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Development of Decision Support System for Optimal Site Selection of Desalination Plants

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Abstract:*In this paper, Decision Support System (DSS)for site selection of seawater desalination plant has beendeveloped. The general methodology includes two main steps for site selection. The first stepis togenerate a list of possible locations depending on the criterion of minimizing water transportation cost. This is established by using non-linear objective function.In the second step, the location is optimized using Multicriteria analysis(MCA) taking into account important factors affecting the optimization process.Each factor is given a weight according to its importance from one to eight. As a case study,the developed DSS is applied on coastal cities of northwest of Libya. Those cities located between Ras-EJdarand Musrata.Sample results are shown in this paper in order to explain the developed DSS.*

Keywords:*Decision Support System, Multi-criteria analysis,Desalination, Libya, Site Selection.*

I. Introduction

The increasing concern of governments and public to meet their multiple water demands within limited budgets made the search for alternative water demands inevitable. Desalination is becoming more effective alternative for water scarcity worldwide. In Libya, desalination becomes more cost competitive as ground water transported from the south needs to be pumped from lower levels which increases its price[1]. In addition, extraction of ground water from the south of Libya to cover the required water demand of the northern cities is recently proved to have serious environmental issues on the southern area of Libya[2].

The installation of a desalination facility represents a high capital cost investment. Therefore, the optimal selection and sitting of these facilities is critical. Site selection of a desalination plant is one of the most important decisions in planning a seawater desalination project. This decision affects the project capital and running cost, the project performance and possibly the project schedule. Site selection issue is not only a challenge related to desalination plants but also it considered a vital decision that might affect many other industries.

There are two general approaches to site selection, the numerical approach and the comparative approach. Usually a combination of the two approaches is required to come up with the site location final decision. Figure 1 shows the approaches used in site selection and some of their main aspects. The current approach to site selection of any desalination facility must take into account, in addition to engineering economic factors, a numerous of non-technical factors.

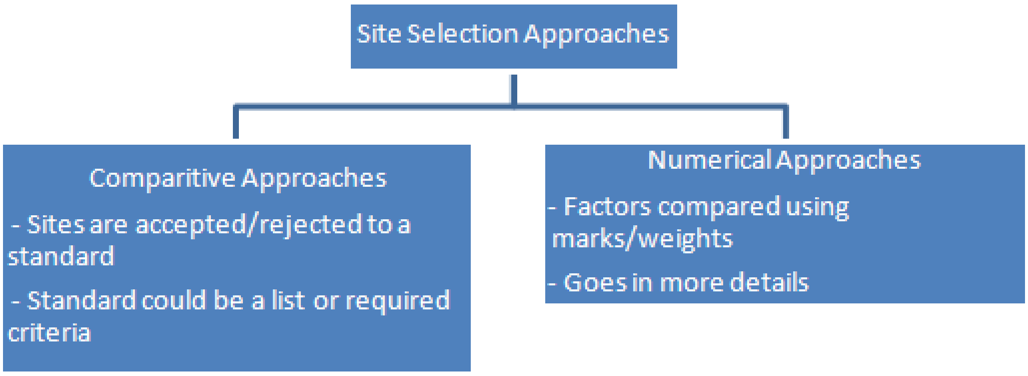

Figure 1: Site selection approaches.

The main objective of this study is to develop a robust decision support system to define optimum locations of desalination plants according to objective function and multi-criteria analysis under a variety of important constraints.

The Libyan coast can be considered as three separate entities, the northwest area, the middle north area, and the northeast area. The northwest area extends from Ras-Ejdair to Musrata and includes the cities ofRas-

Ejdair, Zoltun, Zwara, Subrata, Surman, Zawia, Tripoli, Qarabouli, Khomus, Zliten and Misurata. The middle north area extends from Musrata to Ejdabiaand includes the cities of Towerga, Esdada, Seret, Benjawad, Elsidera and Ejdabia. The northeast area extends from Ejdabia to Assalum and includes the cities of Benghazi, Shahat, Derna, Sosa, Tubruk and Assalum.

