The application of Analytical Network Process to environmental prioritizing criteria for coastal oil jetties site selection in Persian Gulf coasts (Iran)

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A B S T R A C T

Oil jetties are among the most effective land structures, which have cause a different potential for coastal environment destruction. These effects relate to the oil products of these industries that cause extensive oil pollution in coastal regions. Thus, the identification and prioritization of important criteria in site surveying of oil jetties are among the initial steps in preventing the loss of these natural resources. Therefore, the Analytical Network Process (ANP) method was used for this purpose for the first time in Iran. Due to considering feedbacks and interrelations among all used elements of decision making process, ANP is considered an appropriate technique in environmental researches. After screening the selected criteria using Delphi, all criteria were distributed in BOCR merits according to their effects on oil jetties' location. Then, pair comparisons were done among the criteria, based on the ANP method. The prioritized criteria showed that “Compatibility with Land Uses” and “Sensitive Coastal Area” have the most and “Human Population” and “Possibility for Port Development” the least global priority among all. The priority of alternatives is determined under the effect of each criterion. Finally, the suggested linear model through ANP findings showed a high efficiency of this method for ranking the important criteria of environmental construction in coastal regions, especially for oil jetties.

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1. Introduction

Coastal areas are the most important regions, whose natural performances have been threatened by short-sighted planning policies (Pourrebrahim et al., 2010). In the most countries, a major portion of the international trade (export/import), and in some cases also large shares of domestic trade is done through maritime transport. This trade has grown due to the increasing demands for these products in recent years. Berthing structures are constructed in ports to provide safe berthing and mooring conditions, loading and unloading of cargo and for embarking and disembarking of passengers and vehicles (Ranga Rao and Sundaravadivelu, 1999). In order to have an efficient maritime transport system, seaports must be guaranteed to work efficiently (Trujillo and Nombela, 2010). This could prove to be most critical for jetties during construction, as far as excess pore water pressure and its effects on the embankment stability are concerned (Zhang et al., 2008). As a result, the coastal ecosystems adjacent to these oil jetties are losing their environmental potentialities. Also, it is anticipated that non-standard oil jetties’ constructions pose different kinds of risks for these industries and their neighboring environments (Port and Maritime Organization, 2010). So, transfer of these products has caused many maritime risks which take into account several notions such as maritime safety relative to the traffic or the environment protection (Balmat et al., 2011) of marine and coastal regions, in order to specially prevent the oil pollution. On the other hand, the International Convention for the Control and Management of Ships Ballast Water & Sediments was adopted by consensus at a Diplomatic Conference at IMO (2005). Coastal managers, together with planners, need coastal landscape inventories, where the quality of coastal scenery is a part of the inventory (Ergin et al., 2010). Ports play a key role in facilitating trade and establishing a critical interface between marine and land-based transportation all over the world; they are a part of international supply chain networks, the effectiveness of which drives trade competitiveness. Therefore,
it is obvious that an environmental site selection study before the construction of oil terminals can be the best scientific solution to avoid technical problems and coastal environments destruction. Our literature reviews have shown a big information gap about oil terminals site selection researches in other countries. Hence, we chose one of the most important harbors in Iran in Boushehr Port to survey this global problem at considerable local scale. Our field investigations of Boushehr harbor demonstrate the fact that both technical and environmental problems of oil jetties relate to their unfavorable sites. All jetties are located in a shallow depth with a high rate of sedimentation, constructed close to residential areas and have caused many environmental, social and technical problems. Accurate estimation of berthing force is an important matter for appropriate design of mooring piles in these piers (Mostofi and Barghi, 2012).

