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EVALUATION OF PERFORMANCE OF CONTAINER TERMINALS THROUGH DEMATEL-AHP

Abstract: *Maritime transport is considered as one of the most important sectors in the world as it is an engine to drive the national and international trade and economic growth of many countries. Today, container terminals face severe competition and these should respond to the various new requirements of shipping lines to maintain their market position. In this paper, evaluation of the container terminals or ports is carried out using AHP and DEMATEL as hybrid method in fuzzy environment. The hybrid model is illustrated with a numerical example.*

Keywords: *AHP, DEMATEL, Fuzzy number,container terminal, performance measures*

1. Introduction

Performance measurement has been an interesting area of research for the past few years and there have been tremendous effort to propose efficient methodologies to provide ranking the business organizations. Identification of different performance evaluation models and appropriate application of these methods in the organization is one of the most important problems in performance evaluation area.

In case of container terminals (ports), globalization trends have accelerated the necessity of adapting to the changed circumstances in the port service market. The ports should replace their basic activity of confronting the land and sea waterways in order to transfer the goods from one transport branch to another by developing and providing the net of logistic services. In this regard, the port authorities must face new challenges, originated from the changes in the port environment, in shipping, in port management and in the logistic industry.

Container terminals are operating in an extremely complex and competitive environment wherein measuring, monitoring, controlling and improving port performance are key elements of their competitiveness. Measuring performance of container terminals is an essential tool in order to sustain and increase competitiveness.

Ports have traditionally been evaluated by the engineering single-port approach of comparing their actual and engineering optimum throughputs, i.e. the maximum throughputs or cargo tonnage that ports can physically handle under certain conditions. If a port’s actual throughput approaches (departs from) its optimum throughput over time, the conclusion is that its performance has improved (deteriorated) over time.

In the literature, multi-port performance evaluations of the technical efficiency of

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ports generally rely upon frontier statistical models that utilize DEA techniques – non-parametric mathematical programming techniques for deriving the specification of the production frontier model. DEA techniques derive relative efficiency ratings for the ports that are used in the analysis.

Hassan *et al.* (1993) and Hassan (1993) suggested that complicated interconnected port operations are divided into four categories: Ship operations, Cargo handling, and Warehousing and Inland transportation.

There are many classifications of measuring performance of a container terminal. Kisi *et al.* (1999) classifies the port performance indicators in to four levels namely, ship, cargo, berth and labour. Thomas and Monie (2000) suggested that the measures can be divided into four categories also. These are production, productivity, utilization and service measures.

Several researchers have studied issues of (container) ports' performance. According to the review of the port economics, management, and policy literature conducted by Pallis *et al.*, (2008), 23 out of the 273 papers that were published in relevant international scientific journals during the period 1997-2006 within this decade dealt with port performance themes. Most of them (13) applied the methodology of Data Envelopment Analysis (DEA), in various forms, in order to analyse and measure port performance. Other methodologies that have been employed include the Stochastic Frontier Analysis (SFA) and the Total Factor Productivity (TFP). Along with these 'performance studies', the scholars identified 13 published papers examining issues of port choice. The latter can also be regarded as a dimension of port performance because it reveals the factors that influence port choices decisions.

Lirn *et al.*, (2004), applied the Analytic Hierarchy Process (AHP) to reveal and analyze transshipment port selection by global carriers. In all, 47 relevant service attributes were recorded from a literature review. Differences in the performance ranking of six major container ports by global carriers, as revealed in the AHP survey, were then combined with the calculated weights for the 12 transshipment port selection sub-criteria to explore critical attributes where transshipment market strategy could focus.

Kaisa (2006) evaluated the efficiency of major North American container ports and terminals using DEA and FDH models. Te authors concluded that the availability of panel data, rather than cross sectional data, would improve the validity of the efficiency estimates derived from all applied mathematical programming techniques.

Kalyan, (2010), made an empirical study, for evaluating major ports in India using fuzzy multi-criteria analysis.

Chen (2010) developed Analytic Hierarchy Process (AHP) model for simulating the behaviors of carriers' port choice and identifying the importance weight of every influential factor influencing carriers' port choices in the multiple-ports region.

