Application of Delphi Method for Criteria Selection in Site Survey of Oil Jetties in Iran

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Abstract

Oil jetties are known as the most serious threat for coastal environments in recent decades. This refers to the high volume of oil products transmitted to these terminals. Hence, an environmental site selection for them can play a critical role in preventing destructive effects of this type of jetties in coastal regions. The purpose of this study is to identify, select, and prioritize the environmental and technical criteria for site evaluation in Iran using Delphi method for the first time. The results show that "Sensitive Coastal Area" is the criteria with the greatest percentage of importance. After that "Depth", "Marine Meteorology", and "Possibility of Bigger Ships Berthing" are identified as the most, while "Land Value" and "Distance to Development Foundations" are the least important criteria. On the other hand, "Distance to Habitat Area", "Threat for Locals" and "Human Population Density" are given the least percentage of usage among others. Then the "ecologic" criteria can be introduced as the most and "Social" one as the least crucial criteria in oil jetties' site survey, and the suggested linear model can be used as a simple tool for criteria selection of oil jetties. All the results reveal the high efficiency of Delphi method for criteria selection of site survey for oil jetties.

Keywords: Delphi Method, Site Selection Criteria, Oil Jetties, Linear Model

1. Introduction

The rapidly increasing world trade in the last decade has brought about a new round of port (especially, container port) development, and caused the restructuring of the world port network as well as more intensive inter- and intra-port competition. There have been dramatic changes in the mode of world trade and cargo transportation, characterized by the prevalence of business-to-business and integrated supply chains. In the port industry, these changes have been embodied by the increasing demand for value-added logistic services and the integration of various transportation modes such as inter- or multi-modal transportation systems (Yeo & Song, 2006). So, marine transportation has succeeded in obtaining the most inexpensive, compatible and safest title in industry, which has led to distributing 90% of different supplies (Port & Maritime Organization of Iran, 2010). But basic fundaments of this industry have not had enough stability in the Persian Gulf region. Port building without considering constructive principles and environmental standards has created lots of challenges in these ports. The

analysis, design and construction of backshore structures is arguably one of the most demanding sets of tasks faced by the engineering profession, over and above the usual conditions and situations met by land-based structures (Enbridge Northern Gateway Project, 2010). These ports are located in ecotone zone of coasts which makes the environmental site selection more important. Different studies about ports and piers have focused on some environmental factors to reduce environmental impacts and provide extra costs (Kanafan & Malchow, 2003; AMEC Earth and Environmental, 2007). Heffron and others in 2006 introduced environmental monitoring as the main issue for terminal designing. This refers to highrisk products of oil ports that are the main threat for marine environment, health, and safety (Skipper *et al*., 2005; Rytkonen, 2005; FMT Environmental Policy, 2009; Oil Companies International Marine Forum, 2009).

Our observations on the Persian Gulf ports have shown that these ports are exposed to high oil pollution and environmental problems. There are many technical deficiencies in port sites, too. These encouraged us to focus this study on the most important and the first step of an accurate site selection: selecting and ranking the suitable criteria for site selection of oil jrtties by an appropriate method. The capabilities of Delphi method and its precision in screening and ranking factors fascinated us to choose this method. Also a linear formula is suggested that reveals the mathematical relation among different criteria.

