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Measuring the Performance of Dry Bulk Cargo Loading and Unloading Operation: *Latakia* Case Study

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Abstract Aimed at detection and prioritization of causes of delay in dry bulk cargo loading/unloading operation at the relevant terminal of Latakia port of Syria, the present research has been conducted by use of PROMETHEE method in three stages. In the first stage, the number of lags and halts in loading/unloading operation (hereinafter referred to as L/U operation) and the involving causes during a specific period were studied. As well, brain storming cessions attended by experts from the mentioned terminal were held during which seventeen numbers of causes of delay were detected. Then, based on the criteria of determination of causes occurrence probability (occurrence frequency), the extent of causes impact on process after occurrence (severity) and probability of detection of causes before having impact on the process (detection), the causes were scored in form of a scale ranging from 1 to 10. In the second stage, using AHP method, the mentioned criteria were weighted. The criterion of occurrence probability was the most weighted (0.43) and the criterion of detection probability was the least weighted (0.26). 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 PROMETHEE method.

Keywords: *dry bulk cargo, loading/unloading operation, Latakia port, PROMETHEE*

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1. Introduction

Growth and development of transportation industry is one of the important indicators of nations' economic development. Nowadays, the impact of transportation industry on sustainable development is a clear issue [1]. This sector includes activities which are widely involved with production, distribution and consumption of goods as well as services. Such activities possess a prominent role among other economic activities [2]. Marine transportation as one of the bases of this industry and through possessing advantages such as low cost per gross volumes of cargo has a basic role in development of nations' foreign trade [3,4].In this regard, access to free waters is considered as an endowment for nations for their development [5]. The particular geographic situation of Syria and access to international waters is a head start for the country [6,7]. This feature has made it capable of possessing a special place in marine transportation industry.

Ports as one of the main components of marine transportation systems are one of the important rings of global supply chain [8]. Marine services complexes - that based on the opinions of economists, traders and producers are of the significant infrastructures of global trade - play an important role in distribution of goods and optimization of the relevant costs of transportation [9,10]. Taking into consideration the importance of time and cost in the current competitive world, those companies are successful in their job who can deliver their products to customers in time and at a lower cost [11]. 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 [12]. 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 [13,14]. 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 to detect and prioritize the causes

of halt and lag in dry bulk cargo L/U operation by use of PROMETHEE method.

2. Material and Methods

This survey has been accomplished in three stages by use of PROMETHEE method to detect and prioritize the causes of delay in dry bulk cargo L/U operation at Latakia port terminal. In the first stage, the causes of delay are detected and studied. To reach to this goal, the daily data of Latakia 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 indicators of occurrence frequency, severity and detection possibility, the causes have been prioritized by use of PROMETHEE method.

3. AHP

AHP decomposes the complexity in the form of a simple hierarchy, descending from overall goal to criteria, sub-criteria (if exist) and alternatives; allocates relative weights of criteria and sub-criteria to compare the alternatives [15]. The basic principles of AHP can be summarized as defining and determining the problem; decomposing the problem in a hierarchy from top through the intermediate levels; constructing a set of pair-wise comparison matrices; testing the consistency index; synthesizing the hierarchy to find out the ranks of the alternatives. AHP makes use of pair-wise comparisons to simplify the judgment process with 1-9 ratio scaling [16] (see Table 1).

Table 1. The pairwise comparison scale [15]

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favour one activity over another
5	Strong importance	Experience and judgment strongly favour one activity over another
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2,4,6,8		Intermediate values

When it is assumed (A_1, A_2,…A_n) is any set of n elements than a sample of square matrix can be produced as below by pair wise comparisons of each element. Here, each (A_i, A_j) judgment represented as "a_{ij}". Because $a_{ii}=1$ for all *i* diagonal of the matrix contains entries of 1.

$$\begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nm} \end{pmatrix} \quad (1)$$

When (w_1, w_2,…,w_n) are the elements corresponding weights; the dominance of an element in the row over the element in the column represented as w_i/w_j. AHP method compares the related weights of each element in a set with respect to the goal. The general form of comparison matrix of AHP is given as follows;

$$A = \begin{pmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_n} & \cdots & \frac{w_n}{w_n} \end{pmatrix} \quad (2)$$