Chien-Chang Chou and Ker-Wei Yu (2013) purposed a new hybrid fuzzy Analytic Hierarchy Process (AHP) algorithm to deal with the decision-making problems in an uncertain and multiple-criteria environment. In this study, the proposed hybrid fuzzy AHP model is applied to the location choices of international distribution centers in international ports from the view of multiple-nation corporations.

Yang and Yang (2005), developed an index system to evaluate container port competition ability, and to provide theoretical foundation for regional ports' integration. Analytical Hierarchy Process (AHP) is applied to quantify the index system and work out the comprehensive score of each port.

Athanasios (2008), provided a methodological framework which uses and evaluates externally generated information in order to assess port users (customer) satisfaction and loyalty, as key port performance components.

Kolanovic *et al*. (2008) made a study and reduced a great number of the port service quality attributes to a smaller number of attributes, grouped in common factors.

Chou (2010) constructed an Analytic Hierarchy Process (AHP) model for simulating the behaviors of carriers' port choice and identifying the importance weight of every influential factor influencing carriers' port choices in the multiple-ports region.

Decision Making Trial and Evaluation Laboratory (DEMATEL) as a framework for structural modeling approach gathers collective knowledge to capture the causal relationships between strategic criteria (Javad *et al.*, 2011). The DEMATEL model is especially practical and useful for visualizing the structure of complicated causal relationships with matrices or digraphs.

2. Proposed model

In this paper, performance measures reviewed in the existing literature are considered for evaluation of container terminals under multi-criteria decision making. The performance measures are explained below.

Production Measures: These are the level of activity of the business. Throughput measures include Ship (ST) Quay transfer (QT), Container yard (CY) and Receipt/delivery throughput.(R&D)

Productivity Measures: Productivity Measures calculate the ratio of output to input.These performance measures include ship (SP), crane (CP), quay (QP), terminal area (TA), equipment,(EP), labour productivity (LP) and cost effectiveness (CE).

Utilization Measures: Utilization Measures allow management to determine how intensively the production resources are used. The most common and most relevant utilization measures are: quay (QU), Storage (SU), Gate (GU) and Equipment (EQ) utilization.

Services Measures: These measures indicate the satisfaction of the customers with the services offered to them in terms of reliability, regularity and rapidity. The relevant service measures include Ship turnaround time (TA), Road vehicle turnaround time (RT) and Rail service measures (RS).

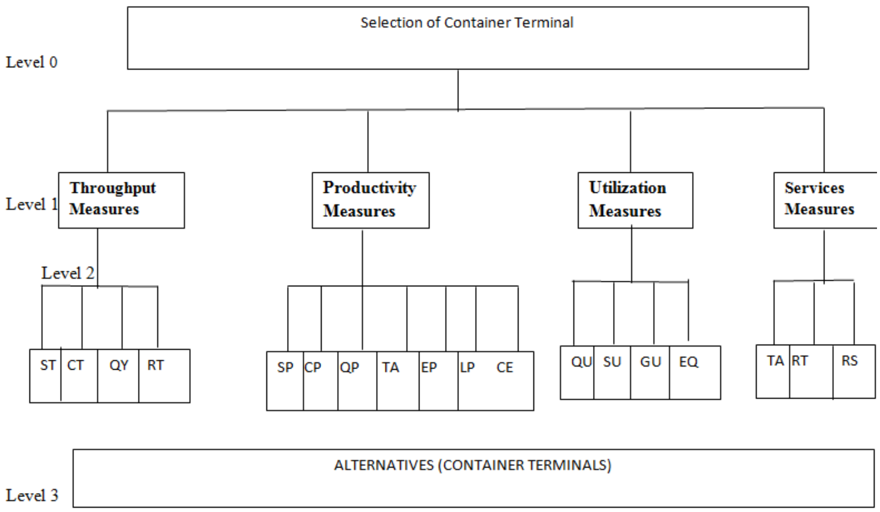

Figure 1. Hierarchical Decomposition of Decision Elements

The decision making problem is structured hierarchically at different levels with each level consisting of a finite number of decision elements. The top level of the hierarchy represents the overall goal, while the lowest level is composed of all possible alternatives. One or more intermediate levels embody the decision criteria and sub-criteria. Hierarchical decomposition of decision elements is shown in figure1. In the proposed model level, level '0' represents the goal i.e., selection of container terminal. Level '1' represents the performance measures of container terminals. Sub criteria are grouped and placed under each performance measure at subsequent level. Final level contains alternative container terminals.

