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Strategic Planning of Water System Projects in Alexandria

Hesham A. Abdel Khalek[1], Remon F. Aziz[2] and Noha M. Sabry[3]

[1] *Professor of Construction, Engineering and Management, Structural Engineering Department, Faculty of Engineering, Alexandria University, Alexandria, Egypt.*
[2] *Associate Professor, Structural Engineering Department, Faculty of Engineering, Alexandria University, Alexandria, Egypt.*
[3] *M. Eng. Candidate, Structural Engineering Department, Faculty of Engineering, Alexandria University, Alexandria, Egypt.*

ABSTRACT
Alexandria is one of the major cities on the Mediterranean Sea. Over the past 40 years, Alexandria's population has doubled. Therefore Water requirements are continuously increasing due to population increase. This paper develops a framework to support decision-makers in water sector for planning major projects in Alexandria till 2037. Firstly, data gathering has been conducted and population forecasting is calculated by arithmetic and geometric methods then the future water demands are calculated, after that major projects outline is proposed. Finally the projects priorities will be determined by applying two methods of solving Multiple Criteria Decision Making MCDM problems. The first method is The Weighted Scoring Method; WSM is a powerful and flexible method of comparing similar items against a standard, prioritized list of requirements or criteria. The second method is Analytical Hierarchy Process. AHP is based on comparative evaluation method. Then Results will be analyzed. First, it was focused on the difference of the criteria weight of alternatives between the two methods. Second, it was compared the preference orders of alternatives between them, there were not much of differences in the final results. The results offered some evidence that AHP makes the selection process very transparent.

Keywords: Planning, Water System Projects, Weighted Scoring Method, Analytical Hierarchy Process, Multiple Criteria Decision Making, Alexandria, Egypt.

I. INTRODUCTION

Alexandria is one of the major cities on the Mediterranean Sea and Egypt's second largest metropolitan. It is the most downstream city on the Nile River, with Egypt being its most downstream country.

Nile water is the main water supply to Alexandria (and indeed the whole of Egypt) to meet agricultural, industrial, municipal and navigation water demands. The available Nile Water for Alexandria Governorate reaches it through two main canals El Nobaria canal and El Mahmoudia canal.

Alexandria is a summer destination, (population increases from 4.5 million capita in winter to 6 million capita in summer).Over the past 40 years, Alexandria's population has doubled, and Therefore Water requirements in Egypt are continuously increasing due to population increase. Also the high population growth rates in Alexandria will exaggerate the problems associated with water sector allocation.

One of the most problems facing the water sector in Egypt is the limited quantity of raw water despite the continuing population increase in addition to the lack of funding for the new infrastructure projects, so decision makers in water sector have to choose carefully the needed projects and determine the appropriate priorities taking into consideration the major criteria affecting the future needs.

This paper develops a framework to support decision-makers in water sector for Planning major projects in Alexandria till 2037 by identifying the gap between the current situation and the future state & suggesting projects needed to fill this gap then applying two methods of solving MCDM problems to determine the priorities of proposed projects, The Weighted Scoring Method (WSM) and The Analytical Hierarchy Process (AHP).

II. BACKGROUND

Utility planning processes typically involve a series of consistent and predictable activities that encompass Identifying goals, setting objectives, assessing alternatives and developing a financial Planning for Sustainability strategy. Relevant information often includes population growth projections, the location and nature of planned development, and zoning changes.

Water demand is the volume of water used by all customer categories including residential, commercial, industrial & governmental. The per capita demands in Alexandria may change a little in the future. Water managers forecast future water demand to help them understand future water use to optimize system operations, plan for future water purchases or system expansion, or for future revenue and expenditures. The most traditional means of forecasting future water demand has been to estimate current per-capita water consumption, and multiply this by expected future population.

III. Planning of water system projects in Alexandria

3.1 Planning criteria

Existing demands for Alexandria were analyzed and computed for the year 2012 based on an analysis for the existing water consumptions and existing population estimates. Water demand projections for all major water users throughout the paper limits were developed for the base year (generally 2012) and then at 5-year intervals from 2012 to 2037.

3.2 Population

Estimates of future population are a critical part of forecasting water demand. In this paper population forecasting is calculated by arithmetic and geometric methods then the future water demands are calculated.

Population growth rates are provided by Master plan of Alexandria Water Company till 2037 which is based on a review of several population studies

3.2.1 Arithmetical increase method

This method is suitable for large and old city with considerable development. If it is used for small, average or comparatively new cities, it will give low result than actual value. Therefore, Population after nth decade will be

Pn = P + n.C

Where, **Pn** is the population after **n** decade and **P** is present population

dP/dt = C i.e. rate of change of population with respect to time is constant.

Table 1. The projected population of Alexandria from 2012 to 2037 calculated by the arithmetical method