Than the problem turns in to general process to calculating the largest eigenvalue corresponding to eigenvector to assess the Consistency Index (C.I.) where *A* is the matrix, *x* is the eigenvector and λ is the eigenvalue. When we divide C.I. by the random consistency number the final value must be less than 0.10 [15].

$$C.I. = \frac{\lambda_{\max} - n}{n-1}, \; Ax = \lambda x \quad (3)$$

4. The PROMETHEE Method

The PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) is a multi-criteria decision- making method developed by Brans et al. [17]. It is a quite simple ranking method in conception and application compared with other methods used for multi-criteria analysis. It is well adapted to problems where a finite number of alternatives are to be ranked according to several, sometimes conflicting criteria [18]. The evaluation table is the starting point of the PROMETHEE method. In this table, the alternatives are evaluated on the different criteria. The implementation of PROMETHEE requires two additional types of information, namely:

(1) Information on the relative importance that is the weights of the criteria considered.

(2) Information on the decision-maker's preference function, which he/she uses when comparing the contribution of the alternatives in terms of each separate criterion. The weights coefficients can be determined according to various methods [19]. AHP method is used to determine the criteria weights in this study. The PROMETHEE method is appropriate to treat the multi-criteria problem of the following type:

$$\max\left\{ f_1(a),\ f_2(a), \ldots,\ f_n(a) \middle| a \in A \right\} \quad (4)$$

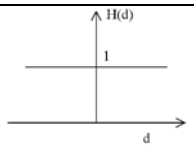
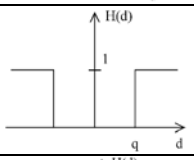
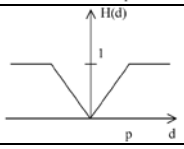
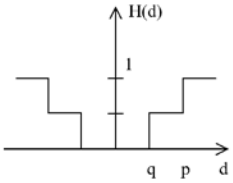
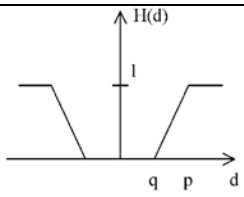
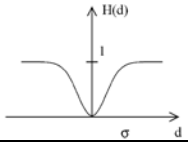
Where A is a finite set of possible alternatives, and f_J denotes n criteria to be maximized. For each alternative, $f_J(a)$ is an evaluation of this alternative. When we

compare two alternatives $a,b \in A$, we must be able to express the result of these comparisons in terms of preference. We, therefore, consider a preference function *P*. The preference function translates the difference between the evaluations of two alternatives (*a* and *b*) in terms of a particular criterion, into a preference degree ranging from 0 to 1. Let

$$P_J(a,b) = G_J\left[f_j(a) - f_j(b)\right], 0 \le P_J(a,b) \le 1 \quad (5)$$

The preference function associated to the criterion, $f_j(i)$ where G_J s a non-decreasing function of the observed deviation (*d*) between $f_j(a)$ and $f_j(b)$. In order to facilitate the selection of specific preference function, six basic types of this preference function are proposed to decision maker by Brans and Vincke [20] as it presented in Table 2.

Table 2. Generalized criteria [20]

Type of genera- lazed criteria	Analytical definition	Shape	Parameters to define
Type I. Usual criterion	$H(d)=\begin{cases}0, & d=0;\\ 1, & \lvert d\rvert>0.\end{cases}$		--
Type II. Quasi-criterion	$H(d)=\begin{cases}0, & \lvert d\rvert\le q;\\ 1, & otherwise.\end{cases}$		*q*
Type III. Criterion with linear preference	$H(d)=\begin{cases}\frac{\lvert d\rvert}{p}, & \lvert d\rvert\le p;\\ 1, & \lvert d\rvert>0.\end{cases}$		*p*
Type IV. Level-criterion	$H(d)=\begin{cases}1, & \lvert d\rvert\le q;\\ 1/2, & q<\lvert d\rvert\le p;\\ 1, & otherwise.\end{cases}$		*q*, *p*
Type V. Criterion with linear preference and indifference area	$H(d)=\begin{cases}1, & \lvert d\rvert\le q;\\ \frac{\lvert d\rvert-q}{p-q}, & q<\lvert d\rvert\le p;\\ 1, & otherwise.\end{cases}$		*q*, *p*
Type VI. Guassian criterion	$H(d)=1-\exp\{-\frac{d^2}{2\sigma^2}\}$		σ

