JOURNAL OF TRANSPORTATION
SYSTEMS ENGINEERING AND INFORMATION TECHNOLOGY
Volume 13, Issue 5, October 2013
Online English edition of the Chinese language journal



**Cite this article as:** J Transpn Sys Eng & IT, 2013, 13(5), 10−15.

RESEARCH PAPER

# The Efficiency Measurement of Coastal Container Terminals in China

**LI Dan, LUAN Weixin*, PIAN Feng**

Transportation Management College, Dalian Maritime University, Dalian 116026, Liaoning, China

**Abstract:** Following the implementation of the twelfth consecutive Five-Year Plan, the development pattern of coastal container ports in China has been shifted, which requires higher port efficiency and an improved development mode. The three-stage DEA (Data Envelopment Analysis) model is applied on the basis of input-output cross-sectional data of 42 coastal container terminals in China. The model statistically evaluates the comprehensive efficiency, the pure technical efficiency and the scale efficiency of coastal container terminals. The outcome shows that the efficiency of coastal container terminals is rather low in China, and scale inefficiency is the primary reason. There is a big difference in terminal efficiency of different port groups. The terminal efficiency of Yangtze River Delta and Bohai Rim is relatively high, but Southeast Coast and Pearl River Delta's is comparatively low. Furthermore, there is an excessive waste in the input of container terminal development in China. In the final section, suggestions are proposed for the existing problems in port developments.

**Key Words:** waterway transportation; comprehensive efficiency; three-stage DEA model; coastal container terminal; scale efficiency; technical efficiency

## 1 Introduction

Coastal container terminals in China have experienced increased development as a result of the reform and openness in the latest 30 years. The added developments provide a solid foundation for container transportation and overall foreign trade. Also it boosts the economic growth of the hinterland cities. Due to the intensive construction, the transport capability of coastal container terminals in China has completed a significant transformation; from insufficient capacity to meeting the required transportation demand. Particularly, certain terminals are in excess of the average transportation capacity. With the implementation of the "12th Five-Year Plan", the pattern of economic development in China has shifted from extensive to intensive, which requires higher processing efficiency of the container port and an optimized development mode.

The studies on port efficiency adopted single or multiple indexes in the early stage, which failed to fully outline the characteristics of port efficiency. Thus, the research methodology mainly focuses on comprehensive assessment. Since port operation is a complicated process that involves multiple inputs and outputs, the Data Envelopment Analysis (DEA) has been recently used in studies on port efficiency. However, most of the studies are based on the one-stage DEA model, which ignores the effect of environmental influences and statistical noise. So the one-stage DEA model is not reliable to some extent. In order to overcome this defect, Liu applied DEA-CCR, DEA-BCC and three-stage DEA models to estimate the change of dynamic efficiency for ten Pacific ports from 1998 to 2001. Conclusions were made that the efficiency estimated by the three-stage DEA model is the most credible one[1]. At present, the study on quantitative research of port efficiency in China is deficient. Pang used the DEA model to analyse operation efficiency of 50 coastal ports in China from 1999 to 2002. Pang applied Malmquist total factor productivity index to evaluate the change of port efficiency, but this study was based on the one-stage DEA model[2]. In 2010, Wang used the three-stage DEA model to evaluate the efficiency of inland ports in China and concluded that China's inland ports have excessive input and insufficient output, which indicates that there are serious problems of resource

Received date: Jan 7, 2013; Revised date: Mar 1, 2013; Accepted date: Mar 11, 2013
*Corresponding author. E-mail: lid1104@163.com

DOI: 10.1016/S1570-6672(13)60121-X

waste in inland ports [3].

The research status shows that port efficiency studies primarily focus on the assessment of comprehensive ports and the methodology is based on the one-stage DEA model. The three-stage DEA model was only used in the studies on the inland ports efficiency in China. This paper uses container terminals as research objects, and attempts to apply the three-stage DEA model to evaluate the efficiency of coastal container terminals in China. Furthermore, a discussion of the existing problems of terminals by analysing the outcomes of assessment, and suggestions for improving the development of coastal container ports in China may be found within.

## 2 Research methodologies

The three-stage DEA model is adopted to evaluate the efficiency of coastal container terminals in China, and this model can be divided into three stages as follows:

Stage one: Traditional DEA model

In this stage, the original input-output data is processed with traditional DEA regression. The DEA model is input-oriented and variable return to scale. Since the model is a sophisticated methodology, its detailed theory and mathematical model will not be introduced.