2. The Necessity of Environmental Criteria for Oil Port Site Selection

Facing various regulatory and community pressures, different organizations have gradually recognized their responsibility for the environmental performance of their suppliers (Seuring & Muller, 2008). The important concern about environmental planning, and designing coastal areas in order to address this concern is a critical issue in the coastal and marine planning process because of its enormous impact on the economy, ecology, and environmental health of the region. Integrated marine and coastal area management (IMCAM) is a participatory process for decision making to prevent, control, or mitigate adverse impacts brought about by human activities in the marine and coastal environment, and also to contribute to the restoration of degraded coastal areas (National Institute for Coastal and Marine Management, 2004). Also the marine transportation planning phases are generally examined in three groups, according to their contents, constant and variable factors, time dimensions, financial costs, and decision-making levels: Strategic, tactical and operational levels. Network design and development, terminal capacity and location determination, marketplace selection and vessel fleet and working-power planning are problems of strategic level planning (Gumus & Yilmaz, 2010). Although many studies have been done on other aspects of marine ports, most of them are weak in recognizing environmental criteria and entering them in these issues. Hence, this gap has exposed coastal and marine planning and their sustainable management to some challenges. Every criterion can be used for developing specific purposes. To identify the criteria of environmental site selection, due to necessity of high-quality as well as low-cost construction of an oil port, selecting appropriate criteria via a comprehensive approach could be useful. Most environmental criteria are set up based on Social, Technological, Economic, Environmental and Political factors (STEEP), whose affects are necessary when the developers conduct a project feasibility analysis (Khumpaisal & Chen, 2007). So, there is a direct link between environmental criteria and choosing objective issues for an oil port site.

3. Methods and Material

3.1 Study area

This study was done in Bushehr province. Bushehr harbor is located at the northern coast of the Persian Gulf in south of Iran, and is known as an important point of oil products distribution This oil port does not have suitable technical and natural conditions for oil ships and oil products, and has faced many types of environmental and technical problems.

3.2 Identification of criteria

Identifying and choosing appropriate criteria is the first step of every management study, especially for the current purpose for which no similar study has ever been conducted. So, we tried to extract the main criteria by precise literature review. Previous studies indicate that atmospheric, oceanic and seafloor conditions; marine biota; constructional, political, demographic, geographic, bathymetric, geological, geophysical and geotechnical factors are the most important criteria (Richards *et al*., 1976; US. Army Corps Group, 1983; Matthew *et al*., 2003; Malchow & Kanafan, 2003; Ching, 2004; Alfred, 2005; Skipper *et al*., 2005; California, 2005; Freguson & Basham, 2005; Veritas, 2010). Other studies have emphasized that planning of the port, locations for transit storage, adequacy of access routes by rail and highway, types and capacities of cargo handling equipments, size and capacity of mooring installations, topography of sites, water depth, hydrographic and hydrological factors, anchorage and berthing areas, physical and topographical features and meteorological factors as major factors of

the location of the port. (US. Army Corps, 1983; Terry *et al.*, 2002; Matthew *et al.*, 2003; Malchow & Kanafan, 2003; Ching, 2004; Alfred, 2005; Freguson and Basham, 2005; Skipper *et al*., 2005; Heffron, 2006; Eskijian, 2007). In other similar studies, Matthew *et al*., (2003) and Trans System consulting engineers, (2007) have shown that different criteria such as land use characteristics of the terminal property, adjacent properties, and landslide features can affect site of a maritime oil port. These studies show that environmental and safety problems in maritime ports often result from inadequate technologies employed. Improving environmental and safety performance goes hand in hand with the economic development of a port or a company. So, we selected the criteria of this study (Table1) based on the literature review combined with the results on the necessary factors which were identified at oil ports of the Persian Gulf (Bushehr harbor).

3.3 Description of selected criteria

Every selected criterion has a category of environmental factors which have different effects on finding an appropriate location for oil ports. As described before, some of these criteria are selected because of the study area necessities. All these criteria were classified in three environmental classes: social, economic, and ecologic. So, they have gotten a meaning based on their role in oil port site selection in the study area. These criteria are described as below:

3.3.1 Social criteria

✓ Human Population Density: This criterion describes the effects of human density on oil port performances, and compares low-density areas to high-density areas with respect to the goal.

✓ Threat for Local Economy: This criterion describes the effects of oil port location on losing job opportunities in coastal and marine regions such as fishery and shipping. So, it compares the alternatives according to the level of economic dependencies of these regions.

✓ Effect on Habitat Area: This criterion describes the effects of oil port location on human societies, such as environmental pollutions and other challenges, and compares different levels of this problem on the final selected site.

3.3.2 Economic criteria

✓ Accessibility to Oil consumption areas: It describes the effects of oil consu,ption distance to the feature oil port (negative and positive impacts).

✓ Possibility of Berthing Bigger Ships: It describes the possibility for bigger ships entrance to the port and, consequently, the arrival of more volumes and types of products.

