Abstract—Nowadays, one of the most critical issues in maritime transportation engineering is to load and discharge cargo as quick as possible to avoid ship idle time at port. Specifically, dry bulk cargo loading and discharging process take a long time compared to the liquid or unitized cargoes. To overcome this weaknesses, port construction engineers and port managers are looking for the most efficient and fastest shiploader type before constructing dry bulk cargo terminals. The aim of this paper is to propose a practical hybrid tool to select most appropriate shiploader type during dry bulk cargo terminal installation. The critical technical and operational features are considered to perform this selection. The paper is expected to contribute to the improvement of cargo handling efficiency, reduction of time wasting as well as enhancement of dry bulk port management strategy.

Keywords—Maritime transportation engineering, shiploader, cargo handling efficiency, multi-criteria decision making, Fuzzy AHP-TOPSIS

I. INTRODUCTION

Maritime transportation has been growing worldwide since it is one of the cheapest way to carry a large amount of liquid or solid bulk cargoes such as grain, coal, iron ore, crude oil, petrochemical products, etc. around the world. The statistic shows that volume of seaborne trade increased about 3.4 percent in last year [1]. Particularly, dry bulk cargo shipment constituted about half of the total in seaborne trade even though most of dry bulk cargoes can be shipped via container as well [1]. Including containerization, the total dry bulk cargo shipment have accounted for over the two thirds of the total. Since the shipment of dry bulk cargoes has an important position among the seaborne trades, dry bulk cargo terminals have to meet requirements, in particular cargo handling efficiency, safe cargo operation and environment-friendly cargo operation. One of the significant aspect is to select most applicable dry bulk cargo loader in course of terminal installation to meet the requirements as the ship loader is one of the most key equipments for bulk material handling in dry bulk ports. In defining and introducing the most operationally efficient and technically safest dry bulk cargo loaders, it is addressed to the environmental-friendly operation, cost-efficiency, performance and versatility features.

There are three main type of shiploader practically used in dry bulk cargo terminals: fix loader, radial loader and parallel (travelling) loader. Additionally, mobile loader may sometimes be used as alternative shiploader depend on the cargo type and ship position. These equipments have some advantages and disadvantages comparing to the each other, terminal infrastructure, ship size and cargo type. In the context of shiploader research, there are limited studies performed in the literature, in particular about dry bulk shiploader. Most of studies were focused on the structural design [2-4], strength of the materials [5], optimization [6] or failure assessment [7-8]. Instead of addressing more generic view, most of them focus on specific research studies. Since the shiploader is one of the substantial equipment for efficient cargo handling in dry bulk cargo terminals, selecting most appropriate loader type in terms of technical and operational aspect is quite onerous work for port managers and port construction engineers. In this context, this paper prompts a methodological approach to select most applicable type of shiploader in dry bulk cargo terminals. To achieve this purposes, a fuzzy Analytic Hierarchy Process (FAHP) is integrated with Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method to select best shiploader type for dry bulk cargo terminals. In the integrated approach, while FAHP method provides determining the relative importance (weight) of technical and operational criterias by adopting triangular fuzzy numbers (TFN) which is to be used in place of crisp values in AHP, TOPSIS technique enables to determine a preference ranking among the alternatives. Thus, expert decision-making in evaluation of the relative importance of the technical and operational criteria is revealed. In this context, the paper organized as follows: this part provides motivation behind the study. The next part expresses research methodologies. Part three shows how proposed approach can be applicable for shiploader selection problem. The final part gives conclusion and contribution of study.

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II. RESEARCH METHODOLOGY

In this part, each method is briefly explained and their integration is provided step by step. This part shows how FAHP methods integrate with TOPSIS.

A. AHP

Analytic Hierarchy Process is one of the powerful techniques in multi-criteria decision making (MCDM) methods as it provides a practical solution to acquire relative weight of criteria on the basis of hierarchy [9]. It is based on the nine-point rating scale where verbal judgment of experts are defined from “equal importance” to “extreme importance”. The basic procedure of method begins with dividing the problem into small parts and ranking them hierarchically. Then, pair-wise comparisons and evaluation the relative importance of each criteria take place. The final step is to obtain overall rating and check consistency of expert judgments.