Districit	Qism	2011	2012		2017		2022		2027		2032		2037	
		population	population	Growth rate	population	Growth rate	population	Growth rate	population	Growth rate	population	Growth rate	population	Growth rate
Montaza	Montaza	1255604	1278205	1.8	1390048	1.75	1508202	1.7	1632629	1.65	1763239	1.6	1899890	1.55
East	Ramel awel	417291	423133	1.4	452329	1.38	483088	1.36	515455	1.34	549475	1.32	585190	1.3
	Sidi gaber	242008	245154	1.3	260844	1.28	277277	1.26	294468	1.24	312431	1.22	331177	1.2
	Ramel tani	392030	397518	1.4	424947	1.38	453844	1.36	484251	1.34	516212	1.32	549765	1.3
Middle	Bab Sharki	220156	221587	0.65	228789	0.65	235652	0.6	241544	0.5	247582	0.5	253153	0.45
	Mohram Bek	313822	316019	0.7	326289	0.65	336078	0.6	345320	0.55	353953	0.5	361917	0.45
	El Ateeren	22803	22963	0.7	23709	0.65	24420	0.6	25092	0.55	25719	0.5	26298	0.45
El Gomerk	El Gomerk	87998	87558	0.5-	84931	0.6-	81959	0.7-	78680	0.8-	75140	0.9-	71383	1-
	El Labaan	37733	37884	0.4	38547	0.35	39125	0.3	39614	0.25	40010	0.2	40310	0.15
	El Manshis	23918	24014	0.4	24434	0.35	24800	0.3	25110	0.25	25362	0.2	25552	0.15
	El Mina	1479	1472	0.45-	1437	0.48-	1400	0.51-	1363	0.54-	1324	0.57-	1284	0.6-
West	Mina El Basel	290035	294821	1.65	318406	1.6	343083	1.55	368814	1.5	395553	1.45	423242	1.4
	Karmoz	128455	129290	0.65	133169	0.6	136831	0.55	140252	0.5	143407	0.45	146275	0.4
El Ameria	El Amria	539189	554286	2.8	634658	2.9	729856	3	842984	3.1	977862	3.2	1139209	3.3
El Agamy	El Dekila	369200	378799	2.6	429937	2.7	490128	2.8	561197	2.9	645376	3	745410	3.1
Part of El Behira governerate served by AWCO	—	148760	152628	2.6	172469	2.6	194890	2.6	220226	2.6	248856	2.6	281207	2.6
Borg El Arab City	Borg El Arab	108541	114619	5.6	147859	5.8	171960	3.26	199473	3.2	219421	2	236974	1.6
The North coast inside the borders of Matrouh Governeratre	—	253022	261118	3.2	302897	3.2	351361	3.2	407578	3.2	472791	3.2	548437	3.2
Total	—	4852044	4941068	—	5395699	—	5883954	—	6424050	—	7013711	—	7666673	—

3.2.2 Geometrical increase method

This method should be applied for a new industrial town at the beginning of development for only few decades. The population at the end of nth decade 'Pn' can be estimated as:

Pn = P (1+ IG/100) n

Where, IG = geometric mean (%) , P = Present population , n = no. of decades.

This method is useful for cities which have unlimited scope for expansion and where a constant rate of growth is anticipated.

Table 2. The projected population of Alexandria from 2012 to 2037 calculated by the geometric method

Districit	Qism	2011	2012		2017		2022		2027		2032		2037	
		population	population	Growth rate	population	Growth rate	population	Growth rate	population	Growth rate	population	Growth rate	population	Growth rate
Montaza	Montaza	1255604	1278205	1.8	1394031	1.75	1516622	1.7	1645941	1.65	1781898	1.6	1924343	1.55
East	Ramel awel	417291	423133	1.4	453146	1.38	484810	1.36	518174	1.34	553289	1.32	590200	1.3
	Sidi gaber	242008	245154	1.3	261251	1.28	278130	1.26	295807	1.24	314297	1.22	333612	1.2
	Ramel tani	392030	397518	1.4	425715	1.38	455462	1.36	486806	1.34	519795	1.32	554472	1.3
Middle	Bab Sharki	220156	221587	0.65	228883	0.65	235832	0.6	241787	0.5	247893	0.5	253521	0.45
	Mohram Bek	313822	316019	0.7	326424	0.65	336335	0.6	345686	0.55	354415	0.5	362462	0.45
	El Ateeren	22803	22963	0.7	23719	0.65	24439	0.6	25118	0.55	25753	0.5	26337	0.45
El Gomerk	El Gomerk	87998	87558	0.5-	84963	0.6-	82030	0.7-	78801	0.8-	75318	0.9-	71627	1-
	El Labaan	37733	37884	0.4	38552	0.35	39133	0.3	39625	0.25	40023	0.2	40324	0.15
	El Manshis	23918	24014	0.4	24437	0.35	24806	0.3	25117	0.25	25369	0.2	25560	0.15
	El Mina	1479	1472	0.45-	1437	0.48-	1401	0.51-	1364	0.54-	1325	0.57-	1286	0.6-
West	Mina El Basel	290035	294821	1.65	319173	1.6	344688	1.55	371327	1.5	399040	1.45	427766	1.4
	Karmoz	128455	129290	0.65	133215	0.6	136919	0.55	140377	0.5	143564	0.45	146458	0.4
El Ameria	El Amria	539189	554286	2.8	639457	2.9	741305	3	863556	3.1	1010855	3.2	1189024	3.3
El Agamy	El Dekila	369200	378799	2.6	432774	2.7	496852	2.8	573197	2.9	664492	3	774075	3.1
Part of El Behira governerate served by AWCO	____	149673	153564	2.6	174593	2.6	198502	2.6	225684	2.6	256589	2.6	291726	2.6
Borg El Arab City	Borg El Arab	108541	114619	5.6	151945	5.8	178380	3.26	208807	3.2	230540	2	249583	1.6
The North coast inside the borders of Matrouh Governeratre	____	255327	263497	3.2	308443	3.2	361055	3.2	422641	3.2	494732	3.2	579120	3.2
Total	—	4855262	4944384	—	5422157	—	5936700	—	6509816	—	7139187	—	7841495	—

3.2.3 The average

In normal practice, arithmetic and geometric growth average is taken, as well as Alexandria had some districts which have achieved saturation conditions specially places near the sea also there is some places in the south & the west which have unlimited scope for expansion so it will be taken the projected population of Alexandria from 2012 to 2037 as the average for the arithmetical and geometric methods.

Table 3. The projected population of Alexandria from 2012 to 2037 calculated by taking the average of the arithmetical and geometric methods

Districit	2011	2012	2017	2022	2027	2032	2037
Montaza	1255604	1278205	1392040	1512412	1639285	1772568	1912116
East	1051329	1065806	1139116	1216305	1297481	1382749	1472208
Middle	556781	560568	578906	596378	612274	627657	641844
El Gomerk	151128	150928	149369	147327	144837	141936	138663
West	418490	424111	451982	480760	510384	540782	571871
El Ameria	539189	554286	637057	735581	853270	994358	1164116
El Agamy	369200	378799	431356	493490	567197	654934	759742
Part of El Behira governerate served by AWCO	149216	153096	173531	196696	222955	252722	286466
Borg El Arab City	108541	114619	149902	175170	204140	224980	243279
The North coast inside the borders of Matrouh Governerate	254174	262308	305670	356208	415110	483762	563779
Total	4853653	4942726	5408928	5910327	6466933	7076449	7754084

3.3 Water Demands Per Capita Demands:

Firstly, Data collection process has been done to collect data about AWCO's Branches consumptions divided into each category of water use (domestic, commercial, industrial, etc) as shown in Table 4, then the percentage of each category of water use in each branch has been calculated.