✓ Possibility for Port Developing: It depends on existence and availability of area for port development.

✓ Neighboring Compatibility: It is about locating different land uses and businesses around oil port, and it is obvious that these land uses should have enough compatibility with each other.

✓ Job Opportunities: It describes the possible increase in job opportunities at oil jetty and its surrounding sites.

✓ Land Value: The price of land will affect the location of the oil port.

✓ Distance to infrastructure: Distance to main roads plays an important role in port performance, distributing the received products, and meeting the current needs.

3.3.3 Ecologic criteria

✓ Depth: It is about the depth of water in the coastal region.

✓ Slope: It is about the slope of the sea bed at depth.

✓ Bathymetry: This criterion depends on sea-bed conditions and their effects on port making processes.

✓ Seismic: The seismic intensity of the study area has effects on port construction and its stability.

✓ Marine Meteorology: The general meteorological condition has a big role on port safety and ships berthing.

✓ Backshore Instability: The stability level of backshore region has effects on port stability and safety.

✓ Sedimentation Points: Vicinity to active sedimentation points will increase the rate of dredging and possible deposited pollutants.

✓ Sensitive Coastal Area: Vicinity of oil port to sensitive areas will threat the survival of these areas.

3.4 Application of Delphi method for selecting criteria of oil ports site selection

Delphi is an appropriate method for grouping relation among experts who are far from each other to solve complicated problems systematically. It was developed in the 1950s at the Rand Corporation, by Helmer and Dalkey as a qualitative research methodology for forecasting and problem solving of complex topics (Benarie, 1988; Woudenberg, 1991). Delphi may be characterized as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem (Turoff & Harold, 2002). In a sense, the Delphi method is a controlled debate. The reasons for extreme opinions are made explicit, fed back coolly and without anger. More often than not, groups of experts move toward consensus; but even when this does not occur, the reasons for disparate positions become crystal clear (Gordon, 1994). Those who seek to utilize Delphi usually recognize a need to structure a group communication process in order to obtain a useful result for their objective. Underlying this is a deeper question: "Is it possible, via structured communications, to create any sort of collective human intelligence capability?" (Turoff & Linstone, 2002). We used Delphi questionnaire in this study and showed that it is an efficient method.

The 18 identified criteria were given to 20 experts, through Delphi questionnaires for determining the level of significance for all criteria for oil port site selection by asking “What is the importance value of every criterion with respect to our interest?”

Delphi method was used as a mathematical method to assess experts’ opinions in this case. Experts were selected among potential organizations, academicians, and experienced individuals in the field of coastal and marine engineering with enough domination on both environmental and technical aspects of our purpose in Bushehr. The experts gave their opinion about each of criteria in form of degrees as 1, 3, 5, 7 and 9 importance values. The “degree of importance” and “percentage of significance” were calculated.

All of the selected criteria were given one of these values with respect to their importance in choosing the best location for an oil port in Bushehr.

3.5 Mathematical equations of Delphi method

First of all, the coefficient of degree of importance was adjusted based on below formula (Danehkar & Hadadinia, 2009):

Moderated coefficient (Xi) = 10/ (∑(1+3+5+7+9))

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

Weighted value (Zi) = Yi × n

Where n is the number of experts who have selected the value for evaluating the importance of each criterion.

Then sum of the weighted values will be estimated by ∑Zi:

So, the percentage of Importance for every criterion was calculated as below:

Percentage of Importance: (∑Zi)/A × 100

Maximum obtainable weighted value (A) = N×10

N= total number of experts

Degree of Importance = (∑ 〖(Xi ×n)〗)/N

After calculating the degree of importance and percentage of importance of all criteria, unsuitable criteria were identified. These criteria were omitted by drawing a 2D graph based on Delphi method. According to this graph, each criterion which gets a percentage of importance or a degree of importance less than the median value of both axes of the Delphi graph should be omitted from the process of the criteria selection. Finally, a Linear Delphi formula is offered based on the normalized values of criteria.