The northern west coast of Libya is considered as a case study in this paper wherenon-linear equation of second degree is applied in first step to determine candidate locations for desalination plants.In the secondstep, the multi-criteria analysis is applied on the candidate locations in order to identify best locations for seawater desalination plant.

II. The Methodology

In this study, the analytical models will be combined with traditional related dataand included in a computer program in order to obtainoptimum site selection of desalination plants. These steps can be described as Decision Support System (DSS) that istraditionally used to support managements and planning levels of business and organizationsin decision-making.

Figure 2 shows the flow chart of the decision support system for site selection of seawater desalination plant proposed in this study. The Decision Support System is developed in this paperfocuses on two important steps that summarize the methodology of the optimization. These two steps are solving the objective function to minimize the water transportation coast and identify candidate locations then applying multi-criteria analysis on all those locations in order to obtain best alternative location(s).

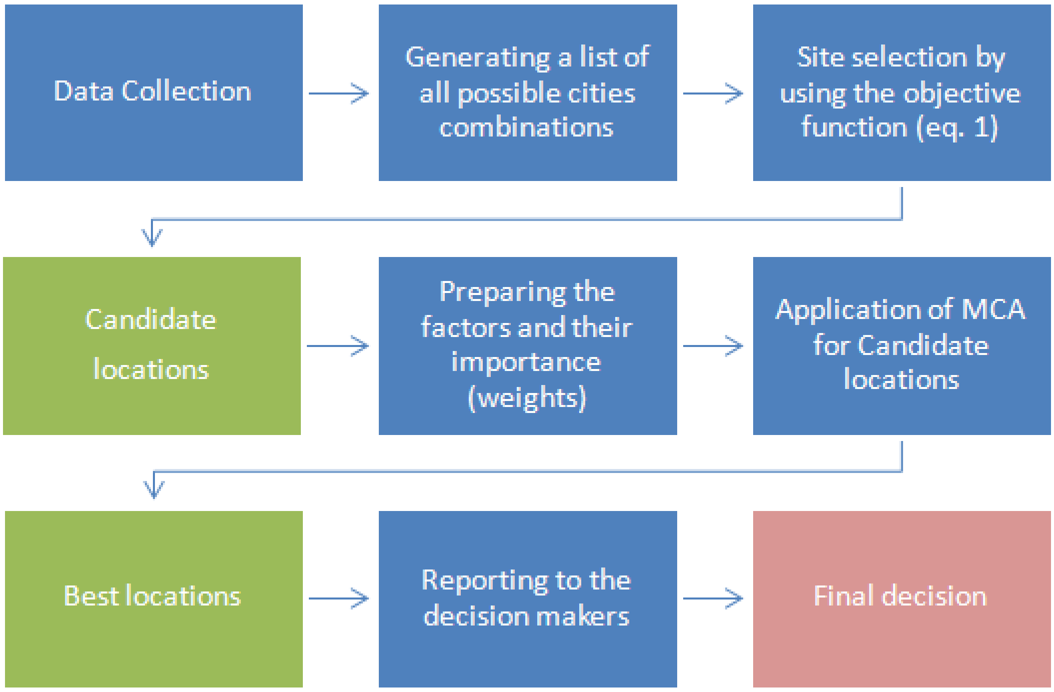

Figure 2: Block diagram of the Decision Support System (DSS) for Desalination Site Selection

1.1 Desalination Plant Site Selection

Methodsapplied in site selection problems offer considerable potential for application of analytical approaches in operations research. These methods can be utilized to find a plant location amongst a variety of possible locations that is considered the best solution according to certain criteria. The new plant can be considered as either a point location or an area location depending on the facility type. Facility location problems can be categorized into six elements: new facility characteristics, existing facility locations, new and existing facility interactions, solution space characteristics, distance measure, and the objective.