These facts encouraged us to carry out this study as a stepping-stone toward further environmental oil terminals site selection studies, and focus on their criteria selection. The Analytical Network Process (ANP) is a flexible method that is able to demonstrate the mutual interactions between all factors in decision-making procedures. This method is an independent decision support model, belonging to the family of multi-criteria analyses, which has recently been developed by Saaty (2005) and Saaty and Vargas (2006). It provides a framework for dealing with complicated decision making challenges and evaluation problems. Engineering decisions involving risk require decision models with systematic frameworks to consider pertinent facets of decision problems and appropriate modeling, analysis, and assessment (Blair et al., 2001). Analytic Network Process (Saaty, 1996) is a multi-criteria decision-making (MCDM) technique that includes dependencies and feedbacks among decisive elements. ANP compares the clusters which include elements and prioritizes them. It’s also more suitable for facing to reciprocal relations, dependencies and feedbacks (Saaty, 2008). In fact, ANP allows researchers to have dependencies among different elements, levels and alternatives. ANP provides a different structure for dealing with different kinds of problems (Gómez-Navarro et al., 2009). It is a method that takes into account both quantitative and qualitative criteria and their interrelations. So, it is the most applicable method in cases where the interactions of a system from a network structure (Isik et al., 2007) have a strong and direct influence on final results. Generally because of feedbacks and interrelations between criteria in ANP structures, it could be the best technique for this study.

So, we make use of this method for prioritizing the suitable criteria and then selecting the best site for oil jetties, based on prioritized criteria for the first time in Iran.

2. Material and methods

The summery of applied methodical steps which were put together and led us to obtaining more precious and clear results are introduced in Fig. 1.

2.1. Surveying study area

This study was done on the shorelines of Boushehr, located in the south of Iran with 197.18 km shoreline with the Persian Gulf waters. A port with a population of 200 thousand people, which has been transformed into a small center for different marine industries, and the source and target of oil products distribution in the south of Iran. The Oil Company does not have any special port and jetty, and the one being used is a non-standard jetty that does not have enough quality and standard condition to be used for oil-related purposes. Hence, an area with a 10-km width in both water and land part of Boushehr coast was selected for finding and prioritizing criteria. Four spatial alternatives of Negin Island, Shif Island, Lashakri and Bandargah sites were chosen for this purpose (Fig. 2).

2.2. Criteria selection

Coastal and estuary regions, as environmental ecosystems, entail planning and management challenges for engineers and scientists (Khoshkholgh and Badiei, 2009). In this study, two approaches were used for criteria selection: the literature review of similar studies and the investigation of a case study to identify the specific factors in this township which were considered to be necessary in this case study.

The identification and selection of criteria were faced with lack of similar studies. So, we surveyed all similar studies about coastal and marine constructions to elicit the important criteria. The critical place of environmental factors in this study fascinated us to focus on ecologic factors as technical. Some researchers have used marine conditions, geographic and bathymetric features in coastal spatial studies (Bruun, 1976; US Army Corps Group, 2005; Ching, 2004; Skipper and Gyi, 2005; Ferguson and Basham, 2005; Zhang et al., 2008; Richards et al., 2009; Khoshkholgh and Badiei, 2009; Veritas, 2008). Other studies have emphasized the constructive design of terminals, suitable locations for transit storage, quality of fundamental structures, cargo handling equipment, free-swinging moorings and standard fleet moorings, the topography at sites, water depth, hydrographic and hydrological factors, anchorage and berthing areas, physical and topographical features, and meteorological factors (US Army Corps Group, 2005; Ching, 2004; Ferguson and Basham, 2005; Skipper and Gyi, 2005; Heffron et al., 2006; Eskijian, 2006; ICF, 2008; OCIMF, 2009). Also, ICF (2008) and Ergin et al. (2010) showed that the population density and safety of locals could have effective impact on finding an appropriate location for these sites. Few reviews have had more attention to the role of land value (Ching, 2004; Skipper and Gyi, 2005; ICF, 2008).

As NOAA (2002) has categorized ESI3 in form of scale coastal habitats in terms of their vulnerability to spilled oil, taking into consideration a number of natural physical and biological factors, we compared study area with this scale too.