Table 4: AWCO's Branches consumptions & also the percentage of each category of water use in each branch

Districit	2011	2012	2017	2022	2027	2032	2037
Montaza	1255604	1278205	1392040	1512412	1639285	1772568	1912116
East	1051329	1065806	1139116	1216305	1297481	1382749	1472208
Middle	556781	560568	578906	596378	612274	627657	641844
El Gomerk	151128	150928	149369	147327	144837	141936	138663
West	418490	424111	451982	480760	510384	540782	571871
El Ameria	539189	554286	637057	735581	853270	994358	1164116
El Agamy	369200	378799	431356	493490	567197	654934	759742
Part of El Behira governerate served by AWCO	149216	153096	173531	196696	222955	252722	286466
Borg El Arab City	108541	114619	149902	175170	204140	224980	243279
The North coast inside the borders of Matrouh Governerate	254174	262308	305670	356208	415110	483762	563779
Total	4853653	4942726	5408928	5910327	6466933	7076449	7754084

no		Branch	Consumption (m3)	Type of use (%)			
				Domestic	commercial , a variety of activites , tourism and investement	Administrtive , Governmental , public gardens and reduced meters	Industrial
1	Middle branches	El Bald	23526805	64.11	15.01	20.88	0.00
2		Muharam Bek	46569163	85.38	1.08	9.08	4.45
3		El Ibrahimia	35471077	77.84	10.29	11.88	0.00
4		El Kabari	45074190	64.02	2.09	8.98	24.91
5		El Nozha	22270381	87.22	3.26	7.19	2.34
6	East branches	El Ramel	57390935	75.50	1.89	19.91	2.71
7		El Mandara	79845775	74.92	11.15	13.93	0.00
8		Sidi Besher	66408753	87.21	3.21	6.40	3.18
9		Abu Kir	24802510	54.96	4.92	36.48	3.63
10	West branches	El Amria	55903643	69.26	25.16	3.65	1.92
11		El Agami	54590283	70.81	10.27	3.19	15.73
12		El sahal	67982013	34.45	64.98	0.16	0.40
13		Borg El Arab	23203284	19.58	1.59	30.76	48.07
14		El Nobaria	17747758	32.91	7.41	59.53	0.16
15		El Mina	1213430	0.00	7.08	92.92	0.00
16		Part of El Behira governerate served by AWCO	4509299	10.98	33.58	55.44	0.00
17		The North coast inside the borders of Matrouh Governeratre	45210988	100.00	0.00	0.00	0.00

Then, AWCO's Branches consumptions will be used to estimate Alexandria's administrative districts water demands through matching the service area maps of AWCO's branches and the service area maps of Alexandria's administrative to estimate the percentage of the area of each branch service area inside the containing district service area and use it to estimate Alexandria's administrative districts service area water demands

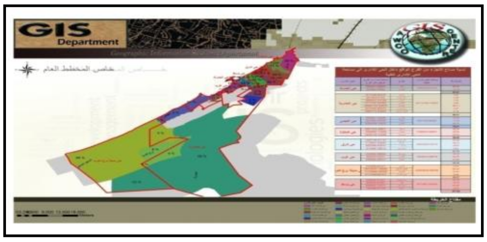


Fig 1: GIS map shows the service area of AWCO's branches and the service area of Alexandria's administrative districts

The consumption will be divided by the population for each service area to compute a per capita demand rate (lit/day/cap) for each district for the year 2011. These calculations are summarized in table 5 and are the basis for all future years.

Table 5: Per capita water consumptions for Alexandria's administrative districts for each category of water use for each district of Alexandria

Districit	Population 2011	District consumption (m3)	per capita consumption (lit/day)	per capita consumption for each category of water use (lit/day)			
				Domestic	commercial	Administrtive	Industrial
Montaza	1255604	162901864	355	268	23	55	9
East	1051329	58425806	152	127	8	15	3
Middle	556781	60267961	297	237	21	32	6
El Gomerk	151128	13493517	245	173	35	26	11
West	418490	39009510	255	179	5	22	50
El Ameria	539189	151890177	772	517	194	20	40
El Agamy	369200	41197495	306	204	26	25	50
Part of El Behira governerate served by AWCO	149216	4509299	83	0	0	0	0
Borg El Arab City	108541	45098038	1138	460	527	84	68
The North coast inside the borders of Matrouh Governeratre	254174	45210988	487	0	0	0	0

The water demands will be computed for future years by multiplying the projected populations by the per capita demand in each service area.

There are also two assumptions which have assumed regarding to AWCO data for previously years, the water fire which is assumed as a constant number and the losses which are assumed as a constant number about 35%.

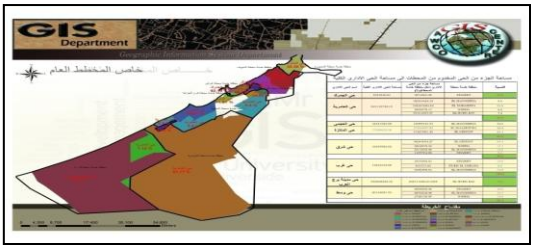
Also the per capita demand will be analyzed and future demands for the future years 2012, 2017, 2022, 2027, 2032 and 2037 are computed for each service area using the per capita demand approach.