In the present study, the facility is considered as a point location, and the new facility characteristic is capacity. Assuming there are no desalination plants in the area of study, the existing facility locationas well as new and existing facility interaction elements can be ignored. The solution space characteristics and distance measures are determined through the prevailing geographic data available. In general, the objective is to find the following quantity[3].

$$\min \left\{ \sum_{i=1}^{n} Q_i \cdot [L_i(F, a_i)]^2 \right\} \qquad 1$$

Where

Q_i = The water demand for city i[m^3/day]

F = The location of the desalination plant

a_i = The location of city i

$L_i(F, a_i)$ = The absolute shortest distance between the desalination plant and city i

This quantity shown above presents the best location, from water transportation point of view, for a certain combination of cities. The solution of the above equation for all possible combination of cities is vital in deciding about cities that must be covered by a certain desalination plant.

1.2 Multi-criteria Evaluation Methods

There are various classifications of multi-criteria evaluation methods: discrete multiple criteria methods versus continuous multiple objective methods, and hard information methods versus soft information methods. Discrete methods only display a finite number of feasible choice possibilities, while continuous methods may encompass an infinite number of choice possibilities. Hard information means information measured on a cardinal scale, whereas soft information means information based on a qualitative scale.

In this study, one of the discrete multi-criteria cardinal methods,know as weighted summation [4], is used to provide a basis for classifying a number of alternative possibilities based on multiple criteria. This method has been chosen because it can handle a large number of objectives and still provide acceptable representation of decision maker’s preference. In addition, the weighted method transforms the multi-objective problem into a single optimization problem for which solution method exist. This method often uses two kinds of input data, an evaluation matrix and a set of political weights attached to the criterion scores that is included in the evaluation matrix.

For the selection of the location where the amount of transferred water is minimum, several alternatives have been studied. These alternatives include the establishment of a separate plant for each city and plants covering the demand of several cities. This choice is as follows:

In the first step of the selection, we determine the best location for the transfer of water using equation 1.

The second step is to subject the seriousness of the selected locations of the first step to multicriteria test so evident impact of external factors on the location chosen. These factors including near water source, water quality, near consumers, etc.

III. Data Collection

During the course of this work, a comprehensive data collection on each city and each potential site were conducted by reviewing the available studies and reports published by the National Water Authority of Libyaand others[5]. In addition to the water demand, the datacollected include among others, the geographical and environmental information, the distances between citiesand electric power generation facilities. By implementing the rating principle, each parameter was rated according to the data collected by assigning a value of eight for the parameter that has perfect conditions for a particular site. This procedure was adapted from a previous study carried out for North Africa [4].

The north-west coast of Libya contains mainly eleven cities starting from Ras-Eljdair at the far west (on the border of Tunisia) and ending at Musrata (in the middle of Libya).

Table ***1*** shows those cities where each city have been assigned an identification number.The water demand for each city and the progressive distance starting from Ras-Ejdair are also shown in the table.Figure 3 shows the cities in the north-west coast of Libya.

Table 1: City Id Number and respective water demand[5-7]

City	Id	Distance from Ras-Ejdair (km)	Water Demand (m^3/day)
Ras-Eljdair	1	0	2000
Zoltun	2	20	7300
Zwara	3	40	5780
Subrata	4	90	8940
Surman	5	100	13530
Zawia	6	120	20000
Tripoli	7	160	248900
Qarabouli	8	220	9000
Khomus	9	280	16670
Zliten	10	320	15000
Musrata	11	360	24940