4. Results

The comparison among different criteria based on their abundance is shown in Figure 1. According to this figure “Possibility of Berthing Bigger Ships”, “Sensitive Coastal Area” and “Depth” have gotten the most usage among other criteria and “Sedimentation Points”, “Threat for Local Economy” and “Human Population Density” have gotten the least, respectively.

Table 2 shows the mathematical calculations of Delphi method. The results show that “Sensitive Coastal Area” and “Depth” have gotten the most and “Land Value” and “Distance to Development Foundations” the least normalized values. Among social criteria, “Threat for Locals” and “Human population Density” have received

the least (equal value) and "Effects on Habitat Area" has received the most degree of importance. Also, "Effects on Habitat Area" has the most and "Threat for Locals" has the least percentage of importance and importance coefficient. Among economic criteria, "Land Value" and "Distance to Development Foundations" have the least and "Possibility of Berthing Bigger Ships" and "Neighboring Compatibility" have the most degree of importance. "Land Value" has the least and "Possibility of Berthing Bigger Ships" has the most percentage of importance and importance coefficient. Among ecologic criteria, "Sensitive Coastal Area" received the most and "Bathymetry" gotthe least degree of importance, percentage of importance and importance coefficient.

The comparison of all screened criteria (Degree of Importance and Percentage of Importance) is shown in Figure 2 as well. Figure 3 shows the screened criteria by Delphi method which are identified as suitable criteria for the purpose of this study. Based on Figure 3, all criteria are received the necessary values (more than the median) and no criteria should be omitted in site survey of oil jetties.

The suggested linear formula based on Delphi method is given in equation1.

Equation1: The linear model among criteria through Delphi method for oil port site selection

PS=(0.066EH)+(0.048AO)+(0.066BB)+(0.047PD)+(0.052NC)+(0.068Dp)+(0.061Sl)+(0.054JO)]-[(-0.044TL)+(-0.046HD)+(-0.041LV)+(-0.046DD)+(-0.048Se)+(0.046BI)+(-0.054SP)+(-0.92SA)+[(+/-0.044Bt)+(+/-0.067MM)]

PS: Oil port site selection model

EH: Effects on Habitat Area

AO: Accessibility to oil storage

BB: Possibility of Berthing Bigger Ships

PD: Possibility for Port Developing

NC: Neighboring Compatibility

Dp: Depth

Sl: Slope

JO: Job Opportunities

TL: Threat for Local Economy

HD: Human Population Density

LV: Land Value

DD: Distance to Development Foundations

Se: Seismic conditions

BI: Backshore Instability

SP: Sedimentation Points

SA: Sensitive Coastal Area

Bt: Bathymetry

MM: Marine Metrology

5. Conclusion

The comparison of criteria's abundance (Figure 1) shows that "Possibility of Berthing Bigger Ships", "Sensitive Coastal Area" and "Depth" are allocated the most usage in the study, respectively, and are introduced as the most important factors in site selection of costal instructions. On the other hand, "Effects on Habitat Area", "Threat for Local Economy" and "Human Population Density" are given the least usage among others. This reveals the place of the most and the least important criteria in oil port site selection. So, it is easy to say "Social" criteria have the least importance for oil jetties location while "Ecologic" and "Economic" criteria have the most.

The main Delphi results (Table 2 and Figure 2) show that "Sensitive Coastal Area" and "Depth" have received the most percentage of importance and degree of importance, respectively, and this is adjusted to the result of Figure1. On the other hand, "Land Value", "Bathymetry", "Threat for Local Economy" and "Backshore Instability" have received the least Importance and degree of importance value and this shows that geomorphologic and social features do not have the first priorities in choosing an appropriate site.

The analysis of Delphi method results (Figure 3) shows that all identified and extracted criteria have taken suitable "Percentage of Importance" and "Degree of Importance" and no criterion should be omitted. Also, "Sensitive Coastal Area" identified as the criterion with the most degree of importance and the most percentage of importance. After that, "Depth", "Marine Meteorology" and "Effects on Habitat Area" were identified as the most important criteria. So, it is clear that "Ecologic" criteria, has taken the most degree of importance and percentage of importance among other main criteria (Economic and Social).

