Selection of Container Port Using ELECTRE Technique

Ayfer Ergin1*, İpek Eker2, Güler Alkan1

1. Istanbul University, Faculty of Engineering, Maritime Transportation Management Engineering Department, Istanbul, Turkey
2. Istanbul University, Institute of Sciences, Istanbul, Turkey

Approximately 90% of world trade is carried by sea transportation. Increasing trend in trade with globalization leads to an increase in maritime transportation. As a result of the increase in trade volumes and enlarging ships emphasize the importance of ports which are forming the start and end points of transportation. In this context, the choice of ports that provide service and potential for ships have high importance in transportation network.

The research presented in this paper applies an ELECTRE (Elimination and Choice Translating Reality) which is one of the multi-criteria decision methods to reveal and analyze the container port selection by global container carriers. In application, Turkey’s largest container handling port is selected which is Ambarlı port region. Since all three container ports are in the same hinterland some criteria that are quite important such as hinterland economy, railway links, transport facilities, customs have not taken into account. In this way, criteria such as port productivity, port infrastructure facilities, price became more important. Results show that the most important criterion is Charge, and least important criteria are Port berthing time length and EDI computer system. X port is the highly ranked port according to method results.

Keywords: Port selection, ELECTRE, Container Transportation

INTRODUCTION

Ports, defined as the start and end points of the sea transportation, are one of the strategic component for the transportation chain. In recent years by the increase in global trade and growth of vessels forced ports through an intensive process of change. The importance of ports in maritime commerce and international trade is growing in economic and technical terms. With the use of containers in sea transportation the reliability of maritime transport has increased. Also, by easily being integrated with other transport modes played an important role in combined transport to
pervade. This caused an increase in container trade each and everyday. According to 2012 UNCTAD data about 17% of the global sea trade is carried by container transportation (STA, 2012), (UNCTAD, 2012) by 2013 in the world 651.1 million TEU container transport is made (UNCTAD, 2014). Parallel to world container handling in our country 7.3 million TEU container transport is realized (MTS, 2013).

In order to reduce the transportation costs and the time spent in ports provokes the competition in between ports. This brings up an important issue as the port selection for the carriers. In this context, ELECTRE has been used as one of decision making techniques. In the study after literature in Chapter 2, electre technique is presented, in chapter 4 case study is given and this is followed by conclusion in chapter 5.

LITERATURE REVIEW

Analytic Hierarchy Process on Port Selection

AHP is one of the commonly used methods on port selection that assess a combination of quantitative and qualitative criteria all together. In many of the port selection studies carriers’ vies were take into account as expert decision-makers (Chou, 2010; Guy and Urli, 2006; Lirn et al, 2004). Ugboma et al used some evaluation criteria for port selection behaviour of shippers (Ugboma et al., 2006). Song and Yeo in their study considered each of shipowners, shippers, port operators and researchers (Song and Yeo, 2004). They used Analytic Hierarchy Process. In recent years, FAHP, FANP methods has been widely used on port selection (Ergin et al., 2012; Onut et al., 2011; Nazemzadeh and Vanselslander, 2015; Wang et. al, 2014).

Discrete choice model (multinomial logic model) on Port Selection

One of commonly used models for port selection is discrete choice models. For solving port selection problem while some studies have focused on the opinions carriers’ (Malchow and Kanafani, 2004; Tiwari et al. 2003), with Discrete choice model the other studies focuses on the opinions shippers’ (Steven and Corsi, 2012; Onwuegbuchunam, 2013; Nir et al., 2003) Garcia-Alonso and Sanchez-Soriano utilized the discrete choice model in Spanish port (Garcia-Alonso and Sanchez-Soriano, 2009). Wu et al. used the model for port choice and inland mode choice in China (Wu et al., 2014).

