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Analysis of Performance in Container Handling Operation by Using Fuzzy TOPSIS Method

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Abstract

Now days the performance charter of most ports of the world is based on increasing the outcomes of L/U operation, the attempt to measure and analyze the status of such operations through appropriate modern methods is necessary. Aimed to analysis of Performance in Container Handling Operation in the BIK container terminal, the present research has been implemented by use of fuzzy TOPSIS method. The obtained results via FUZZY TOPSIS for BIK container terminal show that Opening and closing the container lashing, Defectiveness of horizontal L/U equipment, Defectiveness of vertical onshore transportation equipment, Unpreparedness of ship, Unpreparedness of contractor, were detected as the most important causes of delay creation in the BIK container terminal L/U operation, respectively.

***Key words**: Container Transportation, Marine terminal, BIK, FUZZY, L/U operation, MCDM.*

Introduction

On a macro level, a maritime container terminal can be defined as a facility, which enables the transshipment of intermodal transport units or containers between various modes of transport. The main focus is always on the seaside, where sea transport represents the primary service of the system. In other words, a maritime container terminal is a place where containers leave and enter by different means of transport, such as vessels, trains and trucks; the terminal is hence the basic intermodal node in the logistics network and for this reason, all operations involved in the flow of containers have to be optimized (Saeidi et al., 2013a). The basic role of a maritime container terminal is the transfer and storage of full and empty containers. As far as resource allocation is concerned, the terminal can be interpreted as a system allowing container flows to be directed from their sources to final destinations (Saeidi et al., 2013b).

From the economic point of view, the system has the objective of maximizing the profit. In this respect, efficient container handling operation at terminals is important in reducing vessels service time which in turn can be a cause the reduction of transportation costs and keeping shipping schedules (Beškovnik, 2008). Recently, vessels are becoming more large-scale and high-speed because of the increasing quantity of cargo transported, shipper's requirements for lower transportation fee and shipping companies' effort toward retrenchment of transport cost per shipping unit. Furthermore, shipping companies become more interested in maximizing vessel turnover by minimizing the length of staying time at ports for economical reasons (Jafari, 2013a). These situation forces rival terminal companies to develop into the latest technology of loading and unloading, as well as the renovation of their terminal facilities in order to reduce the length of staying time of vessels at their terminals (Jafari, 2013b). The efficient operation of terminals is another very important factor that is very necessary for improving the competitive status and productivity in the fierce competitive environment between container terminals (Choi et al., 2003). Taking into consideration the nations' daily increasing desire for economic growth and the significant contribution of ports to reach to this - as the main start points of exportation and importation of goods and services - the necessity of fulfillment of studies on performance of ports, for any potential optimization of efficiency, looks more essential than ever. Since the performance charter of most ports of the world is based on increasing the outcomes of L/U operation, the attempt to measure and analyze the status of such operations through appropriate modern methods is necessary. Hence, the objective of this paper is Comparative analysis of Performance in Container Handling Operation in the container terminals by use of TOPSIS method.

MCDM

In traditional MCDM, alternative rating and weights are measured in crisp numbers. Classical MCDM methods require the determination of alternatives rating and criteria weights are made which depend on decision makers' (DM) judgments/preferences. Crisp values are commonly used to represent those ratings and weights. However, in practice, alternative ratings and criteria weights could not be assessed precisely, which may come from various sources, including (1) unquantifiable information, (2) incomplete information, (3) unobtainable information, and (4) partial ignorance (Bojadziev & Bojadziev, 1995). Under many circumstances where performance rating and weights cannot be given precisely, the fuzzy set theory is introduced to model the uncertainty of human judgments and such problems is known as fuzzy multiple criteria decision making (FMCDM) (Wang et al., 2009).
Bellman and Zadeh first introduced fuzzy set theory into MCDM as an approach to effectively dealing with the inherent imprecision, vagueness and ambiguity of the human decision making process. Since then, many researchers have been working on the process with uncertain data. Multi-criteria decision making (MCDM) has been widely used in selecting or ranking a finite set of decision alternatives characterized by multiple and usually conflicting criteria (attributes) (Sakawa, 2002).