Evaluation of container terminals is considered as multi-criteria decision making problem and DAHP (DEMATEL & AHP) method was used as a hybrid model to rank the container terminals. DEMATEL is implemented in fuzzy environment to know the interdependence between the performance measures as well as the sub-criteria under each performance measure. FAHP is adopted to aggregate all local priorities by a simple weighted sum. The global priorities thus obtained are used for final ranking of the container terminals.

3. Methodology

The DAHP methodology is illustrated with a numerical example. The following steps explain the proposed methodology.

STEP1: Calculate the weights of performance measures and sub-criteria

Weights are determined by avoiding the interdependence among performance measures or sub-criteria. Fuzzy pair-wise comparisons of measures/sub-criteria are defined through experts in the field of marine logistics. The fuzzy logarithmic least square method (LLSM) developed by Wang *et al.* (2006) is employed to obtain the weights of performance measures and sub-criteria using fuzzy pair-wise comparison matrices.

STEP 2: Determining Interdependence among performance measures/ sub-criteria

The DEMATEL method, developed by the Science and Human Affairs Program of the Battelle Memorial Institute of Geneva between 1972 and 1976, can convert the relationship between the causes and effects of criteria into an intelligible structural model of the system (Hung, Chou and Tzeng (2006); Tzeng, Chiang and Lee (2007). The DEMATEL, used to research and solve complicated and intertwined problems, has been successfully applied in many situations, such as marketing strategies, R&D project, e-learning evaluation, managers' competencies, control systems and airline safety problems (Chiu *et al.*, 2006; Hori and Shimizu, 1999; Lin and Wu, 2008; Liou *et al.*, 2007; Tzeng *et al.*, 2007; Wu and Lee 2007).

STEP 3: Determine the weights of the performance measures and sub-criteria

Weights of the performance measures and sub-criteria are obtained by multiplying the interdependence matrix obtained in step 2 with weights obtained in step1.

STEP 4: Find Global weights

Global weights of the sub-criteria are calculated by successively multiplying the weights of performance measures with weights of respective sub-criteria.

STEP 5: Rank the alternatives (Container Terminals)

The final ranking of alternatives is arrived by finding out R_j from the following equation.

$$R_j = \sum P_{ij} w_i$$

Here P_{ij} is the normalized sub-criteria value of the j^{th} alternative with respect to the i^{th} sub-criteria. The weight of the i^{th} sub-criteria denoted by w_i. Ranking factor of the j^{th} alternative R_j provides the basis for ranking of the alternatives. Higher the value of R_j, the better is the j^{th} alternative.

4. Illustrative example

In this paper, ranking of container terminal is illustrated with a numerical example through DAHP methodology. Linguistic variables with triangular fuzzy numbers are considered in the study. Input data regarding direct relations, fuzzy pair-wise comparisons of performance measures& sub-criteria and payoff information of 10 container terminals are obtained with expert opinions expressed in terms of linguistic variables are shown table 1, table 2 and table 3 respectively.

Table 1. Direct relation Matrices

	TM	PM	SM	UM	ST	CT	QY	RT	CE	TP	LP	SP	CP	QP	EP	QU	SU	GU	EQ	TA	RT	RS
TM	A	B	C	D																		
PM	A	A	B	C																		
SM	B	A	A	B																		
UM	C	B	A	A																		
ST					A	C	D	E														
CT					B	A	C	D														
QY					C	B	A	C														
RT					D	C	C	A														
CE									A	B	D	D	E	E	E							
TP									B	A	C	C	D	D	E							
LP									B	B	A	B	C	D	D							
SP									D	C	D	A	B	C	D							
CP									D	C	B	B	A	B	C							
QP									D	D	B	B	B	A	B							
EP									D	D	C	B	B	B	A							
QU																A	C	D	E			
SU																B	A	C	E			
GU																C	B	A	C			
EQ																D	B	D	A			
ST																				A	D	E
RT																				C	A	B
RS																				C	E	A

