INTRODUCTION

Nowadays, the individual-system point of view to decision-support, such as decision-support systems (DSS), has been substituted by a new approach which creates an integrated decision-support environment in enterprise and work systems. In the past, DSS were independent systems within an organization and had a weak relationship with other systems (island systems). Now enterprise systems like Port Community Systems (PCS) are the foundation of an organization and practitioners in designing and implementing Business Intelligence (BI) as an umbrella concept to create a comprehensive decision-support environment for management [1]. The increasing use of intelligent tools in business systems has increased the need for BI evaluation, and the evaluation of enterprise software and business systems requires models and approaches which consider intelligence criteria as well as the enterprises’ traditional functional and non-functional requirements and criteria.

There have been some limited efforts to evaluate BI competencies, but these have always considered BI as tools or systems which are separate from the enterprise systems. Lönnqvist and Pirttimäki [2] designed a BI performance model to measure BI, but measurement and evaluation of BI was restricted to the determination of BI investment worth and BI values. Elbashir et al. [3] discussed the measurement of the effects of BI systems on business processes, and presented a model to make these measurements. Lin et al. [4] have also developed a performance assessment model for BI systems using analytic network process (ANP), but again, the BI systems were treated as separate systems.

At present, organizations use non-functional requirements to assess their enterprise systems. This research presents a new, unique technique developed to evaluate the BI competencies of one type of enterprise systems, and answers the research question:

How can organizations evaluate BI competencies of their port community systems?

This research was carried out to present and demonstrate a fuzzy evaluation model so that organizations can assess, select and purchase enterprise systems which will provide efficient support for decision-making. This model can be used to evaluate and rank candidate enterprise systems such as, Enterprise Recourse Planning (ERP), Port Community Systems (PCS), Supply Chain Management (SCM), Customer Relationship Management (CRM), Community Systems (CS) as well as accounting and office automation systems. Organizations can then choose a better way to design, select, evaluate and buy enterprise systems, using criteria which help them to achieve better decision-support environment in their work systems.

The rest of the paper begins with Section 2 which is about the attempts of past research to define BI, including a wide-ranging literature review about BI and a summary of decision-support criteria to evaluate enterprise systems. Section 3
explains the TOPSIS method, and Section 4 presents the stages of the new fuzzy TOPSIS method in detail. Section 5 proposes the fuzzy TOPSIS model to evaluate the BI competencies of enterprise systems. In order to validate the proposed model, an illustrative example is demonstrated in Section 6, through an evaluation of five port community systems across the thirty four criteria for a port and maritime organization. Finally, Section 7 concludes the research work and its findings and proposes future research.

**BUSINESS INTELLIGENCE**

BI refers to a management philosophy and tool which helps organizations to manage and refine business information in order to make effective decisions [5]. The term can be used when referring to the following concepts [2]:

- related information and knowledge of the organization, which describe the business environment, the organization itself, the conditions of market, customers and competitors, and economic issues;
- a systemic and systematic process by which organizations obtain, analyze, and distribute the information for making decisions about business operations.

The purpose of BI is to help control the resources and the information flows of the business, which exist in and around the organization. BI makes a large contribution to the required intelligence and knowledge of the organizations’ management by identifying and processing data in order to explain their hidden meanings [6].

BI is the process through which organizations take advantage of virtual and digital technology to collect, manage, and analyze