Having considered the case study, we found out that “depth”, “sensitive environmental coastal area”, and “sedimentation active points” are among the most important values in Boushehr Port coastal regions affecting jetties construction. Therefore, based on

3 Environmental Sensitivity Index.
previous studies we classified the identified sub-criteria in 3 main criteria types: social, economic and ecologic (Fig. 3) (Bruun, 1976; Maes et al., 1988; RangaRao and Sundaravadivelu, 1999; Isik et al., 2007; Rafiei and Rabbani, 2009; KhoshKholgh and Badiei, 2009; Ozkan and Banar, 2010; Pourebrahim et al., 2010; Bottero, 2010; Ergin et al., 2010).

2.3. Screening criteria by Delphi method

Delphi is an appropriate method for analyzing experts’ opinions in decision-making processes which usually recognizes a need to structure a grouped communication process in order to obtain a useful result for management objectives (Turoff and Linstone, 1975).
2002). This method elicits the suitable criteria with respect to the goal, through “Degree of Importance” and “Percentage of Importance” Delphi values (Danekar and Hadaddinia, 2010), which are described below. So, the 18 identified criteria were given to 20 experts, through Delphi questionnaires for determining importance level of all criteria for coastal oil jetty site selection. These criteria were selected based on literature review and surveying the study area and are comprehensive in the field of coastal constructions. Experts were selected based on their experience and knowledge in coastal and maritime issues.

First of all the coefficient of importance values were adjusted based on below formula:

\[
X_i = \frac{Y_i \times n}{100} 
\]

Then by multiplying this adjusted coefficient by initial values the adjusted values were calculated. The weighted values for each importance value (1, 3, 5, 7 and 9) were calculated based on this equation:

\[
Z_i = \sum Z_i 
\]

Then, sum of weighted values will be estimated as: \( \sum Z_i \)

So “Significant Importance” for every criteria or criteria were calculated as below:

Significant Importance: \( \sum Z_i /A \times 100 \)

Maximum obtainable weighted value (A) = \( N \times 10 \).

\( N \) = Total number of experts.

Significant level = \( \frac{\sum (X_i \times n))}{N} \)

After calculating the significant level and Significant Importance of all criteria, unsuitable criteria were identified. These factors were omitted drawing a 2D graph based on Delphi method. According to this graph each criteria which get a Significant importance or Significant level less than average value should be omitted from criteria selection (Hasanzadeh et al., 2012).

2.4. Analytical Network Process

As we realized ANP method can be used for selecting and prioritizing the effective criteria in such coastal researches. Ports and jetties are located in complicated regions and their best sites are affected by different factors. ANP will be an appropriate technique in first steps of spatial management, like criteria ranking of site selection projects.

First of all, screened criteria were distributed in four BOCR cluster. Then, we prioritized the sub-criteria to find a basic rank among them. Four alternatives were compared and prioritized based on prioritized criteria of before step. ANP pair comparison was applied in these cardinal steps.

The ability of this method for comparing the elements at each level, considering their importance at each spatial alternative, give us the opportunity for ranking selected criteria in both global and local scale.

2.4.1. Classification of identified criteria in BOCR structure

ANP method classifies all criteria in BOCR clusters using the initials of the positive factors (Benefits and Opportunities) before the initials of the negative factors (Costs and Risks). Each of these clusters contributes to the clusters of a decision process and must be rated individually on a set of prioritized criteria (Saaty and Vargas, 2006). Hence, the selected sub-criteria were fixed in these clusters based on different main criteria (Fig. 4). For this purpose, benefits, opportunities, costs and risks analyses were done to demonstrate the effect of each BOCR clusters, and alternatives which were evaluated in terms of their benefits, opportunities, costs and risks, with respect to the goal. Different dependencies in ANP network were considered for preparing ANP to making super matrix.