In each case no more than two parameters (threshold, *q*, *p or s*) have to fix [21]. Indifference threshold *q*: the largest deviation to consider as negligible on that criterion. It is a small value with respect to the scale of measurement. Preference threshold *p*: the smallest deviation to consider decisive in the preference of one alternative over another. It is a large value with respect to the scale of measurement. Gaussian threshold *s*: it is only used with the Gaussian preference function. It is usually fixed as an intermediate value between indifference and a preference threshold. PROMETHEE permits the computation of the following quantities for each alternative *a* and *b*:

$$\pi(a,b) = \frac{\sum_{j=1}^{n} w_j p_j(a,b)}{\sum_{j=1}^{n} w_j} \qquad \Phi^-(a) = \sum_{x\in A} \pi(x,a) \quad (6)$$

$$\Phi^+(a) = \sum_{x\in A} \pi(x,a) \qquad \Phi(a) = \Phi^+(a) - \Phi^-(a) \quad (7)$$

So for each alternative *a*, belonging to the set *A* of alternatives, $\pi(a, b)$ is an overall preference index of *a* over *b*. The leaving flow $\Phi^+(a)$ is the measure of the outranking character of *a* (how *a* dominates all the other alternatives of *A*). Symmetrically, the entering flow $\Phi^-(a)$ gives the outranked character of *a* (how *a* is dominated by all the other alternatives of *A*). $\Phi(a)$ represents a value function, whereby a higher value reflects a higher attractiveness of alternative *a* and is called net flow. The two main PROMETHEE tools can be used to analyze the evaluation problem: (1) the PROMETHEE I partial ranking, (2) the PROMETHEE II complete ranking. The PROMETHEE I partial ranking provides a ranking of alternatives [22]. In PROMETHEE I, alternative *a* is preferred to alternative *b*, *aPb*, if alternative *a* has a greater leaving flow than that of alternative *b* and *a* smaller entering flow than the entering flow of alternative *b*:

$$apb\ if: \Phi^+(a) > \Phi^+(b)\ and\ \Phi^-(a) < \Phi^-(b);\ or \quad (8)$$

$$\Phi^+(a) > \Phi^+(b)\ and\ \Phi^-(a) = \Phi^-(b);\ or \quad (9)$$

$$\Phi^+(a) = \Phi^+(b)\ and\ \Phi^-(a) < \Phi^-(b) \quad (10)$$

PROMETHEE I evaluation allows indifference and incomparability situations. Therefore, sometimes partial rankings can be obtained. In the indifference situation (*aIb*), two alternatives *a* and *b* has the same leaving and entering flows [23]:

$$aib\ if: \Phi^+(a) = \Phi^+(b)\ and\ \Phi^-(a) = \Phi^-(b) \quad (11)$$

Two alternatives are considered incomparable, *aRb*, if alternative *a* is better than alternative *b* in terms of leaving flow, while the entering flows indicate the reverse:

$$aRb\ if: \Phi^+(a) > \Phi^+(b)\ and\ \Phi^-(a) > \Phi^-(b);\ or \quad (12)$$

$$\Phi^+(a) < \Phi^+(b)\ and\ \Phi^-(a) < \Phi^-(b) \quad (13)$$

PROMETHEE II provides a complete ranking of the alternatives from the best to the worst one. Here, the net flow (φ) is used to rank the alternatives. The alternative with the higher net flow is assumed to be superior. Since PROMETHEE I does not provide a complete ranking, resulting ranking cannot be compared with the ranking provided by PROMETHEE II. PROMETHEE I ensure creation of indifferent and incomparable alternatives. In some ranking problems, PROMETHEE I can give a complete ranking depending on the evaluation matrix values and, this ranking cannot be different from the one achieved with PROMETHEE II.

5. Results

5.1. Loading and Unloading Operation

Depicting SIPOC model makes it easy to identify the factors of L/U process and the relationships among them. The beginning point of L/U process is the suppliers of process which include owners of goods, transportation companies, owners of ships, shipping lines and L/U companies. And the final point is connected to the customers of port which include owners of goods, transportation companies, owners of ships and shipping lines. Goods, containers, equipment, labor and other ways of transportation constitute the inputs of the process while transmission of goods and containers in sea between ships and other ways of transportation in land form the outputs of the process. SIPOC model in Figure 1 shows L/U process in port. The operational trend of this process has been presented in Process column.