Table 6: The projected water demand and per capita water demand for Montaza district for future years

Category of water use		Years					
		2012	2017	2022	2027	2032	2037
Population		1278	1392	1512	1639	1773	1912
Domestic	m3/day	342559	373067	405326	439328	475048	512447
Commercial	m3/day	29399	32017	34785	37704	40769	43979
Administrtive	m3/day	70301	76562	83183	90161	97491	105166
Industrial	m3/day	11504	12528	13612	14754	15953	17209
Water fire	m3/day	4320	4320	4320	4320	4320	4320
Total	m3/day	458083	498494	541226	586266	633582	683121
Losses	m3/day	246660	268420	291430	315682	341159	367835
Water demand	m3/day	704743	766914	832656	901948	974741	1050956
Per capita consumption	lit/day	551	551	551	550	550	550

Then, the calculated water demand of Alexandria's administrative districts service area will be used to estimate the required water demand of Alexandria's water treatment plants service area through matching the service area maps of Alexandria's administrative districts and the service area maps of Alexandria's water treatment plants to estimate the percentage of the area of each district service area inside the containing water treatment plant service area to estimate Alexandria's water treatment plants service area required water demand by calculating the sum of multiplication of the previous calculated percentage by the water demand of a each district service area inside the required water treatment plant service area .

Fig2: GIS map shows the service area of Alexandria's administrative districts and the service area of Alexandria's water treatment plants



The results of these calculations for water treatment plants are summarized in Table 7&8.

Table 7: Population, consumption and per capita consumption for each WTP

Table 8: The available water demand, the required water demand and the difference between them for each water treatment plant for future years

In table 8 , The amount of the difference between the available and the required water demand will give us an indication for the needed future projects in Alexandria.

3.4 Determine the projects needed to cover the gap till 2037:

Then the project plan will be determined by suggesting the new projects in water treatment plants & posters needed to cover the Gap in demand till 2037.

Table 9: The major needed projects to fill the water demand gap in Alexandria till 2037

IV. Determine projects priorities

The typical MCDM problem deals with the evaluation of a set of alternatives in terms of a set of decision criteria.

In this paper it will be presented two methods of solving MCDM problems and it will be applied these methods to determine the needed projects priorities, these methods are The Weighted Scoring Method (WSM) & Analytical Hierarchy Process (AHP).

4.1 **Data gathering:**

This step is concerning of collecting the needed data for determining the project priorities.

Table 10: The needed data for each criteria

4.2 The Weighted Scoring Method

4.2.1 Overview

Weighted Scoring method is a technique for using a consistent list of criteria, weighted according to the importance or priority of the criteria to the organization. In a technology evaluation, teams must evaluate and score projects against a set of evaluation criteria in order to determine the best choice to meet their needs

4.2.2 Evaluation criteria & weighing

In this step it will be established a set of evaluation criteria and, as appropriate, dividing the criteria among a set of categories. Then it was assigned weights to each criterion.

Table 11: Evaluation criteria and the weights

No	Criteria	Weight %
1	% of implementation of the project	30
2	Current service quality	25
3	Per capita water consumption	10
4	Project budget/capita	15
5	Population	20
Total		100

Each one of these criteria will be divided into six sub criteria and each one will have its own score

Table 12: Evaluation criteria and sub criteria and weights

4.2.3 Computing the overall score for each project:

Once the evaluation criteria, project scores, and evaluation weights have been determined, then it will be computed the overall score of each project, where n is the number of evaluation criteria.

As an example, the additive utility function with two evaluation criteria, a1 and a2, is:

u(a1, a2,) = w1 u1(a1)+ w2 u2(a2)

u1 and u2, scoring function(s) for criteria a1 and a2, respectively.

w1 and w2, individual weights assigned to each criterion.

Then scores will be determined for each criteria, and the summation of weight time's score for each criteria will be calculated for each project.

Table 13: The summation of weight times score for each criteria for each project

No	Item	Score	No	Item	Score	No	Item	Score
% of implementation :			**Current service quality (**Water pressure):			**Population :**		
1	% of implementation = 0	1	1	more than 20m	1	1	No data	1
2	% of implementation 1 – 10 %	2	2	From 15 to 20m	2	2	1000-10000	2
3	% of implementation 10-20%	3	3	From 12 to 15m	3	3	20000-10000	3
4	% of implementation 20-50%	4	4	From 9 to 12m	4	4	20000-50000	4
5	% of implementation 50-75%	5	5	From 6 to 9m	5	5	50000-500000	5
6	% of implementation more than 75%	6	6	Less than 6m	6	6	More than 500000	6
Per capita water consumption :			**Project budget/capita**					
1	More than or equal the code	1	1	More than 500 LE/cap	1			
2	Less than the code by 10%	2	2	From 400-500 LE/cap	2			
3	Less than the code by 10-20%	3	3	From 300-400 LE/cap	3			
4	Less than the code by 20-30%	4	4	From 200-300 LE/cap	4			
5	Less than the code by 30-40%	5	5	From 100-200 LE/cap	5			
6	Less than the code by more than 40%	6	6	Less than 100 LE/cap	6			

Finally the priorities will be determined as a result of the arrangement of the summation of weight time's score for each criteria for each project

Table 14: The projects arrangement regarding to their priorities

4.3 Analytical Hierarchy process (AHP)

4.3.1 Overview

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach and was introduced by Saaty (1977) and 1994.

The AHP is a decision support tool which can be used to solve complex decision problems. It uses a multi-level hierarchical structure of objectives, criteria, sub criteria, and alternatives.

No	Project	% of implementation of the project			Current service quality			Per capita water consumption			Project budget/capita			Population			Total
		weight	score	total	weight	score	total	weight	score	total	weight	score	total	weight	score	total	
1	Construction of Masnshia 2 WTP	30%	6	1.8	25%	1	0.25	10%	1	0.1	15%	3	0.45	20%	6	1.2	3.8
2	construction of raw water pump station in kafr dawar Booster Pump station.	30%	2	0.6	25%	2	0.5	10%	2	0.2	15%	3	0.45	20%	6	1.2	2.95
3	Feeding Borg el arab WTP from noubaria canal	30%	2	0.6	25%	1	0.25	10%	1	0.1	15%	1	0.15	20%	5	1	2.1
4	Construction of treated water pump station in km21 Booster pump station.	30%	2	0.6	25%	3	0.75	10%	3	0.3	15%	6	0.9	20%	5	1	3.55
5	Construction of reservoir & treated water pump station in sedi abd el kader Booster pump station.	30%	2	0.6	25%	1	0.25	10%	1	0.1	15%	6	0.9	20%	6	1.2	3.05
6	Expansionns of Borg El Arab WTP.	30%	2	0.6	25%	1	0.25	10%	1	0.1	15%	1	0.15	20%	5	1	2.1
7	Expansions of EL siouf WTP.	30%	2	0.6	25%	2	0.5	10%	2	0.2	15%	4	0.6	20%	6	1.2	3.1

AHP is based on comparative evaluation method; The AHP not only clearly identifies the most important alternative but also the preference for each alternative by each decision maker.