2.4.2. Prioritizing the sub-criteria by ANP method

Based on Analytical Network Process method, all classified criteria in BOCR structure were given to 10 experts due to pair comparisons. The experts were specialized in coastal management and the importance of environmental factors for oil jetties site selection. Also, they had enough information about 4 selected alternatives at case study. This awareness of the locations and different conditions of alternatives has a critical role in a correct pair comparison. So, this step was faced with a severe limitation to use proper experts, but this scrupulosity in expert’ selection guaranties their performance in this study. The questionnaires consist of different comparison levels:

- Pair comparison of main criteria for four spatial alternatives
- Pair comparison of sub-criteria under their main criteria, for four spatial alternatives based on BOCR structure (Table 1)
- Pair comparison among all criteria for four alternatives (separately)

We also calculate the value of “control criteria” through another pair comparison. In this step, the criteria which had reciprocal relations among themselves were compared in another level. As this is the one of the main ANP features, it was done with expert opinion’ too (Table 2).

Experts’ opinions were entered to ANP pair super matrix (Fig. 5) with respect to the oil jetty site selection. So, the geometric means were calculated in every column.

The linear model was suggested based on obtained global weights. This weight is calculated based below formula:

\[
\text{Global weight} = \text{Local weight} \times \text{BOCR weight}
\]

Local weights of sub criteria were measured by pair comparisons under each cluster. BOCR’ weights were measured through pair comparisons in previous studies by authors.

The coefficient (global weight) of each sub-criterion can be used in further mapping processes in suggested model. As this model is extracted from global weight of criteria, shows the degree of important of criteria in scope of current paper. We’ve divided all criteria to positive and negative. Positive criteria will have positive effect on jetty’ site and negatives ones reduce the priority of alternatives. For example, appropriate depth is considered as a positive characteristic for ports and jetties location, so deeper alternative gets more priority. On the other hand, sedimentation is known as a common problem in ports, so alternatives with high level of sedimentation will get the last priorities. Putting positive and negative criteria as a linear model provide an opportunity for port making to know the role of different criteria in this site.
selection study. The effect of some criteria depends on the geographical location of alternatives. Therefore, they can reduce or raise alternative’s final priorities (in different condition).

2.4.3. Finding the best coastal site for oil jetty

Prioritization of sub-criteria leads to having a clear ranking of most to least important criteria which affect a site survey of oil jetties. Hence, candidate site alternatives were prioritized based on all used sub-criteria, according to ANP method. $W$ vector was calculated after pairwise comparisons through below formula:

$$AW = \lambda_{max} W$$

$\lambda_{max}$ is the most amount of $A$ matrix. $W$ vector is normalized by this formula:

$$\alpha = \frac{1}{n} \sum_{i=1}^{n} W_i$$

The main result of these measurements is a $W$ which total of every column will be 1. The normalized value of each alternative under effect of each sub-criteria importance was determined by pair comparisons and calculating normalized mean of every column in weighted super matrix.

3. Results

Comparison of study area’s status with NOAA’s sensitivity index showed that these sites are not placed in this categorization. Delphi results showed that all used criteria have obtained the required Degree of Importance and Percentage of Importance value. Fig. 6 shows that all used criteria have gotten a place in Delphi graph which have a value more than median of each axis, adjust to Hasanzadeh et al., 2012 results. One of the strength points of this study is distributing all selected criteria into four BOCR merits. Based on Piantanakulchai (2003), Khumpaisal and Chen (2007), Bottero, 2010 and Ozkan and Banar (2010) researches, this distribution shows the capability of ANP method of including different type of factors which affect a target.
Extracted weights for every merit were considered based on the normalized values in its main criteria. The local and global obtained values are given in Table 2. The comparison of gained local weights under effect of each main criteria in merits showed that under ecologic criteria of benefits cluster, "Depth" obtained the most and "Slope" the least, and under economic criteria, "Accessibility to oil storage" obtained the most and "Possibility for Port Developing" the least value. Under economic criteria of opportunities cluster, "Compatibility with Land Uses" gained the most local value. Under ecologic criteria of costs cluster, "Backshore Instability" got the most and "Bathymetry" the least, and under effect of economic criteria, "Land Value" received the least value. Finally, under social criteria of risks cluster, "Threat for Locals Economy" obtained the most and "Human Population" the least, and under ecologic criteria, "Sensitive Coastal Area" the most and "Seismic" the least one. The global value of all used sub-criteria is given in Table 3. The comparison showed that "Compatibility with Land Uses" and "Sensitive Coastal Area" have the most and "Human Population" and "Possibility for Port Developing" the least global priority among all. Table 3 shows the