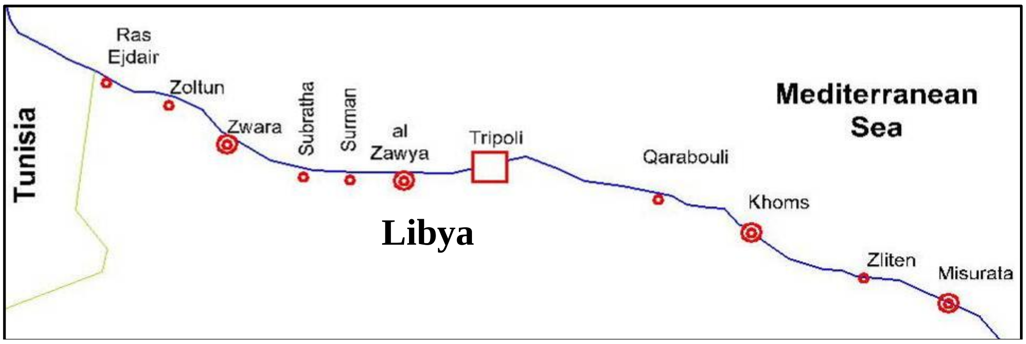

Figure 3:shows the cities of the North West coast

IV. Generation of possible combinations

For the selection of the best location, allpossible combination of the cities have been scheduled in table 2. Those combinations include the establishment of a separate desalination plant for every city (alternative number 56 to 66), one plant for all cities (alternative number 10) and designating a plant covering the demand of some cities (alternative number 1 to 9 and 11 to 55).

Table 2: The cities satisfied by the solutions and its distance to the proposed plant location.

No.	Cities Satisfied	Distance to the Proposed Plant (km)
1	1, 2	16,4
2	1, 2, 3	25,5,15
3	1, 2, 3, 4	49,29,9,41
4	1, 2, 3, 4, 5	68,48,28,22,32
5	1, 2, 3, 4, 5, 6	86,68,46,4,14,34
6	1, 2, 3, 4, 5, 6, 7	146,126,106,56,4,26,14
7	1, 2, 3, 4, 5, 6, 7, 8	148,128,108,58,48,28,12,72
8	1, 2, 3, 4, 5, 6, 7, 8, 9	155,135,115,65, 55,35,5,65,125
9	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	162,142,122,72,62,42,2,58,118,158
10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1775,155,135,85,75,55,15,45,105,145,185
11	2, 3	9,11
12	2, 3, 4	34,14,36
13	2, 3, 4, 5	51,31,19,29
14	2, 3, 4, 5, 6	69,49,1,11,31
15	2, 3, 4, 5, 6, 7	127,107,57,47,27,13
16	2, 3, 4, 5, 6, 7, 8	129,109,59,49,11,71
17	2, 3, 4, 5, 6, 7, 8, 9	136,116,65,55,35,5,65,125
18	2, 3, 4, 5, 6, 7, 8, 9, 10	143,123,73,63,43,3,57,117,157
19	2, 3, 4, 5, 6, 7, 8, 9, 10, 11	156,136,86,76,56,16,44104,144,184
20	3, 4	20,30
21	3, 4, 5	45,5,15
22	3, 4, 5, 6	59,9,1,21
23	3, 4, 5, 6, 7	110,60,50,30,10
24	3, 4, 5, 6, 7, 8	112,62,52,32,8,68
25	3, 4, 5, 6, 7, 8, 9	119,69,59,41,1,59,119
26	3, 4, 5, 6, 7, 8, 9, 10	126,76,66,48,8,52,112,152
27	3, 4, 5, 6, 7, 8, 9, 10, 11	139,89,79,59,19,41,101,141,181
28	4, 5	6,4
29	4, 5, 6	17,7,13
30	4, 5, 6, 7	63,53,33,7
31	4, 5, 6, 7, 8	64,54,34,6,66
32	4, 5, 6, 7, 8, 9	71,61,41,1,59,119
33	4, 5, 6, 7, 8, 9, 10	78,68,48,8,52,111,151
34	4, 5, 6, 7, 8, 9, 10, 11	92,82,62,22,38,98,138,178
35	5, 6	12,8
36	5, 6, 7	54,34,6
37	5, 6, 7, 8	56,36,4,64
38	5, 6, 7, 8, 9	63,43,3,57,117
39	5, 6, 7, 8, 9, 10	70,50,10,50,110,130
40	5, 6, 7, 8, 9, 10, 11	84,64,24,36,99,139,179
41	6, 7	37,3