Fuzzy Methods on Port Selection

Most of the discussed methods above has been improved for exact measurements and crisp assessment. On the other hand, in real life a large amount of selection criteria can not be defined precisely for this reason using fuzzy logic is a more convenient way. In recent years the use of fuzzy methods has increased. Fuzzy Multiple Criteria Decision Making Method (FMCDM) was used for transshipment container port choice (Chou, 2007; Chou, 2010) Chou used a integrated FMCDM and optimization programming model for container port demand split problem (Chou, 2010). Lirn et al. (Lirn et al., 2003) used the model for transhipment port selection for behaviour of carriers’. Wiegmann et al. studied both port selection problem and container terminal problem choice. Wiegmann et al. searched if there is any relationship or similarities in both problems (Wiegmann et al., 2008). Yeo et al. suggested fuzzy evidential reasoning (FER) method for carriers to choice in Northeast Asian container ports (Yeo et al., 2014).

Statistical Applications on Port Selection

One of the methods that are widely used in the port selection problem are statistical methods. Mostly researches has taken into consideration for port selection viewpoint of carriers (Tongzon and Sawant, 2007; Chang et al., 2008; Ng., 2006; Sanchez et al., 2011; Yeo et al., 2008) Tongzon used the method from behaviors of forwarders’ for port selection (Tongzon, 2009). Ng et al. took into consideration shippers and port of origin besides the perspective of carriers. Ng et al. has taken into account perspective carriers’ as well as the shippers and port of origin (Ng et al., 2013).

Hybrid Approaches on Port Selection

In recent years hybrid methods have been utilized in papers regarding the selection ports. An
optimization system development tool was combined AHP with DSS using AIMMS, by Lam and Dai (Lam and Dai, 2012). Tang et al. proposed a new Network-based Integrated Choice Evaluation (NICE) model in Asian ports (Tang et al., 2011). Eker et al. recommended a hybrid model integrated AHP and TOPSIS for port choice (Eker et al., 2013). Sayareh and Alizmini suggested a hybrid model that integrated TOPSIS and AHP for container port selection (Sayareh and Alizmini, 2014).

Data Envelopment Analysis (DEA) on Port Selection

Data envelopment analysis (DEA) are used in literature on port choice problem (Tongzon, 2001; Barros and Athanassiou, 2014; Park and De, 2004; Kelvin and Cullinane, 2006; Suk et al, 2010).

Other Mathematical Models on Port Selection

Other than above mentioned methods different mathematical methods have also been applied on of port selection. Tran set up a non-linear programming model for port selection problems (Tran, 2011). Anderson et al. evaluated a nested logit model, using a huge number of import shipment routing decisions (Anderson et al., 2009). Wu and Peng set up a model for port choice and the inland transport mode choice (Wu and Peng, 2013). Talley and Ng recommended mathematical model considering view of carrier' and shipper' for port selection (Talley and Ng, 2013). Tavasszy et al. suggested a new strategic choice model for transport routes (Tavasszy et al., 2011). Zavadskas et. al. advised a model with integration AHP and Fuzzy Ratio Assessment (ARAS-F) methods (Zavadskas et. al., 2015).

**ELECTRE METHODOLOGY**

**Step 1:** Determine the decision matrix. It is supposed that the problem has m alternatives ($A_1$, $A_2$, ..., $A_m$) and n decision criteria ($C_1$, $C_2$, ..., $C_n$). The decision matrix is shown as below:

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix}$$

**Step 2:** Determine the normalized decision matrix.

$$x_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{kj}^2}} \quad \text{(3.1)}$$

$$X_{ij} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}$$

**Step 3:** The weighted normalized decision matrix $V = (v_{ij})_{m \times n}$ is calculated as follows.

$$V_{ij} = \begin{bmatrix} w_1 x_{11} & w_2 x_{12} & \cdots & w_n x_{1n} \\ w_1 x_{21} & w_2 x_{22} & \cdots & w_n x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ w_1 x_{m1} & w_2 x_{m2} & \cdots & w_n x_{mn} \end{bmatrix}$$

