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An Empirical Study of Factors Affecting Reduction of Performance in Container Handling Operation

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Abstract
Efficiency of ports can create a remarkable influence in decrement of the period of ship stay at port, the period of sedimentation of goods and the decrement of freight payable to shipping companies. Finally, port efficiency also can cause customer satisfaction, demand increase and profitability rising up. In this light, this paper aims to identify and assess the Factors Causing Reduction of Performance in Container Handling Operation at the relevant studied container terminal; the present research has been conducted by use of TOPSIS method. In the first, having considered the daily census of container L/U in the pertinent terminal of the port, As well, brain storming cessions attended by experts from the mentioned terminal were held during which twenty two numbers of causes of delay were detected. Then, based on the criteria occurrence, severity, and probability of detection, the causes were scored. Then based on the obtained scores by each one of the causes, the matrix of decision making was formed and the mentioned causes were ranked by use of TOPSIS method. The obtained results via TOPSIS show that financial and administrative issues (C_i = 0.80048) jointed with the factor of deficiency of horizontal L/U equipment (C_i = 0.80048), then insufficiency of container yard (C_i = 0.67782) and unpreparedness of factors external to the port (C_i = 0.67577) were detected as the most important Factors Causing Reduction of Performance in Container Handling Operation of the studied port, respectively.

Keywords: Container, loading/unloading operation, sea port, TOPSIS, ANP, port performance

Introduction
The globalization of the world economy has led to an increasingly important role for transportation (Jafari, 2013a; Cullinane *et al.*, 2005). In particular, container transportation plays a key role in the process, largely because of the numerous technical and economic advantages it possesses over traditional methods of transportation. Standing at the crucial

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interface of sea and inland transportation, the significance of the container port and its production capabilities cannot be ignored. Compared with traditional port operations, containerization has greatly improved port production performance because of two reasons (Jafari, 2013b; Cullinane *et al*., 2005). To reap economies of scale and of scope, liner shipping companies and container ports are respectively willing to deploy dedicated container ships and efficient container handling systems. In so doing, port productivity has been greatly enhanced (Jafari, 2013c, Cullinane *et al*., 2005). On the other hand, many container ports no longer enjoy the freedom yielded by a monopoly over the handling of cargoes from within their hinterland. They are not only concerned with whether they can physically handle cargo but also whether they can compete for cargo. This inter-port competition, under the orthodox microeconomic framework, is believed to provide an incentive to improve port performance. Productive efficiency, therefore, is a survival condition in a competitive environment. Under such a competitive environment, port performance measurement is not only a powerful management tool for port operators, but also constitutes a most important input for informing regional and national port planning and operations (Cullinane *et al*., 2005).

Port generally can be defined as interface linking marine and inland transportation. Nowadays, nearly ninety percent of global trade is handled through ports. Therefore, a port plays an important role in contributing to the national economy. Moreover, a port's development is related to regional industries, port facilities, government's port policies, and so on. Taking into consideration the importance of time and cost in the current competitive world, therefore the owners of goods wish to expedite the movement of their goods from ports and to decrease the relevant tariffs and transportation costs. Thus the extent of efficiency of ports has a significant impact on realization of their wishes (Jafari, 2013a; Saeidi *et al*., 2005a). Efficiency of ports can create a remarkable influence in decrement of the period of ship stay at port, the period of sedimentation of goods and the decrement of freight payable to shipping companies. Finally, port efficiency also can cause customer satisfaction, demand increase and profitability rising up. Therefore, optimization of L/U operation at ports for decreasing the period of goods transfer from producers to consumers is deemed to be a notable issue (Saeidi *et al*., 2005b). 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.

