International Journal of Innovation and Applied Studies
ISSN 2028-9324 Vol. 3 No. 4 Aug. 2013, pp. 1072-1078

http://www.issr-journals.org/ijias/

Selecting Appropriate Quayside Equipment for Grain Unloading Using TOPSIS and Entropy Shannon Methods

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ABSTRACT: Now day selection of optimum quay Sid equipment for loading and discharging the dry bulk cargo can maximize the overall efficiency of Terminal. For this end the current applied study was implemented by the aim to choose the best equipment for discharging dry bulk cargoes in BIK Grain terminal using TOPSIS and Shannon entropy method in three phases. In the 1st phase, the most important decision-making criteria for choosing the most appropriate equipment were identified by using experts' interview and investigating the previous researches and holding brain storm meetings with the Grain Terminal's experts. Then in the 2nd phase, the weight of every identified criteria using Shannon entropy method, Was determined. The abstained result from Shannon entropy method indicates that service facility criterion with the scale of 0.06 has earned the maximum and operator cost criterion with the scale of 0.034 obtained the least. In the 3rd phase, using scale 1-9 of each equipment regarding shall be scored based on the criteria and according to the obtained scores for each equipment of the decision- making matrix of the TOPSIS method was established and finally, with respect to the weight of each earned criteria, the equipment shall be scored in the 2nd phase and the most optimum shall be selected. The final results from TOPSIS method indicates that unloader with (C_i=0.91346) enjoys the 1st and the vacuum with (C_i=0.26382) the 2nd and grab with (C_i=0.00000) ranks.

KEYWORDS: Grain Terminal, Discharging and loading operation, selection, dry bulk cargo, quay Sid equipment, AHP, TOPSIS.

1 INTRODUCTION

The optimum equipment for loading and discharging can maximize HR sources, facilities and convenience scientifically, cost reduction, also providing services in the current conditions in a progressive way. Thus, the aim of providing equipment is to accelerate loading and discharging processes of goods in the ports [1]. Acceleration in loading and discharging operations not only provides in time delivery throughout the world, but it also prevents vessels' too much waiting in the quay [2]. Therefore, proper selection of equipment shall increase exploitation to a large extent. In choosing jetty's bulk –discharging equipment, lots of things are involved which are all studied in the research and eventually, three types of jetty equipment are compared based on this standard and TOPSIS method and that the optimum is chosen. Bulk carrier is those types of cargos that is not packed and shipped. These cargoes have different types including liquid and solid, small- big or powder like. Generally, for loading and discharging bulk cargos, special equipment is used. Clearly, one can divide bulk cargos in dry and liquid type [3].

Dry bulk cargos are illustrated as follows:

- Granular dry-bulk cargo such as wheat, barley, corn, soya, rice, sugar.
- Dry bulk cargo as mineral or factorial like different types of clay and aluminum and concrete powder.
- Lump of earth dry bulk materials such as different mineral stone and metal types that are carried in big volumes.

Liquid bulk materials also include those types of liquid raw productions that are carried by special vessels. Liquid bulk materials are divided into four types:

- Petroleum
- Refined productions of oil
- Liquid bulk food
- Gaseous liquefied materials

In transporting all bulk materials, the recommended notes relative to juxtapose and marine transportation should be observed. A dry bulk terminal, normally, can load/ discharge a bulk-carrier with the speed 10000-20000 per day. For better access to higher productivity, all loading and discharging equipment are made for special purpose. The most important impacts of the most proper equipment choice for discharging dry-bulk cargos in ports are as follows [4]:

- Increasing efficiency and speed of port operations
- Time saving
- Decrease in expenditure
- Decrease the waiting time in the quay
- Port terminal capacity and their optimization with the least waiting time in port and maximum usage of quay equipment has been estimated.

Discharging methods for dry cargo from ship: Regarding using loading and discharging equipment of bulk carriers, the technical specifications of each part of the mechanical system should be clear for the terminal beforehand; because the so called specifications have wide impact on the performance of the mentioned system. E.g. if the discharging of bulk cargo take place by a special grab, the discharging tonnage will depend on elements such as volume capacity of the grab, special weight and the nature of the cargo, speed of the grab, conveyor belt's speed, brake's system, skills of the system's operators, bilge and valves of the vessel, vessel's width and the plant's arm. Thus, about the system's capacity concerning discharging of dry bulk cargo from the ship, one cannot present any figures whilst vessel's specifications and the related terminal are given [5].

