The International Journal of Social Science and Economics Invention(ijssei)
Volume// 01// Issue// 04//October//2016 page no.1-13
Available Online At: www.isij.in

Offshore support base location of Subsea Engineering Companies (SECs) for Tweneboa, Enyenra and Ntomme (TEN) Project in Ghana Using Analytic Hierarchy Process

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Abstract: - Offshore support base location selection is the determination of a strategic site for institution operations. The facility location decision involves institutions seeking to locate, relocate or expand their operations. The Offshore support base location decision process encompasses the identification, analysis, evaluation and selection among alternatives with respect to criteria selecting the best location among many alternatives is a Multi Criteria Decision Making (MCDM) problem. Analytic Hierarchy Process (AHP) was used for selecting the most suitable location for offshore support base in Ghana for subsea engineering companies for the TEN project in Ghana. The related problem includes four possible alternatives and four criteria to evaluate them. The four locations considered are Takoradi port, Atuabo free port, Lagos Deepwater and Offshore Logistics (LADOL), Tema Shipyard, and the main criteria for evaluation are Quayside facility, Water depth, Plot size, and Cost of operation. The result indicated that the Atuabo Freeport Port has the highest net outranking flow of 0.402643 in comparison with the rest of the locations and hence the best offshore based location.

Keywords: Offshore Support Base, Facility Location, Subsea Engineering, AHP Model, Multi-Criteria Decision Making, TEN

1.0 Introduction

Offshore industries are most of the time located in remote areas and for their effective and efficient output they require support from the shore facility. In a more comprehensive form, shore facility is describe as a logistics base wherein several activities like design, fabrication, storage, handling, reassembly and disassembly, quality control and other activities related to supply chain are undertaking. Making decision regarding a facility location is observed to be of great importance in long-term planning for the organizations. High cost related to property acquisition and facility construction makes the facility location selection a long-term investment decision, (Charles, 2013).

Choosing a new site requires high investment and it cannot then be altered in the short term. The effectiveness of a supply chain depends on the location of the facility. Therefore, offshore support facilities must be well situated. If the facility location is not situated at an appropriate place, unnecessary impact like excess cost may arise.Lagos Deep Offshore Logistics Base, (2012) indicated that the main purpose of an offshore base is to provide logistical, engineering and other support services for deep water offshore oil and gas exploration. Offshore operations are supported by a logistics and service system, which requires a large variation of specialized vessels, helicopters, ports, airports, warehouses, many other components, (PUC, 2013).

The increase in offshore development field requires constant support from the shore therefore there is a need for an offshore support base ready to provide logistics supply for the TEN project. Fabrication of jumpers, Pipe Line End Termination (PLET), Pipe Line End Manifold (PLEM), and other subsea structures require considerable space, terminal with adequate draft of about 9m. However, the current base for these subsea engineering companies for the TEN project is constrained with space, draft and interference in operations. Therefore, this research seeks to determine a suitable location for the planned fabrication yard.

Offshore logistics is a specialized industry which provides expertise for comprehensive offshore and onshore services designed to support the oil and gas production and exploration activities for both short and long term projects. Offshore support base ensure that a myriad of plant, equipment and material from a diverse range of suppliers get to the intended production asset or drilling rig. Running an offshore support base is a complex organizational and physical challenge. Support base services include quayside operations, transport, material management, materials tracking and technology services, (ASCO Group Limited, 2015).

1.1 Overview of facility location

In establishing a new plant, the first question that comes to mind is where to locate the facility? Economists generally consider selection of suitable sites as an important criterion for reducing the cost of production and maximizing profits (Sambidi, 2003).Facility location problem involves theevaluation ofvarious sites for a new facility or relocate an existing facility.Mahadevan (2007), explained that the first decision is whether to build a new facility, expand on an existing site, or relocate to another site. Each choice has advantage and disadvantage. For example, an onsite expansion has the benefit of keeping people together, reducing construction time and costs, and avoiding splitting operations. However, as a firm expands a facility, at some point diseconomies of scale set in.