Material and methods

The objective of this paper is to detect and prioritize the Factors Causing Reduction of Performance in Container Handling Operation by use of TOPSIS method. In the first stage, the causes of delay are detected and studied. To reach to this goal, the daily data of Studied port 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, 2011 to November 20, 2011) have been gathered. In the second stage having considered the detected factors from the first stage, the probability of occurrence of error modes (occurrence frequency), the extent of errors impact on the process after their occurrence (severity) and the probability of their detection before influencing the process (detection) have been scored by experts in form of a scale ranging from one to ten. In the third stage, the mentioned causes have been weighted by use of Analytical Hierarchy Process. Finally, based on the criteria of occurrence frequency, severity and detection possibility, the causes have been prioritized by use of TOPSIS method.

Multi criteria decision making methods

Under the conditions of decision making, in fact, the intended problem can be studied in three forms (Asqarpoor, 2011):

1) **Selective:** selecting the most proper choices from the possible ones
2) **Hierarchical:** prioritizing the choices in order of their preferences
3) **Grouping:** grouping the choices in predetermined classes on the basis of their comparison with existing references and standards

MCDM is mostly divided into two groups of MODM and MADM.

Multi objective decision making (MODM) models

These models can optimize various objectives with different units. Each one of the applied objectives has preference degrees whose solution orders must be observed in optimization process. Choices are posed based on optimization of a set of target functions with regard to the constraints of the problem. In this method, the increment of importance of an objective is possible only when the importance of at least one other objective decreases (Pohekar & Ramachandran, 2004).

Multi attribute decision making (MADM) models:

These models are used to select the most proper choice. Selection is usually made through determination of acceptable level of criteria or comparison between the choices. MADM is usually formulized as below Asqarpoor:

choice	x_1	x_2	…	x_n
A_1	r_{11}	r_{12}	…	r_{1n}
A_2	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮
A_m	r_{m1}	r_{m2}	…	r_{mn}

A_1, A_2, … $A_m$ofthe above decision making matrix form m given choices respectively and X_1, X_2, …, X_n shows n attributes for measuring utility of each choice and finally r_{ij} shows the specific amounts of j^{th} attribute for i^{th} choice.

MADM models themselves are classified into two groups of non compensatory and compensatory models.

1) **Non compensatory models**: this model includes methods in which trade off among the attributes is not permitted; meaning that the weakness existing in an attribute cannot be compensated by strengths which exist in another one. Therefore in such methods each attribute is solely posed and comparisons take place on an attribute to attribute basis.
2) **Compensatory model:** this model includes methods in which trade off among the attributes is permitted. In other words, a variation in an attribute can be modified by a variation in another one or the decrement of an attribute is acceptable if it causes the increment of another attribute. The mentioned models are classified into three subgroups of scoring, compromising and concordance (Asqarpoor, 2011).

Analytic network process (ANP)

Analytic network process (ANP) model to achieve the objectives listed above. ANP is the generalization of Saaty's analytical hierarchy process (ANP), which is one of the most widely employed decision support tools. ANP is limited to relatively static and unidirectional interactions with little feedback among decision components and alternatives (Khan& Faisal, 2008). On the other hand, ANP and its super-matrix technique can be considered as an extension of ANP that can handle a more complex decision structure, as the ANP framework has the flexibility to consider more complex inter-relationships (outer-dependence) among different elements (Gürbüz *et al*., 2009). It incorporates both qualitative and quantitative approaches to a decision problem. It is also capable of capturing the tangible and intangible aspects of relative criteria that have some bearing on the decision making process, but ANP cannot deal with interconnections (inner-dependence) between decision factors in the same level. This is because an ANP model is structured in a hierarchy in which no horizontal links are allowed. In fact, this weakness can be overcome by using the advance multi-criteria making technique, which is ANP. Thus, ANP consists of three parts: the first part is the control hierarchy for the network of the criteria and sub-criteria, the second part is a network of influences among the elements and clusters, and the third is the feedback between the various clusters and elements within a cluster (Khan & Faisal, 2008).