B. Fuzzy AHP

In order to deal with the uncertainty and vagueness from the subjective perception and the experience of humans in the decision-making process, decision-makers usually come across with the fact that it is more secure to give interval judgments than fixed-value judgments. This is mainly due to the fact that he/she is unable to explicit about his/her preferences due to the fuzzy nature of the comparison process [10-18].

Buckley’s fuzzy AHP approach is applied to determine criteria weights since it is easy to extend to the fuzzy case. The steps of fuzzy AHP are as follows [14, 19]:

Step 1: Pairwise comparison matrices among all the criteria in the hierarchical structure is constructed. Linguistic terms is assigned to the pairwise comparisons by asking which is the more important of each two criteria, as presented Table I and Eq. (1).

\[
\tilde{M} = \left( \begin{array}{cccc}
1 & \tilde{a}_{12} & \ldots & \tilde{a}_{1n} \\
\tilde{a}_{21} & 1 & \ldots & \tilde{a}_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
\tilde{a}_{n1} & \tilde{a}_{n2} & \ldots & 1
\end{array} \right) = \left( \begin{array}{cccc}
1 & a_{12} & \ldots & a_{1n} \\
1/a_{21} & 1 & \ldots & 1/a_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
1/a_{n1} & 1 & \ldots & 1
\end{array} \right)
\]

where,

\[
\tilde{a}_{ij} = \left\{ \begin{array}{ll}
1, & i = j \\
\tilde{i}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9} & \tilde{i} \text{ criterion } i \text{ has relative importance to criterion } j \\
\tilde{i}^{-1}, \tilde{3}^{-1}, \tilde{5}^{-1}, \tilde{7}^{-1}, \tilde{9}^{-1} & \tilde{i} \text{ criterion } i \text{ has less importance to criterion } j
\end{array} \right.
\]

Step 2: The consistency of fuzzy pairwise comparison matrices is analysed.

Step 3: Geometric mean technique is applied to calculate the fuzzy geometric mean as follows:

\[
r_{i} = (\tilde{a}_{i1} \otimes \tilde{a}_{i2} \otimes \ldots \otimes \tilde{a}_{in})^{1/n}
\]

where \( \tilde{a}_{im} \) is fuzzy comparison value of criterion \( i \) to criterion \( n \), thus, is geometric mean of fuzzy comparison value of criterion \( i \) to each criterion.

Step 4: the fuzzy weights of each criterion is computed by using Eq. 4,

\[
\tilde{w}_{i} = r_{i} \otimes \left( r_{1} \otimes r_{2} \otimes \ldots \otimes r_{n} \right)^{-1}
\]

where \( \tilde{w}_{i} \) is the fuzzy weight of the ith criterion, can be presented by \( \tilde{w}_{i} = (l_{w_{i}}, m_{w_{i}}, u_{w_{i}}) \). Here \( l_{w_{i}}, m_{w_{i}} \), and \( u_{w_{i}} \) denoted the lower, middle and upper values of the fuzzy weight of the ith criterion.

Step 5: The Best Nonfuzzy Performance (BNP) value (crisp weights) of each criterion is determined using Center of Area (COA) method by the Eq. (5).

\[
BNP_{w_{i}} = [\left( u_{w_{i}} - l_{w_{i}} \right) + \left( m_{w_{i}} - l_{w_{i}} \right)] / 3 + l_{w_{i}}
\]

C. TOPSIS

Hwang and Yoon [20] developed TOPSIS (Technique for Order Performance by Similarity to Ideal Solution) approach as a MCDM method. It is applied to different application areas [21]. Chen [22] proposed an extended TOPSIS method under fuzzy environment. Celik et al. [23] applied fuzzy TOPSIS to material selection problem. The basic steps of proposed fuzzy TOPSIS method can be described as follows.

Step 1: In the first step, a group of experts evaluate the alternatives with respect to linguistic variable as presented in Table II.