The comparison between Figure 1 and Table 2 shows that "Social" criteria are not very important in oil port site selection processes, and so ignoring them cannot have a remarkable influence on our purpose, and experts should consider "Ecologic" and "Economic" factors more seriously. These attentions will avoid coastal and marine environments to be destructed because of non-standard port making.

"Sensitive Coastal Area" and "Depth" have the most normalized value; while Land Value" and "Distance to Development Foundations" have the least normalized values. This shows that we can ignore the price of land or accessibility to the main roads with comparison to other crucial criteria. Regarding to social values, it's clear that because of the impact of industrial land uses such as oil jetties, which have a high potential of environmental pollution making, the "Effects on Habitat Area" is more important than others. Among economic criteria "Possibility of Berthing Bigger Ships" because of making initial condition for the entrance of big ships, and "Neighboring compatibility", for preventing from environmental problems, have obtained the most degree of importance values. Due to vital significance of environmental protected areas, it is very natural that "Sensitive Coastal Area" has gained the most value among ecologic criteria. Allocating the least value to "Bathymetry" refers to the fact that it is possible to construct an oil jetty in every type of seabed, however, the costs will be affected.

Final Delphi results showed that all primary criteria have the needed importance in experts'and the decision makers opinions, and generally in the field of coastal region management these criteria and the suggested model can be used in similar studies.

On the other hand, the suggested linear formula shows a mathematical relationship among screened criteria based on their normalized value through Delphi method. So, it is easy to understand and compare these criteria's importance during practical decision makings. This formula shows that the criteria which get positive points (EH: Effects on Habitat Area, DSh: Distance to Oil Storage, BB: Possibility of Berthing Bigger Ships, PD: Possibility for Port Developing, NC: Neighboring Compatibility, Dp: Depth, and Sl: Slope) can have a positive effect on the site of the oil port, and those which get negative points (TL: Threat for Local Economy, HD: Human Population Density, LV: Land Value, DD: Distance to Development Foundations, Se: Seismic, BI: Backshore Instability, SP: Sedimentation Point, and SA: Sensitive Coastal Area) have a negative effect on it. This formula can be used for mapping processes and coefficients can be multiplied in every criteria layer and lead to an oil jetty site selection by classified maps' overlaying. Finally, the effects of criteria with both positive and negative points (Bt: Bathymetry and MM: Marine Metrology) depend on their current condition in a specific site for an oil port. So, it is obvious that Delphi method is an appropriate tool for selecting, prioritizing, and screening the criteria for site selecting and decision making and this is in accordance with the studies of Benarie (1988), Woudenberg (1991) and Turoff and Harold (2002). Using Delphi method helps us to understand the mathematical relation among all factors and this is according to Gordon (1994) results. So, as Turoff and Linstone (2002) findings show, Delphi is very capable to entering experts' opinions in complicated problems such as environmental science and this is beacuase of its potential for analyzing data and results. This method selects all valuable criteria based on their significant level and significant importance. Therefore, it is able to reduce the bias ratio of basic researches. Finally, it reveals the correct priority among all criteria by using a linear model. This model helps experts to understand importance levels and priority levels of all criteria and makes a suitable decision based on these priorities without destructing environment resources. Hence, Delphi method can be suggested as the most applicable method for site selection studies, especially in coastal regions.

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Table 1. The selected and classified criteria of oil port site selection

Criteria		
Social	Economic	Ecologic
Human Population Density Threat for Local Economy Effects on Habitat Area	Accessibility to Oil Storage Possibility of Berthing Bigger Ships Possibility for Port Developing Neighboring Compatibility Land Value Distance to Development Foundations Job Opportunities	Depth Slope Bathymetry Seismic Marine Meteorology Backshore Instability Sedimentation points Sensitive Coastal Area