<table>
<thead>
<tr>
<th>BOCR merits</th>
<th>Main criteria</th>
<th>Sub-criteria</th>
<th>Control criteria</th>
<th>Local weight</th>
<th>Global weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefits (0.177)</td>
<td>Ecologic (0.857)</td>
<td>Depth</td>
<td>0.062</td>
<td>0.510</td>
<td>0.077</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slope</td>
<td>0.139</td>
<td>0.489</td>
<td>0.074</td>
</tr>
<tr>
<td></td>
<td>Economic (0.142)</td>
<td>Accessibility to oil storage</td>
<td>0.167</td>
<td>0.285</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>Berthing of bigger ships</td>
<td>0.833</td>
<td>0.228</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>Opportunities (0.257)</td>
<td>Economic (1.000)</td>
<td>Compatibility with land uses</td>
<td>0.875</td>
<td>0.860</td>
<td>0.221</td>
</tr>
<tr>
<td></td>
<td>Job opportunities</td>
<td>0.125</td>
<td>0.139</td>
<td>0.035</td>
<td></td>
</tr>
<tr>
<td>Costs (0.269)</td>
<td>Ecologic (0.857)</td>
<td>Backshore instability</td>
<td>0.864</td>
<td>0.197</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sedimentation</td>
<td>0.113</td>
<td>0.025</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bathymetry</td>
<td>0.022</td>
<td>0.005</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Economic (0.142)</td>
<td>Land value</td>
<td>0.825</td>
<td>0.031</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accessibility to development foundations</td>
<td>0.174</td>
<td>0.006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risks (0.299)</td>
<td>Social (0.10)</td>
<td>Human population</td>
<td>0.093</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Job opportunities</td>
<td>0.250</td>
<td>0.454</td>
<td>0.013</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Threat for locals economy</td>
<td>0.750</td>
<td>0.452</td>
<td>0.013</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Effect on habitat area</td>
<td>0.742</td>
<td>0.199</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ecologic (0.90)</td>
<td>Sensitive coastal area</td>
<td>0.128</td>
<td>0.034</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seismic</td>
<td>0.129</td>
<td>0.034</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Marine meteorology</td>
<td>0.1</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

![Fig. 5. ANP un-weighted super matrix.](image-url)
priorities which alternatives have gained under the effect of each sub criteria.

The linear model for coastal oil jetty is:

\[ OJ = [(0.013EH) + (0.011AO) + (0.007BB) + (0.005PD) + (0.021NC) + (0.077Dp) + (0.074SI) + (0.035JO)] \\
+ [(-0.013TL) + (-0.002HP) + (-0.031LV) + (-0.006AF) + (-0.034Se) + (0.197Bl) + (-0.025Sd) + (-0.199SA)] + [\{+/ -0.005Bt\} + (+/-0.034MM)] \]


