine employees at this company is 304 which consist of masters, officers, crew and other ratings. Among the said numbers, 61 persons are permanent employees and 243 hands are temporary workers who are employed by short-term contact from other ship manning companies. The company has opted to have more number of its requirements to be supplied through outsourcing process. This shipping company pays a fixed premium as cost-plus to its contractors in addition to the basic salary which is paid to employees. Therefore, the input for manning process is what they pay to the persons who they supply and the output will be what they get as remuneration for the task performed.

The next sub-process is the Technical Supplies and Provisions. This member is responsible to source out and supply spare parts, provisions for the intended voyage, lubricants, chemicals, paints, fresh water, buying insurance cover, maintaining statutory surveys, and so on. The shipping company normally pays about 3% overhead costs on top of actual purchasing price for subject services.

The following sub-process is the Management and Supervision of Technical Repairs. There are two types of marine repairs:

(1) Periodical and dry docking repairs which are arranged as per requirements of relevant regulations. In other words, parts of these repairs are mandated by statute. The ships are usually taken to dry docks (dry basins) and all ships bottom plating, underwater areas, piping, sea chests, propellers, glands, anodic protections, bottom plugs, and so on are inspected and repaired as necessary.

(2) Voyage repairs which are affected on running and continuous basis. Every part of the ship which may sustain damage or the machinery which exceed certain pre-defined running hours are opened, repaired and overhauled. Certain spare parts need to be replaced after running for defined hours. Usually ships have spare and duplicate machineries. In other words, while one machinery is running, the other one can be repaired and kept in stand-by condition.

The ships are repaired under periodical and continuous modes so that they can be kept at running condition to the maximum possible. It is necessary to have maximum earnings. If the vessel cannot operate due to technical defects, it is taken out of service, the condition which is referred to as off-hire. The number of days which vessel is in operational condition in every 365 days of the year can be taken as an indicator to measure the output of this member.

To evaluate the performance of Ship Technical Supply and Maintenance member, it is understood that all sub-processes of financing, ship building and purchasing, ship repairs, supplies and manning are performed to have the ships at running condition and make earnings. Therefore, the input will be all the cost spent for above processes and sub-processes and the output of this unit is the earnings generated by hiring out the vessel in the form of time charter to end users, that is, commercial department in this case.

4.2. *Stage II, production of service*

This stage is the service production unit. The ship is chartered-in from technical department in full readiness and available condition and goods and passengers are shipped and carried from one place to another place. In other words, the shipping service is generated by this member. The company has two major types of services:

(1) Passenger and car carriage which are performed by RO–RO (Roll on–Roll off) ships and Catamaran High Speed Crafts.
(2) Container carriage which is mainly regional feeder shipments in Persian Gulf, Oman Sea and north of Indian subcontinents with special concentration on Iranian ports.

The vessels are employed for commercial services at this member. Naturally, there are other various cost elements to produce the shipping services in addition to charter hire. These costs include but not limited to fuel and bunker costs, port and terminal costs, tugs, pilots, berth hire, light dues, cargo operation costs, container hire costs, Protection and Indemnity insurances, agency costs, passenger meals, and so on. There are other financial and non-operational costs including tax and financial interests and penalties which are then added to the operational costs and the total cost is calculated. All above elements will form the input for this member. By production of shipping services and carriage of goods and passengers, the output is generated in terms of number of passengers, cars and containers carried which have been shown in our above diagram.

4.3. *Stage III, distribution*

The shipping services of cars, passengers and container carriage which are produced at earlier stage is then sold out and offered to end users by distributing agents, shipping agents, freight forwarders, sales staff, and so on. They are located at different parts of the world as the nature of service is international. The revenue is then generated as output of this member after deducting all earlier costs.

The data have been extracted from the operational reports of a shipping company in Iran. It consists of year-end report for four consecutive years, that is, 2008–2009 up to 2011–2012. The fiscal year for this company is set to be on 21 March which is Iranian New Year. The data have been audited by company official auditors to ensure accuracy. This shipping line is a public listed company and is the second shipping

Table 1. Value the indicator of 4-year shipping line in Iran.

Year	Variable	2008	2009	2010	2011
Ship purchase cost	X_1	11 909.070	11 503.050	10 194.870	9605.850
Crew cost	X_2	534.277	692.137	735.612	854.670
Costs of spare parts, provisions, insurance, etc.	X_3	213.947	332.757	321.434	355.739
Costs of repairs (voyage + dry dock)	X_4	264.924	232.965	164.698	205.135
Commercial container operation cost + other costs	X_5	2248.100	1865.767	2106.591	1601.413
Commercial passenger operation cost + other costs	X_6	230.966	276.909	313.332	366.848
Lease + purchasing (by instalments)	Z_1	406.020	1179.130	549.170	566.190
Ship manning cost	Z_2	555.648	719.823	765.036	888.857
Supply of spares & provisions plus 3% overhead	Z_3	220.365	342.740	331.077	366.412
Total available days per year (on-hire days)	Z_4	3.154	4/061	4/146	4/473
Time charter to service provider (container)	Z_{51}	725.700	1807.540	1295.500	1473.162
Time charter to service provider (passenger)	Z_{52}	746.040	618.180	550.410	761.334
No. of containers carried per year	Z_6	193.929	340.790	305.473	329.486
No. of passenger + cars carried per year	Z_7	153.013	292.920	297.194	346.990
Net income (Profits)	Y	706.100	73.740	1033.100	427.608

company in Iran which was admitted in Tehran Stock Exchange Board. Table 1 shows the inputs, intermediate products and outputs of four consecutive years of this shipping company.

