Smart Thinking for Comparison and Integration Between Quality Function Deployment (QFD) And Analytic Hierarchy Process (AHP) Approach for Proper Utilization of Water Resources in Egypt

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Abstract

Since water is essential for our life, and Egypt faces numerous challenges in providing water, so this research looks at using decision-making method like Quality function deployment, or QFD, and the Analytic Hierarchy Process (AHP) to redistribute water resources for proper utilization of water resources in Egypt. Smart system used to statistically analyze using one-way analysis of variance (ANOVA) using JMP®, Version 13.2.1 (SAS® Institute Inc., Cary, NC, USA) with application of the Tukey–Kramer test for post hoc comparison if needed. First step applying quality function deployment (QFD) method where this method depends on taking the opinion of the customer in considered where customer here means those responsible for making the decision, making relation between the factors affecting the choice and the requirement of the customer using House Of Quality (HOQ) model, The Analytic Hierarchy Process (AHP) decision making techniques taking in consideration the relation between alternative each other with respect to each factor, The two method determine the importance percent for each alternative, Second step making comparison between the two method to compare the results and the ranking of alternatives for each method and it was found that, Even though a slight difference in percentage between the two methods, the water resources remained in the same ranking for all zones in Egypt. Third step is integrating between the two methods for a more accurate result by using HOQ model but using the important percent of AHP in the place of Competitive Analysis, although the result of the integrating is new important percent but the ranking of the water resources for each zone were the same and this This gives us more credibility of the results. The ranking of the alternatives for the five zones of Egypt from QFD or AHP or the integration between them whereas the following: the Upper NILE and the Nile Delta the Nile River being the best source ground water comes after it and desalination being the worst alternative, For the Western Desert the Groundwater being the best source Rain comes after it while the Desalination being the worst alternative, The Red Sea the Desalination being the best source Groundwater comes after it while the Agriculture Drainage being the worst, The North Coast the Desalination being the best source Nile River comes after it while the agriculture drainage being the worst alternative.

KEYWORDS: water resources; Quality function deployment, (QFD); Analytic Hierarchy Process (AHP); Decision Making Techniques; Egypt

1. Introduction

Egypt faces challenges related to inadequate water distribution and almost entire dependence on the Nile, while the existence of other supplies, such as precipitation, seawater desalination, reusing treated agricultural and sanitary drainage water, and groundwater. Redistributing various sources is necessary to achieve sustainability, as Egypt's per capita water share has decreased over time. As an outcome, decision-making is used to select the most suitable alternatives for water resources, such as Quality function deployment, or QFD.

1.1 Quality function deployment, or QFD

Quality function deployment, or QFD, is a management tool that helps teams stay focused on the needs of the customer throughout the whole process or product development cycle by offering a visual connective process. It offers a way to translate client needs. into suitable technical specifications for every phase of the life cycle of a product or process. It aids in the creation of better, more customer-focused products. (Bouchereau, 2000).

The concept of Quality Function Deployment (QFD) originated in Japan in the late 1960s, a time when the country's industries abandoned their post-World War II practice of developing products through imitation and copying and instead focused on developing original products. In this setting, QFD emerged as a concept or methodology for developing new products that fell under the purview of Total Quality Control. Statistical quality control, or SQC, was brought to Japan following World War II and emerged as the primary quality activity, especially in the manufacturing age. Subsequently, it was combined with Dr. Juran's ideas, who stressed the value of incorporating quality control into business management during his 1945 tour to Japan. (Singh, 2018)

Quality Function Deployment (QFD) is a multidisciplinary team approach wherein individual go als and team member preferences frequently clash.
The following are necessary for successful QFD applications: (1) good teamwork in reaching a c onsensus; (2) importance level assignment that takes into account the preferences of each individ ual member; and (3) reciprocal relationship between these two elements (Ho, 1999).

1.2 The Analytic Hierarchy Process (AHP)

has been a valuable instrument utilized by researchers and decision makers alike. It is among the most popular multiple criteria decision-making tools. Numerous excellent publications have been released using AHP; these include numerical extensions of AHP as well as applications of AHP in various disciplines like planning, choosing the best alternative, allocating resources, resolving conflicts, optimization, etc. (Vaidya, 2006).

The Analytic Hierarchy Process (AHP) is a theory of measurement based on pairwise comparisons that creates priority scales based on expert opinions. These are the scales that use relative terminology to quantify intangibles. A scale of absolute judgments is used for the comparisons, which shows how much more one element dominates another in relation to a particular quality. The AHP is concerned about how to quantify conflicting judgments and, when feasible, enhance them to achieve greater consistency (Saaty, 2008).

1.3 AHP and QFD:

Through a case study on the ceramic washbasin, this study attempts to investigate the applicability of Quality Function Deployment (QFD) and Analytical Hierarchy Process (AHP) to change consumer expectations and design quality into the product. Using in-person interviews, observation, and data analysis, we ascertained the demands and requirements of the target market and the nature of the product (Yilmaz, 2009).

The relationship between the requirements for choosing a provider. Engineering and client criteria are considered in conjunction while choosing a supplier. Clients are the businesses that buy the providers' technical know-how. Consequently, a "house of quality" concept might be applied to such a company-supplier relationship. The result of the integrative approach the study presents. Following an overview of QFD and AHP approaches, an integrated hierarchical methodology for supplier selection is developed and outlined (Rajesh, 2013).

Establishing the priority weights for the client needs is a critical and important step in the Quality Function Deployment (QFD) process. Product planning importance weights have been determined using the Analytic Hierarchy Process (AHP), however, this has mostly happened in clear-cut (non-fuzzy) decision applications (Kwong, 2003).

2. Objective

This research aims to develop decision-making for reallocating water resources in Egypt. QFD is used to develop this assessment approach. The developed HOQ considered nine key performance indicators (KPIs), which are planned time, expense, output, client satisfaction, quality, safety and health, risk, communication, and scope to suggest the best improvement strategy considering all viewpoints. Additionally, QFD is a technique that is available to various businesses and is used to assess consumer expectations, which are then reflected in the specifications of the product. Therefore, decision-makers can determine the relative relevance of the criteria used to select the best water resource for different zones in Egypt by applying QFD methodologies

3. Approach design and methodology

The effect of many internal and external factors that effect on decision-making in the selection of the suitable water resource, such as Quality of water (influent), Quality of water (produced water), Distance of water supply resource, Topography of the city and its surroundings, Elevation of source supply, Social, political, and cultural considerations, Construction cost, Operation and maintenance costs. Environmental condition. In-stream and withdrawal uses of water. Cost of transporting water. The quantity of water produced Sustainability of the resource. The main components of the research methodology in this section of the paper include the review of scientific literature, data collection, analysis of data, and interviews with experts. Research literature has been reviewed to identify the factors, issues, and knowledge gaps for a decision support system by value engineering. The data collection process and the type of data collected are described in this section. The data used in this research was collected from a questionnaire survey and was quantitatively analyzed using statistical analysis to identify the factors affecting the water resource choice and it is importance. the questionnaires were distributed to experts. The resulting list of factors, issues and knowledge gaps was subjected to a questionnaire survey for quantitative confirmation and identification of the most important factors, issues and knowledge gaps by distributing the questionnaires to experts, managers in real estate companies, construction industry-academic experts and advisor to identify ambiguous questions/items and to test the techniques used to collect data the results was analyzed to represent the average of votes of each factor set in HOQ model as the important of each of the factor as shown Table 1 (Ibrahim, 2023).