Then rating of alternatives with respect to each criterion can be calculated as

\[
\bar{x}_{ij} = \frac{1}{K} \left( \bar{X}_{ij}^{1} + \bar{X}_{ij}^{2} + \ldots + \bar{X}_{ij}^{K} \right)
\]

where \( \bar{X}_{ij}^{k} \) is the rating of the \( Kth \) expert.
**TABLE II: Linguistic variables for the ratings**

<table>
<thead>
<tr>
<th>Rating</th>
<th>Linguistic variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Poor (VP)</td>
<td>(0, 0, 1)</td>
</tr>
<tr>
<td>Poor (P)</td>
<td>(0, 1, 3)</td>
</tr>
<tr>
<td>Medium Poor (MP)</td>
<td>(1, 3, 5)</td>
</tr>
<tr>
<td>Fair (F)</td>
<td>(3, 5, 7)</td>
</tr>
<tr>
<td>Medium Good (MG)</td>
<td>(5, 7, 9)</td>
</tr>
<tr>
<td>Good (G)</td>
<td>(7, 9, 10)</td>
</tr>
<tr>
<td>Very Good (VG)</td>
<td>(9, 10, 10)</td>
</tr>
</tbody>
</table>

**Step 2:** A decision matrix is constructed.

\[
\tilde{R}_j = \left[ \tilde{r}_{1j} \tilde{r}_{2j} \ldots \tilde{r}_{mj} \right] \quad (7)
\]

These linguistic variables can be defined by triangular fuzzy numbers, \( \tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij}) \).

**Step 3:** In this step, the linear scale transformation is used to transform the various criteria scales into comparable scales in order to avoid complexity of mathematical operations in a decision process. The set of criteria can be divided into benefit criteria and cost criteria. Therefore, the normalized fuzzy-decision matrix can be presented as

\[
\tilde{R}_j = \frac{\tilde{x}_{ij}}{\tilde{x}_{max}} \quad (8)
\]

where B and C are the sets of benefit criteria and cost criteria, respectively, and

\[
\tilde{r}_{ij} = \left( \frac{a_{ij}}{c_{ij}}, \frac{b_{ij}}{c_{ij}}, \frac{c_{ij}}{c_{ij}} \right) \quad j \in B,
\]

\[
\tilde{r}_{ij} = \left( \frac{a_{ij}^*}{c_{ij}^*}, \frac{a_{ij}^-}{b_{ij}^-}, \frac{c_{ij}^-}{b_{ij}^-} \right) \quad j \in C,
\]

\[
c_{ij}^* = \max c_{ij} \quad j \in B,
\]

\[
a_{ij}^- = \min a_{ij} \quad j \in C.
\]

**Step 4:** The weighted normalized decision matrix is computed by multiplying the importance weight of evaluation criteria that are obtained by fuzzy AHP and the values in the normalized decision matrix. The weighted normalized decision matrix \( \tilde{V} \) for each criterion is defined as:

\[
\tilde{V} = \left[ \tilde{v}_{ij} \right]_{max} \quad \text{for } i = 1, 2, \ldots, m \text{ and } j = 1, 2, \ldots, n
\]

Where \( \tilde{v}_{ij} = \tilde{r}_{ij} \times w_{ij} \) here \( \tilde{v}_{ij} \) stand for normalized positive triangular fuzzy numbers.

**Step 5:** Then fuzzy positive \( \tilde{A}^+ \) and fuzzy negative \( \tilde{A}^- \) ideal solutions are determined. The fuzzy positive-ideal solutions (FPIS, \( \tilde{A}^+ \)) and the fuzzy negative ideal solution (FNIS, \( \tilde{A}^- \)) is defined for beneficial criteria.

\[
\tilde{A}^+ = (\tilde{v}_{ij}^-, \tilde{v}_{ij}^-, \ldots, \tilde{v}_{ij}^-) \quad \text{and} \quad \tilde{v}_{ij}^- = (1,1,1)
\]

\[
\tilde{A}^- = (\tilde{v}_{ij}^+, \tilde{v}_{ij}^-, \ldots, \tilde{v}_{ij}^-) \quad \text{and} \quad \tilde{v}_{ij}^+ = (0,0,0)
\]

for \( i = 1, \ldots, n \)

