Hospital Site Selection in Benghazi City in Libya

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Abstract

Selecting a particular site location is a multi-criteria decision making (MCDM) problem which is subjected to multiple conflicting criteria. Some conflicting tangible criteria have been considered such as land cost, building construction cost, traffic access, site specific features, market opportunity, along with other intangible criteria are considered such as climate, pollution, living expense, and traffic congestion. The site selection decision is reviewed and proofed based on the analytic hierarchy process (AHP) and statistical analysis evaluation for site selection. In the current study the selection criteria for hospital site selection in Benghazi city in Libya are studied. Both the main criteria and sub-criteria of hospital site selection are studied and tested with the requirements of Libyans culture requirements and aspects through two designed questionnaires and in the aim of determining the embedded relative importance to each other. Also the criteria are evaluated against the available site locations proposed by the governance of Benghazi. In addition to determining the embedded relative importance for both the main and sub-criteria, the decisions for hospital site selection obtained by the considered decision tools are consistent.

Keywords
AHP- Hospital site selection - MCDM – Site selection – AHP in sites selection

1. Introduction

The selection of a site involves both location and site selection, in other words, identifying the general area for the business and identifying a specific site within the area. Location refers to a general area within a city, while the site is a specific piece of property.The primary consideration in relation to site selection is an appropriate location. The objective of the clinical services strategy is ‘the right care, in the right place, at the right time. The ever increasing population of urban areas amplifies the demand for new hospitals where their construction must accommodate numerous environmental factors such as pollution, distance to health services, economic constraints, temporal restrictions, and social inconvenience [1, 2, and 3]. The selection of an optimum hospital site will be influenced by the uncertainty inherent in describing and ranking available alternatives based on effective parameters. This selection is a multiple criteria decision making. Several methods exist for MCDM where noare better or worse techniques, but some are better suit to particular decision problems than others do [4]. Multiple MCDA techniques have been used to solve site selection problemssuch as PROMETHEE,ELECTRE, and TOPSIS which have been used to rank alternative sites, especially in the case of environmental problems.The MCDM method should not be chosen until the analyst and the decision makers understand the problem; declare the feasible alternatives; realize the different outcomes; understand the conflicts between the criteria; and understand the level of data uncertainty. The Analytical HierarchyProcess (AHP) described by Saaty[5]is one of the more usefulmethodologies, and plays an important role in selecting optimizedalternatives [6]. AHP is a partial form ofthe Analytic Network Process (ANP), which models the decisionprocess as a sequence of unidirectional, hierarchical relationshipsrather than a complex network of objectives.A model for positioning the optimum location of a small size fuel station site with the help of GIS is proposed by Aslaniand Alesheikh [7]. In this model, the two methods for weighting spatial layers, fuzzy analytical hierarchy process (FAHP) and analytical hierarchy process (AHP), are compared. Also, the results of different methods for integrating spatial layers such as Boolean, index overlay and fuzzy operators were compared. A systematic methodology is presented under the consideration of multiple factors and objectives that are witnessed to be crucial to the construction process [8]. The model includes building an analytic hierarchy structure with a tree of hierarchical criteria and alternatives to ease the decision-making. Three alternatives were considered. An Analytical Hierarchy Process was used to assist in building the model and help draw decisions. While deploying the crane selection objectives into layered sub-goals, conclusions could be drawn on the type to be used in construction according to knowledge based evaluation and assessment.Based on the previous literature review, selecting a service facility location requires additional specifications than any other production or distribution facility. In this research a list of site assessment criteria based on some identified key constraints have been developed to help identifying suitable locations and to test theappropriateness of proposed available sites for these criteria. Some of the considered criteria in the current research include site accessibility from arterial routes, pollution, land cost, and capacity to serve large population density. In that research the local access to existing hospitals throughout a city is quantified in terms of travel times, taking into account the road network density. Hospital sites outside a particular time threshold, with respect to current hospitals, have higher priority.The presented model illustrates how the AHP and statistical approach-based on questionnaires analysis are used for determining the best location for hospital site location in Benghazi city. The weighting of the criteria considered during decision making and evaluation of these criteria are performed simultaneously. This approach also views the rule and importance of weighting the criteria which is recognized as an important phase in the decision making process.

