Application of MAPPAC and Fuzzy Analytical Hierarchy Process Methods for Optimum Equipment Selection

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ABSTRACT

Current applied study was implemented by the aim to select optimum equipment for discharging dry bulk cargoes in BIK Grain terminal using MAPPAC and FAHP method in three steps. In the first step, 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 second step, the weight of every identified criteria using FAHP method was determined. In the third step, 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 MAPPAC method was established and finally, with respect to the weight of each earned criteria, the equipment shall be scored in the second step and the most optimum shall be selected. The final results from MAPPAC method indicates that unloader enjoys the first and the vacuum the second and grab ranks the third rank.

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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 MAPPAC 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

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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 [5].

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 [5]. 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 1500-2000 tons per hour is used. This system with special design for discharging ships has the capacity of between 100-150 thousand tons [3]. 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

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 using MAPPAC and FAHP methods. In this regard achieving the goals is implemented within 3 steps.

In the first step, 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 second step, the identified decision making criteria in the first step for the most appropriate choice in discharging dry bulk cargo from ship at the jetty shall be weighted using FAHP method.

In the third step, 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 MAPPAC method
was established and finally, with respect to the weight of each earned criteria, the equipment shall be scored in the second step and the most optimum shall be selected.

Data analysis software:
In this study, in order to analyze the gathered data and for calculation of FAHP and MAPPAC methods MATLAB software has been used.

Fuzzy Analytical Network Process:
Analytical Network Process is developed type of the Analytical Hierarchy Process method which is designed by saaty [6]. This method is one of the general performances for analysis decision of organizations [7]. The hieratical analysis methods is a decision framework which is with hieratical connection in the one orientation between the decision level/area and remove the essential defects of the measurement level, but it doesn’t consider to the possible internal Dependency. While the regular networks are make internal clusters of elements between the other clusters. The traditional network analysis process method as the Analytical Hierarchy Process method needs an accurate judgment, but the complexity and distrustfulness of the real world decision, sometimes make the accurate comparison unreal or impossible. In fact the assessments or human judgment in the each type of decision somehow is vague. so first the experts and the decision makers cannot express their ideas and their judgments with the accurate numeral numbers. And they cannot make use of linguistic words or qualitative expression, otherwise converting the superior qualitative conversion is not wise to point estimate points. The step set theory is an effective approach for modeling the uncertainty or accuracy of the human brain. The numerical data which obtained this form is called Fuzzy data. The reason of the application of words or phrases instead of numbers is that in all linguistic descriptions rather than numerical description. Somehow is more is, more accurate and more trustful. So in this research the Analytical Network Process method has been used to determine the weights of balanced scorecard perspective. There are different methods for calculating the weights which this research to determine the priority vector for each matrix the Chang’s extent analysis has been used[8, 9].

Triangular fuzzy numbers (TFNs):
A TFN can be defined by a triplet \((l, m, u)\) and the membership function can be defined by Equation (1) [10].

\[
\mu(x) = \begin{cases} 
\frac{x - l}{m - l} & l \leq x \leq m \\
\frac{m - x}{u - m} & m \leq x \leq u \\
0 & x < l \text{ and and } x > u 
\end{cases}
\]

(1)

Algebraic Operations on TFNs:
The algebraic operation for the triangular fuzzy number can be displayed as follows:

- Addition of a fuzzy number \(\oplus\)

\[
(L_1, M_1, U_1) \oplus (L_2, M_2, U_2) = (L_1 + L_2, M_1 + M_2, U_1 + U_2)
\]

(2)

- Multiplication of a fuzzy number : \(\otimes\)

\[
(L_1, M_1, U_1) \otimes (L_2, M_2, U_2) = (L_1L_2, M_1M_2, U_1U_2)
\]

(3)

- Any real number \(k\):

\[
K(L, M, U) = (KL, KM, KU)
\]

(4)

- Subtraction of a fuzzy number \(\ominus\)

\[
(L_1, M_1, U_1) \ominus (L_2, M_2, U_2) = (L_1 - L_2, M_1 - M_2, U_1 - U_2)
\]

(5)

- Division of a fuzzy number
\[(L_1, M_1, U_1)(L_2, M_2, U_2) = (L_1 / L_2, M_1 / M_2, U_1 / U_2)\]