**Step 4:** Concordance set $(C_d^l)$ and Discordance set $(D_d^l)$ are determined and calculated, respectively.

$$C_d^l = \left\{ j, v_{ij} \geq v_{lj} \right\} \quad \text{(3.2)}$$

$$C_d^l = \sum_{j \in C_d^l} w_j \quad \text{(3.3)}$$
Discordance ($D_{kl}$) matrix is calculated as below;

$$d_{kl} = \frac{\max_{j \in D_{kl}} |v_j - v_i|}{\max_{j} |v_j - v_i|}$$

(3.4)

$$D = \begin{bmatrix}
-c_{12} & c_{13} & \ldots & c_{1m} \\
c_{21} & - & c_{23} & \ldots & c_{2m} \\
\vdots & \vdots & \ddots & \vdots & \vdots \\
c_{m1} & c_{m2} & c_{m3} & \ldots & -
\end{bmatrix}$$

Step 5: Concordance and discordance dominance matrices are formed as below.

$$c = \frac{1}{m(m-1)} \sum_{k=1}^{m} \sum_{l=1}^{m} c_{kl}$$

(3.5)

If $c_{kl} \geq c \Rightarrow f_{kl} = 1$, otherwise $f_{kl} = 0$.

$$d = \frac{1}{m(m-1)} \sum_{k=1}^{m} \sum_{l=1}^{m} d_{kl}$$

(3.6)

If $d_{kl} \geq d \Rightarrow g_{kl} = 1$, otherwise $g_{kl} = 0$.

Step 6: Determine the aggregate dominance matrix (E)

Step 7: Eliminate the less favorable alternative and rank them (Roy, 1991; Figueira et al., 2005).

CASE STUDY

In practice, Turkey's largest container handling port is selected which is the Ambarlı port region.

Due to the principle of competition the names of the ports are named as X, Y, and Z. Since all three container ports are in the same hinterland some criteria that are quite important such as hinterland economy, railway links, transport facilities, customs have not taken into account. In this way, criteria such as port productivity, port infrastructure facilities, price became more important. Table 1 presents the port selection criteria used.

(1) Table 1: Weight of Each Criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1 Infrastructure condition (IC)</td>
<td>0.1</td>
</tr>
<tr>
<td>C2 Port facilities and equipment (PFE)</td>
<td>0.1</td>
</tr>
<tr>
<td>C3 Port berthing time length (PBTL)</td>
<td>0.1</td>
</tr>
<tr>
<td>C4 Container handling efficiency (CHE)</td>
<td>0.1</td>
</tr>
<tr>
<td>C5 Container yard efficiency (CYE)</td>
<td>0.1</td>
</tr>
<tr>
<td>C6 Charge (PC)</td>
<td>0.1</td>
</tr>
<tr>
<td>C7 EDI computer system (EDI)</td>
<td>0.1</td>
</tr>
<tr>
<td>C8 Good reputation related to damage and delays (GRDD)</td>
<td>0.1</td>
</tr>
<tr>
<td>C9 Personnel quality (PQ)</td>
<td>0.1</td>
</tr>
</tbody>
</table>

The nine criteria are used to find a convenient container port in Ambarlı region. The importance weights of the criteria are presented in Table 2 below.

(2) Table 2: Weight of Each Criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>C7</th>
<th>C8</th>
<th>C9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Decision Matrix is determined. Table 3 presents the decision matrix.

Table 3: Decision Matrix

<table>
<thead>
<tr>
<th>Criteria</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>C7</th>
<th>C8</th>
<th>C9</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>16.50</td>
<td>4.67</td>
<td>1.560</td>
<td>4.50</td>
<td>17.425</td>
<td>4.50</td>
<td>4.83</td>
<td>4.67</td>
<td>4.67</td>
</tr>
<tr>
<td>Y</td>
<td>15.50</td>
<td>4.17</td>
<td>2.024</td>
<td>4.00</td>
<td>10.000</td>
<td>4.33</td>
<td>4.50</td>
<td>4.33</td>
<td>4.50</td>
</tr>
</tbody>
</table>
After normalization of the decision matrix by multiplying the weight of each criteria the weighted normalized matrix is obtained as shown in Table 4.