Therefore, ANP is a more powerful technique in modeling complex decision environments than ANP because it can be used to model very sophisticated decisions involving a variety of interactions and dependencies. That exists in real-world problems is a complex network of various issues (Khan & Faisal, 2008).

TOPSIS

Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is a multi-criteria decision analysis method, which was originally developed by Hwang and Yoon in 1981 (Hwang and Yoon, 1981). With further developments by Yoon in 1987, (Yoon, 1987) and Hwang, Lai and Liu in 1993 (Hwang *et al*., 1993). TOPSIS is based on the concept that the chosen alternative should have the shortest geometric distance from the positive ideal solution and the longest geometric distance from the negative ideal solution. It is a method of compensatory aggregation that compares a set of alternatives by identifying weights for each criterion, normalising scores for each criterion and calculating the geometric distance between each alternative and the ideal alternative, which is the best score in each criterion. An assumption of TOPSIS is that the criteria are monotonically increasing or decreasing. Normalisation is usually required as the parameters or criteria are often of incongruous dimensions in multi-criteria problems (Yoon and Hwang, 1995; Zavadskas *et al*., 2006). Compensatory methods such as TOPSIS allow trade-offs between criteria, where a poor result in one criterion can be negated by a good result in another criterion. This provides a more realistic form of modelling than non-compensatory methods, which include or exclude alternative solutions based on hard cut-offs (Greene *et al*., 2011; Huang *et al*., 2011) the steps of TOPSIS method are as follow (Shanian and Savadogo, 2006; Rouhani *et al*., 2012):

First step: Construct the normalized decision matrix. This step converts the various attribute dimensions into non dimensional attributes. An element r_{ij} of the normalized decision matrix R is calculated as follows: (x_{ij} is the value of ith alternative in jth criteria) (Shih *et al*., 2007; Kelemenis and Askounis, 2010),

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}^2} \qquad (1)$$

Second step: Obtain a weighted normalized decision matrix, where w_j is the weight of j th criteria (Kang *et al*., 2012; Alsayed *et al*., 2012).

$$\Sigma wj = 1, \quad W = \{w_1, w_2, \dots w_n\}$$

$$R = \begin{bmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \cdots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{bmatrix}$$

Third step: Determine the positive ideal solution (V^+) and negative ideal solution (V^-) (Lin *et al*., 2008).

$$V^+ = \left\{ \begin{matrix} \left(\max_i v_{ij} \,|\, j \in j_1 \right), \\ \left(\min_i v_{ij} \,|\, j \in j_2 \right) \\ |\, i = 1,2,\ldots,m \end{matrix} \right\} \quad (2)$$

$$V^- = \left\{ \begin{matrix} \left(\min_i v_{ij} \,|\, j \in j_1 \right), \\ \left(\max_i v_{ij} \,|\, j \in j_2 \right) \\ |\, i = 1,2,\ldots,m \end{matrix} \right\} \quad (3)$$

V^+ and V^- are the best and the worst weighted normalized values for all alternatives according to jth criterion, respectively. j_1 Is the set of benefit attributes while j_2 is the set of cost attributes (Lavasani *et al*., 2012).

Fourth step: In this step the Euclidean distance of each alternative from the overall ideal and negative ideal solution is determined, respectively, as follows (Lavasani *et al*., 2012).

$$d_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij}\ v_{ij}^{+})^2}\ , i = 1,2,\ldots,m \quad (4)$$

$$d_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij}\ v_{ij}^{+})^2}\ , i = 1,2,\ldots,m \quad (5)$$

Fifth step: Calculate the relative closeness to the ideal solution (Perez *et al*., 2012).

$$c_i^* = \frac{s_i}{(s_i^+ + s_i)}\ , 0 < c_i^+ < 1, i = 1,2,\ldots,m \quad (6)$$

$$C_i^* = 1 \ \text{if} A_i = A^+ \quad (7)$$

$$C_i^* = 0 \ \text{if} A_i = A$$

Sixth step: Rank the alternatives in descending order of C_i^* or select alternatives with maximum value of C_i^* (Lavasani *et al*., 2012).