Bumb (2010) listed four elements in his overview of facility location which are: a set of positions where facilities could be built, a set of demand points which occupy geographical positions related to facilities location, a list of all conditions to be met by the built facilities and demand points and a function that associates each set of possible facilities with the cost incurred if all the facilities in the set are opened, with demand points assigned so that all requirements are fulfilled. In some facility location cases, the goal is to arrive at a single or multiple center position in order to minimize the maximal distance between the point of the demand and the facility that is nearest to it. These types of problems are called the K-center problems, where k is the number of facilities to be located (Hamacher & Nickel, 1998).

Several researchers have already applied different techniques to solve the facility location selection problems. But most of those techniques use complex mathematical formulations, while ignoring qualitative information about the considered criteria (Benning, 2013).Weber (1868-1958) began modern location theories. He formulated many theories, the popular ones being Weber's Least Cost theory and Weber's Weight Losing case. In the Least Cost theory, he tried to find a location for a manufacturing plant which minimizes three categories of cost: transportation, labor, and agglomeration. In his Weight Losing case, firms which produce goods less bulky than the raw material used in their production should settle near to the raw material source; and vice versa. Calvo and Marks (1973) constructed p-median model to locate multi-level hierarchical health care facilities including central hospitals, community hospitals and local reception centers. The model minimized distance and user costs, and maximized distance and utilization.

2.0 AHP Model

The AHP model is one of the multi criteria decision making approach which was develop by Saaty L. Thomas. AHP has broken through the academic community to be widely used by practitioners. This widespread use is certainly owing to its ease of applicability, intuitive way in which managers solve problems, hierarchical modelling of the problem, possibility to adopt verbal judgments and verification of the consistency are its major assetsYe & Wu, (2014) reiterated the widely used of the AHP model to handle a simple multi-criteria decision-making problem. They indicated that due to the complexity nature of the Analytic Network Process (ANP) approach, it is a better way to use the AHP approach to deal with the selection of a logistics service provider. Winston and Albright, (2009), point out that the AHP model is very useful when the decision maker is faced with multiple objectives. Moreover, Syamsuddin & Hwang, (2009) stated that one of the main advantages of Saaty's AHP is the simplicity of the model as compared to previous decision support methods. The model makes it possible to have both the qualitative and quantitative data into the same decision making methodology. This will give a basis for eliciting, discussing, recording, and evaluating the elements of a decision. Xi & Qin (2013) in their research explain that the AHP model is a simple way to make decisions for complex and fuzzy problems, especially if the problem cannot be completely analysed quantitatively. They further indicated that in a situation where teams of people are working on very complex problems, AHP is most useful tool in helping them to make a rightful decision. Zeshui, (2000) believes that where it is difficult to quantify or compare decision, or where communication among team members is affected due to differences in specializations, terminologies, or perspectives, AHP is a very useful in this situation.

2.1 AHP Procedure

The first procedure is to model the problem as a hierarchical structure, see figure 1 below. The structure contains decision problem, the alternatives and the criteria for evaluating the alternatives.

The second procedure is the pairwise comparison matrix where priority among the elements of the hierarchy are established by making a series of judgments based as shown in table 1 below.

Intensity of importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Somewhat more important	Experience and judgment slightly favor one over the other
5	Much more important	Experience and judgment strongly favor one over the other
7	Very much more important	Experience and judgment very strongly favor one over the other. Its importance is demonstrated in practice
9	Absolutely more important	The evidence favoring one over the other is of the highest possible validity
2,4,6,8	Intermediate values	When compromise is needed

(Adapted from Saaty, 1980)

Table 1, Values interpretation in the Pairwise Comparison Matrix Intensity of importance Definition Explanation

1 Equal importance two factors contribute equally to the objective

3 Somewhat more important Experience and judgment slightly favor one over the other

5 Much more important Experience and judgment strongly favor one over the other

7 Very much more important Experience and judgment very strongly favor one over the other. Its importance is demonstrated in practice