Table 4: Weighted Normalized Matrix

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>C7</th>
<th>C8</th>
<th>C9</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>0.0581</td>
<td>0.0776</td>
<td>0.0533</td>
<td>0.0851</td>
<td>0.0758</td>
<td>0.0543</td>
<td>0.0718</td>
<td>0.0543</td>
<td>0.0663</td>
</tr>
<tr>
<td>Y</td>
<td>0.0545</td>
<td>0.0693</td>
<td>0.0692</td>
<td>0.0499</td>
<td>0.0787</td>
<td>0.0506</td>
<td>0.0667</td>
<td>0.0506</td>
<td>0.0640</td>
</tr>
<tr>
<td>Z</td>
<td>0.0563</td>
<td>0.0637</td>
<td>0.0311</td>
<td>0.0662</td>
<td>0.0208</td>
<td>0.0469</td>
<td>0.0641</td>
<td>0.0469</td>
<td>0.0640</td>
</tr>
</tbody>
</table>

Concordance Sets and Discordance Sets are shown in Table 5.

Table 5: Concordance Sets and Discordance Sets

<table>
<thead>
<tr>
<th>CONCORDANCE SET</th>
<th>DISCORDANCE SET</th>
</tr>
</thead>
<tbody>
<tr>
<td>C(1,2) 1,2,4,5,6,7,8,9</td>
<td>D(1,2) 3</td>
</tr>
<tr>
<td>C(1,3) 1,2,3,4,5,6,7,8,9</td>
<td>D(1,3) -</td>
</tr>
<tr>
<td>C(2,1) 3</td>
<td>D(2,1) 1,2,4,5,6,7,8,9</td>
</tr>
<tr>
<td>C(2,3) 2,3,4,5,6,7,8,9</td>
<td>D(2,3) 1</td>
</tr>
<tr>
<td>C(3,1) 6</td>
<td>D(3,1) 1,2,3,4,5,7,8,9</td>
</tr>
<tr>
<td>C(3,2) 1,9</td>
<td>D(3,2) 2,3,4,5,6,7,8</td>
</tr>
</tbody>
</table>

Concordance and Discordance matrices are obtained by using the equations (3.3) and (3.4). The matrices are shown below:

\[
C = \begin{bmatrix}
-0.91 & 1.00 \\
0.09 & -0.90 \\
0.14 & 0.21 & -
\end{bmatrix}
\]

\[
D = \begin{bmatrix}
-0.43 & 0 \\
1.00 & -0.05 \\
1.00 & 1.00 & -
\end{bmatrix}
\]

The threshold value \( \xi \) is calculated by using the equation (3.5). The threshold value \( \delta \) is calculated by using the equation (3.6). The values are 0.54 and 0.58 respectively. After finding the threshold values Concordance Dominance and Discordance Dominance Matrices are formed as follows.

\[
F = \begin{bmatrix}
-1 & 1 \\
0 & 0 \\
- & 0 & 0
\end{bmatrix}
\]

\[
G = \begin{bmatrix}
1 & - \\
0 & 0 \\
1 & 1 & -
\end{bmatrix}
\]

From these two matrices the Aggregate Dominance Matris (E) is obtained finally. The Aggregate Dominance Matris (E) is determined as;

\[
E = \begin{bmatrix}
-1 & 1 \\
0 & 1 \\
0 & 0 & -
\end{bmatrix}
\]

Finally the rank in ELECTRE method is as X, Y, and Z.

**RESULTS**

The importance of the ports in Economy and transportation system in the country reveal that port management needs to be done with a competitive manner in order to get maximum efficiency. Rapid development in technology and increasing importance of intermodal transportation forces ports to adapt into new technology. In order to give the best service and keep the cost at minimum level high performance method ans systems must be applied. In this context, one of the multi-criteria decision-making techniques, electre is used. The most important criterion is Charge, while the least important criteria are Port berthing time length and EDI computer system. X port is the highly ranked port according to method results.

For the future work to be done, different multi-criteria decision-making methods of choice in the port and different hybrid methods can also be used. Also, a choice among container ports with differet hinterland can be studied. Most of the studies on the port selection are made on the ideas of the carrier. But some studieis that consider the
ideas of carriers, shippers, freight forwarders, and the port authority.

REFERENCES


Onwuegbuchunam, D.E. (2013), Port Selection Criteria by Shippers in Nigeria: A