<table>
<thead>
<tr>
<th>Criteria ID</th>
<th>Criteria Name Evaluation Criteria</th>
<th>Related Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Group sorting tools and methodology (Groupwar)</td>
<td>[8-11]</td>
</tr>
<tr>
<td>C2</td>
<td>Group decision-making</td>
<td>[12-14]</td>
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<tr>
<td>C3</td>
<td>Flexible models</td>
<td>[4, 10, 15]</td>
</tr>
<tr>
<td>C4</td>
<td>Problem clustering</td>
<td>[10, 16, 17]</td>
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<tr>
<td>C5</td>
<td>Optimization technique</td>
<td>[18-22]</td>
</tr>
<tr>
<td>C6</td>
<td>Learning technique</td>
<td>[23-26]</td>
</tr>
<tr>
<td>C7</td>
<td>Import data from other systems</td>
<td>[1, 22, 27, 28]</td>
</tr>
<tr>
<td>C8</td>
<td>Export reports to other systems</td>
<td>[22, 27, 29]</td>
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<tr>
<td>C9</td>
<td>Simulation models</td>
<td>[22, 24, 26, 28]</td>
</tr>
<tr>
<td>C10</td>
<td>Risk simulation</td>
<td>[13, 30]</td>
</tr>
<tr>
<td>C11</td>
<td>Financial analyses tools</td>
<td>[31-33]</td>
</tr>
<tr>
<td>C12</td>
<td>Visual graphs</td>
<td>[18, 24, 34-36]</td>
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<tr>
<td>C13</td>
<td>Summarization</td>
<td>[24, 37-39]</td>
</tr>
<tr>
<td>C14</td>
<td>Evolutionary prototyping model</td>
<td>[31, 37, 40, 41]</td>
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<tr>
<td>C15</td>
<td>Dynamic model prototyping</td>
<td>[37, 42-45]</td>
</tr>
<tr>
<td>C16</td>
<td>Backward and forward reasoning</td>
<td>[13, 41, 46]</td>
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<tr>
<td>C17</td>
<td>Knowledge reasoning</td>
<td>[13, 27, 47]</td>
</tr>
<tr>
<td>C18</td>
<td>Alarms and warnings</td>
<td>[39, 41, 48]</td>
</tr>
<tr>
<td>C19</td>
<td>Dashboard/Recommender</td>
<td>[49-51]</td>
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<tr>
<td>C20</td>
<td>Combination of experiments</td>
<td>[46, 48, 51-54]</td>
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<td>C21</td>
<td>Situation awareness modeling</td>
<td>[32, 47, 55]</td>
</tr>
<tr>
<td>C22</td>
<td>Environmental awareness</td>
<td>[56-58]</td>
</tr>
<tr>
<td>C23</td>
<td>Fuzzy decision</td>
<td>[14, 15, 59-61]</td>
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<td>C24</td>
<td>OLAP</td>
<td>[29, 62-66]</td>
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<td>C25</td>
<td>Data mining techniques</td>
<td>[29, 37, 62, 67]</td>
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<td>C26</td>
<td>Data warehouses</td>
<td>[66, 68-70]</td>
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<td>C27</td>
<td>Web channel</td>
<td>[39, 66, 71, 72]</td>
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<td>C28</td>
<td>Mobile channel</td>
<td>[39, 67, 73]</td>
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<td>C29</td>
<td>E-mail channel</td>
<td>[73-75]</td>
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<tr>
<td>C30</td>
<td>Intelligent agent</td>
<td>[14, 31, 64]</td>
</tr>
<tr>
<td>C31</td>
<td>Multi agent</td>
<td>[75-77]</td>
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<tr>
<td>C32</td>
<td>MCDM tools</td>
<td>[9, 78-80]</td>
</tr>
<tr>
<td>C33</td>
<td>Stakeholders’ satisfaction</td>
<td>[2, 13, 42, 81]</td>
</tr>
<tr>
<td>C34</td>
<td>Reliability and accuracy of analysis</td>
<td>[2, 15, 39, 42, 82, 83]</td>
</tr>
</tbody>
</table>
structural or non-structural data. In other words, the technology and commercial processing procedures in the decision-making are supported through the extraction, integration, and analysis of data. Business intelligence is an instrument of analysis providing automated decision-making about business conditions, sales, customer demand, product preference, and so on. It uses huge-database (data-warehouse) analysis, as well as mathematical, statistical, artificial intelligence, data mining and On-line Analysis Processing (OLAP). Eckerson Wayne [7] understood that BI must be able to provide the following tools: production reporting tools, end-user query and reporting tools, OLAP, dashboard/screen tools, data mining tools, and planning and modeling tools.

Considering the recent literature and above described related work, organizations need models and approaches to evaluate and assess the BI capabilities and competencies of their work systems, in order to achieve competitive advantage by making the right decisions at the right time. In this research its authors have identified the relevant evaluation criteria and have created an approach to evaluate the intelligence of enterprise systems. To identify the criteria, a comprehensive review of the relevant literature was conducted in 2010 and 2011. Articles from journals, conference proceedings, doctoral dissertations, and textbooks were identified, analysed, and classified. It was also necessary to search through a wide range of studies from different disciplines, since many criteria are related to the intelligence of a system and to decision support. Therefore, the scope of the search was not limited to specific journals, conference proceedings, doctoral dissertations, and textbooks. Management, IT, Computing and IS are some common academic disciplines in BI research. Consequently, the following on-line journals, conference databases, dissertation databases, and textbooks were searched to provide a comprehensive bibliography of the target literature: ABI/INFORM database, ACM Digital Library, Emerald Fulltext, J Stor, IEEE Xplore, ProQuest Digital Dissertations, Sage, Science Direct, and Web of Science. The literature search was based on the descriptors, ‘BI capabilities’, ‘decision support’, ‘decision-support criteria’, ‘BI evaluation criteria’, ‘BI assessment criteria’, ‘BI requirements’, and ‘intelligent tools capabilities’. The identified criteria are listed in Tab. 1 as BI evaluation criteria.