The distance of each alternative from the positive ideal solution \( \tilde{A}^+ \) and the negative ideal solution \( \tilde{A}^- \) are calculated.

\[
d_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij}^- - \tilde{v}_{ij}^-)^2} \quad (12)
\]

\[
d_i^- = \sqrt{\sum_{j=1}^{n} (\tilde{v}_{ij}^+ - \tilde{v}_{ij}^-)^2} \quad (13)
\]

**Step 6:** The fuzzy closeness coefficient \( CC_i \) is calculated.

\[
CC_i = d_i^+ / (d_i^+ + d_i^-) \quad (14)
\]

**Step 7:** Rank the preference order in decreasing order.

**III. APPLICATION**

This part shows how proposed approach can be applicable for shiploader selection problem in dry bulk cargo terminal installation.

**A. Shiploader types used in dry bulk cargo terminals**

The shiploader is a special equipment used for loading of dry bulk cargo into ship’s cargo holds continuously. There are different types of shiploader currently used in dry bulk cargo terminals and those designed to load different size of ships. They have various features such as flexibility, versatility, loading rate, practicality, durability, etc. Namely, the most preferred ones are fix loader, parallel (travelling) loader, radial loader and mobile loader which each of them presents its own benefits. Table III gives brief description about shiploader [24]. Since there are four alternatives for handling dry bulk cargoes, a variety of critical factors need to be evaluated when deciding the proper one.

**TABLE III: Types of shiploader**

<table>
<thead>
<tr>
<th>Shiploader</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Fix loader (A1)</td>
<td>Consist of a fixed shut served by a feed elevator. The vessel is to be shifted along with the jetty by moorings to ensure that cargo is loading the correct sequences.</td>
</tr>
<tr>
<td>2 Parallel</td>
<td>Consist gantry framed structure capable of traversing along the quay. The loading sequences could be followed easily by positioning gantry.</td>
</tr>
<tr>
<td>3 Radial</td>
<td>Not to require bulk carrier to be moved/shifted to enable for loading sequences. By pivoting at the tail end, the ship loader is afforded access to the entire length of the ship.</td>
</tr>
<tr>
<td>4 Mobile</td>
<td>Consist of a mobile unit and move along with quay. Provides flexibility and fast track availability on the terminal.</td>
</tr>
</tbody>
</table>

**B. Problem statement**

As the dry bulk cargo trade has been growing gradually, the demand for modern terminal requirement increased. At this point, dry bulk cargo loading and discharging duration can pose critical issue for port mangers to avoid ship idle time at port. In order to speed up cargo loading process and allow ship to leave from the berth as much as possible, the most efficiency
ship loading equipment becomes essential for dry bulk cargo terminals. Therefore, it is quite substantial to select most proper ship loader considering critical factors that affecting the evaluation.

C. Technical and operational evaluation criteria

In order to select best appropriate shiploader in the event of dry bulk cargo terminal installation, a variety of technical and operational critical factors that need to be assessed are ascertained with assistance of experts. The experts profile include professional port managers and construction engineers who have wide knowledge and experience. The average professional experience are about ten years. In the view of experts, Table IV shows critical technical and operational factors for evaluation when selecting the proper shiploader type.

<table>
<thead>
<tr>
<th>No</th>
<th>Evaluation criteria</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Installation cost</td>
<td>Technical</td>
</tr>
<tr>
<td>2</td>
<td>Loading rate capacity</td>
<td>Operational</td>
</tr>
<tr>
<td>3</td>
<td>Versatility</td>
<td>Operational</td>
</tr>
<tr>
<td>4</td>
<td>Physical endurance</td>
<td>Technical</td>
</tr>
<tr>
<td>5</td>
<td>Cost-efficiency</td>
<td>Technical</td>
</tr>
<tr>
<td>6</td>
<td>Power/fuel consumption</td>
<td>Operational</td>
</tr>
<tr>
<td>7</td>
<td>Environment-friendly operation</td>
<td>Operational</td>
</tr>
</tbody>
</table>

D. Importance weights of criteria using fuzzy AHP

In order to select the best proper shiploader in the event of dry bulk cargo terminal installation, seven technical and operational factors are considered. For example, Expert 1 evaluated the pairwise comparison of criteria as presented in Table V.