4.3.2 AHP analysis steps

The creator of analytical hierarchy process, Thomas L. Saaty, has stated that there are four different priorities which should be noted when performing an analysis based on analytical hierarchy process.

1. Define the problem and determine the kind of knowledge sought.
2. Structure the decision hierarchy from the top with the goal of the decision, then the objectives from a broad perspective, through the intermediate levels (criteria on which subsequent elements depend) to the lowest level (which usually is a set of the alternatives).
3. Construct a set of pairwise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it.
4. Use the priorities obtained from the comparisons to weigh the priorities in the level immediately below. Do this for every element. Then for each element in the level below add its weighed values and obtain its overall or global priority. Continue this process of weighing and adding until the final priorities of the alternatives in the bottom most level are obtained

4.3.3 AHP comparison scale

Pairwise comparisons are quantified by using a **scale**. It is noticed that people cannot compare between two very close values of importance. Also individuals cannot compare more than 7objects (plus or minus two). This is the main reasoning used by Saaty to establish 9 as the upper limit of his scale, 1 as the lower limit.

Table 15: Scale of Relative Importance

Intensity of Importance	Intensity of Importance	Intensity of Importance
1	Equal Importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgment slightly favor one activity over another
5	Essential or strong Importance	Expedience and judgment strongly favor one activity over another
7	Demonstrated Importance	An activity is strongly favored and its dominance demonstrated in practice
9	Absolute importance	the evidence favoring one activity over another is of the highest possible order of affirmation
2.4.6.8	Intermediate values between the two adjacent judgments	when compromise is needed

4.3.4 AHP Structure

The structure of the typical decision problem considered in this paper consists of a number, say M, of alternatives and a number, say N, of decision criteria. Each alternative can be evaluated in terms of the decision criteria and the relative importance (or weight) of each criterion can be estimated as well.

Let aij (i=1,2,3,...,M, and N=1,2,3,...,N) denote the performance value of the i-th alternative (i.e., Ai) in terms of the j-th criterion (i.e., Cj). Also denote as Wj the weight of the criterion Cj. Then, the core of the typical MCDM problem can be represented by the following decision matrix:

	C_1	C_2	C_3		C_N
Alt	W_1	W_2	W_3	.....	W_N
A1	a_{11}	a_{12}	a_{13}	.....	A_{1N}
A2	a_{21}	a_{22}	a_{23}	.....	A_{2N}
A3	a_{31}	a_{32}	a_{33}	.....	A_{3N}
.	.	.	.	.....	.....
.	.	.	.	.....	.....
A_M	a_{MI}	a_{M2}	a_{M3}	.....	a_{MN}

The AHP the pairwise comparisons in a judgment matrix are considered to be adequately consistent if the corresponding consistency ratio CR) is less than 10%.The CR coefficient is calculated as follows:

- λmax is found by λmax = average{Ax/x}
- Consistency index , CI is found by CI = (λmax-n)/(n-1)
- Consistency ratio , CR is found by CR=CI/RCI

Table 16: Scale RCI values for different values n.

n	1	2	3	4	5	6	7	8	9
RCI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Where A is the comparison matrix of size n×n, for n criteria, also called the priority matrix, x is the Eigenvector of size n×1, also called the priority vector, λmax is the Eigenvalue.

4.3.5 Determine Alexandria water system projects priorities using AHP

4.3.5.1 Establishment of the Hierarchical Structure:

1. <u>Objective:</u>
   Determine Alexandria water system projects priorities.
2. <u>Criteria</u>**:**
   In this point there is going to be five main criteria:
   1. % of implementation
   2. Current service quality.
   3. Per capita water consumption.
   4. Project budget/capita.
   5. Population.
3. <u>Alternatives:</u>
   1. Construction of Masnshia 2 WTP
   2. Construction of treated water pump station in km21 Booster pump station.
   3. Construction of reservoir & treated water pump station in Sedi abd el kader Booster pump station.
   4. Construction of raw water pump station in kafr Dawar Booster Pump station.
   5. Expansions of EL Siouf WTP.
   6. Feeding Borg el Arab WTP from Noubaria canal
   7. Expansions of Borg El Arab WTP.

4.3.5.2 Ranking Scale for Criteria and Alternatives

Table 17 :Ranking Scale for Criteria and Alternatives

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 over one activity 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	Absolute more important	The evidence favoring one over other is of the highest possible validity.
2.4.6.8	Intermediate Values.	Wien compromise is needed

4.3.5.3 Evaluation Criteria and Weighing

4.3.5.3.1 Weight between the Elements on

Different Levels

A=

1	2	4	3	2
1/2	1	5	4	1/3
1/4	1/5	1	1/3	1/4
1/3	1/4	3	1	1/3
1/2	3	4	3	1
2.58	6.45	17.00	11.33	3.92

Consider [$Ax = \lambda_{max}x$] where A is the comparison matrix of size n×n, for n criteria, also called the priority matrix, x is the Eigenvector of size n×1, also called the priority vector, λmax is the Eigenvalue.

4.3.5.3.2 **Normalize** the column entries by dividing each entry by the sum of the column.

Normalized columns =

0.39	0.31	0.24	0.26	0.51
0.19	0.16	0.29	0.35	0.09
0.10	0.03	0.06	0.03	0.06
0.13	0.04	0.18	0.09	0.09
0.19	0.47	0.24	0.26	0.26

4.3.5.3.3 **Take** the overall row averages.