Discharging by Grab: In this way which is still the same in the past 50 years, the bulk cargo is moved by a mobile arm attached to a grab along the jetty on a railway which is taken from the ship's stevedore and then transferred into a hopper with a base situated on the jetty. Then, the bulk cargo is taken from under the hopper onto the conveyor belt and to the depot point or the silos. The discharging capacity of this method (by grab) is variable between 1000-500 ton per hour and subject to different elements including the average loading capacity, no. of the maneuvers per hour, the speed by which a grab is closed, movement speed of the carne carrying the grab, width, depth and the shape of the vessel's stevedore and finally the skill of the operational personnel. To increase efficiency in this method they have tried that the taken portion average weight be more in comparison to the grab. Previously, this proportion was around one but with the new wave of grabs, this amount has doubled. The dry bulk cargo that in discharging them this method is used are as Iron ore, coal, bauxite, alumina, phosphorous, other non- major bulk commodities like sugar, fertilizer, for coal industry and grain by a mobile smaller crane equipped by a grab [6].

Discharging by compressed air system: For different types of dry cargo that have special weight and low adhesion such as grain through compressed air system for discharging is used. This equipment functions as vacuum, suction and pressure. Vacuum method in collecting bulk cargo from several places and deliver them in one place uses vacuum and pressure methods to do so. Compression methods create dust and environmentally are drastic. Before erecting terminals, an economical and technical comparison between air compression and mechanical method should be taken. The capacity of the small mobile discharging unit on average is said to be 50 tons per hour, this is while the same amount for the different installed types on the gate cranes is 200 tons per hour. In some ports like Rotterdam of Netherlands the discharging compressed air system with the capacity of 1500-200 tons per hour is used. This system with special design for discharging ships has the capacity of between 100-150 thousand tons [6]. Other ways of discharging are available in Iran that is not of common use which is as follows:

- Vertical conveyor belt
- The bucket left system
- Vessels equipped with discharging machine

2 RESEARCH METHODOLOGY

The current research is practical and from its essence and method aspects is said to be descriptive and is a branch of field work and as the title of the research indicates it aims at choosing the most appropriate equipment for discharging dry bulk cargo in BIK suing TOPSIS and Shannon Entropy methods. In this regard achieving the goals is implemented within 3 stages.

In the 1st phase, the most important decision making criteria for selecting the most proper choice for discharging dry bulk cargo from ship at the jetty shall be identified by using interview with experts, investigating previous researches and holding brainstorm sessions with the Grain Terminal Persian Gulf's experts.

In the 2nd phase, the identified decision making criteria in the 1st phase for the most appropriate choice in discharging dry bulk cargo from ship at the jetty shall be weighted using Shannon Entropy method.

In the 3rd phase, using scale 1-9 of each equipment regarding shall be scored based on the criteria and according to the obtained scores for each equipment of the decision- making matrix of the TOPSIS method was established and finally, with respect to the weight of each earned criteria, the equipment shall be scored in the 2nd phase and the most optimum shall be selected.

2.1 TOPSIS

TOPSIS method was introduced for the first time by Yoon and Hwang and was appraised by surveyors and different operators. TOPSIS is a decision making technique [7]. It is a goal based approach for finding the alternative that is closest to the ideal solution. In this method, options are graded based on ideal solution similarity [8]. If an option is more similar to an ideal solution, it has a higher grade [9]. Ideal solution is a solution that is the best from any aspect that does not exist practically and we try to approximate it. Basically, for measuring similarity of alternative (or option) to ideal level and non-ideal, we consider distance of that alternative from ideal and non-ideal solution [10]. The steps of TOPSIS method are as follow [11]:

First step: Construct the normalized decision matrix. This step converts the various attribute dimensions into non dimensional attributes. An element rij of the normalized decision matrix R is calculated as follows: (x_{ij} is the value of ith alternative in jth criteria),

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}^2} \tag{1}$$

Second step: Obtain a weighted normalized decision matrix, where w_j is the weight of jth criteria.

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

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

Third step: Determine the positive ideal solution (V^+) and negative ideal solution (V^-).

$$V^+ = \{(\max_i v_{ij} | j \in j_1), (\min_i v_{ij} | j \in j_2) | i = 1,2,\dots,m\} \tag{2}$$

$$V^- = \{(\min_i v_{ij} | j \in j_1), (\max_i v_{ij} | j \in j_2) | i = 1,2,\dots,m\} \tag{3}$$

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 [12]-[13]-[14].