2. Theoretical Background

The process of site selection typically involves two main phases: screening in which the identification of a limited number of candidatesites from a broad geographical area given a range of selectionfactors and the evaluation in-depth examination of alternatives todetermine the most suitable site [9]. A multitudeof sometimes contradictory factors are involved in both phases.In such a situation, a number of tools are available to determinethe optimum site or the best satisfied one [10]. These tools include ExpertSystems (ES) for well-defined and structured problems, DecisionSupport System (DSS) for ill-structured problems, the combinationof both ES and DSS, or a statistical evaluation process analyses for the available sites based on the crucial required parameters.When making complex decisions involving multiple criteria, the first step is to decompose the main goal into its constituent sub-goals or sometimes called objectives, progressing from the general to the specific. In its simplest form, this structure comprises a goal, criteria or objective and alternative level. Each set of criteria would then be further divided into an appropriate level of detail, recognizing that the more criteria included, the less important each individual criterion may become as presented in Fig. 1 [5].Generally, the main goal is laid on the top hierarchy while the decision alternatives are at the bottom.Between the top and bottom levels reside the relevantattributes of the decision problem such as the selection criteria and objectives. Next, relative weights to each item in the corresponding level are assigned. Eachcriterion has a local and global priority. Thesum of all the criteria beneath a given parent criterion ineach layer of the model must equal one. The globalpriority shows alternatives relative importance within theoverall model.After the criteria factors are identified, scoring ofeach level with respect to its parent is carried out using a relative relational basis by comparing one choice to another.

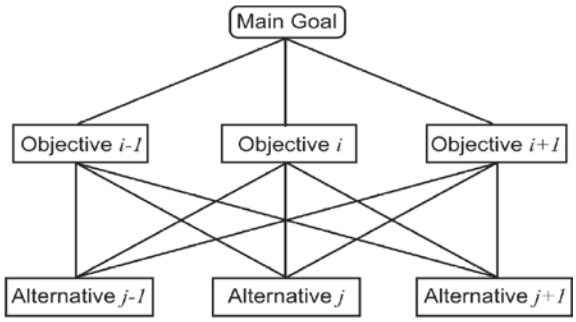

Figure 1: Analytical hierarchy process (AHP)

Relative scores for each choice are computedwithin each leaf of the hierarchy. Scores are thensynthesized through the model, yielding a compositescore for each choice at every layer, as well as an overallscore.This relative scoring within each level will result in amatrix of scores, say *a* (*i*, *j*). The matrix holds the expertjudgment of the pair-wise comparisons. However, thejudgment should be consistent. Therefore, inconsistencytest is required to validate the expert knowledge. Theinconsistency measure is useful for identifying possibleerrors in judgments data entry as well as actualinconsistencies in the judgments themselves.

2.1 Analytical Hierarchy Process AHP

The AHP is a flexible, quantitativemethod for selecting among alternatives based on their relativeperformance with respect to one or more criteria of interest[11, 12]. The hierarchy of AHP is constructed throughpairwise comparisons of individual judgments, rather thanattempting to prioritize the entire list of decisions and criteriasimultaneously [5].The AHP procedure generally involves six steps [13, 14]:

- Define the unstructured problem, identification of input/output parameters,
- Representation of a structure by a hierarchy,
- Paired comparison between elements at each level,
- Calculations of the weight at each level,

- Test the consistency of each matrix and
- Priority of an alternative by a composition of weights

The process incorporates judgments on intangible qualitative criteria along with tangible quantitative criteria [3, 4, and 5]. Once the problem has been decomposed and the hierarchy is constructed, prioritization procedure starts in order to determine the relative importance of the criteria within each level. The pairwise judgment starts from the second level and finishes in the lowest level, alternatives. In each level, the criteria are compared pairwise according to their levels of influence and based on the specified criteria in the higher level [5].In AHP, multiple pairwise comparisons are based on a standardized comparison scale of nine levels, Table 1. Let C = {Cj | j = 1, 2,.., n} be the set of criteria. The result of the pairwise comparison on n criteria can be summarized in an (n _ n) evaluation matrix A in which every element aij (i,j = 1,2, . . . ,n) is the quotient of weights of the criteria, as shown:

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}, \quad a_{ii} = 1, a_{ji} = 1/a_{ij}, a_{ij} \neq 0$$

At the last step, the mathematical process commences to normalize and find the relative weights for each matrix. The relative weights are given by the right eigenvector (w) corresponding to the largest eigenvalue (λ_{max}), as:

$$A_w = \lambda_{max} w$$

If the pairwise comparisons are completely consistent, the matrix A has rank 1 and λ_{max} = n. In this case, weights can be obtained by normalizing any of the rows or columns of A [6]. It should be noted that the quality of the output of the AHP is strictly related to the consistency of the pairwise comparison judgments. The consistency is defined by the relation between the entries of A: $a_{ij} \times a_{jk} = a_{ik}$. The consistency index (CI) is:CI = (λ_{max} – n) / (n – 1)

The final consistency ratio (CR) is used to decide whether the evaluations are sufficiently consistent. It is calculated as the ratio of the CI and the random index (RI), as indicated:CR =CI / RI

The measurement of consistency can be used to evaluate the consistency of decision makers as well as the consistency of overall hierarchy[6].

Table 1: Intensity of importancescale.