Results

In the first stage, 20 causes of halt and lag in container L/U operation at studied port have been detected. This was done by consideration of port 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, 2012.Besides, to detect such causes, some brain storming sessions were held by attendance of several experts from the port. 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	Defectiveness of vertical onshore transportation equipment	12	Delayed start and early finish
2	Unpreparedness of factors outside the port	13	Unpreparedness of contractor
3	Unpreparedness of owners of goods	14	Labor issues
4	Incompleteness of documents	15	Passing and quarantine formalities
5	Shortage of trucks	16	Detainment by PSC
6	vessel passing and container quarantine formalities	17	Inefficiency of ship equipments
7	Financial and administrative issues	18	Adjusting the balance of ship
8	Defectiveness of horizontal L/U equipment	19	Foul weather and tide prediction
9	Incompetence of unloading equipment	20	Formal and general holidays

10	Quay traffic
11	Insufficiency of container yard

In the second stage having considered the detected factors from the first stage, by determining the probability of the causes occurrence (occurrence frequency), the extent of impact of causes on process after their occurrence (severity) and probability of causes detection before having effect on process (detection) have been scored by experts in form of a scale ranging from one to ten.

In this stage of TOPSIS, based on the probability of occurrence of cause's modes, the extent of their effect on the process after their occurrence and probability of their detection before having impact on the process will be ranked through the following steps.

Step 1: Decision making matrix is created based on the scores of each one of the causes. This matrix has been normalized by use of relation 1 and noted in tables 2 and 3.

Table 2: Decision making matrix / **Table 3: Normalized matrix**

	Decision Making Matrix			**Normalized Matrix**		
Code	**D MAX**	**O MAX**	**S MAX**	**D MAX**	**O MAX**	**S MAX**
1	6	5	4	0.18215	0.15467	0.14055
2	10	8	6	0.30359	0.24748	0.21082
3	10	6	6	0.30359	0.18561	0.21082
4	9	9	5	0.27323	0.27841	0.17568
5	10	6	6	0.30359	0.18561	0.21082
6	7	8	5	0.21251	0.24748	0.17568
7	8	9	8	0.24287	0.27841	0.28109
8	8	9	8	0.24287	0.27841	0.28109
9	9	8	6	0.27323	0.24748	0.21082
10	8	7	5	0.24287	0.21654	0.17568
11	8	7	8	0.24287	0.21654	0.28109
12	7	7	2	0.21251	0.21654	0.07027
13	5	6	4	0.15179	0.18561	0.14055
14	6	10	3	0.18215	0.30934	0.10541
15	8	10	4	0.24287	0.30934	0.14055
16	3	4	9	0.09108	0.12374	0.31623
17	6	6	4	0.18215	0.18561	0.14055
18	6	4	4	0.18215	0.12374	0.14055
19	3	3	10	0.09108	0.09280	0.35136
20	3	7	5	0.09108	0.21654	0.17568
21	3	2	10	0.09108	0.06187	0.35136

Step 2: Using ANP, the weights of each one the criteria of occurrence frequency, severity and detection have been computed. The results have been noted in table 4.

Table 4: The weights of criteria

criteria	**D**	**O**	**S**
Weight	0.26	.043	0.31

Then, by use of relation and weights of each one of the criteria, the normalized matrix of weighted matrix has been obtained. Table 5 shows the weighted matrix.