Fuzzy MCDM with Linguistic Terms

In fuzzy MCDM, performance ratings and weights are usually represented by fuzzy numbers. An alternative is calculated by aggregating all criteria weights and alternatives ratings, where alternatives with a higher utility are preferred (Sakawa, 2002).
While crisp data are inadequate to model the real life situations in MCDM, we use linguistic variables to specifically describe the degrees of a criterion. In order to facilitate the making of subjective assessment by the DM using fuzzy numbers, two sets of linguistic terms are used for assessing criteria weights and performance rating on each qualitative criterion respectively. A linguistic variable is a variable which apply words or sentences in a natural or artificial language to describe its degree of value, and we use this kind of expression to compare each criteria by linguistic variables in a fuzzy environment as "extremely important", "very important", "important", "very unimportant", and "extremely unimportant" with respect to a fuzzy five level scale. The triangular fuzzy numbers are used to represent the approximate value, denoted as (a1, a2, a3) where $1 \leq a_1 \leq a_2 \leq a_3 \leq 9$ (Bojadziev & Bojadziev, 1995).

This research applied the framework of Wang and Lee's approach. Wang and Lee (2009), proposed a TOPSIS approach that integrates subjective and objective weight. The advantage of the proposed approach is that it not only benefits from decision makers' expertise, but also involve end-users into the whole decision making process. Besides subjective weights determined by decision makers, the Shannon's entropy is utilized to calculate subjective weights. The aim of adopting the information entropy concept is to confirm the weight of evaluating attribute which can effectively balance the influence of subjective factors. The framework of Wang and Lee's approach is summarized as follows (Wang et al., 2009):

Step 1: Construct a decision matrix

Assume there m alternatives $A_i(i = 1,2,\cdots,m)$ to be evaluated against n selection criteria $C_i(i = 1,2,\cdots,n)$. Subjective assessments are to be made by DM to determine the weighting vector $W(w_1, w_1, \cdots, w_j, \cdots, w_n)$. The weighting vector W represents the relative importance of n selection criteria $C_i(i = 1,2,\cdots,n)$ for the problem. The decision matrix $X = \{x_{ij}, i = 1,2,\cdots,m; j = 1,2,\cdots,n\}$ represents the utility ratings of alternative A_i with respect to selection criteria C_i.

Step 2: In this step, we both use subjective weighting method and entropy-based objective weighting method (Wang et al., 2009).

(a). Subjective: Determine the DM's weights for each criterion

$$\tilde{W}_j = \frac{1}{2}\left[\sum_{j=1}^{n} w_j^e\right] \quad j = 1,2,\cdots,n \tag{2-1}$$

(b). Objective: In order to determine objective weights by the entropy measure, the decision matrix needs to be normalized for each criterion $C_i(i = 1,2,\cdots,n)$ to obtain the projection value of each criterion:

$$P_{ij} = \frac{X_{ij}}{\sum_{I=1}^{M} X_{ij}} \tag{2-2}$$

After normalized the decision matrix, we can calculate the entropy values X_j as

$$e_j = -k\sum_{j=1}^{n} p_{ij}\, ln\, p_{ij} \tag{2-3}$$

k is a constant, let $k = (ln(m))^{-1}$

The degree of divergence d_i of the intrinsic information of each criterion $C_i(i = 1,2,\cdots,n)$ may be calculated as

$$d_j = 1 - e_j \tag{2-4}$$

The value d_j represents the inherent contrast intensity of c_i.The higher the d_j is, the more important the criterion c_i is for the problem. The objective weight for each criterion can be obtained.

$$W_j = \frac{d_j}{\sum_{k=1}^{n} d_k} \tag{2-5}$$

Step 3: Calculate the aggregate weights for each criterion W_j as follows:

$$\tilde{X}_{ij} = \frac{1}{n}\left[\sum_{e=1}^{n} \tilde{x}_{ij}^e\right] \qquad i = 1,2,\cdots,m \tag{3}$$

Step 4: Obtain the decision matrix to identify the jth criteria with respect to ith alternative.