Definition	Intensity of importance
Equally important	1
Moderately more important	3
Strongly more important	5
Very strongly more important	7
Extremely more important	9
Intermediate values	2, 4, 6, 8

3. Site Selection

In the location selection process, locations are evaluated with respect to certain specified criteria. These criteria are significantly different from location to the other. Selecting the criteria that the locations will be evaluated against them is affected by some factors. Some locations require a location with certain geographical specifications, in a good environment. Some criteria will be defined with respect to the objectives of the facility. Also the stakeholders have a point of view that recommends some criteria to be used in the location selection evaluation process.In the current work the selection of hospital location is considered as the main objective under consideration. In order to achieve this target, first of all the criteria of selection should be determined for hospital location selection and examined with the environmental requirements. Three locations have been proposed by specialists in the field of clinical services in Benghazi city for hospital site selection evaluation. These location sites are Geliana, Budezeera, and Bufakhra. Many different criteria are considered for hospital site selection in many different researches such as in [1, 2, and 3] and based on the considered situations for each research case. These criteria are integrated in the current research and classified into nine main criterion under each the sub-criteria are determined. These main and sub criteria are listed as:

- Operational considerations (Cooperativeness of local government, Regulation approval issues, Presence of an established health maintenance organization (HMO), Proximity to clinical research and faculty, Ability to accommodate patient-family housing onsite or nearby, and Water resources).
- Accessibility and traffic (Public transport link, Bicycle, Pedestrian, and Commute time for hospital staff).
- Patient/emergency access consideration (Helicopter access and Access to road network).

- Site conditions and surrounding (Site size, Site preparation time, Parking: Surrounding street network to accommodate adequate parking, Proximity to banking facility, Proximity to community services, and Attractive outlook).
- Future considerations (Expansion ability and Represent different geographic regions).
- Regional impacts (Availability of physicians [physician to population ratio], Health insurance contracts around, Proximity to targeted prospective patients, and Secure region).
- Nuisance (Atmosphere conditions and Noise).
- Cost (Site preparation cost, Operational cost, and Maintenance cost)
- Means of waste visual management (Influence in terms of size and scale, Heat treatments, Efficiency, and Improve energy).

In the current work, the classified criteria and sub-criteria are tested of their importance and relative importance to each other against the Libyanculture and their influence of determining the best site for hospital.In order to achieve this objective the above criteria are constructed in a questionnaire and distributed to the specialists in the domain of clinic services to measure the importance of each main criteria and sub-criteria. Also the relative importance of both the main criteria and sub-criteria are measured from this questionnaire. The designed questionnaire considered the basic main items, features, and formatting listed by Goldfarb [15] for hospital site selection questionnaire. The designed questioners are distributed on 250 respondents. These respondents are asked to fill the questions in the questionnaires. 210 of them where interesting to fill the questioners. Some of them their responding were wrong. Thesequestionnaires are returned back to these respondents and they are asked to rewrite the questioner in correct formatting. This process has been done in the aim of increasing the considered search space or population. This selection of respondents is considered in the aim of increasing the value of investigation questioner analysis where all the respondents are selected from the experts and specialists in either the clinical staff members or of the higher managers that are working the field of providing the clinical services centers in Benghazi city. However the questioners are distributed in the biggest hospitals and clinical centers in Benghazi city such as 7 October hospitals, Elgomhouria hospitals, accident clinical centers, Heart clinical centers, Alglaa hospitals, and Elhawary hospitals. The results of the distributed questioners are analyzed in the aim of determining the degree of priorities of these main criteria and the priorities of sub-criteria under the main criteria. The frequency histogramsfor both the main criteria and sub-criteria are presented in Figures 2-11 respectively.

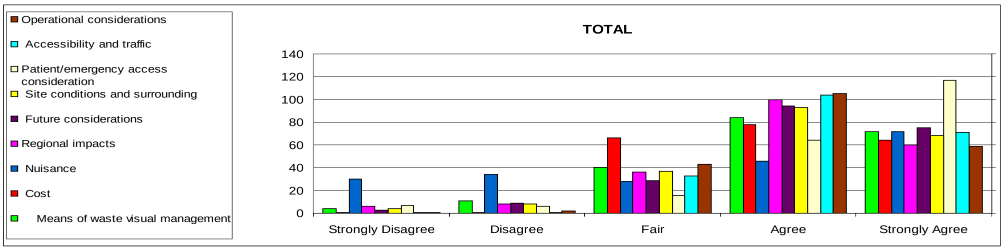

Figure 2: Frequency histogram for main criteria.