Fourth step: In this step the Euclidean distance of each alternative from the overall ideal and negative ideal solution is determined, respectively, as follows:

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

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

Fifth step: Calculate the relative closeness to the ideal solution.

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

$$C_i^* = 1 \text{ if } A_i = A^+$$

$$C_i^* = 0 \text{ if } A_i = A \tag{7}$$

Sixth step: Rank the alternatives in descending order of C_i^* or select alternatives with maximum value of C_i^*.

2.2 Shannon Entropy and Objective Weights

Shannon and Weaver proposed the entropy concept, which is a measure of uncertainty in information formulated in terms of probability theory. Since the entropy concept is well suited for measuring the relative contrast intensities of criteria to represent the average intrinsic information transmitted to the decision maker, conveniently it would be a proper option for our purpose. Shannon developed measure H that satisfied the following properties for all pi within the estimated joint probability distribution P [14]-[15]:

It is proved that the only function that satisfied these properties is:

$$H_{shannon} = -\sum_i p_i \log(p_i) \tag{8}$$

Shannon's concept is capable of being deployed as a weighting calculation method, through the following steps:

Step 1: Normalize the evaluation index as:

$$p_{ij} = \frac{x_{ij}}{\sum_j x_{ij}} \tag{9}$$

Step 2: Calculate entropy measure of every index using the following equation:

$$e_J = -K \sum_{i=1}^{m} P_{ij}\, 1n\,(P_{ij}) \tag{10}$$

$$\text{Where } K = (1n(m))^{-1} \tag{11}$$

Step 3: Define the divergence through:

$$div_j = 1 - e_j \tag{12}$$

The more the div_j is the more important the criterion jth

Step 4: Obtain the normalized weights of indexes as:

$$p_{ij} = \frac{div_j}{\sum_j div_j} \tag{13}$$

3 RESULTS

First phase: To choose the most appropriate option for discharging the dry bulk cargo from the vessel at the jetty, there are 3 decision making criteria which are studied:

Operational criteria: paying attention to characteristics and technical specifications of the equipment used in the ports and the extent of their consistency with the port manager's demands is considered one of the strategies to improve the performance of the ports. The most important decision making operational sub-criteria concerning choosing the most appropriate equipment for discharging the dry bulk carriers are as the followings:

- Operation time: the total time needed for discharging cargoes
- Operation space: a space needed for rotating and performing the operation by equipment
- Unloading capacity: the load that a plant is able to discharge through one phase
- Accessories: the main equipment to join operations

Economic criteria: there's no doubt that the limitations and economic elements are among the most important decision making criteria for ports' strategies. The most important sub-criteria for studying the best discharging instrument for dry bulk cargo are as below:

- Cost of equipment purchase: sub-criteria of equipment purchase depend on factors such as order time, place of purchase and seller, equipment specification and market situation.
- HR and operators' expenses: presence of an expert operator is one of the requirement of using machineries in an optimum way at the bulk terminals
- Maintenance and repair of machineries: sub-criterion for machineries depends on use of equipment and handling the plants and the type of fuel.
- Depreciation cost of equipment: depreciation costs and decreasing no. of equipment is one of the constant challenges facing the industrial managers. Incorrect assessment of these costs, definitely; shall lead plants non-profit (inefficiency).
- Leases: in case the equipment purchase for ports has no economic justification, the ports officials shall decide on rental of equipment.

Logistics criteria: the most important logistics standards that can be considered for selecting the best equipment for discharging dry bulk are as follows:

- Continuous development: getting feedback from each operation and identifying the weak points and amending them for the subsequent operations for operations development and more efficiency
- Service features: all presented services that are necessary for operation's process.
- Berth's infrastructure improvement: includes all conditions, facilities and basic requirements that ought to be there at the berth.

Table 1. Decision making criteria for choosing the most appropriate bulk cargo discharging equipment from the vessel

Criterion	Code	Criterion	Code
Loading Capacity	(L)	Cost Of Equipment	(PC)
Accessories	(F)	Operator's Cost	(OC)
Ease Of Implementation	(E)	Maintenance Cost	(MC)
Operational Space	(OY)	Leases	(LC)
Continuous Development	(QC)	Depreciation Cost	(DC)
Service Facilities	(S)	Operational Cost	(OPC)
Berth's Foundations	(B)		

2nd phase: At this stage the scale for each criterion is identified in the previous phase using SHANON entropy method, the results of this stage are shown in table 2.