Table 5: Weighted matrix

Code	D	O	S
	MAX	**MAX**	**MAX**
1	0.04736	0.06651	0.04357
2	0.07893	0.10641	0.06535
3	0.07893	0.07981	0.06535
4	0.07104	0.11972	0.05446
5	0.07893	0.07981	0.06535
6	0.05525	0.10641	0.05446
7	0.06315	0.11972	0.08714
8	0.06315	0.11972	0.08714
9	0.07104	0.10641	0.06535
10	0.06315	0.09311	0.05446
11	0.06315	0.09311	0.08714
12	0.05525	0.09311	0.02178
13	0.03947	0.07981	0.04357
14	0.04736	0.13302	0.03268
15	0.06315	0.13302	0.04357
16	0.02368	0.05321	0.09803
17	0.04736	0.07981	0.04357
18	0.04736	0.05321	0.04357
19	0.02368	0.03991	0.10892
20	0.02368	0.09311	0.05446
21	0.02368	0.02660	0.10892

Step 3: in this stage, using relations 2 and 3, the positive and negative ideal solutions have been determined as below.

Positive ideal solution

$A_{ij}^{+} =$ (0.07893, 0.13302, 0.10892)

Negative ideal solution

$A_{ij}^{-} =$ (0.02368, 0.02660, 0.02178)

Then, the interval and the extent of proximity of each one of the causes, positive ideal solution and negative ideal solution have been computed based on which the mentioned causes have been ranked. Table 6 displays the obtained results.

Table 6: The ratio of negative and positive ideal solutions and the ranks of the causes

Code	Causes	di+	di-	ci	Rank
1	Deficiency of vertical onshore transportation equipment	0.09845	0.05126	0.34241	19
2	Unpreparedness of factors outside the port	0.05105	0.10640	0.67577	3
3	Unpreparedness of owners of goods	0.06877	0.08822	0.56194	9
4	Document incompleteness	0.05662	0.10946	0.65909	5
5	Shortage of trucks	0.06877	0.08822	0.56194	10
6	Vessels passing and quarantine formalities	0.06507	0.09184	0.58529	**7**
7	Administrative and financial issues	0.03001	0.12041	0.80048	1
8	Deficiency of Horizontal L/U equipment	0.03001	0.12041	0.80048	1
9	Incompetency of unloading equipment	0.05166	0.10252	0.66496	4
10	Quay traffic	0.06934	0.08396	0.54768	11
11	Insufficiency of container yard	0.04813	0.10125	0.67782	2
12	Delayed start and early finish	0.09872	0.07362	0.42718	15
13	Unpreparedness of contractor	0.09306	0.05962	0.39050	18
14	Labor issues	0.08252	0.10956	0.57037	8
15	Passing and quarantine formalities	0.06723	0.11557	0.63221	6
16	Confiscation by PSC	0.09768	0.08075	0.45257	13
17	Deficiency of ship's equipment	0.08999	0.06218	0.40861	17
18	Adjustment of vessel's balance	0.10788	0.04175	0.27902	20
19	Foul weather and tide prediction	0.10827	0.08815	0.44877	14
20	Official and general holidays	0.08724	0.07410	0.45928	12
21		0.11990	0.08714	0.42087	16

Discussion and conclusion

With the goal of detection and prioritization of causes of halt and lag in container L/U operation at studied port, the present study has been done in three stages by use of TOPSIS model. In the first stage, having considered the daily census of container L/U in the pertinent terminal of the port during eight months starting from 21st March, 2011, the aforementioned causes were detected and investigated. In the second stage, the detected causes have been scored by the experts based on the occurrence probability, the extent of their influence on process after occurrence (severity) and detection probability. In the third stage, the recognized Causes were ranked by use of TOPSIS model. The obtained results via TOPSIS show that financial and administrative issues (C_i = 0.80048) jointed with the factor of deficiency of horizontal L/U equipment (C_i = 0.80048), then insufficiency of container yard (C_i = 0.67782) and unpreparedness of factors external to the port (C_i = 0.67577) were detected as the most important causes of delay creation in container L/U operation of the port, respectively. Considering the obtained results via TOPSIS, it can be also concluded that this method may be applied as an efficient and reliable tool for prioritization of causes of halt and lag in L/U operations.

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