No influence (A): (0,0,0); Low influence (B): (1,1,1); Medium influence (C): (1,2,3); High influence (D): (2, 3, 4); Very high influence (E): (3, 4, 5);

Table 2. Fuzzy pair-wise Matrices

	TM	PM	SM	UM	ST	CT	QY	RT	CE	TP	LP	SP	CP	QP	EP	QU	SU	GU	EQ	TA	RT	RS
TM	A	C	D	D																		
PM		A	C	D																		
SM			A	C																		
UM				A																		
ST					A	B	C	D														
CT						A	B	C														
QY							A	B														
RT								A														
CE									A	B	B	C	C	D	D							
TP										A	B	C	C	D	D							
LP											A	C	C	D	D							
SP												A	C	D	D							
CP													A	C	D							
QP														A	C							
EP															A							
QU																A	A	B	B			
SU																	A	A	B			
GU																		A	B			
EQ																			A			
ST																				A	C	D
RT																					A	C
RS																						A

Note: Equal Important (A): (1, 1, 1); Low important (B): (1, 2, 3); Medium important (C): (2, 3, 4);

High important (D): (3, 4, and 5); Very high important (E): (3, 4, and 5);

Lower triangular matrix is such that if (1,2) element in the matrix is C =(2,3,4) then (2,1)=(1/4,1/3,1/2)

Table 3. Payoff matrix of Sub-criteria

	ST	CT	QY	RT	CE	TP	LP	SP	CP	QP	EP	QU	SU	GU	EQ	TA	RT	RS
CT1	E	C	D	D	D	E	D	D	D	D	E	D	C	D	C	E	C	C
CT2	D	E	D	D	C	D	E	E	C	D	C	C	E	E	A	C	A	C
CT3	C	C	E	E	C	C	A	E	E	E	C	C	A	E	E	E	A	E
CT4	D	A	E	E	E	E	A	E	D	A	A	E	D	D	D	A	E	A
CT5	C	A	E	B	A	A	C	A	B	A	B	B	B	A	A	B	B	A
CT6	A	C	E	A	E	A	B	E	E	B	A	C	E	A	C	A	E	C
CT7	B	E	A	B	A	A	E	B	B	B	B	B	C	C	E	B	C	C
CT8	B	B	C	E	D	B	C	E	D	D	B	B	D	B	C	B	C	B
CT9	C	E	B	C	E	D	B	D	C	D	D	B	B	C	C	C	B	C
CT10	E	B	E	E	B	E	B	B	E	C	E	B	E	C	C	B	E	E

Note: Very Low (A): (1, 1, 1); Low (B): (1, 2, 3); Medium (C): (2, 3, 4); High (D): (3, 4, 5); Very high (E): (3, 4, 5);

5. Results and discussion

DEMATEL method is implemented to know the interdependence between the performance measures as well as the sub-criteria under each performance measure. The prominences and relations of the performance measures and sub-criteria are obtained. Prominence values indicate the strength of influences given and received by the others. On the other hand if relation is negative, the performance measure/sub-criteria receives influence from other. If relation is positive, the performance measure/sub-criteria dispatches the influence to other enablers. Prominence and relation is explained graphically in the figure 2.

In case of performance measures, the prominence and relation values indicate that UM and SM is effect group which are influenced by TM and PM. It means that TM and PM are to be improved in order to improve UM and SM. Sub-criteria namely, QY, RT, QP, EP, LP, CE, GU, EQ and RT are clustered into effect group basing on the relation values. The prominence and relations are useful in analyzing the container terminals for improving their performances.