9 Absolutely more important the evidence favoring one over the other is of the highest possible validity 2,4,6,8 Intermediate values When compromise is needed (Adapted from Saaty, 1980)

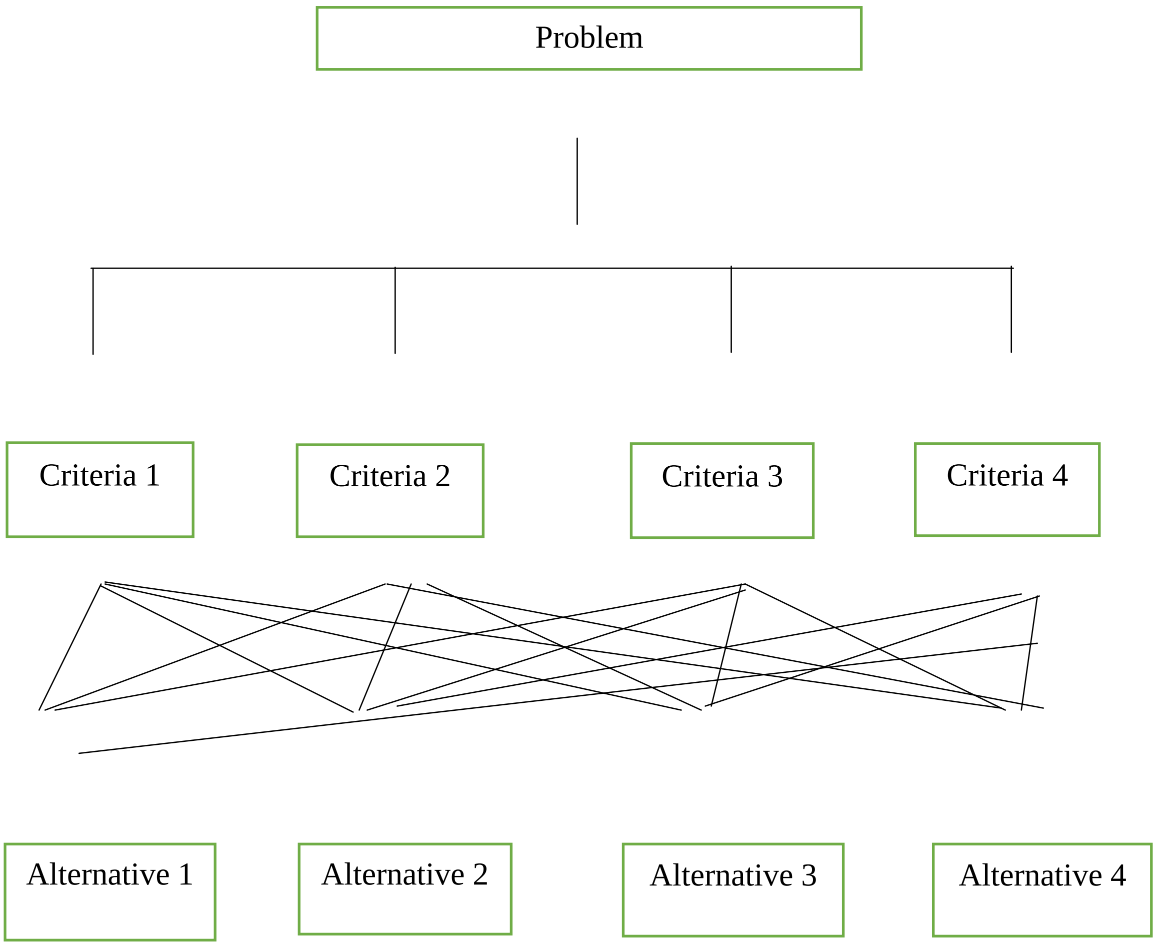


Figure 1, AHP hierarchical structure model

The third procedure is where the judgments made are synthesized to obtain a set of overall priorities for the hierarchy. In finding the matrix algebra, we need to calculate the "principal vector" of the matrix. This is obtained by adding the members of each column to get the total. In order to normalize each column to sum up to 1.0 or 100%, divide the elements of each column by the total of that column and sum them up. You then add the elements in each row and divide this sum by the number of elements in the row to get the average.