Table 1: Average Rate of Factors Affecting the Choice of Suitable Water Resources Based on Questionnaire Results (Ibrahim, 2023)

Factors influencing water resource selection	**Average**
Source Sustainability	4.73
Quantity of water	4.47
Operation and maintenance cost	4.17
Environmental Conditions	4.00
Water quality (produced water)	4.05
In-stream and Withdrawal Uses of Water	3.69
Socio-political and cultural considerations	3.66
Cost of transporting water	3.45
Quality of water (influent)	3.45
Tab Elevation of the source of water supply	3.18
Construction cost	3.19
Distance of the water supply source	3.11
Topography of the city and its surroundings	2.93

The objective of this survey was to determine how to use the QFD in the choice a suitable water resource. The study was performed for the owners and decision-makers of water resource management in Egypt.

The Quality House is the main planning instrument utilized in the QFD. Its resemblance to a house is the reason behind its name. The majority of engineers and management think of it as the main instrument for high-quality planning. Individuals with varying roles and challenges can choose design priorities based on information motives found beneath the house's roof (Sameni-Keivani, (2013)). The steps in the construction of the quality house are given below (Chan, 2002); (Sameni-Keivani, (2013)); (Sameni Keivani, 2014) (Elhegazy, 2021)) as shown in Figure 1

- The construction of the customer requirements part (Part A).
- The analysis of customer satisfaction level- customer perception analysis (Part B).
- The determination of technical specifications (Part C).

- The determination of relations or correlation matrix (Part D).
- The calculation of the technical importance and normalized technical importance.
- The determination between technical importance and correlations (Part E).
- The comparison with rivals and the indication of targets (Part F)

Each stage of the QFD process is represented by a chart or matrix. Building at least four dwellings, each of which represents a QFD phase, over the course of the system's development life cycle is necessary for the full QFD process (Figure 1). The most crucial engineering features from the first phase, which meet the majority of customer needs, as shown by the bottom of the house score, serve as the input for the QFD process's second step.

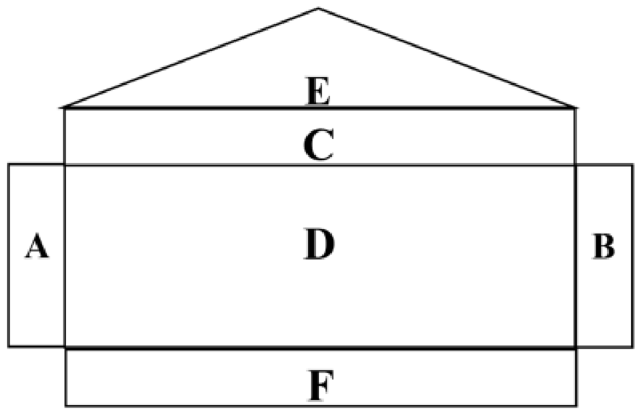

Figure 1: General house of quality structure

The QFD process involves four phases: (1) Product planning: house of quality. (2) Product design: parts deployment. (3) Process planning. (4) Process control (quality control charts (Bouchereau, 2000)

The requirement of the customer is set in HOQ model as the following: The best Topography of City and Its Surroundings, The least Distance of Water Supply Source, The least Elevation of Source of Water Supply, The minimum Construction Cost, The better Quality of Water (Influent), The minimum Cost of Transporting Water, The best Social-Political and Cultural Considerations, Used for most purposes In Stream and Withdrawal Uses of Water, The suitable Environmental Conditions, The best Water Quality (Produced Water), Minimum Operation and Maintenance Cost, More Quantity of Water, The most sustainable resource

For reliable results, Egypt has been separated into five zones: Upper Egypt Zone, Nile Delta Zone, the Western Desert Zone, the Red Sea Zone, and the North Coast Zone. These divisions are based on population density and natural features. The goal of this division's implementation was to determine which water resource was best for each Zone

Comparison between QFD and AHP Methods: After applying QFD for the five zones in Egypt comparison will be illustrated between the results of the QFD process and AHP fuzzy analysis for an accurate result for a proper utilization of water resources in Egypt, and the results of AHP analysis are shown in the following Table 2

Table 2: Results of AHP fuzzy analysis

Zone	Water resources	Nile River	Desalination	Rains	Wastewater Treatment	Agricultural Drainage	Ground Water
Upper Nile	AHP results (% impacts)	31.9%	4.70%	7.1%	14.1%	20.2%	22.0%
Nile Delta		32.4%	4.60%	7.0%	13.6%	20.5%	21.8%
Western Desert		9.0%	6.60%	23.0%	8.30%	15.9%	37.2%
Red Sea		17.3%	26.30%	12.60%	17.70%	6.00%	20.10%
North Coast		18.30%	28.20%	13.40%	16.30%	5.70%	18.10%

Integration between QFD and AHP: The priority weights for the client needs are a critical and important step in the Quality Function Deployment (QFD) process. Produce alternative importance weights have been determined using the Analytic Hierarchy Process (AHP), so integration between the two processes give us results include the client needs and the importance of the alternatives for more accurate results.

Integrating them is by using the previous HOQ (house of quality) model, where Competitive Analysis will be results of AHP analysis were added in the model.

4. RESULTS AND DISCUTIONS.

Use QFD process, to allocate water resources in a way that maximizes priority and supports sustainable use taking in consider the requirement of the customer (the customer here is the responsible of taking decision), by making matrix between the factors affecting the choice and the requirement of the customer. Applying QFD process, taking into consideration the various factors that affect our decision, to determine the reliable source of water available for each zone.

4.1 Results of Upper Egypt Zone:

By implementing the procedures of HOQ (House of Quality) on Upper Nile Zone, as demonstrated, the corresponding input and outcomes were obtained and illustrated in Figure 2 in the following section.