Table 2. Mathematical calculations for Delphi method

Criteria		Percentage of Importance	Degree of Percentage	Importance Coefficient	Normalized value
Social	Threat for Locals	23	5.75	1.28	0.046
	Human population Density	24	5.75	1.38	0.046
	Effects on Habitat Area	28	7	1.96	0.066
Economic	Land Value	22	5.5	1.21	0.041
	Distance to Development Foundations	25	5.5	1.21	0.041
	Distance to Oil Shortage	24	6	1.44	0.049
	Possibility of Berthing Bigger Ships	28	7	1.96	0.066
	Possibility for Port Developing	25	5.62	1.40	0.047
	Neighboring Compatibility	25	6.25	1.56	0.052
	Job Opportunities	26	6.18	1.60	0.054
Ecologic	Depth	30	6.75	1.82	0.068
	Slope	27	6.75	1.82	0.061
	Bathymetry	23	5.75	1.32	0.044
	Seismic	24	6	1.44	0.048
	Backshore Instability	23	6	1.38	0.046
	Marine Meteorology	28	7.12	1.99	0.067
	Sedimentation Points	26	6.18	1.60	0.054
	Sensitive Coastal Area	33	8.25	2.72	0.092
Total				29.49	1

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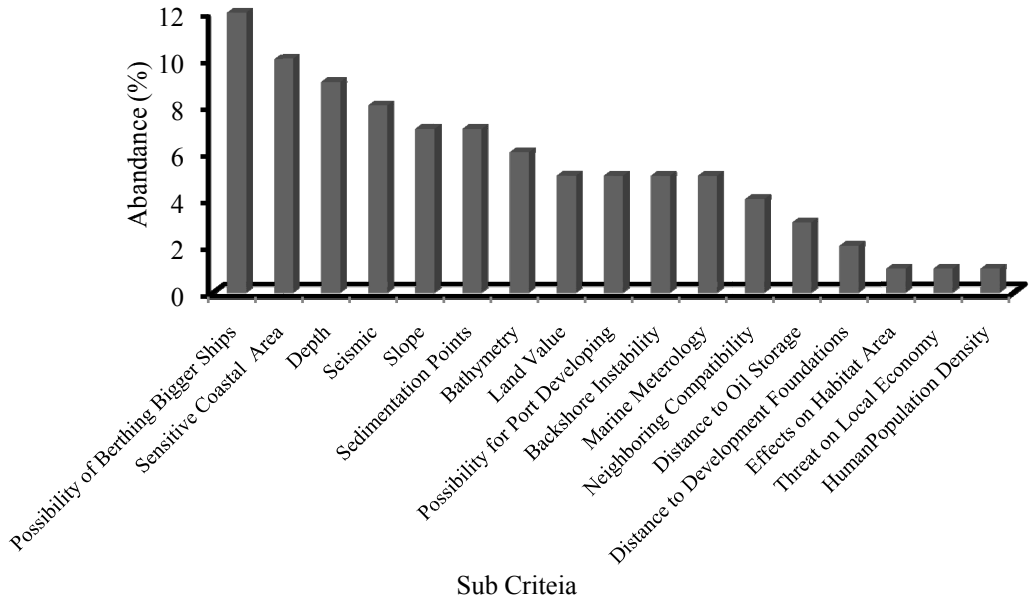