### Table 3

<table>
<thead>
<tr>
<th>Sub-criteria</th>
<th>Alternatives</th>
<th>Bandargah</th>
<th>Lashkari</th>
<th>Negin</th>
<th>Shiff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td></td>
<td>0.047</td>
<td>0.190</td>
<td>0.431</td>
<td>0.330</td>
</tr>
<tr>
<td>Slope</td>
<td></td>
<td>0.043</td>
<td>0.318</td>
<td>0.441</td>
<td>0.196</td>
</tr>
<tr>
<td>Accessibility to oil storage</td>
<td></td>
<td>0.035</td>
<td>0.490</td>
<td>0.243</td>
<td>0.230</td>
</tr>
<tr>
<td>Berthing of bigger ships</td>
<td></td>
<td>0.053</td>
<td>0.104</td>
<td>0.592</td>
<td>0.249</td>
</tr>
<tr>
<td>Possibility for port developing</td>
<td></td>
<td>0.207</td>
<td>0.092</td>
<td>0.131</td>
<td>0.568</td>
</tr>
<tr>
<td>Job opportunities</td>
<td></td>
<td>0.063</td>
<td>0.329</td>
<td>0.592</td>
<td>0.015</td>
</tr>
<tr>
<td>Compatibility with land uses</td>
<td></td>
<td>0.154</td>
<td>0.334</td>
<td>0.452</td>
<td>0.058</td>
</tr>
<tr>
<td>Backshore instability</td>
<td></td>
<td>0.070</td>
<td>0.287</td>
<td>0.512</td>
<td>0.129</td>
</tr>
<tr>
<td>Sedimentation</td>
<td></td>
<td>0.044</td>
<td>0.380</td>
<td>0.417</td>
<td>0.157</td>
</tr>
<tr>
<td>Bathymetry</td>
<td></td>
<td>0.077</td>
<td>0.281</td>
<td>0.366</td>
<td>0.274</td>
</tr>
<tr>
<td>Land value</td>
<td></td>
<td>0.046</td>
<td>0.096</td>
<td>0.574</td>
<td>0.282</td>
</tr>
<tr>
<td>Accessibility to development foundations</td>
<td></td>
<td>0.184</td>
<td>0.237</td>
<td>0.528</td>
<td>0.048</td>
</tr>
<tr>
<td>Human population</td>
<td></td>
<td>0.257</td>
<td>0.246</td>
<td>0.393</td>
<td>0.102</td>
</tr>
<tr>
<td>Threat for locals economy</td>
<td></td>
<td>0.086</td>
<td>0.179</td>
<td>0.662</td>
<td>0.072</td>
</tr>
<tr>
<td>Effect on habitat area</td>
<td></td>
<td>0.151</td>
<td>0.254</td>
<td>0.481</td>
<td>0.111</td>
</tr>
<tr>
<td>Sensitive coastal area</td>
<td></td>
<td>0.520</td>
<td>0.222</td>
<td>0.222</td>
<td>0.034</td>
</tr>
<tr>
<td>Seismic</td>
<td></td>
<td>0.250</td>
<td>0.250</td>
<td>0.250</td>
<td>0.250</td>
</tr>
<tr>
<td>Marine meteorology</td>
<td></td>
<td>0.094</td>
<td>0.483</td>
<td>0.122</td>
<td>0.299</td>
</tr>
</tbody>
</table>

**Fig. 6. Screened criteria through Delphi method.**

### 4. Discussion

Delphi results showed that all selected criteria had enough suitability to apply in coastal and marine studies and this is similar to results of Hasanzadeh et al. (2012), and as Danelkar and Hadadinia (2010) have shown, this method is very suitable in criteria selection of environmental researches. Ranking of sub-criteria in every merit shows that each alternative that has the most “Depth” or “Accessibility to Oil Storage” in its site, will have the most “benefits” for a coastal oil jetty location. Having enough depth is coastal regions allows port makers to construct a jetty in appropriate depth which big ships can transmit in to it and berth easily. Obviously, bigger ships and tankers can load and transport more oil or other products. Also, there is no need to digging deep channels under water, which increase costs and solubility of heavy metal. Therefore, “Depth” can bring more benefits for this site (by reducing costs and engineering operations and keeping marine and coastal environment safe). More “Accessibility to Oil Storage” will reduce length of transitions pipe lines from jetty to storage. So, this leads us to reduce costs and environmental pollution and risks. “Compatibility with Land Uses” in spatial sites brings more “opportunities” for the purpose of this study. If we chose a site that being an oil jetty in it has more compatibility with neighbor land uses and industries, basic similarity of this industries will make more commercial opportunities for official and private businesses.