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Column Number	Max Relationship Value	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	the best Topography of City and Its Surroundings	the least Distance of Water Supply Source	the least Elevation of Source of Water Supply	the minimum Construction Cost	the better Quality of Water (Influent)	the minimum Cost of Transporting Water	the best Social-Political and Cultural Considerations	used for most purposes In Stream and Withdrawal Uses Of Water	the suitable Environmental Conditions	the best Water Quality (Producted Water)	minimum Operation and Maintenance Cost	gives more Quantity of Water	the most sustainable	weight/Importance	Relative Weight	Competitive Analysis (0=Worst,5=Best): nile river	desalination	rains	waste water treatment	agricultural drainage	ground water	Relative Weight (Relative Importance)
1	9	Topography of City and Its Surroundings	9	9	9	9	1	3	1	1	1	1	3	3	3	2.93	6.09	4	1	1	2	3	3	6.60%
2	9	Distance of Water Supply Source	9	9	1	9	1	9	1	1	9	1	3	3	3	3.11	6.47	4	1	1	1	3	4	6.68%
3	9	Elevation of Source of Water Supply	9	1	9	9	1	9	1	1	1	1	3	3	3	3.18	6.61	4	1	1	4	4	2	5.67%
4	9	Construction Cost	9	9	9	9	9	3	3	9	3	9	9	9	9	3.19	6.63	5	2	5	3	3	4	11.73%
5	9	Quality of Water (Influent)	1	1	1	9	9	3	1	9	1	9	9	1	9	3.45	7.18	5	1	1	2	3	4	7.73%
6	9	Cost of Transporting Water	3	9	9	3	3	9	1	3	3	1	1	3	9	3.45	7.18	4	1	1	2	3	4	6.64%
7	9	Social-Political and Cultural Considerations	1	1	1	3	1	1	9	1	1	9	3	3	3	3.66	7.61	4	1	1	2	3	2	4.58%
8	9	In Stream and Withdrawal Uses Of Water	1	1	1	9	9	3	1	9	1	9	9	9	9	3.69	7.67	5	1	1	3	4	5	8.88%
9	9	Environmental Conditions	1	9	1	3	1	3	1	1	9	1	3	3	9	4	8.32	5	1	1	1	2	5	5.56%
10	9	Water Quality (Producted Water)	1	1	1	9	9	1	9	9	1	9	9	1	3	4.05	8.42	5	1	1	2	3	4	7.54%
11	9	Operation and Maintenance Cost	9	3	3	9	9	1	3	9	3	9	9	9	9	4.17	8.67	5	2	5	3	3	4	9.74%
12	9	Quantity of Water	3	3	3	9	1	3	3	9	3	1	9	9	9	4.47	9.3	5	1	1	3	4	2	8.04%
13	9	Source Sustainability	3	3	3	9	9	9	3	9	9	3	9	9	9	4.73	9.84	5	1	1	2	3	3	10.61%
		Column Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	Technical importance score		4.698	1.232	1.859	2.375	3.119	3.606	16.8895136
		Max Relation ship in column	9	9	9	9	9	9	9	9	9	9	9	9	9	% Importance		27.82	7.293	11.01	14.06	18.47	21.35	100
		Required Weight	428.5	433.2	367.8	761	502	431	297.2	576.1	361	489	632	522	##									
		Relative Weight	6.6	6.68	5.67	12	7.73	6.6	4.58	8.88	5.6	7.5	9.74	8.04	11									
		Relation ship between requirments: 9-strong 3 moderate 1 weak																						

Figure 2: HOQ for upper Nile

The outcomes of the HOQ model list the alternatives for the Upper Nile Zone's water resources for this region as illustrated in the following table.

Table 3: Importance percent of the water resources (alternatives) for the Upper Nile zone

Water resources	Nile River	Desalination	Rains	Wastewater Treatment	Agricultural Drainage	Ground Water
QFD results (%Importance)	27.82%	7.29%	11.01%	14.06%	18.47%	21.35%

From Table 3, it is obvious that the Nile River, with an importance percentage of 27.82% is the best option for the upper Nile zone. Ground water follows in second place with a percentage of 21.35%, agriculture drainage is the third option with a percentage of 18.47%, wastewater treatment is the fourth option with a percentage of 14.06%, rains are the fifth option with a percentage of 11.01%, and desalination is the last option with a percentage of 7.30%.

4.2 Results of the Nile Delta Zone:

By implementing the procedures of HOQ (House of Quality) on Nile Delta Zone, as demonstrated, the corresponding outcomes were obtained and illustrated in Figure 3 in the following section.

The outcomes of the HOQ model list the alternatives for the Nile Delta Zone's water resources for this region, as illustrated in the following table.

Table 4: Importance percentage of the water resources (alternatives) for the Nile Delta zone

Water resources	Nile River	Desalination	Rains	Wastewater Treatment	Agricultural Drainage	Ground Water
QFD results (%Importance)	27.86%	7.13%	10.75%	14.09%	18.66%	21.51%

Table 4 clearly shows that the Nile River, with an importance percentage of 27.86%, is the best option for the upper Nile zone. Groundwater is ranked second, at 21.51%, followed by agriculture drainage in third place (18.66%), wastewater treatment in fourth place (14.09%), rainfall in fifth place (10.75%), and desalination in last place (7.13%).