- Average of fuzzy number:

\[A_{\text{ave}} = (A_1 + A_2 + \ldots + A_n)\]

\[A_{\text{ave}} = [(L_1 + \ldots + L_n) + (M_1 + \ldots + M_n) + (U_1 + \ldots + U_n)] / n\]

Chang’s extent analysis:

The extent Chang’s extent analysis is utilized in four steps, as stated below [11]:

Let \(X = \{x_1, x_2, \ldots, x_n\}\) be an object set, and \(G = \{g_1, g_2, \ldots, g_m\}\) be a goal set. According to the method of Chang’s extent analysis, each object is taken and extent analysis for each goal, \(g_i\), is performed, respectively [12]. Therefore, \(m\) extent analysis values for each object can be obtained with the following signs:

\[M_{g_1}^j, M_{g_2}^j, \ldots, M_{g_m}^j \quad i = 1, 2, \ldots, n\]

Where, all of the \(M_{g_i}^j\) \(j = 1, 2, \ldots, m\) are TFNs. Followings are the steps of Chang’s extent analysis [13]:

**Step 1:** The value of fuzzy synthetic extent with respect to the \(i\)th object is defined as:

\[S_i = \sum_{j=1}^{m} M_{g_i}^j \otimes \left[ \frac{n}{\sum_{j=1}^{m} M_{g_i}^j} \right]^{1/n}\]

To obtain the \(\sum_{j=1}^{m} M_{g_i}^j\) we perform the fuzzy addition operation of \(m\) extent analysis values for a particular matrix such that [11]:

\[\sum_{j=1}^{m} M_{g_i}^j = \left[ \sum_{i=1}^{n} i_{ij} \sum_{j=1}^{m} m_{ij}, \sum_{j=1}^{m} u_{ij} \right]\]

Obtaining the \(\left[ \sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1}\) we perform the fuzzy addition operation of \(M_{g_i}^j\) \(j = 1, 2, \ldots, m\) values such that [12]:

\[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j = \left( \sum_{i=1}^{n} L_i, \sum_{i=1}^{n} M_i, \sum_{i=1}^{n} U_i \right)\]

Compute the inverse of the vector above, such that:

\[\left[ \sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1} = \left( \frac{1}{\sum_{i=1}^{n} L_i}, \frac{1}{\sum_{i=1}^{n} M_i}, \frac{1}{\sum_{i=1}^{n} U_i} \right)\]

As \(\bar{M}_1 = (l_1, m_1, u_1)\) and \(\bar{M}_2 = (l_2, m_2, u_2)\) are two TFNs, the degree of possibility of \(\bar{M}_2 \geq \bar{M}_1\) is defined as:

\[V(\bar{M}_2 \geq \bar{M}_1) = \sup_{y \in \mathbb{R}} \min(\mu_{\bar{M}_2}(x), \mu_{\bar{M}_1}(y))\]

This can equivalently be expressed as:

\[V(\bar{M}_2 \geq \bar{M}_1) = \kappa_{gt}(\bar{M}_1 \cap \bar{M}_2) = \mu_{\bar{M}_2}(d) = \begin{cases} \frac{1}{m_2 - u_1} & \text{if } (m_2 \geq m_1) \\ \frac{l_2 - u_1}{m_2 - u_2 - m_1 + l_1} & \text{if } (l_1 \geq u_2) \\ 0 & \text{otherwise} \end{cases}\]
Step 3: The possibility degree for a convex fuzzy number to be greater than $k$ convex fuzzy numbers can be defined by:

$$V(M_i \geq M_j, M_2, \ldots, M_k) = \min V(M_i \geq M_j, M_2, \ldots, M_k, i = 1, 2, \ldots, k)$$

Assume that $d'(A_i) = \min V(S_i \geq S_k)$ for $(k = 1, 2, \ldots, n)$ $k \neq i$ the weight vector is given by:

$$W' = (d'(A_1), d'(A_2), \ldots, d'(A_n))$$

Wherein, $A_i = (1, 2, \ldots, n)$ are $n$ elements.

Step 4: Via normalization, the normalized weight vectors would be:

$$W = (d(A_1), d(A_2), \ldots, d(A_n))$$

Where $W$ is a non-fuzzy number.

**MAPPAC Method:**

The MAPPAC method is a multi-objective ranking method. The method constructs two complete preorders of variants, which common part constitutes the final ranking. The MAPPAC method algorithm is composed of 3 steps: definition of input data (variants, criteria), pairwise comparison of variants for each pair of criteria resulting in the definition of indifference (I) and preference (P) relations and aggregation of preferences constructing the final Ranking [13, 14].