Next procedure is the checking for consistency. This is done to ascertain whether any pairwise comparison matrix suffer from inconsistencies. To calculate a consistency ratio, you divide the consistency index by the index for the corresponding random matrix. According to Saaty, (1980), if Consistency Ratio (CR) is greater than 0.1 then serious inconsistencies exist. Where the CR is less than 0.1, then the degree of inconsistency is satisfactory and in a situation where CR is 0 it means that the decision is perfectly consistent.

The final decision is based on the determination of best alternative to find out how well each location is compared to other location with regards to the objective. Here, each alternative is to be calculated a numerical value. These numerical priorities represent the alternatives' relative ability to achieve the objective.

3.0 Method

3.1 Research Design

The research design used in this study is the empirical research design. The research study makes use of surveys and observations

3.2 Study Area

This study broadly focuses on selecting an offshore logistics base and the criteria for evaluating the offshore logistics base considers only present scenario since available data are collected from recent years. Potential locations are selected for the consideration based on subsea engineering companies' perspective. Moreover, the study only considers four locations; Tema shipyard, Takoradi port, proposed Atuabo free port complex and Lagos Deepwater and Offshore Logistics (LADOL).

3.3 Population, Sample Size and technique

All the staff of the Technip, Subsea 7, Seaweld Engineering Ltd, Orsam Ltd, Hydra offshore limited and Wood group Limited and Harlequin International Ghana Ltd form the population. Non probability sampling based on purposive method was used to select 7 people with expert knowledge on AHP model. Judgmental approach was preferred over the random sampling methods due to the small nature of the population and the technicality of the study.

3.4 Data Collection Methods

The methods used in collecting data are;

- Questionnaires: questionnaires were given to respondents to gather relevant information as to the weights assigned to parameters under consideration.

- Observations: personal observation of the proposed locations to help determine the nature of the land, as well as the state of facilities on the location.

3.5 Data Collection

A questionnaire was constructed by the researcher to tap perception of experts and stakeholders towards factors associated with facility location. The questionnaire was administered to seven respondents (each from the 7 subsea engineering companies) with the aim to identify their perceptions of factors associated with offshore support base location selection. Respondents need to judge the relative comparison between criteria and the relative comparison between alternative with respect to criterion in linguistic scales. Each of these judgments is then assigned an integer on a scale. In this study, the original definition of scale given by Saaty (1980) was adopted.

4.0 Locations and variables Considered

The four locations considered are Takoradi port, Atuabo free port, LADOL and Tema Shipyard, and the four criteria used in evaluating the alternatives are Quayside facility, Water depth, Plot size, and Cost of operation.

4.1 Assessment of the Possible Locations

4.1.1Tema Shipyard

Tema shipyard provides dry-dock and slipway facilities which has a 100,000 dwt capacity. The facility is served by 60 tonnes which is out of service and 20 tonnes mobile cranes which are in a good operating condition. The dock is 277.4 meters long, 45.4 meters wide and has a draught of 6.7 meters. Tema shipyard also provides a quay facility of 248m long with a water depth ranging from 6.2 to 6.4m at low tides. Size of available land: 22,600 m², Cost of the land: 5 USD/m2/day for short term plan. The land does not have a direct access, but it can still use the quay available for the shipyard and the water depth around the quay varies from 6.3 to 6.5 m at low tide.