$$\tilde{R} = [\tilde{r}_{ij}]_{m\times k} \quad \textbf{(4)}$$

Step 5: Normalize the decision matrix in order to make each criterion value is limited between 0 and 1, so that each criterion is comparable. The initial data with respect to each criterion will be normalized by dividing the sum of criterion values. For fuzzy data denoted by triangular fuzzy number as (a_{ij}, b_{ij}, c_{ij}), the normalized values for benefit-related criteria and cost-related criteria are calculated as follows.

$$\tilde{r}_{ij} = \left\{ \langle \frac{a_{ij}}{c_{ij}^{+}}, \frac{b_{ij}}{c_{ij}^{+}}, \frac{c_{ij}}{c_{ij}^{+}} \rangle ,\ j \in B \right. \quad \textbf{(5-1)}$$

$$\tilde{r}_{ij} = \left\{ \langle \frac{a_{ij}}{c_{ij}^{-}}, \frac{b_{ij}}{c_{ij}^{-}}, \frac{c_{ij}}{c_{ij}^{-+}} \rangle ,\ j \in C \right. \quad \textbf{(5-2)}$$

Step 6: Calculate the overall performance evaluation for each alternative by multiplying the aggregate weights for each normalized criterion.

$$\tilde{V} = [\tilde{v}_{ij}]_{m\times k} \qquad i = 1,2,\cdots,m \qquad j = 1,2,\cdots,n \quad \textbf{(6-1)}$$

$$\tilde{v}_{ij} = \tilde{r}_{ij} \otimes \tilde{r}_{ij} \quad \textbf{(6-2)}$$

Step 7: Determine the positive ideal solution A^{+} and the negative ideal solution A^{-}. Sort the weighted normalized values for each criterion in descending order.

$$A^{+} = (\tilde{v}_1^{+}, \tilde{v}_2^{+}, \cdots, \tilde{v}_k^{+}) \quad \textbf{(7-1)}$$

$$A^{-} = (\tilde{v}_1^{-}, \tilde{v}_2^{-}, \cdots, \tilde{v}_k^{-}) \quad \textbf{(7- 2)}$$

Step 8: Calculate the distance from the positive ideal solution and the negative ideal solution for each alternative. According to Bojadziev and Bojadziev (1995), the distance between two triangular fuzzy numbers $A_1(a_1, b_1, c_1)$ and $A_1(a_2, b_2, c_2)$ is calculated as

$$d(A_1, A_2) = \sqrt{\frac{1}{3}[(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2]}$$

$$d_i^{+} = \sum_{j=1}^{k} d\langle \tilde{v}_{ij}, \tilde{v}_j^{+} \rangle \qquad i = 1,2,\cdots,m \quad \textbf{(8)}$$

$$d_i^{-} = \sum_{j=1}^{k} d\langle \tilde{v}_{ij}, \tilde{v}_j^{-} \rangle \qquad j = 1,2,\cdots,n$$

Step 9: Calculate the closeness coefficient (CC). And rank each CC of each alternative in descending order. The alternative with the highest CC value will be the best choice.

$$CC_i = \frac{d_i^{-}}{d_i^{+} + d_i^{-}} \quad i = 1,2,\cdots,m \quad \textbf{(9)}$$

Results

At the first by consideration of BIK container terminals daily censuses including the census of lag and halt in L/U operation and their relevant causes as well as the number of vessels traffic to the port during 20th March to 20th November, 2013In the first stage, 27 causes of halt and lag in container L/U operation at studied container terminals have been detected. The causes have been noted in table 1.