5. Results

By applying Models (5) and (6) and using LINGO 8.0 the supply chain and members' efficiencies were calculated. The results are shown in Table 2. As a result of the relational model, the supply chain efficiency is the product of the eight members' efficiencies.

The figures obtained for this supply chain for all years are less than one. They have been varying from 0.05354 up to 0.74041. It indicates that in no year the company supply chain has achieved full efficiency. The obtained results are consistent with actual outside

Table 2. Efficiency scores of supply chain and members of shipping line in Iran.

Year		2008	2009	2010	2011
Efficiency	Supply chain	0.661877	0.053542	0.740407	0.340462
	Ship finance	0.332599	1.000000	0.525504	0.575013
	Ship manning	1.000000	1.000000	1.000000	1.000000
	Technical provision	0.999996	1.000000	0.999998	1.00000
	Technical repairs	0.472933	0.692471	1.00000	0.866200
	Technical supply and maintenance	1.000000	1.000000	0.954341	1.000000
	Container service	1.000000	0.847651	1.000000	1.000000
	Passenger service	0.514734	1.000000	1.000000	0.893885
	Selling agents	1.000000	0.055549	0.926011	0.355489

Table 3. The maximum, minimum and mean-values of supply chain and members.

Year		Mean	Max	Min
Efficiency	Supply chain	0.449072	0.740407	0.053542
	Ship finance	0.608279	1.000000	0.332599
	Ship manning	1.000000	1.000000	1.000000
	Technical provision	0.999999	1.000000	0.999996
	Technical repairs	0.757901	1.000000	0.472933
	Technical supply and maintenance	0.988585	1.000000	0.954341
	Container service	0.961913	1.000000	0.847651
	Passenger service	0.852155	1.000000	0.514734
	Selling agents	0.584262	1.000000	0.055549

impression and market image of the company too as we notice that company has had managerial reforms and changes in year 2009 in view of low productivity and poor performance. The maximum efficiency has been experienced in year 2010. There has been a drop in 2011 which is in line with the world trade downturn and poor operational performance of all world major shipping lines.

The shipping line under our studies has two major fields of operations, that is, passengers and containers which only in the year 2010–2011 maximum efficiency in both sectors have been recorded whereas the passenger service shows a drop back in the year 2011.

Table 3 indicates the maximum, minimum and mean-values for all departments during all the years in our research. Only Ship Manning shows to have maximum efficiencies throughout the years while selling agents show the lowest performance among all members in this chain. The company management believes the reason for low performance of their selling agents is partially due to international economic crisis and partially because of foreign pressures and sanctions on Iranian companies due to political reasons.

A review of the indicators in Table 2 reveals that the sales efficiency of the company is dropping in passenger trade. Therefore, the recommendation is made to the company to have more concentration on domestic passenger trade as it is not affected by sanctions. Also another recommendation is made for the company to look at other domestic business opportunities which is available in Iran and it is believed that Iranian oil and offshore industry can make a major business and prosperous future for the company.

6. Conclusion

The world shipping industry in general remains highly competitive. The competition gets tougher as the recession in world economy gets deeper. It is now very well recognized that in order for a shipping company to be competitive, its whole supply chain must be competitive. Therefore, it is highly necessary to continuously measure and monitor the efficiencies of supply chains of shipping companies. This paper is the first study for measuring the relative efficiency of supply chain in shipping industry. Most studies relative to maritime industries have used traditional DEA to evaluate the efficiency, while it is not a suitable approach for evaluating the performance of supply chain. This is due to the fact that traditional DEA considers the system as a whole and ignores the performance of their members and sub-processes in calculating the relative efficiency of supply chain.

For first time, this research utilizes the relational network DEA to construct a model to calculate the efficiency of a shipping company. The model evaluates the efficiency of the supply chain as a whole and at the same time the efficiency of various members inside the chain is measured. As a case study, a major shipping company in Iran has been taken for evaluation, using this methodology. The results indicate that in no year the company's supply chain has achieved full efficiency. The maximum efficiency has been experienced in year 2010. The obtained results are consistent with actual outside and market image of the company too as there has been complete managerial restructuring within the company after this year. Finally, recommendation for improving company's performance is proposed which is to have more concentration on domestic passenger trade rather than international businesses at this juncture of time in view of current special circumstances and company to look at new domestic business opportunities available in Iran. Iranian oil and offshore industry can be considered for this purpose. The network and methodology that proposed may be utilized by most of the shipping companies worldwide which usually use similar pattern in this business.

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