### THE TOPSIS METHOD

One of the popular methods applied to multiple-criteria decision-making is TOPSIS. For example, this method has been used in [84-92]. It has also been used for problem-solving in fuzzy Multi-criteria Decision-making (MCDM).

The TOPSIS method, proposed by Hwang and Yoon [93], is a technique to establish order preference by similarity to the ideal solution. The ideal solution (also called the positive ideal solution) is a solution which maximizes the benefit criteria/attributes and minimizes the cost criteria/attributes, while the negative ideal solution (also called the anti-ideal solution) is a solution which maximizes the benefit criteria/attributes and minimizes the cost criteria/attributes.

The steps of the TOPSIS method are as follows:
1. Normalize the decision matrix $X = (x_{ij})_{n \times m}$ by using the equation below:
   \[
   r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{k=1}^{m} x_{ik}^2}}; \quad i = 1, ..., n; \quad j = 1, ..., m \quad (1)
   \]
2. Calculate the weighted normalized decision matrix $V = (v_{ij})_{n \times m}$:
   \[
   v_{ij} = w_j r_{ij}; \quad i = 1, ..., n; \quad j = 1, ..., m \quad (2)
   \]
   $w_j$ is the relative weight of the j th criterion and $\sum_{j=1}^{m} w_j = 1$
3. Determine the ideal and negative-ideal solutions:
   \[
   A^* = \{v_{1j}^*, ..., v_{mj}^*\} = \{(\max_j v_{ij} | j \in \Omega_b), (\min_j v_{ij} | j \in \Omega_c)\} \quad (3)
   \]
   \[
   A^- = \{v_{1j}^-, ..., v_{mj}^-\} = \{(\min_j v_{ij} | j \in \Omega_b), (\max_j v_{ij} | j \in \Omega_c)\} \quad (4)
   \]
   $\Omega_b$ are the sets of benefit criteria and $\Omega_c$ are the sets of cost criteria.
4. Calculate the Euclidean distances of each alternative from the ideal solution and the negative-ideal solution:
   \[
   D^*_i = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_{ij}^*)^2}; \quad i = 1, ..., n \quad (5)
   \]
   \[
   D^-_i = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_{ij}^-)^2}; \quad i = 1, ..., n \quad (6)
   \]
5. Determine the relative closeness of each alternative to the ideal solution. The relative closeness of the alternative $A_i$ concerning to $A^*$ is characterized below:
   \[
   RC_i = \frac{D^-_i}{D^*_i + D^-_i}; \quad i = 1, ..., n \quad (7)
   \]

### THE FUZZY TOPSIS METHOD

In many real examples, the human preference model is uncertain and decision-makers might be hesitant or unable to assign crisp values for their judgments [95, 96]. Often, decision-makers are more interested in interval judgments than in pointing out their judgments in crisp values [97]. Therefore, one of the limitations of traditional TOPSIS is using crisp values in the evaluation process. Some criteria are difficult to measure by crisp values, so during the evaluation, these criteria are often ignored.

The use of fuzzy set theory [98] allows decision-makers to use qualitative information, incomplete information, non-obtainable information and somewhat unmeasurable facts in the decision model [99].

Thus, fuzzy TOPSIS is developed to solve ranking problems [94, 100-102].

Current research uses triangular fuzzy numbers for fuzzy TOPSIS because of the ease of use for decision-makers in making calculations. Furthermore, it has been demonstrated that modelling with triangular fuzzy numbers is an effective way to formulate decision problems when the available information is subjective and inaccurate [103-105].
Some important, basic definitions of fuzzy sets are given below [97].