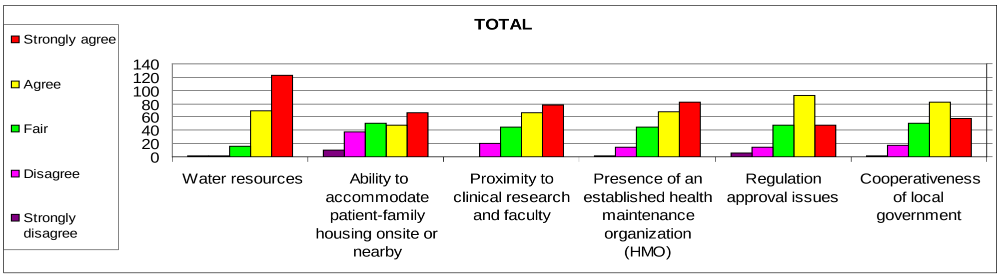

Figure 3: Frequency histogram for all sub-criteria of criterion

1.

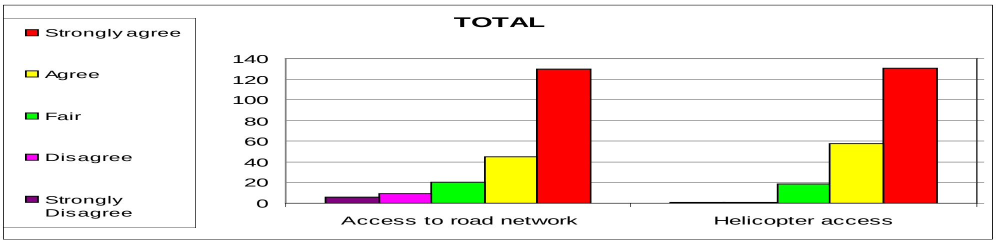

Figure 4: Frequency histogram for all sub-criteria of criterion 3.

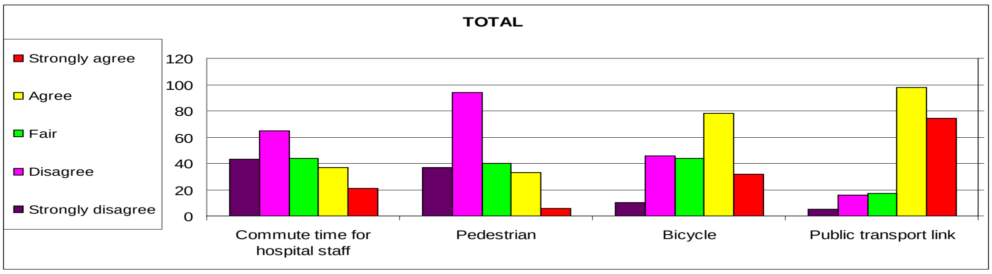

Figure 5: Frequency histogram for all sub-criteria of criterion 4.

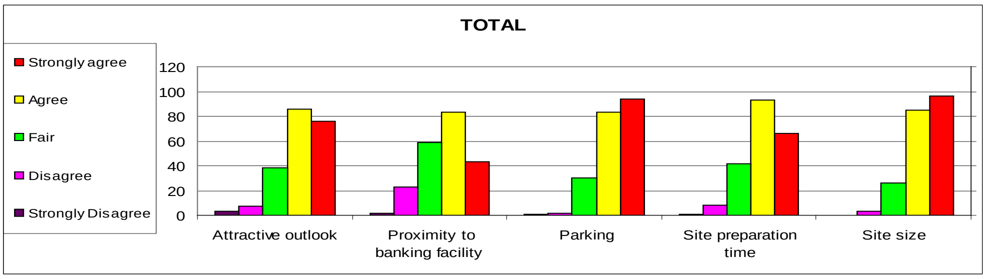

Figure 6: Frequency histogram for all sub-criteria of criterion 5.

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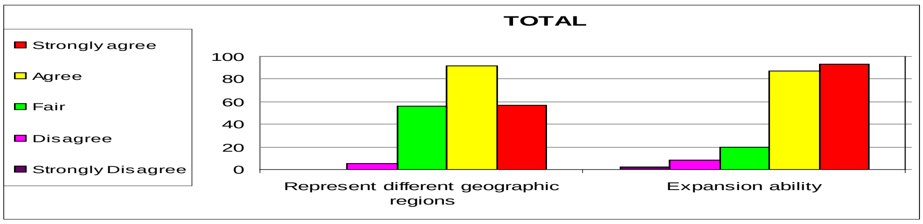

Figure 7: Frequency histogram for all sub-criteria of criterion 6.

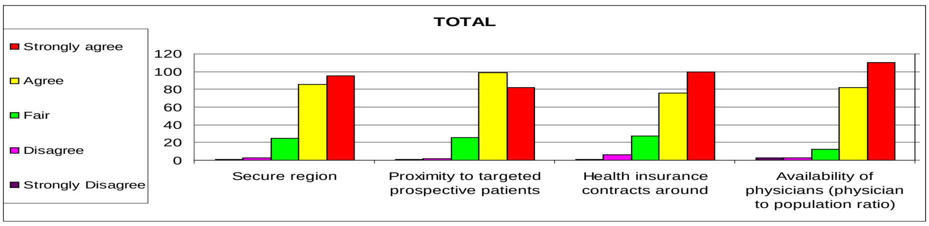

Figure 8: Frequency histogram for all sub-criteria of criterion 7.