4.1.1 Takoradi Port

The port of Takoradi was opened in 1928 which has four multipurpose berths with drafts between 9.0m to 10.0m and dedicated berths for Manganese, Bauxite and Oil. There are also buoys with a maximum draft of 11.0m. It has a slipway which is being expanded to accommodate vessels and crafts up to 500 tonnes deadweight and a length of 40 – 45m. The dry-dock is being extended to a length of 55m and a breadth of 14.5m.Size of available land: 9,000 to 11,000 m², cost of the land: 6 USD/m/months for long term plan, the land has access to the quay and the water depth around the quay is of minimum of 6.8 m at low tide.

4.1.2 LADOL

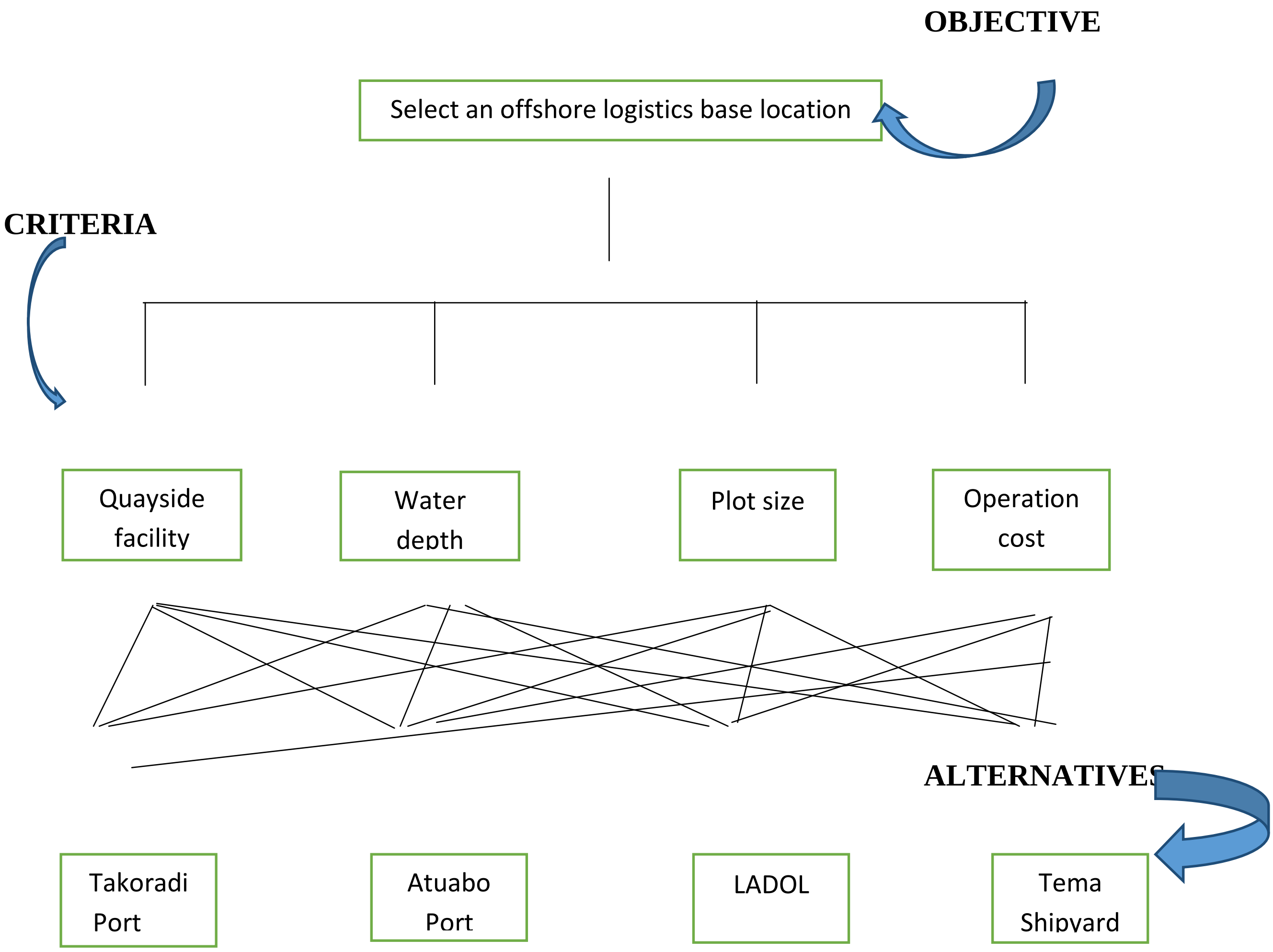
LADOL (Lagos Deepwater and Offshore Logistics) is a Nigerian company that provides offshore facilities such as fabrication yard, warehouses and others. In Ghana, they are located in Takoradi and they own a land in Takoradi port that has a warehouse and an open area with a concrete floor. Size of available land: 8,000 m², Cost of the land: 10-12 USD/m/day for long term plan, the land do not have a direct access to the quay, it is located about 200m away from the quay and the water depth around the quay varies from 6.3 to 6.5 m at low tide