1. A triangular fuzzy number \( \tilde{a} \) can be defined by a triplet \((a_1, a_2, a_3)\) as shown in Fig. 1. The membership function \( \mu_a(x) \) is defined as:

\[
\mu_a(x) = \begin{cases} 
0 & x < a_1 \\
\frac{x - a_1}{a_2 - a_1} & a_1 < x < a_2 \\
\frac{x - a_3}{a_2 - a_3} & a_2 < x < a_3 \\
0 & x < a_3 
\end{cases}
\] (8)

![Fig. 1. A triangular fuzzy number \( \tilde{a} \)](image)

2. If \( \tilde{a} \) and \( \tilde{b} \) are two triangular fuzzy numbers which are shown by the triplets \((a_1, a_2, a_3)\) and \((b_1, b_2, b_3)\), respectively, then the operational laws of the two triangular fuzzy numbers are as follows:

\[
\tilde{a} + \tilde{b} = (a_1 + b_1, a_2 + b_2, a_3 + b_3)
\] (9)

\[
\tilde{a} - \tilde{b} = (a_1 - b_1, a_2 - b_2, a_3 - b_3)
\] (10)

\[
\tilde{a}(\cdot)\tilde{b} = (a_1a_2a_3)(b_1b_2b_3)
\] (11)

\[
\tilde{a}/\tilde{b} = (a_1/a_1, a_2/a_2, a_3/a_3)
\] (12)

3. A linguistic variable which is indicated by words such as very low, low, medium, high, and very high, is used to describe a complex condition [106]. The linguistic values can also be represented by fuzzy numbers [97].

4. If \( \tilde{a} \) and \( \tilde{b} \) are two triangular fuzzy numbers represented by the triplets \((a_1, a_2, a_3)\) and \((b_1, b_2, b_3)\), respectively, then a vertex method is used to determine the distance between \( a \) and \( b \):

\[
d(\tilde{a}, \tilde{b}) = \sqrt{\frac{1}{3}[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2]}
\] (14)

5. The weighted, normalized, fuzzy-decision matrix is calculated by using the formula below:

\[
\overline{V} = \left[ \overline{V}_{ij} \right]_{n\times m}; \quad i = 1, 2, \ldots, n; \quad j = 1, 2, \ldots, m
\] (15)

\[
\overline{V}_{ij} = \frac{x_{ij}}{W_i}
\]

A set of the presentation rating of \( A_j = (j = 1, 2, \ldots, m) \), concerning the criteria \( C_i = (i = 1, 2, \ldots, n) \) is called \( \tilde{x} = (X_{ij}) \).

A set of importance weights of each criteria is determined by \( W_i = (i = 1, 2, \ldots, n) \).

The steps of the fuzzy TOPSIS method, introduced by Onüt and Soner [102] and applied in this paper, can be summarized as follows:

**Step 1:**
Choose the linguistic values \((x_{ij} = i = 1, 2, \ldots, n; j = 1, 2, \ldots, m)\) for alternatives concerning the criteria. The fuzzy linguistic rating \((x_{ij})\) keeps the ranges of normalized triangular fuzzy numbers which belong to \([0, 1]\) interval; hence, there is no need for normalization.

**Step 2:**
Compute the weighted, normalized, fuzzy-decision matrix by using Eq. (15)

**Step 3:**
Determine positive-ideal (FPIS, \( A^* \)) and negative-ideal (FNIS, \( A^- \)) solutions from the equations below:

\[
A^* = \{v^*_1, \ldots, v^*_n\} = \{\max_{j} v_{ij} \mid i \in \Omega_b\}, \{\min_{j} v_{ij} \mid i \in \Omega_c\}
\] (16)

\[
A^- = \{v^-_1, \ldots, v^-_n\} = \{\min_{j} v_{ij} \mid i \in \Omega_b\}, \{\max_{j} v_{ij} \mid i \in \Omega_c\}
\] (17)

\( \Omega_b \) are the sets of benefit criteria and \( \Omega_c \) are the sets of cost criteria.

**Step 4:**
Calculate the distance of each alternative from \( A^* \) and \( A^- \) by using the following equations:

\[
D^*_i = \sum_{j=1}^{m} d(\overline{V}_{ij}, \overline{V}_{j*}); \quad i = 1, 2, \ldots, n
\] (18)

\[
D^-_i = \sum_{j=1}^{m} d(\overline{V}_{ij}, \overline{V}_{j-}); \quad i = 1, 2, \ldots, n
\] (19)

**Step 5:**
Compute similarities to the ideal solution:

\[
FC_i = \frac{D^-_i}{D^-_i + D^*_i}
\] (20)