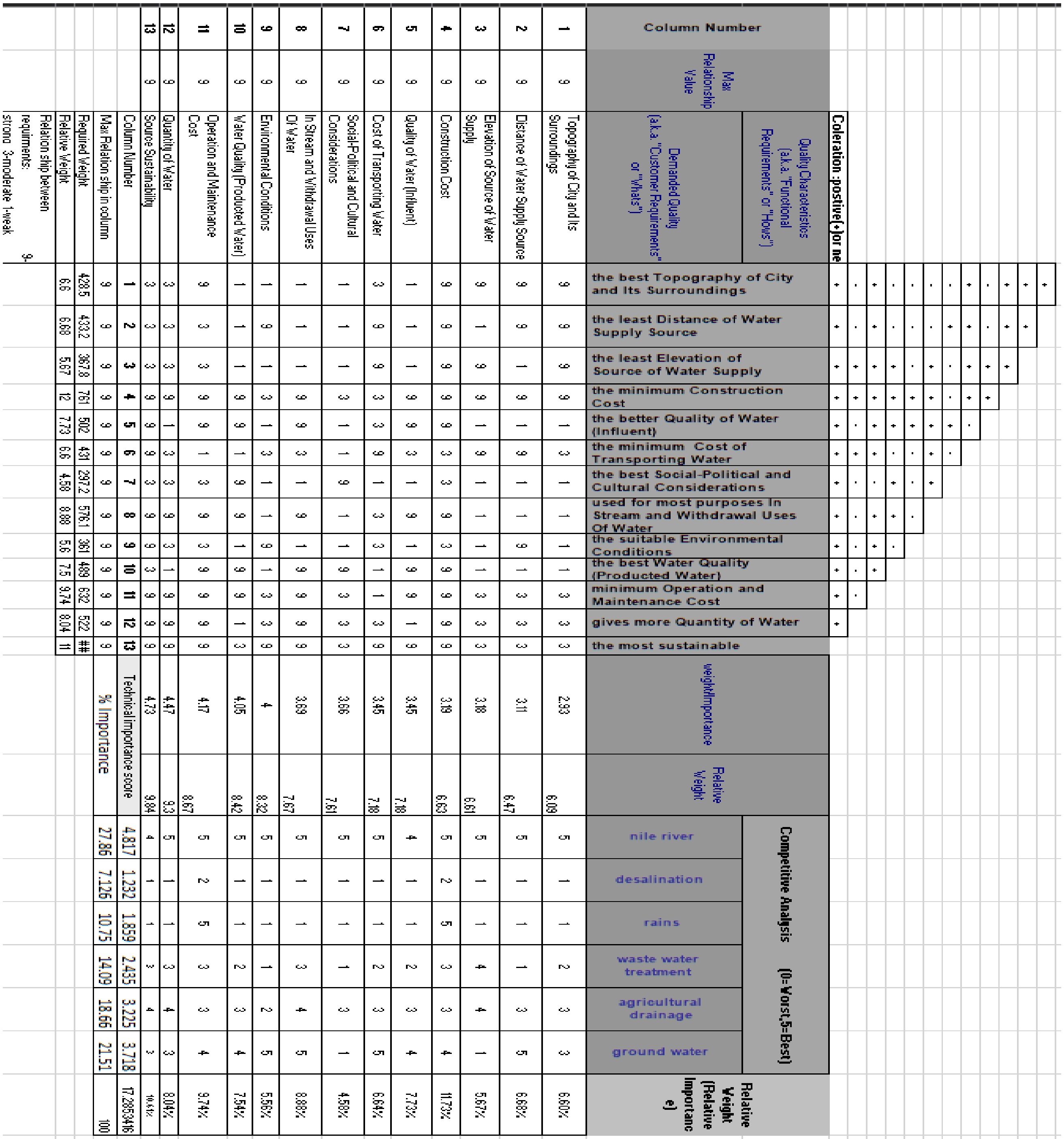

Figure 3: HOQ for Nile Delta

4.3 Results of Western Desert Zone:

By implementing the procedures of HOQ (House of Quality) on the Western Desert Zone, as demonstrated, the corresponding outcomes were obtained and illustrated in Figure 4 in the following section.

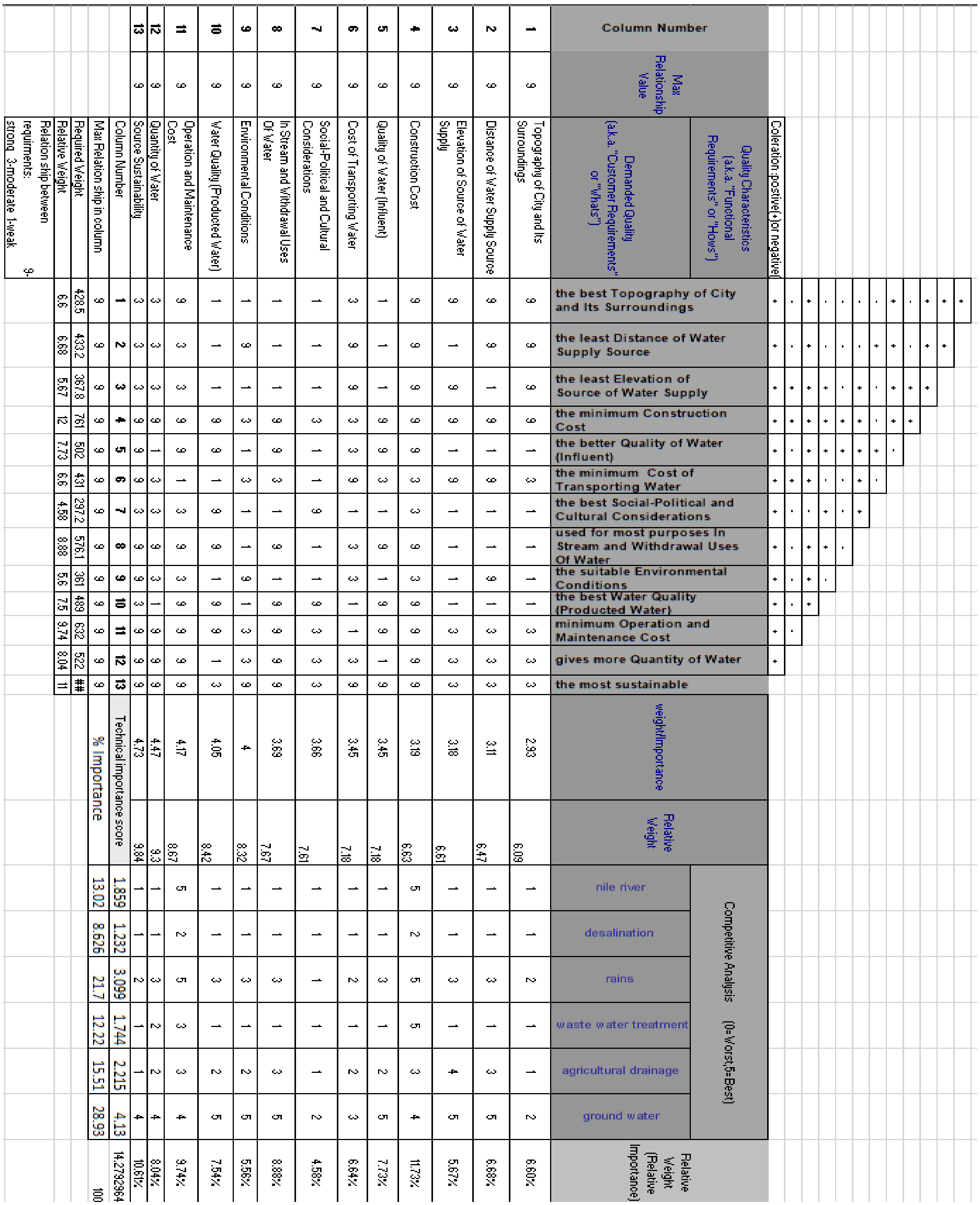

Figure 4: HOQ for Western Desert

The outcomes of the HOQ model list the alternatives for the Western Desert Zone's water resources for this region as illustrated in the following table.

Table 5: Importance percent of the water resources (alternatives) for the Western Desert Zone

Water resources	Nile River	Desalination	Rains	Wastewater Treatment	Agricultural Drainage	Ground Water
QFD results (%Importance)	13.02%	8.63%	21.70%	12.22%	15.51%	28.93%

Table 5 makes it clear that the groundwater with an importance percentage of 28.93% is the best option for the western desert zone. rains follow in second place with a percentage of 21.35%, agriculture drainage is the third option with a percentage of 15.51%, Nile River is the fourth option with a percentage of 13.02%, wastewater treatment are the fifth option with a percentage of 12.22%, and desalination is the last option with a percentage of 8.63%.

4.4 Results of Red Sea Zone:

By implementing the procedures of HOQ (House of Quality) on the Red Sea Zone, as demonstrated, the corresponding outcomes were obtained and illustrated in Figure 5 in the following section.

The outcomes of the HOQ model list the alternatives for the Red Sea Zone's water resources for this region as illustrated in the following table.

Table 6: Importance percent of the water resources (alternatives) for the Red Sea Zone

Water resources	Nile River	Desalination	Rains	Wastewater Treatment	Agricultural Drainage	Ground Water
QFD results (%Importance)	17.60%	24.11%	14.88%	17.75%	7.83%	17.82%

The optimal choice for the Red Sea zone is evident from Table 6, where Desalination has a significance percentage of 24.11%. The next highest percentage, 17.82%, is attributed to Ground Water followed by Wastewater Treatment in third place, 17.75 %, Nile River in fourth place, 17.60%, Rain in fifth place, 14.88%, and Agriculture Drainage in last place, 7.83%.