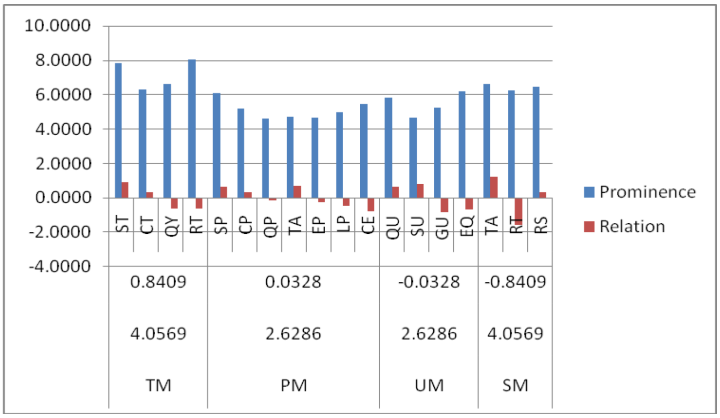

Figure 2. Prominence and relation Graph

Global weights: The weights of performance measures and the global weights of sub criteria are shown in the following figure 3.

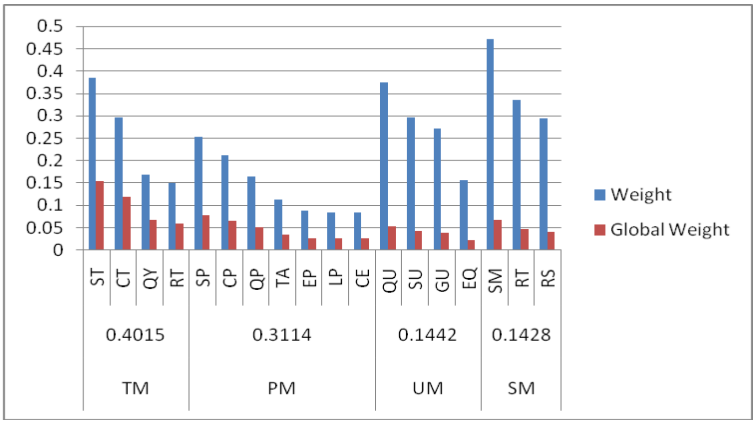

Figure 3. Global weights

From figure 2, it is understood that TM is the most import performance measure having highest weight (0.4015) followed by PM, UM and SM with weights 0.3114, 0.1442 and 0.1428 respectively. Also, the figure indicates the global weights of the sub-criteria under each performance measure.

Ranking of Container Terminals

Payoff values shown in the table 3 in terms of linguistic values are converted into crisp values using the methodology proposed by Gharakhani (2012). Using these values ranking of container terminals is obtained as discussed in the step 5 in the methodology section. Ranking of container terminal is shown in table 4.

Table 4. Ranking of container Terminals

CTs	CT1	CT2	CT3	CT4	CT5	CT6	CT7	CT8	CT9	CT10
Rankig Factor	0.7528	0.8005	0.8118	0.6903	0.7958	0.7465	0.7575	0.7723	0.8172	0.7380
Rank	VI	III	II	X	IV	VIII	VI	V	I	IX

The results indicate that Container terminal nine one (CT9) shows the best performance and (CT4) shows the least performance. Ranking of the alternatives mainly depend on the decision makers perspective in specifying the preferences of the sub-criteria of the performance measures and their payoff in these sub-criteria.

6. Conclusion

AHP frame work is developed with level 0 as goal of analyzing the container terminals performance. Performance measures are considered in level1. Level 2 contains sub-criteria of the performance measures of container terminals. Level 3 contains ten alternative container terminals. DAHP methodology is proposed and illustrated with a numerical example. The proposed methodology is a robust multi-attribute decision-making technique for synthesizing the container terminals performance measures and their sub-criteria in fuzzy environment Weights of performance measures and their sub-criteria are determined through fuzzy LLSM without interdependence. DEMATEL method is adopted to determine the influence between the performance measures and their sub-criteria. Weighs of the sub-criteria on the basis of interdependence is calculated by multiplying influence matrix with the relative weights obtained through fuzzy LLSM. Global weights of sub-criteria are also obtained. Ranking of ten container terminals is carried out by using the global weights of the enablers and the payoff of the alternative container terminals. Further, the study made in this paper is useful to analyze the strategic decisions to improve the performance of other business and service sectors.

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