**THE PROPOSED MODEL**

In this research, fuzzy TOPSIS has been used to evaluate enterprise systems with respect to the criteria presented in Tab. 1. There are three stages to the evaluation and selection of the enterprise system, based on BI evaluation criteria: (1) determining enterprise systems to be evaluated as alternatives, and recognizing the criteria to be used in the assessment process; (2) structuring the fuzzy decision-matrix and assigning criteria weights; (3) computing the scores of alternatives with fuzzy TOPSIS and finally, ranking the evaluation report. A schematic diagram of these stages is illustrated in Fig. 2. In the following sections this model is applied to solve a numerical example.
as ES I, ES II, ES III, ES IV and ES V. All of the explored evaluation criteria from the literature review were assessed, and 34 criteria were selected, as shown in Tab. 1. These were named C1, C2 … C34. Linguistic values were used for the evaluation of the alternatives and weights of the criteria. The membership functions of the linguistic values and the triangular fuzzy numbers related to the variables are shown in Tab. 2. In applications it is often convenient to work with triangular fuzzy numbers (TFNs) because of their simplicity, and they are useful in promoting representation and information processing in a fuzzy environment. Therefore in the current research TFN is chosen.

Structuring the fuzzy decision-matrix and assigning weights to the criteria

Based on the linguistic variables (Tab. 2), alternatives of the criteria were assessed by the decision-making team which also assigned appropriate weights to each criterion. A fuzzy decision-averages matrix for port community systems was created, based on the judgment of experts, as shown in Tab. 3.

Evaluating alternatives and determining the final rank

After the fuzzy decision-matrix has been established, the next step is to compute the fuzzy, weighted decision-matrix which is presented in Tab. 4. The matrix is calculated with Eq. (15). Eq. (16) and (17) are then applied to define the fuzzy positive-ideal solution (FPIS, A*) and negative-ideal solution (FNIS, A‾). Tab. 5 shows the results of this step. Then, the Euclidean distance of each alternative from A* and A‾ is computed by using Eq. (18) and (19). Subsequently, the similarities to an ideal solution are solved by means of Eq. (20). Finally, the values of each alternative (PCS) for the final ranking are illustrated in Tab. 6. Detailed calculations for FC1 similarities to an ideal solution are as follows:

Identification of alternatives and criteria

In the first stage, five port community systems (enterprise systems) were considered for evaluation, identified in the paper as ES I, ES II, ES III, ES IV and ES V. All of the explored evaluation criteria from the literature review were assessed, and 34 criteria were selected, as shown in Tab. 1. These were named C1, C2 … C34. Linguistic values were used for the evaluation of the alternatives and weights of the criteria. The membership functions of the linguistic values and the triangular fuzzy numbers related to the variables are shown in Tab. 2. In applications it is often convenient to work with triangular fuzzy numbers (TFNs) because of their simplicity, and they are useful in promoting representation and information processing in a fuzzy environment. Therefore in the current research TFN is chosen.

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### Tab. 3. Fuzzy decision-matrix for port community systems

<table>
<thead>
<tr>
<th>Port community systems</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ES I</strong></td>
<td>(0, 0, 0.2)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
</tr>
<tr>
<td><strong>ES II</strong></td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
</tr>
<tr>
<td><strong>ES III</strong></td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
</tr>
<tr>
<td><strong>ES IV</strong></td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
</tr>
<tr>
<td><strong>ES V</strong></td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
<td>(0.2, 0.4, 0.6)</td>
</tr>
</tbody>
</table>

| **Weight**             | (0.4, 0.6, 0.8) | (0.6, 0.8, 1) | (0.6, 0.8, 1) | (0.6, 0.8, 1) | (0.6, 0.8, 1) | (0.6, 0.8, 1) | (0.6, 0.8, 1) | (0.6, 0.8, 1) | (0.6, 0.8, 1) |

| **ES I**               | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) |
| **ES II**              | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) |
| **ES III**             | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) |
| **ES IV**              | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) |
| **ES V**               | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) |

| **Weight**             | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) | (0.2, 0.4, 0.6) |
Tab. 4. Weighted, normalized, fuzzy decision-matrix