42	6, 7, 8	39,1,61
43	6, 7, 8, 9	46,6,54,114
44	6, 7, 8, 9, 10	53,13,47,107,147
45	6, 7, 8, 9, 10, 11	58,18,42,102,142,182
46	7, 8	2,58
47	7, 8, 9	9,51,111
48	7, 8, 9, 10	17,43,103,143
49	7, 8, 9, 10, 11	32,28,88,128,168
50	8, 9	39,21
51	8, 9, 10	61,1,39
52	8, 9, 10, 11	91,31,9,49
53	9, 10	19,21
54	9, 10, 11	46,6,34
55	10, 11	25,15
56	1	0
57	2	0
58	3	0
59	4	0
60	5	0
61	6	0
62	7	0
63	8	0
64	9	0
65	10	0
66	11	0

V. Results and Discussion

In the first step mentioned before,equation 1is applied on the 66 possibilities shown in Table 2,thebest location for the desalination plant is determined for every alternative. The third column in table shows the distances between the cities of consideration and the best-chosen location of the desalination plant, where demand of different cities affect the calculated best location.

Alternative number two is studied in details in order to illustrate the decision support system developed in this work. Alternativenumber two includes the three cities of Ras-Eljdair (Id 1), Zoltun(Id 2) and Zwara (Id 3). Figure 4 shows the results obtained by using equation 1 along the distance between the three cities. The curve represents the objective functions at different locations. It is clear from the curve that the minimum point of the objective function occurs in a point between the selected cities. However, for any other alternative the suggested location should be found in some point in between or on the border cities for the selected alternative. When the objective function is applied on alternative number2the minimum value of the objective function found to be between the cities of Zoltun and Zwara. The suggested location by the first step is at place of25 km from Ras-Eljdair and it is tooclose to the city of Zoltun due to the high water demand at this city. This location is also shown on Figure 5.

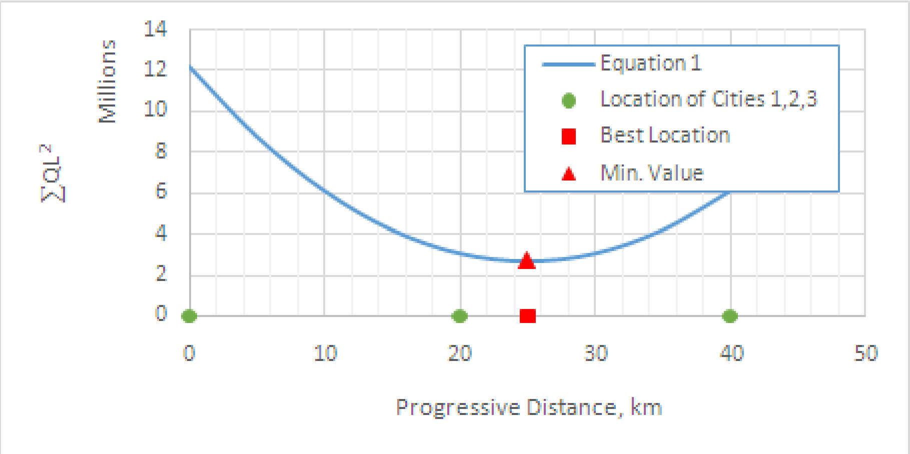

Figure 4: Desalination plant site selection for alternative number 1 according to equation 1.

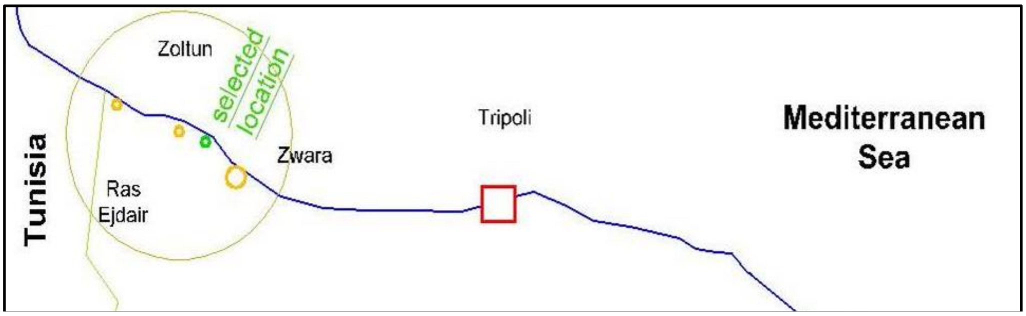

Figure 5: Desalination plant site selection for alternative number 2 according to equation 1.