Multicriterion Analysis of Preferences by Means of Pairwise Actions and Criterion Comparisons method (MAPPAC), firstly introduced by Matarazzo [15], is based on the comparison of pairs of feasible actions taking into account all possible pairs of criteria. The proposed method, known as MAPPAC, is based on a pairwise comparison of alternatives relative to each pair of criteria, defining the two relations P (preference) and I (indifference), which constitute a complete preorder. Moreover, by aggregating these preferences, it is possible to obtain a variety of relations on a set of feasible actions [14].

The MAPPAC method has three assumptions [15];

1. For each $K_i$ a quantitative, $V_{ij}$ can be assigned to each alternative, $a_j$ representing the performance of $a_j$ with respect to $K_i$.
2. A quantitative value, $V_{ij}$, can be assigned to each alternative, $a_j$, on the basis of each criterion, $K_i$.
3. The value, $\mathbf{v}(v_{ij})$ of each $V_{ij}$ can be quantified on the interval [0,1].
4. The criteria are mutually difference independent.

For each $K_i$ a value, $V_{ij}$ is assigned to each $a_j$ representing the performance of $a_j$ on the basis of $K_i$. A numerical weight, $w_i$ is assigned to each $K_i$ representing the importance of $K_i$ with

$$\sum_{i=1}^{n} w_i = 1$$

For each $K_i$ representing the importance of $\mathbf{v}(v_{ij})$ to each $V_{ij}$ with $0 \leq \mathbf{v}(v_{ij}) \leq 1$. Basic preference indices, $\pi_{gh}(a_g, a_h)$, are then calculated between each pair of alternatives, $w_g$ and $w_f$, on the basis of each pair of criteria, $K_g$ and $K_f$ with [16],

$$\pi_{gh}(a_g, a_h) = \begin{cases} 1 & \text{if } \mathbf{v}(v_{gh}) > \mathbf{v}(v_{gf}) \wedge \mathbf{v}(v_{gh}) \geq \mathbf{v}(v_{hf}) \\ 0 & \text{if } \mathbf{v}(v_{gh}) < \mathbf{v}(v_{gf}) \wedge \mathbf{v}(v_{gh}) \leq \mathbf{v}(v_{hf}) \\ \frac{1}{2} & \text{if } \mathbf{v}(v_{gh}) = \mathbf{v}(v_{gf}) \wedge \mathbf{v}(v_{gh}) = \mathbf{v}(v_{hf}) \end{cases}$$

$$\pi_{gh}(a_g, a_h) = \begin{cases} \frac{w_g(\mathbf{v}(v_{gh}) - \mathbf{v}(v_{gf}))}{w_g(\mathbf{v}(v_{gh}) - \mathbf{v}(v_{gf})) + w_h(\mathbf{v}(v_{gh}) - \mathbf{v}(v_{hf}))} & \mathbf{v}(v_{gh}) > \mathbf{v}(v_{gf}) \wedge \mathbf{v}(v_{gh}) \leq \mathbf{v}(v_{hf}) \\ \mathbf{v}(v_{gh}) = \mathbf{v}(v_{gf}) \wedge \mathbf{v}(v_{gh}) \leq \mathbf{v}(v_{hf}) \\ \frac{w_g(\mathbf{v}(v_{gh}) - \mathbf{v}(v_{gf}))}{w_g(\mathbf{v}(v_{gh}) - \mathbf{v}(v_{gf})) + w_h(\mathbf{v}(v_{gh}) - \mathbf{v}(v_{hf}))} & \mathbf{v}(v_{gh}) \leq \mathbf{v}(v_{gf}) \wedge \mathbf{v}(v_{gh}) > \mathbf{v}(v_{hf}) \end{cases}$$

$$\pi_{gh}(a_g, a_h) = \begin{cases} 1 & \mathbf{v}(v_{gh}) > \mathbf{v}(v_{gf}) \wedge \mathbf{v}(v_{gh}) \leq \mathbf{v}(v_{hf}) \\ 0 & \mathbf{v}(v_{gh}) < \mathbf{v}(v_{gf}) \wedge \mathbf{v}(v_{gh}) \leq \mathbf{v}(v_{hf}) \\ \frac{1}{2} & \mathbf{v}(v_{gh}) = \mathbf{v}(v_{gf}) \wedge \mathbf{v}(v_{gh}) = \mathbf{v}(v_{hf}) \end{cases}$$