X =

0.34
0.22
0.06
0.10
0.28

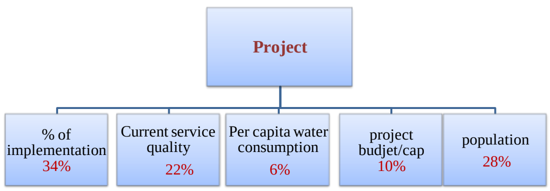


Fig 3: Hierarchy of criteria and criteria weight

4.3.5.3.4 **Checking** for consistency:

a) Calculation of **λmax:**

A

1	2	4	3	2
1/2	1	5	4	1/3
1/4	1/5	1	1/3	1/4
1/3	1/4	3	1	1/3
1/2	3	4	3	1

x		Ax
0.34		1.87
0.22		1.18
0.06	=	0.29
0.10		0.53
0.28		1.64

Consider [Ax = λmax x]

Ax		x
1.87		0.34
1.18		0.22
0.29	= λmax	0.06
0.53		0.10
1.64		0.28

b) Calculation of **Consistency index (CI) :**

CI = (λmax-n)/(n-1)

CI =(5.41-5)/(5-1)= 0.0.41/4= 0.1

c) Calculation of **Consistency ratio (CR) :**

CR=CI/RCI =0.1/1.12=0.09

0.09<0.1, so the evaluations are consistent!

4.3.5.4 Ranking of Alternatives:

<u>Criteria (1) : % of implementation of the project</u>

a) Weight between the Elements

A =

1	7	7	7	7	7	7
1/7	1	3	3	2	3	3
1/7	1/3	1	3	1/3	2	2
1/7	1/3	1/3	1	1/3	1/3	1/3
1/7	1/2	3	3	1	3	3
1/7	1/3	1/2	3	1/3	1	2
1/7	1/3	1/2	3	1/3	1/2	1
1.86	9.83	15.33	23.00	11.33	16.83	18.33

b) Normalize the column entries

c) Take the overall row averages.

x =

0.49
0.15
0.08
0.03
0.13
0.07
0.06

d) Checking for consistency:
Calculation of **λmax:**

A

1	7	7	7	7	7	7
1/7	1	3	3	2	3	3
1/7	1/3	1	3	1/3	2	2
1/7	1/3	1/3	1	1/3	1/3	1/3
1/7	1/2	3	3	1	3	3
1/7	1/3	1/2	3	1/3	1	2
1/7	1/3	1/2	3	1/3	1/2	1

x		Ax
0.49		4.06
0.15		1.18
0.08		0.59
0.03	=	0.26
0.13		0.98
0.07		0.48
0.06		0.39

Normalized columns =

0.54	0.71	0.46	0.30	0.62	0.4	
0.08	0.10	0.20	0.13	0.18	0.18	0.16
0.08	0.05	0.07	0.13	0.03	0.12	0.11
0.08	0.03	0.02	0.04	0.03	0.02	0.02
0.08	0.05	0.20	0.13	0.09	0.18	0.16
0.08	0.03	0.03	0.13	0.03	0.06	0.11
0.08	0.03	0.03	0.13	0.03	0.03	0.05

Consider [Ax = λmax x]

Ax		x
4.06		0.49
1.18		0.15
0.59		0.08
0.26	= λmax	0.03
0.98		0.13
0.48		0.07
0.39		0.06

λmax x]

- λmax = average{Ax/x}= <u>7.63</u>
- CI =(7.63-7)/(7-1)= <u>0.1</u>
- RCI= 1.32 for n=7
- CR =0.1/1.32= 0.08
- 0.08<0.1, so the evaluations are consistent!

<u>Criteria (2) : Current service quality</u>

a) Weight between the Elements

1	1/5	1/3	1/5	2	1/3	1/5
5	1	3	1/3	5	3	2
3	1/3	1	1/3	3	2	1/3
5	3	3	1	5	3	3
1/2	1/5	1/3	1/5	1	1/3	1/5
3	1/3	1/2	1/3	3	1	1/3
5	1/2	3	1/3	5	3	1
22.50	5.57	11.17	2.73	24.00	12.67	7.07

b) Normalize the column entries

Normalized columns =

0.04	0.04	0.03	0.07	0.08	0.03	0.03
0.22	0.18	0.27	0.12	0.21	0.24	0.28
0.13	0.06	0.09	0.12	0.13	0.16	0.05
0.22	0.54	0.27	0.37	0.21	0.24	0.42
0.02	0.04	0.03	0.07	0.04	0.03	0.03
0.13	0.06	0.04	0.12	0.13	0.08	0.05
0.22	0.09	0.27	0.12	0.21	0.24	0.14

c) Take the overall row averages.

x = [0.05, 0.22, 0.10, 0.32, 0.04, 0.09, 0.18]

d) Checking for consistency:
Calculation of **λmax:**

Consider [Ax = λmax x]

- λmax = average{Ax/x}= 7.44
- CI =(7.63-7)/(7-1)= 0.07
- RCI= 1.32 for n=7
- CR =0.07/1.32= 0.06
- 0.06<0.1, so the evaluations a consist ent!

A

1	1/5	1/3	1/5	2	1/3	1/5
5	1	3	1/3	5	3	2
3	1/3	1	1/3	3	2	1/3
5	3	3	1	5	3	3
1/2	1/5	1/3	1/5	1	1/3	1/5
3	1/3	1/2	1/3	3	1	1/3
5	1/2	3	1/3	5	3	1

x = [0.05, 0.22, 0.10, 0.32, 0.04, 0.09, 0.18] = **Ax** = [0.77, 2.52, 0.27, 0.63, 1.39]

Ax = [0.78, 1.69, 0.20, 2.70, 0.30, 0.24, 2.08] = **λmax** **x** = [0.10, 0.20, 0.03, 0.34, 0.04, 0.03, 0.25]

Ax = [0.33, 1.68, 0.77, 2.52, 0.27, 0.63, 1.39] = **λmax** **x** = [0.05, 0.22, 0.10, 0.32, 0.04, 0.09, 0.18]