<table>
<thead>
<tr>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>C7</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>E</td>
<td>E-MI</td>
<td>1/E-MI</td>
<td>MI</td>
<td>1/SI-DI</td>
<td>SI</td>
</tr>
<tr>
<td>C2</td>
<td>E</td>
<td>1/DI</td>
<td>SI</td>
<td>SI</td>
<td>E-MI</td>
<td>SI</td>
</tr>
<tr>
<td>C3</td>
<td>E</td>
<td>MI</td>
<td>1/MI</td>
<td>MI</td>
<td>MI</td>
<td></td>
</tr>
<tr>
<td>C4</td>
<td>E</td>
<td>1/DI</td>
<td>1/MI</td>
<td>E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C5</td>
<td>E</td>
<td>MI-SI</td>
<td>SI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C6</td>
<td>E</td>
<td>E-MI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C7</td>
<td>E</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The consistency ratio of linguistic evaluation is 0.91, hence the evaluation of criteria of obtaining importance weight is consistent. The obtained fuzzy importance weight using equ. (1-4), the defuzzified (using Eq. (5)) and normalized importance weights of criteria is presented in Table VI.

<table>
<thead>
<tr>
<th>Fuzzy value</th>
<th>Defuzzified</th>
<th>Normalized</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>(0.107, 0.169, 0.277)</td>
<td>0.184</td>
</tr>
<tr>
<td>C2</td>
<td>(0.057, 0.09, 0.147)</td>
<td>0.098</td>
</tr>
<tr>
<td>C3</td>
<td>(0.145, 0.234, 0.359)</td>
<td>0.246</td>
</tr>
<tr>
<td>C4</td>
<td>(0.031, 0.047, 0.079)</td>
<td>0.052</td>
</tr>
<tr>
<td>C5</td>
<td>(0.232, 0.358, 0.537)</td>
<td>0.376</td>
</tr>
<tr>
<td>C6</td>
<td>(0.043, 0.069, 0.114)</td>
<td>0.075</td>
</tr>
<tr>
<td>C7</td>
<td>(0.024, 0.035, 0.056)</td>
<td>0.038</td>
</tr>
</tbody>
</table>

According to the results reported in the last column of Table VI, the experts evaluated cost-efficiency (0.351) as the most important criteria, followed in order of importance by versatility (0.230) and installation cost (0.172).

E. Shiploader selection using fuzzy TOPSIS

In this paper, we aim to select most suitable shiploader between four alternatives with respect to seven criteria. Fix loader (A1), parallel (travelling) loader (A2), radial loader (A3), and mobile loader (A4) are considered by three experts. The linguistic evaluation of the three experts is presented in Table VII.

<table>
<thead>
<tr>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
</tr>
</thead>
<tbody>
<tr>
<td>(P, P, MP)</td>
<td>(G, F, MP)</td>
<td>(MP, F, G)</td>
<td>(F, MP, F)</td>
</tr>
<tr>
<td>(G, G, G)</td>
<td>(F, F, G)</td>
<td>(G, G, F)</td>
<td>(F, G, G)</td>
</tr>
<tr>
<td>(F, MP, MP)</td>
<td>(P, P, MP)</td>
<td>(F, MP, MP)</td>
<td>(F, MP, MP)</td>
</tr>
<tr>
<td>(G, MP, G)</td>
<td>(F, G, G)</td>
<td>(G, MP, G)</td>
<td>(F, G, G)</td>
</tr>
<tr>
<td>(F, MP, MP)</td>
<td>(F, MP, MP)</td>
<td>(F, MP, MP)</td>
<td>(F, MP, MP)</td>
</tr>
</tbody>
</table>

Linguistic evaluation is converted into triangular fuzzy numbers to construct the fuzzy decision matrix and it is presented in Table VIII. Then, the normalized fuzzy decision matrix is obtained using the aggregated fuzzy decision matrix (Table IX).