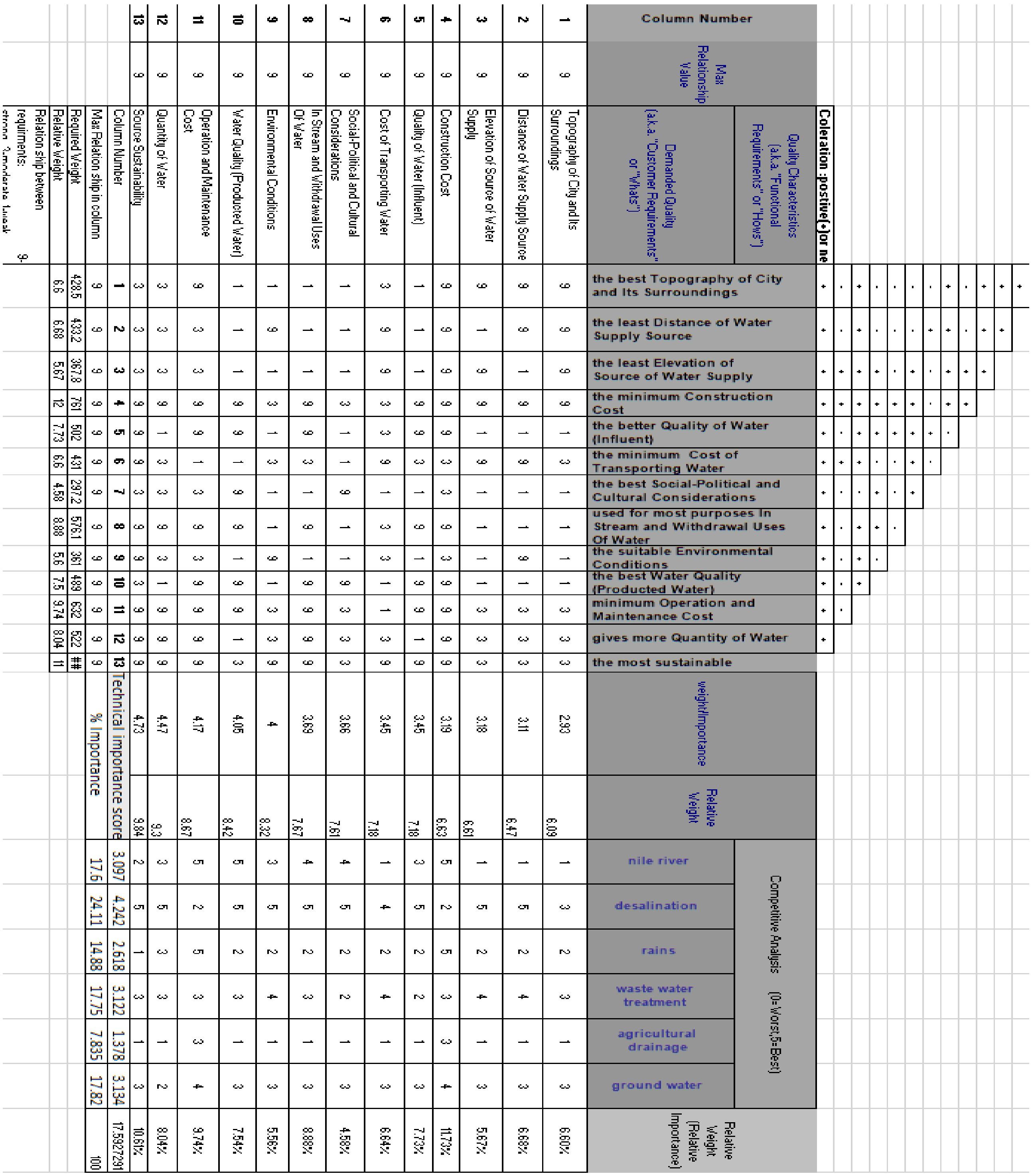

Figure 5:HOQ for Red Sea

4.5 Results of the North Coast Zone:

By implementing the procedures of HOQ (House of Quality) on North coast Zone, as demonstrated, the corresponding input and outcomes were obtained and illustrated in Figure 6 in the following section.

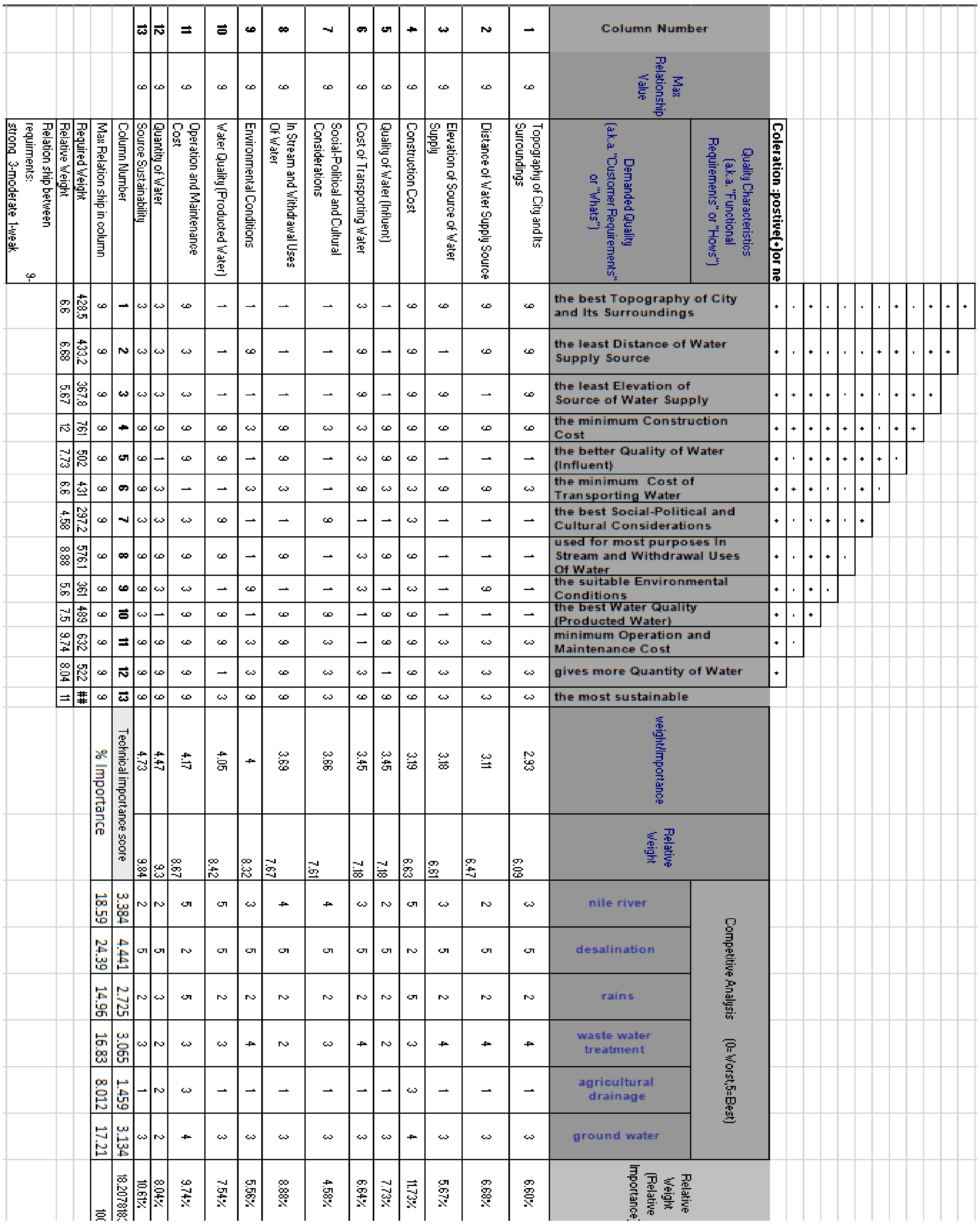

Figure 6: HOQ for North Coast Zone

The outcomes of the HOQ model list the alternatives for the North Coast Zone's water resources for this region and are illustrated in the following table.