Normalized columns =

0.06	0.03	0.16	0.08	0.18	0.17	0.05
0.30	0.15	0.23	0.14	0.25	0.24	0.12
0.01	0.02	0.03	0.06	0.02	0.02	0.03
0.30	0.45	0.23	0.41	0.25	0.24	0.48
0.01	0.02	0.06	0.06	0.04	0.07	0.03
0.01	0.02	0.06	0.06	0.02	0.03	0.03
0.30	0.30	0.23	0.20	0.25	0.24	0.24

<u>Criteria (3): Current Per capita water consumption</u>

a) Weight between the Elements

A =

1	1/5	5	1/5	5	5	1/5
5	1	7	1/3	7	7	1/2
1/5	1/7	1	1/7	1/2	1/2	1/7
5	3	7	1	7	7	2
1/5	1/7	2	1/7	1	2	1/7
1/5	1/7	2	1/7	1/2	1	1/7
5	2	7	1/2	7	7	1
16.60	6.63	31.00	2.46	28.00	29.50	4.13

Normalize the column entries

c) Take the overall row averages.

x =

0.10
0.20
0.03
0.34
0.04
0.03
0.25

d) Checking for consistency:
Calculation of **λmax:**

A

1	1/5	5	1/5	5	5	1/5
5	1	7	1/3	7	7	1/2
1/5	1/7	1	1/7	1/2	1/2	1/7
5	3	7	1	7	7	2
1/5	1/7	2	1/7	1	2	1/7
1/5	1/7	2	1/7	1/2	1	1/7
5	2	7	1/2	7	7	1

x		Ax
0.10		**0.78**
0.20		**1.69**
0.03		**0.20**
0.34	=	**2.70**
0.04		**0.30**
0.03		**0.24**
0.25		**2.08**

Consider [Ax = λmax x]

- λmax = average{Ax/x}= 7.65
- CI =(7.63-7)/(7-1)= 0.11
- RCI= 1.32 for n=7
- CR =0.11/1.32= 0.08
- 0.08<0.1, so the evaluations are consistent!

Criteria (4): : Project budget/capita

a) Weight between the Elements

A =

1	2	5	1/3	1/3	5	1/2
1/2	1	5	1/3	1/3	5	1/2
1/5	1/5	1	1/7	1/7	3	1/5
3	3	7	1	2	7	3
3	3	7	1/2	1	7	3
1/5	1/5	1/3	1/7	1/7	1	1/7
2	2	5	1/3	1/3	7	1
9.90	11.40	30.33	2.79	4.29	35.00	8.34

b) Normalize the column entries

c) Take the overall row averages.

x =

0.12
0.10
0.04
0.31
0.25
0.03
0.15

d) Checking for consistency:
Calculation of **λmax:**

Normalized columns =

[illegible]	0.18	0.16	0.12	0.08	0.14	0.06
0.05	0.09	0.16	0.12	0.08	0.14	0.06
0.02	0.02	0.03	0.05	0.03	0.09	0.02
0.30	0.26	0.23	0.36	0.47	[illegible]	0.36
0.30	0.26	0.23	0.18	0.23	0.20	0.36
0.02	0.02	0.01	0.05	0.03	0.03	0.02
0.20	0.18	0.16	0.12	0.08	0.20	0.12

A

1	2	5	1/3	1/3	5	1/2
1/2	1	5	1/3	1/3	5	1/2
1/5	1/5	1	1/7	1/7	3	1/5
3	3	7	1	2	7	3
3	3	7	1/2	1	7	3
1/5	1/5	1/3	1/7	1/7	1	1/7
2	2	5	1/3	1/3	7	1

x		Ax
0.12		0.90
0.10		0.74
0.04		0.27
0.31	=	2.38
0.25		1.97
0.03		0.18
0.15		1.15

Consider [Ax = λmax x]

Ax		x
0.90		0.12
0.74		0.10
0.27		0.04
2.38	= **λmax**	0.31
1.97		0.25
0.18		0.03
1.15		0.15

- λmax = average{Ax/x}= 7.46
- CI =(7.63-7)/(7-1)= 0.08
- RCI= 1.32 for n=7
- CR =0.08/1.32= 0.06
- 0.06<0.1, so the evaluations are consistent

Ax		x
1.94		0.23
3.01		0.37
0.35		0.05
0.20	= **λmax**	0.03
0.55		0.07
0.28		0.04
1.75		0.21

Criteria (5) : Population

a) Weight between the Elements

A =

1	1/3	7	7	5	7	2
3	1	7	7	7	7	3
1/7	1/7	1	3	1/3	2	1/7
1/7	1/7	1/3	1	1/3	1/3	1/7
1/5	1/7	3	3	1	3	1/7
1/7	1/7	1/2	3	1/3	1	1/7
1/2	1/3	7	7	7	7	1
5.13	2.24	25.83	31.00	21.00	27.33	6.57

b) Normalize the column entries

Normalized columns =

0.19	0.15	0.27	0.23	0.24	0.26	0.30
0.58	0.45	0.27	0.23	0.33	0.26	0.46
0.03	0.06	0.04	0.10	0.02	0.07	0.02
0.03	0.06	0.01	0.03	0.02	0.01	0.02
0.04	0.06	0.12	0.10	0.05	0.11	0.02
0.03	0.06	0.02	0.10	0.02	0.04	0.02
0.10	0.15	0.27	0.23	0.33	0.26	0.15

c) Take the overall row averages.

$$x = \begin{bmatrix} 0.23 \\ 0.37 \\ 0.05 \\ 0.03 \\ 0.07 \\ 0.04 \\ 0.21 \end{bmatrix}$$

d) Checking for consistency:
Calculation of **λmax:**

Consider [Ax = λmax x]

$$\underbrace{\begin{bmatrix} 1 & 1/3 & 7 & 7 & 5 & 7 & 2 \\ 3 & 1 & 7 & 7 & 7 & 7 & 3 \\ 1/7 & 1/7 & 1 & 3 & 1/3 & 2 & 1/7 \\ 1/7 & 1/7 & 1/3 & 1 & 1/3 & 1/3 & 1/7 \\ 1/5 & 1/7 & 3 & 3 & 1 & 3 & 1/7 \\ 1/7 & 1/7 & 1/2 & 3 & 1/3 & 1 & 1/7 \\ 1/2 & 1/3 & 7 & 7 & 7 & 7 & 1 \end{bmatrix}}_{A} \underbrace{\begin{bmatrix} 0.23 \\ 0.37 \\ 0.05 \\ 0.03 \\ 0.07 \\ 0.04 \\ 0.21 \end{bmatrix}}_{x} = \underbrace{\begin{bmatrix} 1.94 \\ 3.01 \\ 0.35 \\ 0.20 \\ 0.55 \\ 0.28 \\ 1.75 \end{bmatrix}}_{Ax}$$

- λmax = average{Ax/x}= 7.73
- CI =(7.73-7)/(7-1)= 0.12
- RCI= 1.32 for n=7
- CR =0.12/1.32= 0.09
- 0.09<0.1, so the evaluations are consistent!