Stage Two: Apply Stochastic Frontier Analysis (SFA) model to decompose the slack variables

This stage uses SFA model to regress the environmental influences with statistical noise in order to make up the defect of the one-stage DEA model. The input slack variables obtained from the first stage DEA model is the gap between ideal input and actual input. In addition, slack variables generally come from three factors: environmental influences, managerial inefficiencies and statistical noise. The effect of those three factors can be observed through SFA model.

Initially, establish slack variables for each input:

$$S_{ni} = x_{ni} - x_{ni} \times \lambda, n = 1, 2, \cdots, N; i = 1, 2, \cdots, I \qquad (1)$$

where, $x_{ni}$ is input $n$ of decision making unit (DMU) $i$; $x_{ni} \times \lambda$ is the best radial on efficiency frontier of input $n$ for DMU $i$; $S_{ni}$ is relevant input slack variable.

Secondly, build SFA regression model using input slack variables as explained variables and environmental influences as explanatory variables:

$$S_{ni} = f^n(z_i; \beta^n) + v_{ni} + u_{ni}, n = 1, 2, \cdots, N; i = 1, 2, \cdots, I \qquad (2)$$

where, $S_{ni}$ is input slack variable; $z_i$ is environmental variable, which is the observed value of environmental explanatory variables of DMU; $\beta^n$ is the unknown parameter of environmental explanatory variables which requires evaluation; $f^n\left(z_i; \beta^n\right)$ is the method how environmental variables effect input slack variables, generally defines $f^n\left(z_i; \beta^n\right) = z_i \beta^n$ ; $v_{ni}$ is statistical noise; $u_{ni}$ is management inefficiency; $v_{ni}$ is independent of $u_{ni}$ . Suppose $v_{ni}$ obeys normal distribution $N(0, \sigma_{vn}^2)$ and $u_{ni}$ obeys half-normal distribution $N^+(\mu^n, \sigma_{un}^2)$ .

Finally, adjust input slack variables in two steps:

Step One: obtain the estimated value of statistical noise through the estimated value of managerial inefficiencies, then separate tatistical noise from comprehensive error. Luo stated that most academic papers in China adopted Jondrow's formula directly [4], but the formula was set up for stochastic frontier analysis of production function, the comprehensive error was $v_{ni} - u_{ni}$ . Contrarily, the three-stage DEA model proposed by Fried uses cost function stochastic frontier analysis model, which means its comprehensive error is $v_{ni} + u_{ni}$ . Therefore, the formula used in this paper for separating statistical noise is different from the formula established by Jondrow.

Step Two: adjust DMU to the same level of environment and fortune:

$$X_{ni} = x_{ni} + [\max_i(z_i\hat{\beta}^n) \text{-} z_i\hat{\beta}_n] + [\max_i(\hat{v}_{ni}) - \hat{v}_{ni}], \\ n = 1, 2, \cdots, N; i = 1, 2, \cdots, I \qquad (3)$$

where, $X_{ni}$ and $x_{ni}$ represent the adjusted input values and original input values respectively; $z_i$ is the observed value of environmental variable. The first bracket on right in Eq. (3) adjusts samples to the same environment, and the second bracket modifies statistical noise to the same level. Finally, each sample will obtain the same environment and fortune.

Stage Three: Adjust the DEA model

In this stage, the adjusted DEA is established on the basis of adjusted input value obtained from the second stage and the original output value. Then, the new efficiency of DMU is acquired excluding the environmental variables and statistical noise. Efficiency generated by three-stage DEA model removes the interference of operation environment and statistical noise, which can more precisely evaluate the actual efficiency.

## 3 Empirical analysis

### 3.1 Index selection and data sources

3.1.1 Selection of input and output index

At present, input indexes in literatures that adopt DEA model to analyse port efficiency mainly focus on capital, labour, and land. As far as output index, most studies use cargo throughput, and some research adopts customer satisfaction and port profit as output indexes. Considering the availability of data, a selection of three input indexes are chosen as follows: terminal length, handling equipment quantity and staff quantity. The handling equipment includes bridge crane, mobile crane and beam crane. Furthermore, the container throughput represents the output index.

3.1.2 Selection of environmental variable

Environmental variables indicate the factors affecting the efficiency of coastal container terminals, but are not in the control of samples; including natural environment and social