Figure 1. The comparison of different sub criteria based on abundance

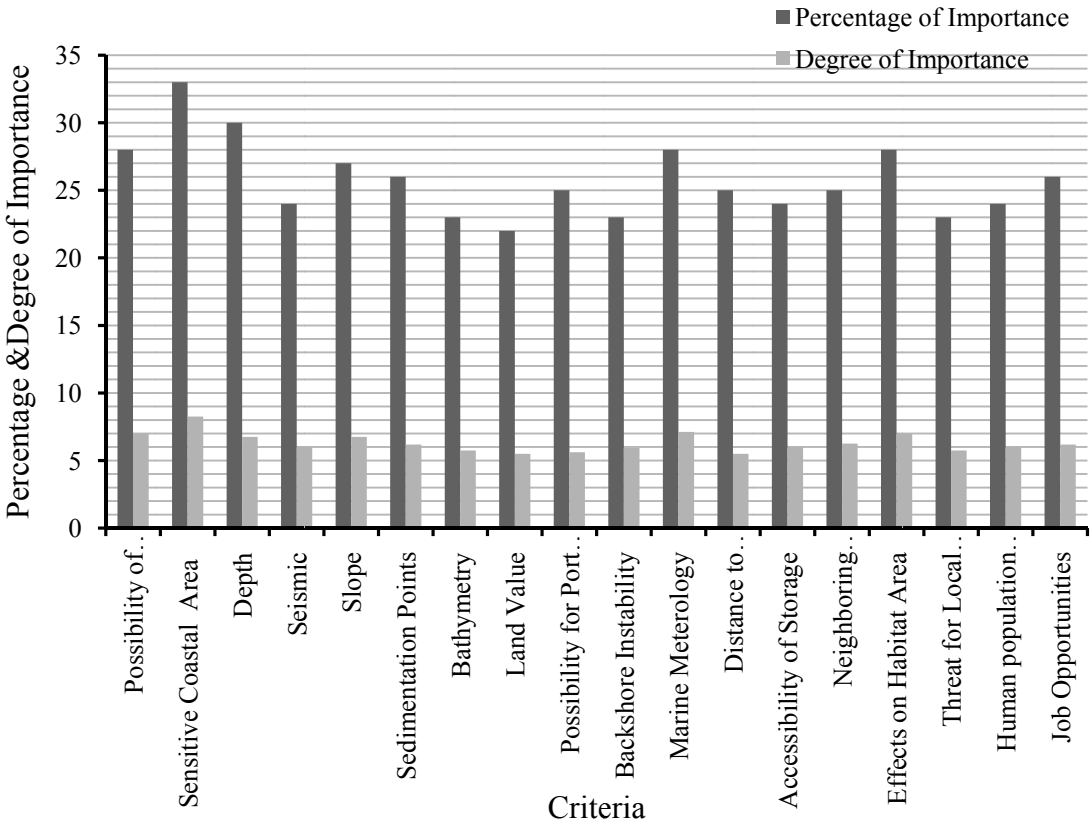

Figure 2. The comparison of Percentage and Degree of importance among all criteria

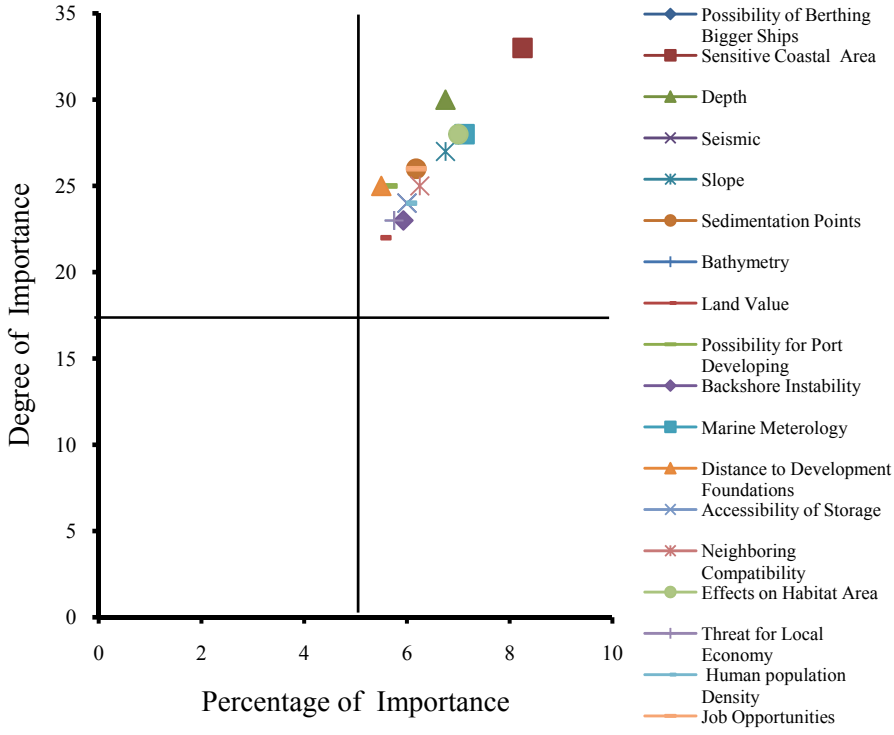

Figure 3. Screening of criteria by Delphi method

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