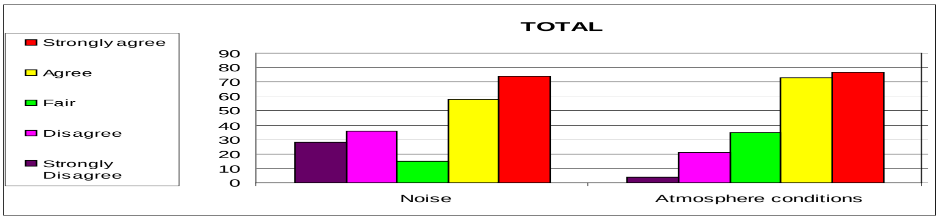

Figure 9: Frequency histogram for all sub-criteria of criterion 8.

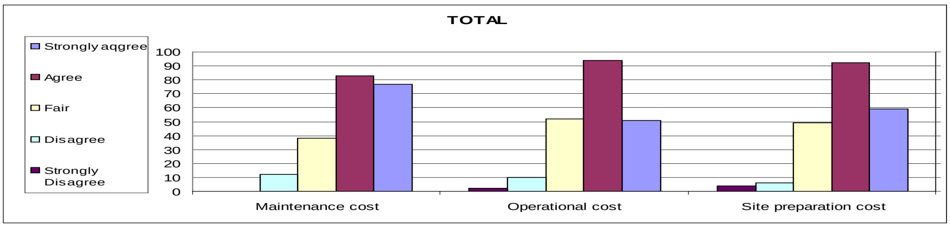

Figure 10: Frequency histogram for all sub-criteria of criterion 9.

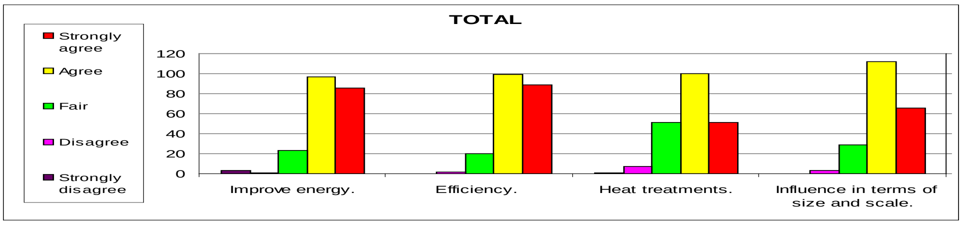

Figure 11: Frequency histogram for all sub-criteria of criterion 10.

In order to determine the relative importance of both the main criteria and sub-criteria, the frequencies are treated with numeric value indices 1, 0.5, 0, -0.5, and -1 and then normalized.Table 2 presents both the main criteria and sub-criteria arranged in a descending orders based on the statistical analysis.

Table 2: .Relative importance of main criteria.

MAIN CRITERIA	Normalized
Patient/emergency access consideration	14.70
Accessibility and traffic	12.85
Future considerations	12.11
Operations considerations	11.58
Site conditions and surrounding	11.26
Means of waste visual management	11.11
Cost	10.74
Regional impacts	10.58
Nuisance	5.08

The designed questionnaires correlated to the considered three sites of hospitals are also distributed to the respondents and the frequency tables for these sites against both the main and sub-criteria are presented in Table 3.

Table 3: Sites frequency distribution against all sub-criteria elements.

Main sub-criteria	Gelian Site	Bodezera Site	Bofakra Site
Cooperativeness of local government	967	707	426
Regulation approval issues	964	694	442
Presence of an established	918	744	438
Proximity to clinical research and faculty	820	710	570
Ability to accommodate patient	872	721	507
Water resources	910	754	436
Public transport link	882	749	469
Bicycle	921	701	478
Pedestrian	1017	646	437
Commute time for hospital staff	837	735	528
Helicopter access	802	752	546
Access to road network	911	773	416
Site size	818	757	525
Site preparation time	860	757	483
Parking	890	711	499
Proximity to banking facility	975	674	451
Attractive outlook	885	698	517
Expansion ability	844	731	525
Represent different geographic regions	822	748	530
Availability of physicians	936	738	426
Health insurance contracts around	911	745	444
Proximity to targeted prospective patients	904	715	481
Secure region	961	681	458
Atmosphere conditions	907	652	541
Noise	950	701	449
Site preparation cost	895	702	503
Operational cost	914	702	484
Maintenance cost	903	706	491
Influence in terms of size and scale.	907	685	508
Heat treatments.	894	740	466
Efficiency.	861	751	488
Improve energy.	862	741	497
TOTAL	**28720**	**23021**	**15509**

Table 4 presents the voting percent for the considered three sites and against the sub-criteria elements. Also Table 5 presents the voting percent for the considered three sites and against the main criteria elements. These tablesindicate that Giliana is the best site location for the hospital construction in Benghazi city. The following Figures present the histograms for both the main criteria and sub-criteria arranged in descending orders based on the statistical analysis obtained from the frequency tables of the hospital selection criteria and taking into consideration the voting for the considered sites.These Figures are exhibited from Figure 12 to Figure 20.