Table 7: Importance percentage of the water resources (alternatives) for the North Coast zone Zone

Water resources	Nile River	Desalination	Rains	Wastewater Treatment	Agricultural Drainage	Ground Water
QFD results (%Importance)	18.59%	24.39%	14.96%	16.83%	8.01%	17.21%

Table 7 clearly shows that desalination is the best option for the North Coast zone, with a significant percentage of 24.39%. Nile River is responsible for the second greatest amount (18.59%), which is followed by Ground Water (17.21 %), the wastewater treatment (16.83 %), rain (14.88%), and the least is agriculture drainage (8.01%).

5 Integration between AHP results and QFD results

A combination of the three approaches was used to get more accurate results. The House of Quality (HOQ) model was used, but the consumer's place was changed out for the ratios of alternatives that showed up in the AHP method. The results included the relationship between the alternatives for each factor from the AHP method and the relationship between the factors to each other from the QFD method.

5.1 Integration between AHP results and QFD for Upper Nile zone

By implementing the procedures of HOQ (House of Quality) as %AHP results were used in the model in place of Competitive Analysis for Upper Nile Zone, as demonstrated, the corresponding input and outcomes were obtained and illustrated in Figure 7 in the following section.

The outcomes of the HOQ model list the alternatives using AHP results for the Upper Nile Zone's water resources, which are illustrated in the following table.

Table 8: Importance percentage of the water resources (alternatives) using AHP results for Upper Nile

Water resources	Nile River	Desalination	Rains	Wastewater Treatment	Agricultural Drainage	Ground Water
QFD results (%Importance)	31.25%	4.96%	8.29%	13.99%	19.56%	21.96%

From Table 8 it is obviously that the Nile River with an importance percentage of 31.25%% is the best option for the upper Nile zone. Ground water follows in second place with a percentage of 21.96%, agriculture drainage is the third option with a percentage of 19.56%, wastewater treatment is the fourth option with a percentage of 13.99%, rains are the fifth option with a percentage of 8.29%, and desalination is the last option with a percentage of 4.96%.

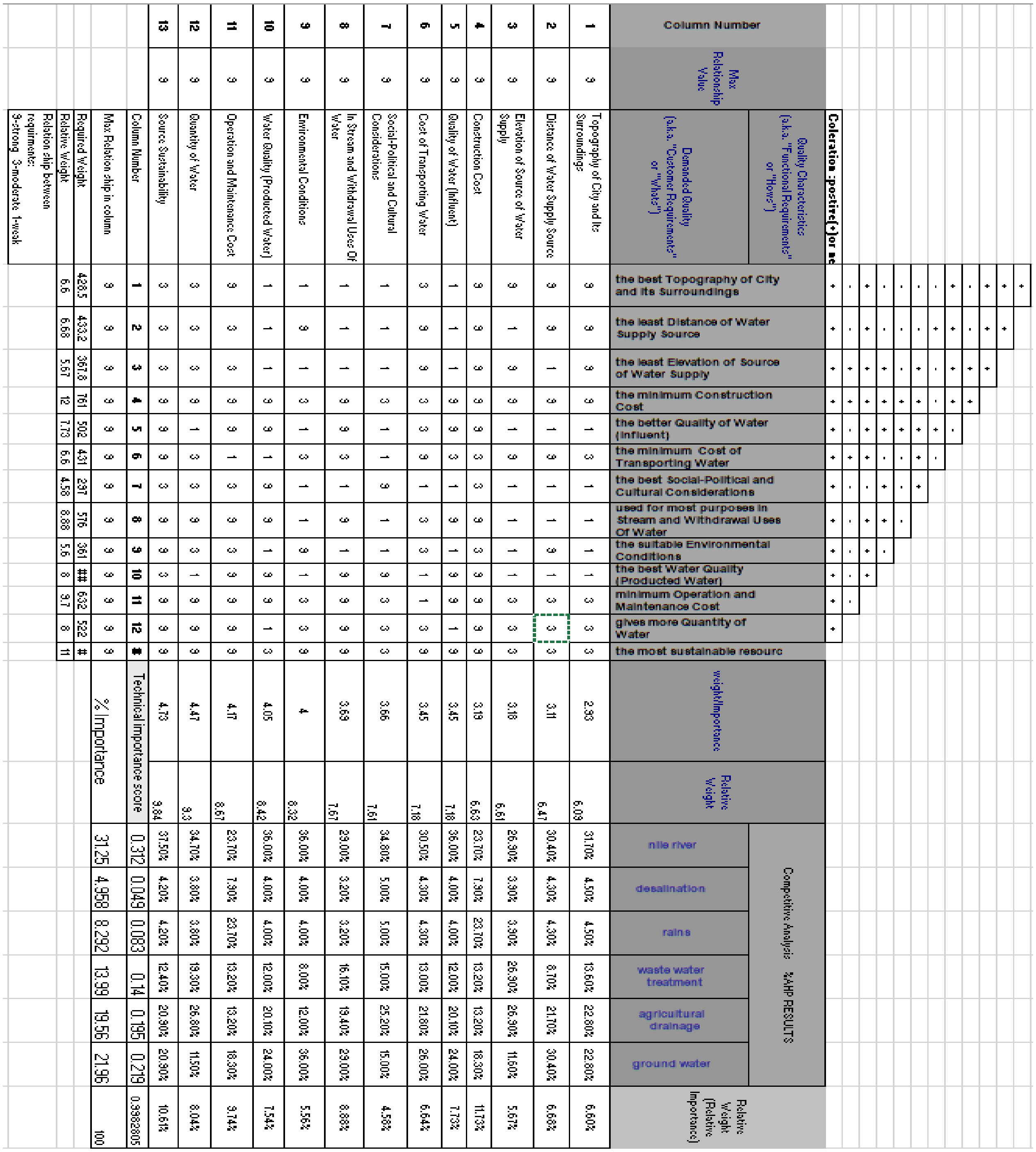

Figure 7: HOQ for Upper Nile zone using AHP results

5.2 Integration between AHP results and QFD for Nile Delta zone

By implementing the procedures of HOQ (House of Quality) as %AHP results were used in the model in the place Competitive Analysis for Upper Nile Zone, as demonstrated, the corresponding input and outcomes were obtained and illustrated in Figure 8 in the following section.