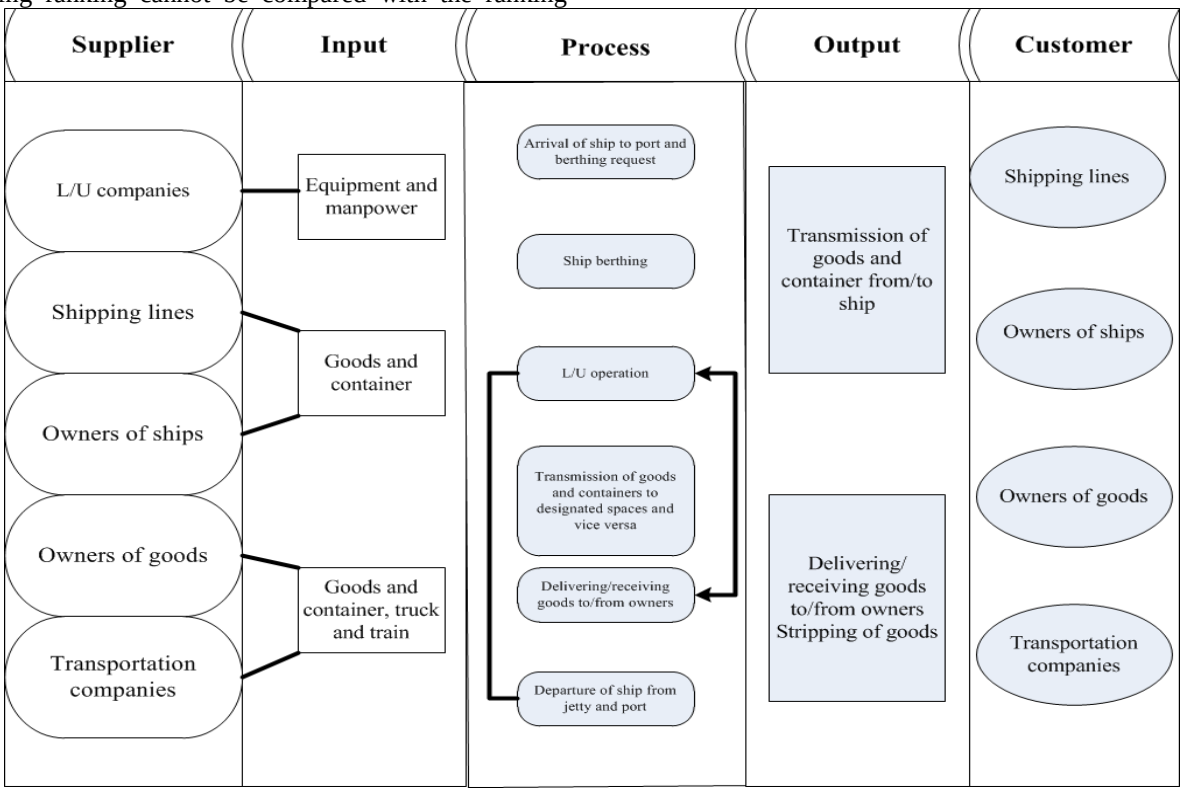


Figure 1. SIPOC diagram of L/U process in

Then at the first stage, 20causes of halt and lag in dry bulk cargo L/U operation at Latakia 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 cessions were held by attendance of several experts from the port. The causes have been noted in Table 3.

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. The results of this stage have been noted in Table 4.

Table 3. causes of lag and halt in L/U operation and their effects

Code	Causes
1	Foul weather and tide prediction
2	Administrative and financial issues
3	Unpreparedness of owners of goods
4	Deficiency of Horizontal L/U equipment
5	Shortage oftruck
6	Deficiency of vertical onshore transportation equipment
7	Document incompleteness
8	Passing and quarantine formalities
9	Confiscation by PSC
10	Labor issues
11	Unpreparedness of contractor
12	Deficiency of ship's equipment
13	Adjustment of vessel's balance
14	CleaningDocks
15	Incompetency of unloading equipment
16	Delayed start and early finish
17	Official and general holidays

In this stage of PROMETHEE, based on the probability of occurrence of causes 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.