<table>
<thead>
<tr>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0.34, 0.76, 1.0)</td>
<td>(0.03, 0.2, 0.3)</td>
<td>(0.5, 0.7, 0.8)</td>
<td>(0.2, 0.3, 0.4)</td>
</tr>
<tr>
<td>(0.5, 1.0, 1.0)</td>
<td>(0.1, 0.2, 0.3)</td>
<td>(0.5, 0.7, 0.8)</td>
<td>(0.2, 0.3, 0.4)</td>
</tr>
<tr>
<td>(0.7, 0.9, 1.0)</td>
<td>(0.2, 0.4, 0.5)</td>
<td>(0.3, 0.5, 0.6)</td>
<td>(0.1, 0.2, 0.3)</td>
</tr>
<tr>
<td>(0.8, 0.9, 1.0)</td>
<td>(0.1, 0.2, 0.3)</td>
<td>(0.3, 0.5, 0.6)</td>
<td>(0.1, 0.2, 0.3)</td>
</tr>
<tr>
<td>(0.9, 1.0, 1.0)</td>
<td>(0.1, 0.2, 0.3)</td>
<td>(0.3, 0.5, 0.6)</td>
<td>(0.1, 0.2, 0.3)</td>
</tr>
</tbody>
</table>

The weighted fuzzy decision matrix is calculated by multiplying normalized fuzzy decision matrix and importance weights of seven criteria. In this step, importance weights of criteria is obtained using fuzzy AHP.

<table>
<thead>
<tr>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0.01, 0.03, 0.05)</td>
<td>(0.01, 0.03, 0.05)</td>
<td>(0.01, 0.03, 0.05)</td>
<td>(0.01, 0.03, 0.05)</td>
</tr>
<tr>
<td>(0.02, 0.04, 0.06)</td>
<td>(0.02, 0.04, 0.06)</td>
<td>(0.02, 0.04, 0.06)</td>
<td>(0.02, 0.04, 0.06)</td>
</tr>
<tr>
<td>(0.03, 0.06, 0.09)</td>
<td>(0.03, 0.06, 0.09)</td>
<td>(0.03, 0.06, 0.09)</td>
<td>(0.03, 0.06, 0.09)</td>
</tr>
<tr>
<td>(0.04, 0.08, 0.12)</td>
<td>(0.04, 0.08, 0.12)</td>
<td>(0.04, 0.08, 0.12)</td>
<td>(0.04, 0.08, 0.12)</td>
</tr>
<tr>
<td>(0.05, 0.10, 0.15)</td>
<td>(0.05, 0.10, 0.15)</td>
<td>(0.05, 0.10, 0.15)</td>
<td>(0.05, 0.10, 0.15)</td>
</tr>
</tbody>
</table>

Then fuzzy positive and negative ideal solution is computed. For each shiploader, the closeness coefficient is calculated and it is presented in Table XI.
According to the results, parallel (travelling) loader (A2) is determined as the most suitable alternatives. Mobile loader is selected as the second alternatives, followed in order of ranking by radial loader and fix loader.

### IV. CONCLUSION

Due to the time limitation in most of modern dry bulk cargo terminals, shiploader type has been a critical concern to prevent port congestion and shipment delay in maritime transportation. In most of hub dry bulk cargo terminals, very large bulk carriers come alongside to load a wide range of dry bulk cargoes. To speed up process and avoid congestion, port managers and port construction engineers focus on type of shiploader before dry bulk terminal installation. Considering the potential problem, this paper offers a methodological solution combining fuzzy AHP with TOPSIS to select proper shiploader type among the four alternatives. To accomplish this, a set of technical and operational critical factors are utilized for evaluation. The findings show that parallel (travelling) loader is the most proper and applicable shiploader type since it has various advantages such as highly efficient loading processes with minimal impact on the environment through advanced technology.

In conclusion, the paper is expected to remedy the gap about shiploader selection in maritime transportation engineering since there is a lack of research to deal with decision-making in evaluating the importance of technical and operational critical factors. In addition, the paper may contribute to port managers and port construction engineers to enhance cargo handling efficiency, reduce port congestion and improve port management strategy in maritime transportation. The further study may involve to extend the method by adopting internal type-2 fuzzy sets to reflect much better the uncertainty of decision-makers.

### REFERENCES