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<td>(0.16, 0.4)</td>
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<td>(0.08, 0.24)</td>
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<td>(0.36, 0.64)</td>
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<tr>
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<td>(0.12, 0.32)</td>
<td>(0.12, 0.32)</td>
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<td>(0.0, 0.12)</td>
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<td>(0.36, 0.64, 1)</td>
<td>(0.16, 0.36, 0.64)</td>
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<tr>
<td><strong>ES III</strong></td>
<td>(0.08, 0.24, 0.48)</td>
<td>(0.24, 0.48, 0.8)</td>
<td>(0.12, 0.32)</td>
<td>(0.08, 0.24)</td>
<td>(0.08, 0.24)</td>
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<td><strong>ES IV</strong></td>
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<td>(0.08, 0.24, 0.48)</td>
<td>(0.04, 0.16, 0.36)</td>
<td>(0.12, 0.32, 0.6)</td>
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<tr>
<td><strong>ES V</strong></td>
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<td>(0.12, 0.32)</td>
<td>(0.08, 0.24)</td>
<td>(0.04, 0.16)</td>
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<td>(0.32, 0.6, 0.8)</td>
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<td>(0.0, 0.12)</td>
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<tr>
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<td>(0.04, 0.16, 0.36)</td>
<td>(0.04, 0.16, 0.36)</td>
<td>(0.32, 0.6, 0.8)</td>
<td>(0.32, 0.6, 0.8)</td>
<td>(0.12, 0.32, 0.6)</td>
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<td>(0.04, 0.16, 0.36)</td>
<td>(0.08, 0.24, 0.48)</td>
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<td>(0.16, 0.36, 0.64)</td>
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<td>(0.12, 0.32, 0.6)</td>
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<td>(0.32, 0.6, 0.8)</td>
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<td>(0.08, 0.24, 0.48)</td>
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<td><strong>ES III</strong></td>
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<td>(0.08, 0.24)</td>
<td>(0.04, 0.16, 0.36)</td>
<td>(0.08, 0.24, 0.48)</td>
<td>(0.12, 0.32, 0.6)</td>
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<td><strong>ES V</strong></td>
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<td>(0.16, 0.4)</td>
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<td>(0.32, 0.6, 0.8)</td>
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<td>(0.08, 0.24)</td>
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<td>(0.04, 0.16, 0.36)</td>
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Tab. 5. Fuzzy positive and negative ideal solutions (FPIS & FNIS)

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<th>C4</th>
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<td>(0.48, 0.8, 1)</td>
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<td>C16</td>
<td>C17</td>
<td>C18</td>
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<tr>
<td>A*</td>
<td>(0.08, 0.24, 0.48)</td>
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<td>C21</td>
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<td>C24</td>
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<td>C27</td>
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<tr>
<td>A*</td>
<td>(0.64, 1, 1)</td>
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<td>(0.08, 0.24)</td>
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<td>(0.16, 0.36, 0.64)</td>
<td>(0.48, 0.8, 1)</td>
<td>(0.48, 0.8, 1)</td>
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Tab. 6. Final computation results

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A comparison of D₁, D₂, ..., D₁₄ values shows that the decision-support in the organization. The rankings of the evaluated port community systems are shown in Fig. 4 (ES IV > ES V > ES I > ES II > ES III).
CONCLUSION

The increasing trend to use intelligent tools in work systems has increased the need for BI evaluation of enterprise systems. In the past, BI evaluation was considered to be a tool or an independent system, separated from the evaluation of enterprise systems such as, Enterprise Recourse Planning (ERP), Port Community Systems (PCS), Supply Chain Management (SCM), Customer Relationship Management (SCM), as well as accounting and office automation systems. In this research an evaluation model for enterprise systems, using fuzzy TOPSIS was developed by using BI competencies as evaluation factors of an enterprise system. BI definitions and its evaluation criteria were gathered by means of a comprehensive review of the literature of BI research. After describing the general TOPSIS method, a new customized fuzzy TOPSIS method was presented in detailed stages. The applicability of the proposed model is validated through a case study of an evaluation and selection port community system project in the port and maritime organization of Iran. In this actual evaluation five port community systems were assessed by a decision-making team using the thirty-four criteria to determine the fuzzy positive and negative ideal solutions. The final fuzzy score was computed for each system and the ranking of the evaluated port community systems was presented.

To point the current research limitations, dependency on the priorities and goals of the organization/industry, case dependence upon criteria weights and heavy dependence upon experts’ competence and proficiency both in the subject of BI and business characteristics, are listed.

For future research, the authors recommend the application of other MCDM methods in a fuzzy environment to evaluate enterprise systems, comparing these methods and developing an expert system to select the best enterprise system with an appropriate level of BI. They believe that this research will enable organizations to make better decisions for the design, selection, evaluation and purchase of enterprise systems, and using this new model, they will be able to create a better decision-support environment in their work systems.

BIBLIOGRAPHY


CONTACT WITH THE AUTHORS

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fax: +98-21-77936752,
address: 43, Reyhani Pamchi Allay, Allameh Amin St, West Mobarez St, Abouzar Blvd, Pirouzi Ave, Tehran 17789-14361, IRAN