$$\pi_{gh}(a_g, a_h) = \begin{cases} \frac{w_g(\mathbf{v}(v_{gh}) - \mathbf{v}(v_{gf}))}{w_g(\mathbf{v}(v_{gh}) - \mathbf{v}(v_{gf})) + w_h(\mathbf{v}(v_{gh}) - \mathbf{v}(v_{hf}))} & \mathbf{v}(v_{gh}) > \mathbf{v}(v_{gf}) \wedge \mathbf{v}(v_{gh}) \leq \mathbf{v}(v_{hf}) \\ \mathbf{v}(v_{gh}) = \mathbf{v}(v_{gf}) \wedge \mathbf{v}(v_{gh}) \leq \mathbf{v}(v_{hf}) \\ \frac{w_g(\mathbf{v}(v_{gh}) - \mathbf{v}(v_{gf}))}{w_g(\mathbf{v}(v_{gh}) - \mathbf{v}(v_{gf})) + w_h(\mathbf{v}(v_{gh}) - \mathbf{v}(v_{hf}))} & \mathbf{v}(v_{gh}) \leq \mathbf{v}(v_{gf}) \wedge \mathbf{v}(v_{gh}) > \mathbf{v}(v_{hf}) \end{cases}$$

$$\pi_{gh}(a_g, a_h) = \begin{cases} 1 & \mathbf{v}(v_{gh}) > \mathbf{v}(v_{gf}) \wedge \mathbf{v}(v_{gh}) \leq \mathbf{v}(v_{hf}) \\ 0 & \mathbf{v}(v_{gh}) < \mathbf{v}(v_{gf}) \wedge \mathbf{v}(v_{gh}) \leq \mathbf{v}(v_{hf}) \\ \frac{1}{2} & \mathbf{v}(v_{gh}) = \mathbf{v}(v_{gf}) \wedge \mathbf{v}(v_{gh}) = \mathbf{v}(v_{hf}) \end{cases}$$
An overall value, $\pi_e$, is assigned to each alternative, $\alpha_e$ with $\pi_e = \sum_{a \in A} a \pi_{ae}$. Then the $\alpha_e$ with the greatest associated $\pi_e$ is selected and set aside as the optimal alternative. The $\pi_e$ are recalculated, excluding the optimal alternative from $A$, and the remaining $\alpha_e$ with the greatest associated $\pi_e$ is selected as the second best alternative [17]. This Process is repeated until each of the alternatives have been ranked. A similar Process is then performed, beginning with the selection of the least optimal alternative from $A$. This alternative is then removed from $A$, the $\pi_e$ are recalculated, and the remaining $\alpha_e$ with the lowest $\pi_e$ is selected as the second worst alternative. This Process is continued until each of the alternatives has been ranked. These ascending and descending rankings are then combined to arrive at a weak linear ordering of $A$ [18].

Results:

First step:
To select 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 step
- **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>
<thead>
<tr>
<th>Criterion</th>
<th>Code</th>
<th>Criterion</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loading Capacity</td>
<td>(L)</td>
<td>Cost Of Equipment</td>
<td>(PC)</td>
</tr>
<tr>
<td>Accessories</td>
<td>(F)</td>
<td>Operator’s Cost</td>
<td>(OC)</td>
</tr>
<tr>
<td>Ease Of Implementation</td>
<td>(E)</td>
<td>Maintenance Cost</td>
<td>(MC)</td>
</tr>
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<td>Operational Space</td>
<td>(OY)</td>
<td>Leases</td>
<td>(LC)</td>
</tr>
<tr>
<td>Continuous Development</td>
<td>(QC)</td>
<td>Depreciation Cost</td>
<td>(DC)</td>
</tr>
<tr>
<td>Service Facilities</td>
<td>(S)</td>
<td>Operational Cost</td>
<td>(OPC)</td>
</tr>
<tr>
<td>Berth’s Foundations</td>
<td>(B)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Second step:
At this stage the scale for each criterion is identified in the previous step using FAHP method, the results of this stage are shown in table 2.