Table 4: Votingpercent for hospital sites against the sub criteria elements

MAIN SUB CRITEIRA	Galiana	Bodezera	Bofakra
Helicopter access	0.38	0.36	0.26
Access to road network	0.43	0.365	0.23
Public transport link	0.42	0.36	0.22
Bicycle	0.44	0.33	0.44
Pedestrian	0.48	0.31	0.21
Commute time for hospital staff	0.4	0.35	0.25
Expansion ability	0.4	0.35	0.25
Represent different geographic regions	0.39	0.36	0.25
Water resources	0.43	0.36	0.21
Presence of an established health maintenance organization (HMO)	0.44	0.35	0.21
Proximity to clinical research and faculty	0.39	0.34	0.27
Cooperativeness of local government	0.46	0.34	0.2
Regulation approval issues	0.46	0.33	0.21
Ability to accommodate patient-family housing onsite or nearby	0.42	0.34	0.24
Site size	0.39	0.36	0.25
Parking	0.42	0.34	0.24
Attractive outlook	0.42	0.33	0.25
Site preparation time	0.41	0.36	0.23
Proximity to community services	0.46	0.32	0.22
Proximity to banking services	034	0.29	0.29
Efficiency.	0.41	0.36	0.23
Improve energy.	0.41	0.35	0.24
Influence in terms of size and scale.	0.43	0.33	0.24
Heat treatments	0.43	0.35	0.22
Maintenance cost	0.43	0.34	0.23
Site preparation cost	0.43	0.33	0.24
Operational cost	0.44	0.33	0.23
Availability of physicians (physician to population ratio)	0.45	0.35	0.2
Secure region	0.46	0.32	0.22
Health insurance contracts around	0.44	0.35	0.21
Proximity to targeted prospective patients	0.43	0.34	0.23
Atmosphere conditions	0.43	0.31	0.26
Noise	0.45	0.34	0.21

Table 5: Voting percent for hospital sites against the main criteria elements.

MAIN CRITERIA	Galiana	Bodezera	Bofakra
Patient/emergency access consideration	0.405	0.365	0.23
Accessibility and traffic	0.435	0.3375	0.2275
Future considerations	0.395	0.355	0.25
Operational considerations	0.44	0.34	0.22
Site conditions and surrounding	0.42	0.342	0.238
Means of waste visual management	0.42	0.35	0.23
Cost	0.44	0.33	0.23
Regional impacts	0.445	0.34	0.215
Nuisance	0.44	0.325	0.235
TOTAL	**0.427**	**0.342**	**0.231**