Table 1 – causes of lag and halt in L/U operation and their effects

Code	Causes	Code	Causes
1	Financial and administrative issues	15	Detainment by PSC
2	Unpreparedness of terminal	16	Defectiveness of vertical onshore transportation equipment
3	Shortage of trucks	17	improper container stowage
4	vessel passing and container quarantine formalities	18	improper container lashing
5	Incompleteness of documents	19	Adjusting the balance of ship
6	Defectiveness of horizontal L/U equipment	20	Foul weather
7	Inefficiency of ship equipment	21	tide changes
8	occupied container yard	22	Formal and general holidays
9	Quay traffic	23	Unpreparedness of factors outside the port
10	Unpreparedness of owners of goods	24	Not specialized companies stevedores
11	The structure and layout of the dock and container terminal	25	Lack of trained workers.
12	Inelasticity of container yard	26	Lack of adequate and specialized equipment
13	Unpreparedness of contractor	27	Lack of modern technology
14	Labor issues	28	

In the second step First of all, a committee is formed including two decision makers (which selected from the studied container terminal as decision maker) D_1, D_2. Then the criteria are determined as Detection D, occurrence O, and severity S. Firstly, two decision makers evaluate the importance of each criterion by using linguistic variables in Table 2. The importance weights of each criterion determined by decision makers are shown in Table 3.

Table 2.Fuzzy linguistic terms and correspondent fuzzy numbers for each criterion(Chen & Hwang, 1992)**.**

Importance	Abbreviation	Fuzzy Number
Very Low	VL	(0, 0, 0.2)
Low	L	(0.05, 0.2, 0.35)
Medium Low	ML	(0.2, 0.35, 0.5)
Medium	M	(0.35, 0.5, 0.65)
Medium High	MH	(0.5, 0.65, 0.8)
High	H	(0.65, 0.8, 0.95)
Very High	VH	(0.8, 1, 1)

Table 4. Each criterion weight in linguistic term

DM C	D1	D2	D3	D4
D	MH	ML	M	MH
O	MH	H	M	H
S	H	VH	H	VH

By utilizing (2), the aggregated fuzzy weights of criteria are shown in Table 4.

Table 5. Each criterion weight fuzzy number

Criterion	Fuzzy number
D	(0.352,0.485,0.738)
O	(0.612,0.841,0.921)
S	(0.819,0.941,0.977)

As the fuzzy linguistic terms and correspondent fuzzy numbers for each alternative listed in Table 6, the original DMs rating table obtained from DMs, the initial DMs rating table constructed Table 7.

Table 6. Fuzzy linguistic terms and correspondent fuzzy numbers for each alternative

NO	Performance			Fuzzy Number	Abbreviation
	Severity	Occurrence	Detection		
1	No	Almost never	Almost certain	(0, 0, 0.2)	VP
2	Slight	Very slight	High	(0.05, 0.2, 0.35)	P
3	Moderate	Low	Medium	(0.2, 0.35, 0.5)	MP
4	Significant	Medium	Low	(0.35, 0.5, 0.65)	F
5	Major	Moderately high	Slight	(0.5, 0.65, 0.8)	MG
6	Serious	Very high	Remote	(0.65, 0.8, 0.95)	G
7	Hazardous	Almost certain	Almost impossible	(0.8, 1, 1)	VG

Table 7.The initial DM rating table

No	Causes	Detection		Occurrence		Severity	
		D2	D1	D2	D1	D2	D1
1	Financial and administrative issues	MP	F	MP	P	MP	MP
2	Unpreparedness of terminal	MG	MG	MG	F	F	MP
3	Shortage of trucks	MG	F	F	MP	MP	P
4	vessel passing and container quarantine formalities	F	MG	MG	G	F	F
5	Incompleteness of documents	G	MG	G	MG	F	MG
6	Defectiveness of horizontal L/U equipment	G	MG	VG	MG	G	G
7	Inefficiency of ship equipment	F	MG	MG	MG	F	F
8	occupied container yard	VP	VP	P	MP	MP	P
9	Quay traffic	P	P	VP	P	MP	P
10	Unpreparedness of owners of goods	F	MG	F	F	MG	F
11	The structure and layout of the dock and container terminal	VP	P	P	P	P	P
12	Inelasticity of container yard	MP	P	VP	VP	VP	VP
13	Unpreparedness of contractor	VG	G	G	G	VG	MG
14	Labor issues	P	VP	VP	P	P	P
15	Detainment by PSC	P	P	P	VP	P	VP
16	Defectiveness of vertical onshore transportation equipment	MG	G	VG	G	VG	MG
17	Unpreparedness of ship	MG	MG	MG	G	VG	VG
18	Opening and closing the container lashing	G	VG	G	VG	G	VG
19	Adjusting the balance of ship	MP	MP	P	MP	VP	P
20	Foul weather	P	VP	P	VP	P	P
21	tide changes	P	MP	MP	F	MP	P
22	Formal and general holidays	P	VP	P	VP	VP	VP