Table 2: the weight of decision making criteria abstained from FAHP method

<table>
<thead>
<tr>
<th>Criteria</th>
<th>(PC)</th>
<th>(E)</th>
<th>(B)</th>
<th>(LC)</th>
<th>(MC)</th>
<th>(QC)</th>
<th>(OY)</th>
<th>(F)</th>
<th>(DC)</th>
<th>(OC)</th>
<th>(S)</th>
<th>(L)</th>
<th>(OPC)</th>
</tr>
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<tbody>
<tr>
<td>Scale</td>
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<td>0.041</td>
<td>0.047</td>
<td>0.45</td>
<td>0.041</td>
<td>0.05</td>
<td>0.049</td>
<td>0.044</td>
<td>0.044</td>
<td>0.034</td>
<td>0.06</td>
<td>0.047</td>
<td>0.043</td>
</tr>
</tbody>
</table>

Third step:
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 MAPPAC method has been made as per equipment and is described in the following table. Regarding each criterion’ obtained weight in the second step, the mentioned equipment was assessed and the most optimum shall be identified. According to the obtained results the decision matrix of MAPPAC method formed as presented in Table 3.

Table 3: MAPPAC method decision making matrix

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>(PC)</th>
<th>(E)</th>
<th>(B)</th>
<th>(LC)</th>
<th>(MC)</th>
<th>(QC)</th>
<th>(OY)</th>
<th>(F)</th>
<th>(DC)</th>
<th>(OC)</th>
<th>(S)</th>
<th>(L)</th>
<th>(OPC)</th>
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<tbody>
<tr>
<td>Suction</td>
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<td>4</td>
<td>3</td>
<td>6</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>8</td>
<td>5</td>
<td>8</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Unloader</td>
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<td>8</td>
<td>7</td>
<td>7</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Grab</td>
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<td>3</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>7</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>4</td>
</tr>
</tbody>
</table>

The Results of MAPPAC Methods:
The first step of the MAPPAC method is determining the ideal and base values of each criteria. The ideal and base values of the criteria are shown in Table 4.

Table 4: C matrix, ideal and base values of the criteria

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>(PC)</th>
<th>(E)</th>
<th>(B)</th>
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<th>(OC)</th>
<th>(S)</th>
<th>(L)</th>
<th>(OPC)</th>
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<tbody>
<tr>
<td>Suction</td>
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<td>0.00</td>
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<td>0.67</td>
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<td>1.00</td>
<td>1.00</td>
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<td>1.00</td>
<td>1.00</td>
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<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Grab</td>
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<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<td>0.00</td>
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<td></td>
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<tr>
<td>Weights</td>
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<td>0.04</td>
<td>0.05</td>
<td>0.45</td>
<td>0.04</td>
<td>0.05</td>
<td>0.05</td>
<td>0.04</td>
<td>0.03</td>
<td>0.06</td>
<td>0.05</td>
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<td>5</td>
<td>4</td>
<td>7</td>
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<td>8</td>
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<td>6</td>
<td>5</td>
<td>5</td>
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<td>7</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>4</td>
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</table>

After the obtaining the ideal and base values, normalized criterion matrix is calculated as seen in table 4 (C matrix). And so, for each $K_i$ a value function is produced and used to assign a value, $v_{ij}$ to each $V_{ij}$, with $0 \leq \pi_{ij} \leq 1$. Basic preference indices, $\pi_{ij}(w_e, v_f)$, are then calculated between each pair of alternatives, $w_e$ and $v_f$ on the basis of each pair of criteria, $K_e$ and $K_f$ with equation (18 to 23). The calculation result of the equations (18 to 23) is represented in table 9 (P matrix). After the obtaining the P matrix, alternatives are ranked from upper to lower. The Ranking of the alternatives is shown in table 14.

Table 5: Preference relations matrix (P matrix)

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Unloader</th>
<th>Grab</th>
<th>Suction</th>
<th>From Above</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suction</td>
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<td>0.95517</td>
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<tr>
<td>Unloader</td>
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<td>0.00000</td>
<td>1.00000</td>
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<tr>
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<td>0.0483</td>
<td>0.00000</td>
<td>0.00000</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>From Below</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conclusion:
The abstained result from FAHP 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 third stage, all equipment shall be classified using 1-9 criterion and according to the obtained grants, MAPPAC method was made for every decision making equipment matrix. Finally, with regard to each criteria’ obtained scale in the second step, the mentioned equipment were prioritized and the most optimum shall be identified. The final gained results through MAPPAC show that in the order of unloader the first rank the vacuum the second rank and grab the third rank. Thus it can be understood that the most optimum and appropriate berth equipment is the vacuum and also the unloader which holds the second 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.
REFERENCES