4.1.3 Atuabo Free Port Complex

Atuabo Free Port project is expected to become a West African logistics hub and will also serve the oil and gas industry. The $650million contract will be fully funded by Lonrho and its partners (private investors). The project will provide an 18.5m deep channel and three quays varying depths of 16.6m, 12m and 9m.The project has not started yet due to dispute between GPHA and the investors. Nevertheless some data were available such as: Size of available land: 18,000 m², cost of the land: not yet determined, the land would have a direct access to the quay, the water depth around the quay will vary from 10 to 15 m at low.

4.2 AHP Analysis

4.2.1 Hierarchical tree/structure showing decision objective, the alternatives and the criteria for evaluating the alternatives



4.2.2 Constructing the Pairwise Comparison Matrix

From the questionnaires, decision-makers determined relative values for the criteria and each alternative using Saaty (1980) rating scale. Information gathered from the questionnaires of the criteria with respect to the objectives are shown in matrix A below.

Factors	Quayside facility	Water Depth	Plot Size	Cost of operation
Quayside facility	1	5	6	2
Water Depth	1/5	1	3	2
Plot Size	1/6	1/3	1	¼
Cost of operation	½	½	4	1
Total	1.86	6.83	14	5.25

4.2.3 Computation of Analytic Hierarchy Process (AHP)

Calculation of Analytic Hierarchy Process involves a series of computations that are done in the following stages:

4.2.3.1 Normalization

Normalizing of the Matrix A to get A_{norm} where each column entry is divided by the column sum

Matrix A_{norm}=

0.537634	0.732064	0.428571	0.380952
0.107527	0.146413	0.214286	0.380952
0.086022	0.048316	0.071429	0.047619
0.268817	0.073206	0.285714	0.190476

In determining the weight or scores, each row is averaged to obtain vector of scores.

Weight (w_1) = row sum/n=

0.519806
0.212294
0.063346
0.204554

4.2.3.2 Determining the Score of each Decision Alternative

Having determined the weights for the various objectives, we need to determine how well each location scores on each objective.

T = Takoradi Port

A = Atuabo Free Port

L = LADOL Ghana

Te = Tema Shipyard

Alternative 1 (A1) Quayside Facility

Pairwise comparison matrix for A1 =

	T	A	L	Te
T	1	1	3	5
A	1	1	3	5
L	0.33	0.33	1	3
Te	0.2	0.2	0.33	1
Total	2.53	2.53	7.33	14

The corresponding normalized matrix $A1_{norm}$ =

0.395257	0.395257	0.409277	0.357143
0.395257	0.395257	0.409277	0.357143
0.130435	0.130435	0.136426	0.214286
0.079051	0.079051	0.04502	0.071429