23	Unpreparedness of factors outside the port	MG	G	G	G	G	F
24	Not specialized companies stevedores	MP	MP	F	MG	MP	P
25	Lack of trained workers.	MP	MP	MP	MP	MP	MP
26	Lack of adequate and specialized equipment	P	MP	P	VP	P	P
27	Lack of modern technology	VP	F	P	MP	MP	MP

Finally, by using fuzzy TOPSIS software 2013 the PIS and NIS for each alternative can be calculated and closeness coefficients are used to rank the optimal alternative. The result is shown in Table 8.

Table 8. Final results of fuzzy TOPSIS

No	Causes	di-	di+	CC	Ranking
1	Financial and administrative issues	0.10153	0.03251	0.76352	7
2	Unpreparedness of terminal	0.07124	0.06698	0.51123	20
3	Shortage of trucks	0.10153	0.03300	0.74911	8
4	vessel passing and container quarantine formalities	0.07698	0.06344	0.54956	19
5	Incompleteness of documents	0.11233	0.03856	0.74269	9
6	Defectiveness of horizontal L/U equipment	0.11621	0.01852	0.86585	2
7	Inefficiency of ship equipment	0.10841	0.02653	0.80441	6
8	occupied container yard	0.09242	0.06268	0.59456	15
9	Quay traffic	0.08985	0.06022	0.59936	14
10	Unpreparedness of owners of goods	0.06742	0.0751	0.47441	23
11	The structure and layout of the dock and container terminal	0.06623	0.07033	0.48421	22
12	Inelasticity of container yard	0.10352	0.04023	0.71731	10
13	Unpreparedness of contractor	0.10952	0.02562	0.8069	5
14	Labor issues	0.1026	0.0442	0.71236	11
15	Detainment by PSC	0.07926	0.06265	0.55956	18
16	Defectiveness of vertical onshore transportation equipment	0.1223	0.02093	0.85442	3
17	Unpreparedness of ship	0.11662	0.02282	0.84081	4
18	Opening and closing the container lashing	0.11778	0.01583	0.88455	1
19	Adjusting the balance of ship	0.09125	0.04159	0.68785	12
20	Foul weather	0.07788	0.05985	0.56501	17
21	tide changes	0.07444	0.0796	0.48897	21
22	Formal and general holidays	0.09054	0.05977	0.60185	13
23	Unpreparedness of factors outside the port	0.08258	0.06132	0.57392	16
24	Not specialized companies stevedores	0.01826	0.12197	0.1282	25
25	Lack of trained workers.	0.01551	0.12271	0.11061	26
26	Lack of adequate and specialized equipment	0.01241	0.1274	0.08808	27
27	Lack of modern technology	0.06019	0.07215	0.45489	7

Conclusion

Aimed to analysis of Performance in Container Handling Operation in the BIK container terminal, the present research has been implemented by use of fuzzy TOPSIS method in two stages. To reach research goal in first stage, the daily data of BIK container terminal events - including halts and lags in L/U operation, the pertinent causes and the number of port incoming and outgoing vessels - during the period of study (March 21, 2013 to November 20, 2013) have been gathered. Then In the second stage, based on the criteria of determination of causes occurrence probability (occurrence frequency), the extent of its impact on process after occurrence (severity) and probability of its identification prior to having impact on the process (detection), and by using fuzzy TOPSIS identified Cause Of Delay have been prioritized. The obtained results via FUZZY TOPSIS for BIK container terminal show that Opening and closing the container lashing, Defectiveness of horizontal L/U equipment, Defectiveness of vertical onshore transportation equipment, Unpreparedness of ship, Unpreparedness of contractor, were detected as the most important causes of delay creation in the BIK container terminal L/U operation, respectively.

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