Step1– decision making matrix is created based on the scores of each one of the causes as presented in Table 2.

Step2-using AHP and EXPERT CHOICE 2000, the weights of each one the indicators of occurrence frequency, severity and detection have been computed. The results have been noted in Table 5.

Table 4. Decision making matrix of PROMETHEE

Code	D	O	S
1	9	9	5
2	8	7	8
3	8	9	8
4	8	9	8.1
5	6	7	5
6	8	10	4
7	10	8	6
8	5	6	4
9	6	10	3
10	8	7	4
11	3	4	9
12	6	6	4
13	6	4	4
14	3	3	10
15	3	7	5
16	3	2	10
17	5	6	4

Table 5. the weights of indicators

Indicator	D	O	S
Weight	0.26	.043	0.31

Step 3 – finally in this step the mentioned causes of delay were ranked by use of PROMETHEE method as presented in Table 6.

Table 6. Final result PROMETHEE method

Ranking	Alternative	F	F-	F+
1	Document incompleteness	0.57688	0.21156	0.78844
2	Shortage oftruck	0.57198	0.15661	0.72859
3	Deficiency of Horizontal L/U equipment	0.47716	0.18821	0.66538
4	Unpreparedness of owners of goods	0.43770	0.20575	0.64345
5	Administrative and financial issues	0.41497	0.25653	0.67149
6	Cleaning Docks	0.06811	0.41038	0.47849
7	Delayed start and early finish	0.05934	0.41476	0.47410
8	Deficiency of vertical onshore transportation equipment	-0.00663	0.36909	0.36246
9	Unpreparedness of contractor	-0.01356	0.46482	0.45126
10	Foul weather and tide prediction	-0.02212	0.43312	0.41099
11	Labor issues	-0.06801	0.39539	0.32739
12	Incompetency of unloading equipment	-0.33728	0.54547	0.20820
13	Deficiency of ship's equipment	-0.34023	0.59217	0.25194
14	Adjustment of vessel's balance	-0.35920	0.55863	0.19943
15	Confiscation by PSC	-0.46646	0.69127	0.22482
16 -- 17	Official and general holidays	-0.49633	0.65151	0.15518
16 -- 17	Passing and quarantine formalities	-0.49633	0.65151	0.15518

6. Discussion and Conclusion

With the goal of detection and prioritization of causes of halt and lag in dry bulk cargo L/U operation at Latakia port, the present study has been done in three stages by use of PROMETHEE model. In the first stage, having considered the daily census of dry bulk cargo 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 PROMETHEE model.

The obtained results via PROMETHEE show that Document incompleteness (F = 0.57688) Shortage of truck (F = 0.57198), then Deficiency of Horizontal L/U equipment (F =0.47716) and Unpreparedness of owners of goods (F = 0.43770) and Administrative and financial issues (F = 0.41497) were detected as the most important causes of delay creation in dry bulk cargo L/U operation of the port, respectively. And also Passing and quarantine formalities (F = -0.49633), Official and general holidays (F = -0.49633), Confiscation by PSC (F = -0.46646),

Adjustment of vessel's balance (F = -0.35920), Deficiency of ship's equipment (F = -0.34023), were detected as the least important causes of delay creation in dry bulk cargo L/U operation of the port, respectively. Considering the obtained results via PROMETHEE, 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.

7. Policy Implication

The followings are suggested to reduce halt and lags in L/U operation:

Deficiency of Horizontal L/U equipment: fulfillment of periodic inspections, repair and maintenance according to manufacturers' standards, purchasing new equipment, making the depreciated and old equipment out of service and providing spare equipment for emergency events can to a large extent remove the existing problems. Considering the promotion of the generation of ships, the equipment of ports has to be changed proportionately to these evolutions. It is obvious that nonconformity of equipment with ships generations can cause halt and lag in L/U process. Promotion of equipment generation proportionately to tonnage and generation of incoming ships is an appropriate way to remove this problem.

Document incompleteness: this factor has caused halts and lags in a lot of cases. Application of electronic services for implementing administrative procedures and obtaining the permission of certificate issuance as well as establishment of an efficient communicative system between port and owners can in to some extent remove this deficiency.

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