Table 2. The weight of decision making criteria abstained from SHANON entropy method

Criteria	(PC)	(E)	(B)	(LC)	(MC)	(QC)	(OY)	(F)	(DC)	(OC)	(S)	(L)	(OPC)
Scale	0.05	0.041	0.047	0.45	0.041	0.05	0.049	0.044	0.044	0.034	0.06	0.047	0.043

3rd phase: At this stage using scale 1-9 per equipment with regard to the criteria, they shall be ranked and based on the obtained grants, the TOPSIS method has been made as per equipment and is described in the following table. Regarding each criterion' obtained weight in the 2nd phase, the mentioned equipment was assessed and the most optimum shall be identified. The 1st step is that the decision making matrix is made based on one of the reasons and using 1equition of this matrix was normalized as it is illustrated in table 3.

Table 3. Decision making matrix

Criteria	(PC)	(E)	(B)	(LC)	(MC)	(QC)	(OY)	(F)	(DC)	(OC)	(S)	(L)	(OPC)
unloader	5	4	3	6	7	6	5	6	8	5	8	8	5
suction	6	5	4	7	6	9	8	7	7	7	9	8	6
grab	4	4	3	6	5	5	4	5	7	4	6	7	4

Table 4. Normalization Matrix

Criteria	(PC)	(E)	(B)	(LC)	(MC)	(QC)	(OY)	(F)	(DC)	(OC)	(S)	(L)	(OPC)
unloader	0.57	0.53	0.51	0.55	0.67	0.50	0.49	0.57	0.63	0.53	0.59	0.60	0.57
suction	0.68	0.66	0.69	0.64	0.57	0.76	0.78	0.67	0.55	0.74	0.67	0.60	0.68
grab	0.46	0.53	0.51	0.55	0.48	0.42	0.39	0.48	0.55	0.42	0.45	0.53	0.46
Weights	0.05	0.04	0.05	0.45	0.04	0.05	0.05	0.04	0.04	0.03	0.06	0.05	0.04

At the 3rd step, in this step by using equations number 2 and 3, we nominate ideal positive and negative solution as Table 5.

Table 5. Positive and Negative solutions

Criteria	(PC)	(E)	(B)	(LC)	(MC)	(QC)	(OY)	(F)	(DC)	(OC)	(S)	(L)	(OPC)
Ideal	0.03419	0.02715	0.03224	0.28636	0.02736	0.03776	0.03826	0.02937	0.02766	0.02509	0.04014	0.02826	0.02940
Basal	0.02279	0.02172	0.02418	0.24545	0.01955	0.02098	0.01913	0.02098	0.02420	0.01434	0.02676	0.02473	0.01960

And then the Euclidean distance of each alternative from the overall ideal and negative ideal solution is determined. Finally according to relative closeness to the ideal solution the identified measures have been prioritized. Results are represented on table 6.

Table 6. Final result of TOPSIS method

	di+	di+	ci	rank
unloader	0.04772	0.01710	0.26382	2
suction	0.00522	0.05508	0.91346	1
grab	0.05561	0.00000	0.00000	3

4 CONCLUSION

The abstained result from SHANON entropy method indicates that service facility criterion with the scale of 0.06 has earned the maximum and operator cost criterion with the scale of 0.034 obtained the least. At the 3rd stage, all equipment shall be classified using 1-9 criterion and according to the obtained grants, TOPSIS method was made for every decision making equipment matrix. Finally, with regard to each criteria' obtained scale in the 2nd phase, the mentioned equipment were classified and the most optimum shall be identified. The final gained results through TOPSIS show that in the order of unloader with $((C_i = 0.91346)$ the 1st rank the vacuum with $(C_i = 0.26382)$ the 2nd rank and grab with $(C_i = 0.00000)$the 3rd rank. Thus it can be understood that the most optimum and appropriate berth equipment is the vacuum and also the unloader which holds the 2nd rank. Considering using the above mentioned equipment, important effects on efficiency and terminal's operation, saving time, lowering costs and waiting time of vessels at BIK's quay shall eventuated.

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