4.3.5.5 Determine projects priorities

The last step in determining the best solution is to perform a matrix calculation between a matrix which includes weights for each alternative in terms of criteria and a matrix which includes all the weights for the criteria. When these two matrixes are added up, the final weights are received which then determine the final results to this analytical hierarchy process

$$\underbrace{\begin{bmatrix} 0.49 & 0.05 & 0.10 & 0.12 & 0.23 \\ 0.15 & 0.22 & 0.20 & 0.10 & 0.37 \\ 0.08 & 0.10 & 0.03 & 0.04 & 0.05 \\ 0.03 & 0.32 & 0.34 & 0.31 & 0.03 \\ 0.13 & 0.04 & 0.04 & 0.25 & 0.07 \\ 0.07 & 0.09 & 0.03 & 0.03 & 0.04 \\ 0.06 & 0.18 & 0.25 & 0.15 & 0.21 \end{bmatrix}}_{\text{Alternative weight}} \underbrace{\begin{bmatrix} 0.34 \\ 0.22 \\ 0.06 \\ 0.10 \\ 0.28 \end{bmatrix}}_{\text{Criteria weight}} = \underbrace{\begin{bmatrix} 0.26 \\ 0.22 \\ 0.07 \\ 0.14 \\ 0.10 \\ 0.06 \\ 0.15 \end{bmatrix}}_{\text{Priorities}}$$

Table 18 the projects arrangement regarding to their priorities

Priority	Project	Total
1	Construction of Masnshia 2 WTP	0.26
2	construction of raw water pump station in kafr dawar Booster Pump station.	0.22
6	Expansions of EL siouf WTP.	0.15
7	Construction of treated water pump station in km21 Booster pump station.	0.14
4	Construction of reservoir & treated water pump station in sedi abd el kader Booster pump station.	0.1
3	Feeding Borg el arab WTP from noubaria canal	0.07
5	Expansionns of Borg El Arab WTP.	0.06

V. Result Analysis

First, it was focused on the difference of the criteria weight of alternatives between the WS method

Table 19: weights of different criteria for the two methods

No	Criteria	Weighted Scoring Method %	Analytical Hierarchy process %
1	% of implementation of the project	30	34
2	Current service quality	25	22
3	Per capita water consumption	10	6
4	Project budget/capita	15	10
5	Population	20	28

Second, it was compared the preference orders of alternatives between the WS method and the AHP as shown in table 20.

Table 20 :the final score for projects for the two methods

Prioirty	Weighted Scoring Method		Analytical Hierarchy Process	
	Project	Score	Project	Score
1	Construction of Masnshia 2 WTP	3.8	Construction of Masnshia 2 WTP	0.26
2	Construction of treated water pump station in km21 Booster pump station.	3.55	Construction of raw water pump station in kafr dawar Booster Pump station.	0.22
3	Expansions of EL siouf WTP.	3.1	Expansions of EL siouf WTP.	0.15
4	Construction of reservoir & treated water pump station in sedi abd el kader Booster pump station.	3.05	Construction of treated water pump station in km21 Booster pump station.	0.14
5	Construction of raw water pump station in kafr dawar Booster Pump station.	2.95	Construction of reservoir & treated water pump station in sedi abd el kader Booster pump station.	0.1
6	Feeding Borg el arab WTP from noubaria canal	2.1	Feeding Borg el arab WTP from noubaria canal	0.07
7	Expansionns of Borg El Arab WTP.	2.1	Expansionns of Borg El Arab WTP.	0.06

VI. Conclusions:

Water managers forecast future water demand for a variety of purposes. These analyses can help manager's future of water use to optimize system operations, plan for future water purchases or system expansion, or for future revenue and expenditures.

Design of water supply projects is based on the projected population of a particular city, estimated for the design period. Any underestimated value will make system inadequate for the purpose intended; similarly overestimated value will make it costly.

The simplest and most traditional means of forecasting future water demand has been to estimate current per-capita water consumption, and multiply this by expected future population.

Change in the population of the city over the years occurs, and the system should be designed taking into account of the population at the end of the design period.

The Weighted Scoring Method is a powerful but flexible method of comparing similar items against a standard, prioritized list of requirements or criteria. It can be used for technology, project and product selection, risk response analysis and solution design.

The AHP not only clearly identifies the most important alternative but also the preference for each alternative by each decision maker. Therefore, using AHP to analyze the decision-making process may result in a precise clarification of preference for alternatives.

The AHP also allows group decision making, where group members can use their experience, values and knowledge to break down a problem into a hierarchy and solve it by the AHP steps. Brainstorming and sharing ideas and insights often lead to a more complete representation and understanding of the issues

AHP doesn't take to account the uncertainty the decision maker feels when assigning the quantitative number to it so there is always some kind of uncertainty present in the AHP.

VII. Recommendations

The recommended future research must contain the last update of forecasting data In addition, a methodology for estimating the impacts of water conservation efforts is recommended.

It's recommended to use the MCDM methods as a decision support tools and not as the means for deriving the final answer also to find the truly best solution to a MCDM problem.

Its recommended to take the conclusions of the solution lightly and used only as indications to what may be the best answer. Although the search for finding the best MCDM method may never end, research in this area of decision-making is still critical and very valuable in many scientific and engineering applications.

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