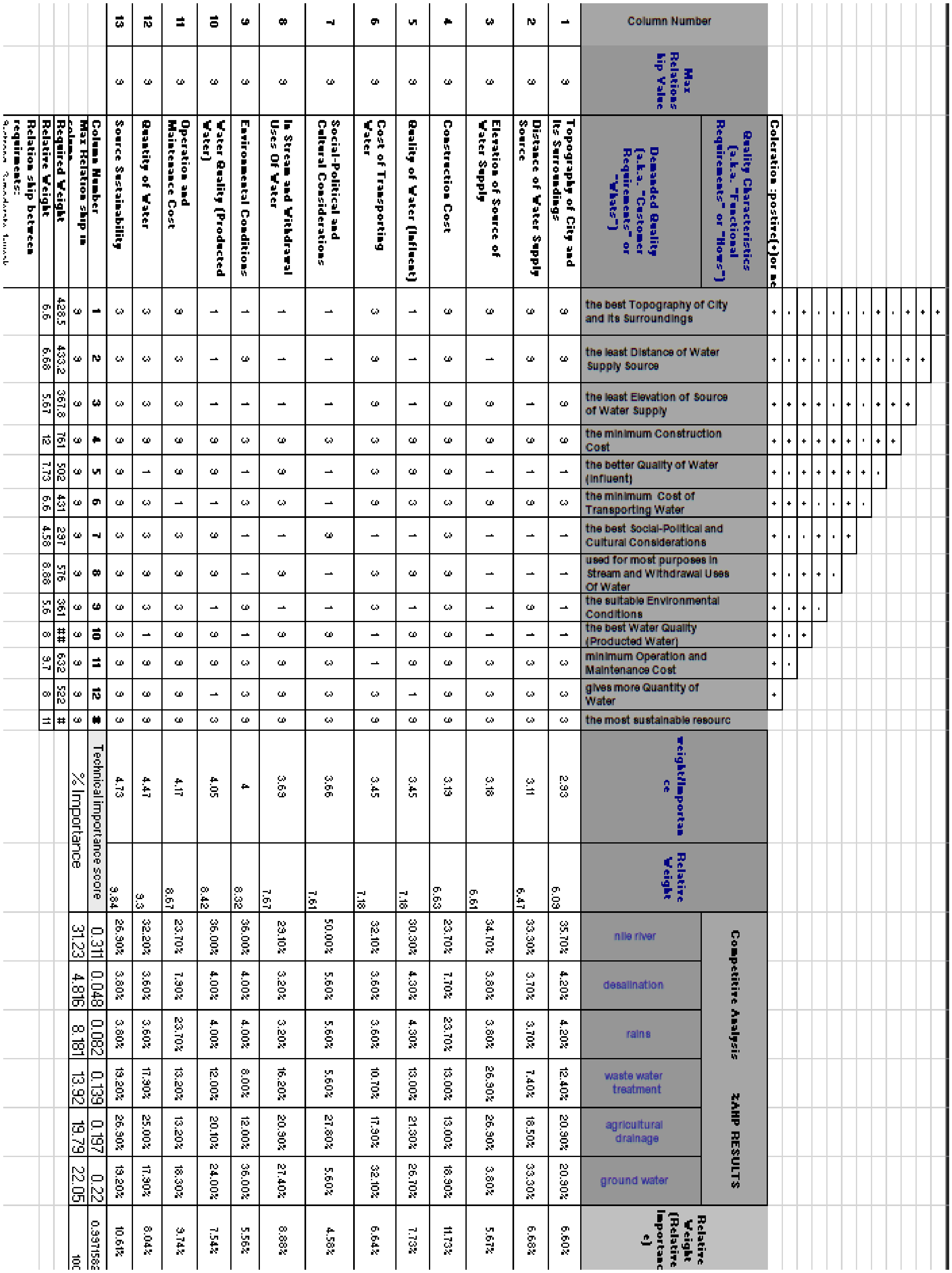

Figure 8: HOQ for Nile Delta zone using AHP results

The outcomes of HOQ model List the alternatives using AHP results for the Nile Delta Zone's water resources were illustrated in the following table.

Table 9: Importance percent of the water resources (alternatives) using AHP results for Nile Delta zone

Water resources	Nile River	Desalination	Rains	Wastewater Treatment	Agricultural Drainage	Ground Water
QFD results (%Importance)	31.23%	4.82%	8.18%	13.924%	19.79%	22.053%

Table 9 clearly shows that the Nile River, at an importance percentage (31.23%), is the best option for the upper Nile zone. Groundwater is ranked second, at 22.05%, followed by agriculture drainage in third place (19.79%), wastewater treatment in fourth place (13.92%), rainfall in fifth place (8.18%), and desalination in last place (4.82%).

5.3 Integration between AHP results and QFD for the Western Desert Zone

By implementing the procedures of HOQ (House of Quality), as %AHP results were used in the model in place of Competitive Analysis for Western Desert Zone, as demonstrated, the corresponding input and outcomes were obtained and illustrated in Figure 9 in the following section.

The outcomes of the HOQ model list the alternatives using AHP results for the Western Desert Zone's water resources, which are illustrated in the following table.

Table 10: Importance percentage of the water resources (alternatives) using AHP results for the Western Desert zone

Water resources	Nile River	Desalination	Rains	Wastewater Treatment	Agricultural Drainage	Ground Water
QFD results (%Importance)	9.95%	6.63%	23.35%	8.49%	15.53%	36.04%

Table 10 makes it clear that the groundwater with an importance percentage of 36.04% is the best option for the western desert zone. rains follow in second place with a percentage of 23.35%, agriculture drainage is the third option with a percentage of 15.53%, Nile River is the fourth option with a percentage of 9.95%, wastewater treatment are the fifth option with a percentage of 8.49%, and desalination is the last option with a percentage of 6.63%.

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Functional Requirement ("Hows")	1	2	3	4	5	6	7	8	9	10	11	12
the best Topography of City and its Surroundings	+	.	+	.	.	.	.	+	.	+	+	+
the least Distance of Water Supply Source	+	.	+	.	.	.	+	+	.	+	+	
the least Elevation of Source of Water Supply	+	+	+	+	.	+	.	+	+	+		
the minimum Construction Cost	+	+	+	+	+	+	.	+	+			
the better Quality of Water (Influent)	+	.	+	+	+	+	+	.				
the minimum Cost of Transporting Water	+	+	+	.	.	+	.					
the best Social-Political and Cultural Considerations	+	.	.	+	.	+						
used for most purposes In Stream and Withdrawal Uses Of Water	+	.	+	+	.							
the suitable Environmental Conditions	+	.	+	.								
the best Water Quality (Producted Water)	+	.	+									
minimum Operation and Maintenance Cost	+	.										
gives more Quantity of Water	+											
the most sustainable resourc												