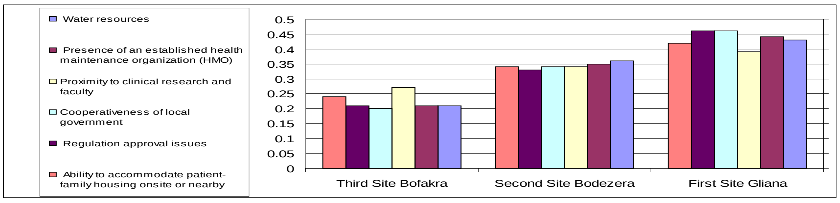

Figure 12: Frequency histogram for criterion 1

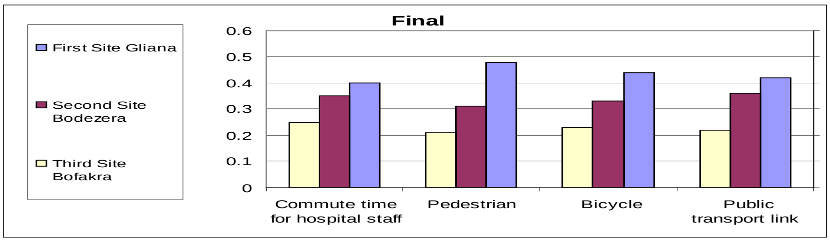

Figure 13: Frequency histogram for criterion 2

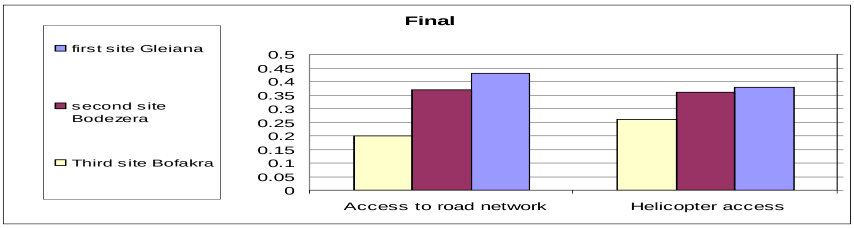

Figure 14: Frequency chart histogram for criterion 3

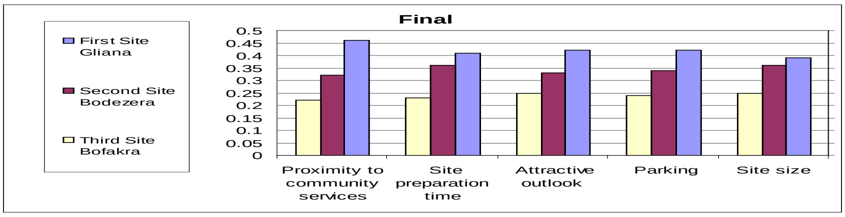

Figure 15: Frequency histogram for criterion 4

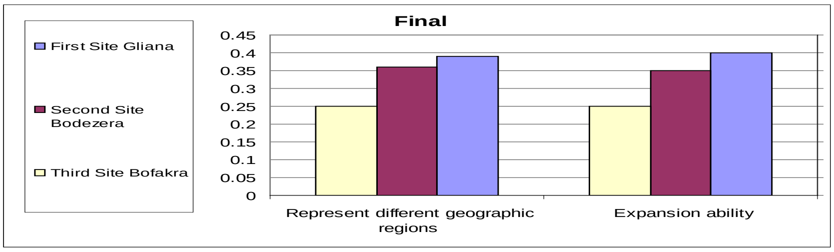

Figure 16: Frequency histogram for criterion 5

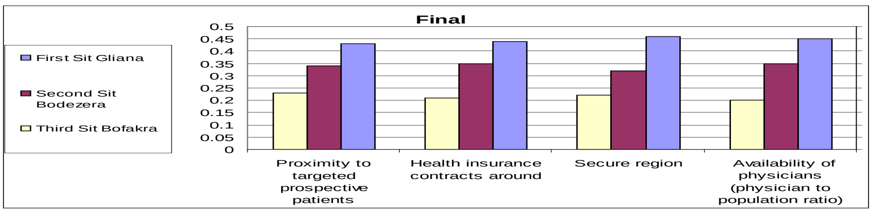

Figure 17: Frequency histogram for criterion 6

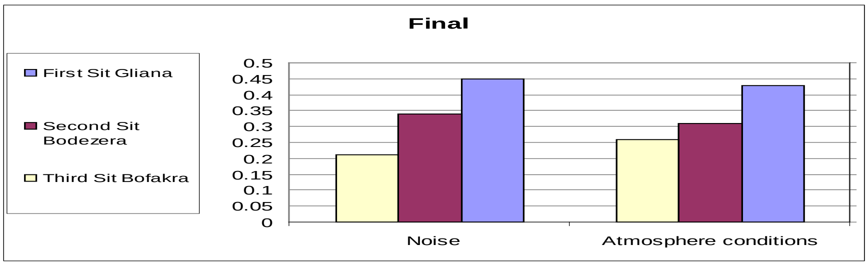

Figure 18: Frequency histogram for criterion 7

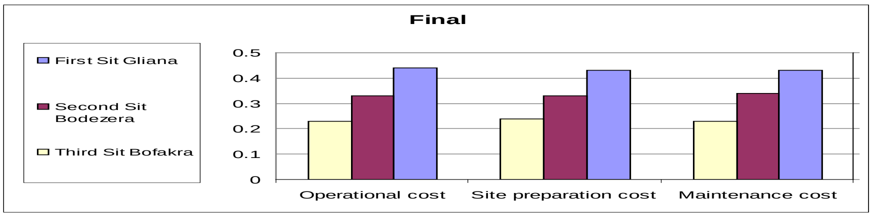

Figure 19: Frequency histogram for criterion 8

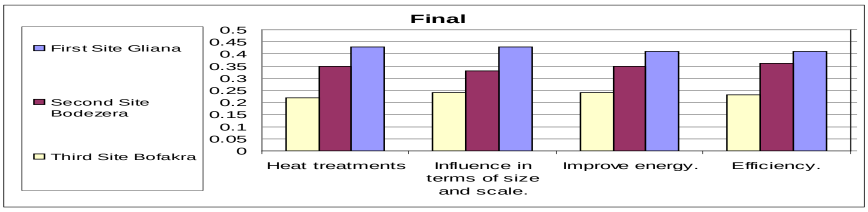

Figure 20: Frequency histogram for criterion 9

4. AHP Implementation

The weighted values rendered from the questionnaires for both the main criteria of the sub-criteria under the main criteria are considered in the AHP technique in the aim to determine the most suitable hospital location site of the available three site location. However the matrix is constructed for each site to determine the total weight for that site. However these matrices are presented and calculated as follows:

Criteria	Gilliana		Bodezera		Bofakhara	
1	0.34095	$= \sum 5.72515/9 = 0.64$	0.256275	$= \sum 3.944175/9 = 0.44$	0.1053	$= \sum 1.65214/9 = 0.18$
2	0.2771		0.471825		0.210425	
3	0.33165		0.24925		0.114375	
4	1.0916		0.829885		0.312755	
5	0.88015		0.59514		0.27756	
6	0.70345		0.485675		0.1625	
7	0.535		0.352625		0.1625	
8	0.74535		0.4756		0.19915	
9	0.3699		0.2279		0.107575	

From the above calculation of the three matrices it is clear that the same result has been obtained for the same site which is Giliana.

5. Conclusions

Selecting a particular site location is a multi-criteria decision making (MCDM) problem which is subjected to multi conflicting tangible and intangible criteria. Some of the locations under consideration for selection process might be good with respect to some criteria, but poor under other criteria. In the current study the selection criteria for hospital location selection are studied in the aim of determining the hospital selection criteria. The criteria are determined and tested with the requirements of Libyans culture through two designed questionnaires in the aim of determining the relative importance to each other. Also the sub-criteria under each main criteria element are determined and their relative importances are determined. All these criteria elements are evaluated against the proposed available sites. A statistical analysis has been used to determine the best location of the available locations and it is recommended that Giliana is the best location for construction of a new hospital in Benghazi. Also the AHP technique is used to evaluate these three sites based on the main criteria and sub-criteria priorities rendered from the analyzed questionnaires and it proofed that also Giliana site is the best location for hospital construction.

References

1. Vahidnia M., Alesheikh A., and Alimohammadi A., Hospital site selection using fuzzy AHP and its derivatives. Journal of Environmental Management, **90**(10): p. 3048-3056. 2009.
2. Jordan H., et al., Distance, reality and the need for care: access to health services in South West England. International Journal of Health Geographic's, **3**: p. 1-9. 2004.
3. Brabyn L. and Skelly C., Modeling population access to New Zealand public hospitals. International Journal of Health Geographic's, **1**: p. 1-9. 2002.
4. Mergias, I., et al., Multi-criteria decision aid approach for the selection of the best compromise management scheme for ELVs: The case of Cyprus, Journal of Hazardous Materials, **147**: p. 706-717, 2007.
5. Saaty, T.L., The analytic hierarchy process, New York: McGraw-Hill, 1980.
6. Dey, P.K., Ramcharan, E.K., Analytic hierarchy process helps select site for limestone quarry expansion in Barbados. Journal of Environmental Management, 88, 1384–1395, 2008.
7. Aslani, M., and Alesheikh, A., A., Site selection for small gas stations using GIS, Scientific Research and Essays Vol. 6(15), pp. 1361-3171, 2011.
8. Dalalah, D., Faris, A.,O., and Hayajneh, M.,Application of the Analytic Hierarchy Process (AHP) in Multi-Criteria Analysis of the Selection of Cranes, Jordan Journal of Mechanical and Industrial Engineering, JJMIE Volume 4, Number 5, November, pp. 567-578, 2010.
9. Chang, N.B., Parvathinathan, G., Breeden, J.B., Combining GIS with fuzzy multi-criteria decision-making for landfill siting in a fast-growing urban region. Journal of Environmental Management 87, 139–153, 2008.
10. Witlox, F., Expert systems in land-use planning: an overview. Expert Systems with Applications 29, 437–445, 2005.
11. Boroushaki, S., Malczewski, J., Implementing an extension of the analytical hierarchy process using ordered weighted averaging operators with fuzzy quantifiers in ArcGIS. Computers & Geosciences 34, 399–410, 2008.
12. Linkov, I., Satterstrom, F.K., Steevens, J., Ferguson, E., Pleus, R.C., Multi-criteria decision analysis and environmental risk assessment for nanomaterials. Journal of Nanoparticle Research 9, 543–554, 2007.
13. Lee, A.H.I., Chen, W.C., Chang, C.J., A fuzzy AHP and BSC approach for evaluating performance of IT department in the manufacturing industry in Taiwan. Expert Systems with Applications 34, 96–107, 2008.
14. Hosseinali, F., Alesheikh, A.A., Weighting spatial information in GIS for copper mining exploration. American Journal of Applied Sciences 5, 1187–1198, 2008.
15. Norman M. Goldfarb, Questions in Site Selection Questionnaires, journal of clinical research best practices, Vol. 5, No. 11, 2009.