The least “Backshore Instability” and “Land Value” of alternatives make more ecologic and economic “costs” and certainly reduce that alternative priority to be chosen. Finally, much “Threat for Locals Economy” and vicinity to “Sensitivity of Coastal Area” will bring about many social and ecologic “risks” for the target site, respectively.
The preferred sub-criteria show that “economic” and “ecologic” criteria are the most, and “social” criteria the least important factor in coastal oil jetties site selection studies. This ranking refers to the impact of some industrial land uses such as oil and petroleum industries which have a high potentiality for pollution making. As “Compatibility with Land Uses” has obtained the first priority among others, it is crystal clear that decision makers should be more careful about the compatibility of land uses and their reciprocal impacts which can also affect the surrounding sensitive coastal area.

Comparison of alternatives’ priorities based on sub-criteria effects showed that with respect to the “depth”, “slope” and “possibility of bigger ships berthing” Negin Island has obtained the most and Bandargah the least priority. It shows the difference of water depth around the alternatives locations, because the existence of enough depth plays a vital role in entrance and berthing of bigger ships and also these ports the opportunity for receiving more different oil products. For, “accessibility to oil storage” Lashakri has received the most and Bandargah the least value, the distance of alternatives to current oil storage admitted this result, and reasons are described before. For “possibility of port development”, Shiff Island has the most and Lashakri the least priorities, because having more area in jetties sites provides the usage of all security equipment’s, temporary keeping of products and finally more possibility of port spatial development. For “Job Opportunities” and “Compatibility with Land Uses”, Negin Island has the most and Shiff Island the least priorities. This result reflects the location of alternatives and land uses which are around them. First priority refers to much industrial land uses that make more job opportunities after oil jetty construction. Our field investigations have admitted these ranking too. Priorities which are received by some factors such as “land value”, “Bathymetry”, “Seismic”, and “Sedimentation” refer to economic, geotechnical and geomorphologic features of alternatives, respectively, and demonstrate the effects of these criteria on “Costs” and “Risks” value. Wherever these criteria are considered as positive factors for an oil jetty, they have reduced costs and risks merits value and increased the priority of alternatives and vice versa. “Human Population”, “Threat for Locals Economy” and “Effect on Habitat Area” are social sub-criteria that show the effects of environmental and security level of oil jetties on local people whom are affected directly and indirectly. But obtained priorities under “Sensitive Coastal Area”, as the most important ecologic criteria in this study, draw more attention for an environmental site selection.

The results of this study portrayed the high efficiency of ANP method for identifying and prioritizing all important criteria for oil jetties which will be located in coastal regions. On the other hand, because of interfering environmental criteria in this study, there are many reciprocal relations among all levels of ANP structure in this study such as goal cluster, BOCR merits, main criteria and sub-criteria elements like which Isik et al. (2007), Khumpaisal and Chen (2007), Rafiei and Rabbani (2009), Ozkan and Banar (2010), Pourerebrahim et al. (2010) and Bottero (2010) were found before.

So it is concluded that ANP is capable of employing all these relations and derives the most comprehensive results which are reliable enough for practical studies. The suggested model is completed by global priorities which are extracted from ANP processes, and then it makes a single opportunity for everyone who is eager to work more on environmental site selection of coastal jetties and terminals.

5. Conclusion

Analyzing prioritized sub-criteria and evaluating the alternatives’ priorities under effect of these sub-criteria in the meantime, fascinated us to choose and wrap up this site survey according to factors which obtained the first priorities, and whose sensitivity analysis showed no change in alternatives’ priorities; “Compatibility with Land Uses”, “Backshore Instability” and “Sensitive Coastal Area”. As both “Compatibility with Land Uses” and “Backshore Instability” have suggested Negin Island as the best site and “Sensitive Coastal Area” has suggested Bandargah as the best one for a coastal oil jetty location, based on all Analytical Network Process method, generally, Negin Island was identified as the best site under Costs and Opportunities merits and Bandargah under Risks one. But as “Compatibility with Land Uses” has gained the first global priority, Negin Island was proposed as the most suitable site. Considering all distributed criteria at BOCR structure, means ANP, Negin Island is the best site for this purpose. Because of the complex and sensitive coasts in Persian Gulf, constructing oil jetties and ports can be more safe and environmental friendly by practical methods such as ANP.

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