And by averaging we have score S1 =

0.389233
0.389233
0.152895
0.068638

Alternative 2 (A2) Water Depth

Pairwise comparison matrix for A2 =

	T	A	L	Te
T	1	1	1	5
A	1	1	1	5
L	1	1	1	5
Te	0.2	0.2	0.2	1
	3.2	3.2	3.2	16

The corresponding normalized matrix $A2_{norm}$ =

0.3125	0.3125	0.3125	0.3125
0.3125	0.3125	0.3125	0.3125
0.3125	0.3125	0.3125	0.3125
0.0625	0.0625	0.0625	0.0625

And by averaging we have score S2 =

0.3125
0.3125
0.3125
0.0625

Alternative 3 (A3)Plot Size

Pairwise comparison matrix for A3 =

	T	A	L	Te
T	1	1	2	1
A	2	1	2	1
L	0.5	0.5	1	0.5
Te	1	1	2	1
Total	4.5	3.5	7	3.5

The corresponding normalized matrix $A3_{norm}$ =

0.222222	0.285714	0.285714	0.285714
0.444444	0.285714	0.285714	0.285714
0.111111	0.142857	0.142857	0.142857
0.222222	0.285714	0.285714	0.285714

And by averaging we have score S3 =

0.269841
0.325397
0.134921
0.269841

	T	A	L	Te
T	1	0.33	2	1
A	3	1	5	3
L	0.5	0.2	1	0.5

Alternative 4 (A4) Cost of operation

Te	1	0.33	0.5	1
Total	5.5	1.86	8.5	5.5

Pairwise comparison matrix for A4 =

The corresponding normalized matrix$A4_{norm}$ =

0.181818	0.177419	0.235294	0.181818
0.545455	0.537634	0.588235	0.545455
0.090909	0.107527	0.117647	0.090909
0.181818	0.177419	0.058824	0.181818

And by averaging we have score S4 =

0.194087
0.554195
0.101748
0.14997

The next step is to determine the best alternative by combining the scores in each objective (priority matrix) with the weights in the w1vector. We form a matrix of these score vectors and multiply this matrix by w; we obtain a vector of overall scores for each location, as shown below.

Sw=

0.325462	T
0.402643	A

0.175177	L
0.096717	Te

Sw =

4.2.3.3 Check for consistency

You have to calculate Average weight = matrix A1 × w_1 and this gives

2.370463
0.915402
0.267711
0.823989

Random Indices for Consistency Check for the AHP

N	2	3	4	5	6	7	8	9	10
RI	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.51

$\lambda max = 4.281652$

C.I. = $(\lambda max - n)/(n-1) = 0.093884$

C.R. = C.I./R.I = 0.10

The Pairwise comparison does not exhibit any serious inconsistency.

Saaty's rule of thumb is that 10 per cent of the inconsistency of the random matrix is allowed. This implies that a value of the C.R ≤ 0.1 can be considered acceptable.

4.3 Discussion of the result

From the results generated Atuabo Freeport Port has the highest net outranking flow of 0.402643 in comparison with the rest of the locations. The AHP method ranking for the facility location is: (T) Takoradi (score: 0.325462), (A) Atuabo Free Port (score: 0.402643), (L) LADOL (score: 0.175177) and (Te) Tema Shipyard (score: 0.096717). According to the final score of the aggregated weight, we can determine the optimal location of the offshore logistics base as Atuabo Freeport which has the highest aggregated weight of 0.402643. Incomparability existed when using partial ranking to rank all alternatives from best to worst, hence complete ranking was used since there was no incomparability.

5.0 Conclusion

Offshore support base in Ghana decisions often come down to a few alternatives that seem very close in their development potential. Using the criteria developed in this study along with multi-criteria Decision analysis tool (AHP method) allows decision makers to more effectively make distinctions between offshore logistics base capabilities. Overall, the criteria developed in this research provide a solid basis for determining the strengths and weaknesses of a region for an offshore support base development. The importance of each criterion and the alternatives chosen for comparison varies based on the conditions and decision makers, but the criteria are relevant for all offshore support base development decisions. Quayside facility, water depths, plot size and cost of operation were dominant factors which form basis for selection from alternative locations.

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