The second step is to subject the selected locations obtained from the first step to multi-criteria tests. Table 3 shows the candidate locations for the site selection for alternative number two. Four locations are suggested in this work. The locations are the three cities (1,2, 3) and the suggested location obtained by the objective function which is about 25 km from city 1.

Table 3 shows that for this alternative the category scores are equal for most criterion such as existing sources of water products, vicinity electricity sources, product water selling price, regulations and land availability. The main parameter that affects the total score is the quality of seawater.

The suggested location (last column) is easier to access and presents the best water quality between the four places. Overall the forth location has a higher score than the other locations (the three included cities in this alternative).

Table 3: Relative weight for each city in the North West area according to each criteria(MCA applied on alternative number 2)

Weight per category %	Maker criteria	single criterion weight %	City id number							
			1		2		3		Suggested location	
			Rating		Rating		Rating		Rating	
20	Raw water proximity	50	8	4	8	4	8	4	8	4
	Raw water quality	50	4	2	2	1	2	1	6	3
	• category total			6		5		5		7
	• category share			1.2		1		1		1.4
15	Existing source of product supply	100	2	2	2	2	2	2	2	2
	• category total			2		2		2		2
	• category share			0.3		0.3		0.3		0.3
15	product water distribution net work	30	2	0.6	2	0.6	4	1.2	2	0.6
	proximity of consumers	50	2	1	2	1	4	2	2	1
	integration in industrial network	20	2	0.4	2	0.4	2	0.4	2	0.4
	• category total			2		2		3.6		2
	• category share			0.3		0.3		0.54		0.3
15	vicinity power plants/electrical network	100	4	4	4	4	4	4	4	4
	• category total			4		4		4		4
	• category share			0.6		0.6		0.6		0.6
10	product water selling price	40	6	2.4	6	2.4	6	2.4	6	2.4
	energy cost	20	6	1.2	6	1.2	6	1.2	6	1.2
	manpower cost	20	6	1.2	6	1.2	6	1.2	6	1.2
	financial parameters	20	6	1.2	6	1.2	6	1.2	6	1.2
	• category total			6		6		6		6
	• category share			0.6		0.6		0.6		0.6
10	local regulation and applicable standard	100	6	6	6	6	6	6	6	6
	• category total			6		6		6		6
	• category share			0.6		0.6		0.6		0.6
10	skill of labor/contractor	100	2	2	2	2	2	2	2	2
	• category total			2		2		2		2
	• category share			0.2		0.2		0.2		0.2
5	land availability	25	5	1.25	5	1.25	5	1.25	5	1.25
	Access	75	6	4.5	6	4.5	6	4.5	6	4.5
	• category total			5.75		5.7		5.7		5.7
	• category share			0.29		0.29		0.29		0.29
Total				4.09		3.89		4.13		4.29

Finally, all possibilities shown in table 1 should be subjected to the same Multicriteria analysis in order to conclude the final locations.

VI. Summary and Conclusions

In this paper a Decision Support System for seawater desalination plant citing and sizing is developed. The system consists of two main steps: applying the objective function to minimize water transportation costs and then applying Multicriteria analysis to select the best locations.

Based on the analysis along with the case study and results and dissuasion presented in this paper, the following conclusions can be drawn; first, the work provides a suitable tool for the decision makers concerning the optimum location of desalination facilities.In order to obtain good results from the multi-criteria methodology, an accurate knowledge of the various parameters and their weights is required. Although the numerical approach is used in this study, comparative approach on some factors needs to be conducted in order to allow professional personals to make their final decisions.

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