Column Number	Max Relationship Value	Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	the best Topography of City and its Surroundings	the least Distance of Water Supply Source	the least Elevation of Source of Water Supply	the minimum Construction Cost	the better Quality of Water (Influent)	the minimum Cost of Transporting Water	the best Social-Political and Cultural Considerations	used for most purposes In Stream and Withdrawal Uses Of Water	the suitable Environmental Conditions	the best Water Quality (Producted Water)	minimum Operation and Maintenance Cost	gives more Quantity of Water	the most sustainable resourc	weight/Importance	Relative Weight	nile river	desalination	rains	waste water treatment	agricultural drainage	ground water	Relative Weight (Relative Importance)
1	9	Topography of City and its Surroundings	9	9	9	9	1	3	1	1	1	1	3	3	3	2.93	6.09	10.00%	10.00%	30.00%	10.00%	10.00%	30.00%	6.60%
2	9	Distance of Water Supply Source	9	9	1	9	1	9	1	9	1	1	3	3	3	3.11	6.47	4.50%	4.50%	22.70%	4.50%	22.70%	40.90%	6.68%
3	9	Elevation of Source of Water Supply	9	1	9	9	1	9	1	1	1	1	3	3	3	3.18	6.61	4.20%	4.20%	20.80%	4.20%	29.10%	37.60%	5.67%
4	9	Construction Cost	9	9	9	9	9	3	3	3	3	9	9	9	9	3.19	6.63	23.70%	7.90%	23.70%	13.20%	13.20%	18.30%	11.73%
5	9	Quality of Water (Influent)	1	1	1	9	9	3	1	9	1	9	9	1	9	3.45	7.18	5.00%	5.00%	25.10%	5.00%	14.90%	45.00%	7.73%
6	9	Cost of Transporting Water	3	9	9	3	3	9	1	3	3	1	1	3	9	3.45	7.18	7.10%	7.10%	21.30%	7.10%	21.30%	35.90%	6.64%
7	9	Social-Political and Cultural Considerations	1	1	1	3	1	1	9	1	1	9	3	3	3	3.66	7.61	12.50%	12.50%	12.50%	12.50%	12.50%	37.50%	4.58%
8	9	In Stream and Withdrawal Uses Of Water	1	1	1	9	9	3	1	9	1	9	9	9	9	3.69	7.67	4.50%	4.50%	22.70%	4.50%	22.70%	40.90%	8.88%
9	9	Environmental Conditions	1	9	1	3	1	3	1	1	9	1	3	3	9	4	8.32	5.00%	5.00%	25.10%	5.00%	14.90%	45.00%	5.56%
10	9	Water Quality (Producted Water)	1	1	1	9	9	1	9	9	1	9	9	1	3	4.05	8.42	5.00%	5.00%	25.10%	5.00%	14.90%	45.00%	7.54%
11	9	Operation and Maintenance Cost	3	3	3	9	9	1	3	9	3	9	9	9	9	4.17	8.67	23.70%	7.90%	23.70%	13.20%	13.20%	18.30%	9.74%
12	9	Quantity of Water	3	3	3	9	1	3	3	3	3	1	9	9	9	4.47	9.3	5.00%	5.00%	25.20%	15.00%	15.00%	34.80%	8.04%
13	9	Source Sustainability	3	3	3	9	9	9	3	3	9	3	9	9	9	4.73	9.84	7.10%	7.10%	21.50%	7.10%	7.10%	49.90%	10.61%
		Column Number	1	2	3	4	5	6	7	8	9	10	11	12	#									
		Max Relation ship in column	9	9	9	9	9	9	9	9	9	9	9	9	9									
		Required Weight	428.5	433.2	367.8	761	502	431	297	576	361	##	632	522	#									
		Relative Weight	6.6	6.68	5.67	12	7.73	6.6	4.58	8.88	5.6	8	9.7	8	11									
		Technical importance score																0.099	0.066	0.233	0.085	0.155	0.36	0.9980048
		% Importance																9.948	6.634	23.35	8.494	15.53	36.04	100

Quality Characteristics (a.k.a. "Functional Requirements" or "Hows"); Competitive Analysis %AHP RESULTS; Relation ship between requirements: 9-strong 3-moderate 1-weak

Figure 9: HOQ for Western Desert zone using AHP results

5.4 Integration between AHP results and QFD for the Red Sea zone

By implementing the procedures of HOQ (House of Quality), as %AHP results were used in the model in place of Competitive Analysis for Red Sea Zone, as demonstrated, the corresponding input and outcomes were obtained and illustrated in Figure 10 in the following section.

	1	2	3	4	5	6	7	8	9	10	11	12
	+											
	+	+										
	+	+	+									
	-	-	+	+								
	+	+	+	+	-							
	-	+	-	-	+	-						
	-	-	+	+	+	+	+					
	-	-	-	+	+	-	-	-				
	-	-	+	+	+	-	+	+	-			
	+	+	+	+	+	+	-	+	+	+		
	-	-	+	+	-	+	-	-	-	-	-	
Coleration :postive(+)or ne	+	+	+	+	+	+	+	+	+	+	+	+

Column Number	Max Relationship Value	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	the best Topography of City and its Surroundings	the least Distance of Water Supply Source	the least Elevation of Source of Water Supply	the minimum Construction Cost	the better Quality of Water (Influent)	the minimum Cost of Transporting Water	the best Social-Political and Cultural Considerations	used for most purposes in Stream and Withdrawal Uses Of Water	the suitable Environmental Conditions	the best Water Quality (Producted Water)	minimum Operation and Maintenance Cost	gives more Quantity of Water	the most sustainable resourc	weight/Importance	Relative Weight	Competitive Analysis %AHP RESULTS: nile river	desalination	rains	waste water treatment	agricultural drainage	ground water	Relative Weight (Relative Importance)
1	9	Topography of City and Its Surroundings	9	9	9	9	1	3	1	1	1	1	3	3	3	2.93	6.09	5.00%	25.10%	14.80%	25.10%	5.00%	25.10%	6.60%
2	9	Distance of Water Supply Source	9	9	1	9	1	9	1	1	9	1	3	3	3	3.11	6.47	3.80%	34.70%	11.50%	26.80%	3.80%	19.30%	6.68%
3	9	Elevation of Source of Water Supply	9	1	9	9	1	9	1	1	1	1	3	3	3	3.18	6.61	3.80%	34.70%	11.50%	26.80%	3.80%	19.30%	5.67%
4	9	Construction Cost	9	9	9	9	9	3	3	9	3	9	9	9	9	3.19	6.63	23.70%	7.70%	23.70%	13.00%	13.00%	18.90%	11.73%
5	9	Quality of Water (Influent)	1	1	1	9	9	3	1	9	1	9	9	1	9	3.45	7.18	12.40%	37.50%	12.40%	12.40%	4.20%	21.00%	7.73%
6	9	Cost of Transporting Water	3	9	9	3	3	9	1	3	3	1	1	3	9	3.45	7.18	4.20%	29.10%	12.50%	29.10%	4.20%	20.90%	6.64%
7	9	Social-Political and Cultural Considerations	1	1	1	3	1	1	9	1	1	9	3	3	3	3.66	7.61	24.80%	32.20%	10.70%	10.70%	3.60%	18.00%	4.58%
8	9	In Stream and Withdrawal Uses Of Water	1	1	1	9	9	3	1	9	1	9	9	9	9	3.69	7.67	24.80%	32.20%	10.70%	10.70%	3.60%	18.00%	8.88%
9	9	Environmental Conditions	1	9	1	3	1	3	1	1	9	1	3	3	9	4	8.32	36.00%	4.00%	4.00%	8.00%	12.00%	36.00%	5.56%
10	9	Water Quality (Producted Water)	1	1	1	9	9	1	9	9	1	9	9	1	3	4.05	8.42	28.10%	28.10%	9.30%	15.70%	3.10%	15.70%	7.54%
11	9	Operation and Maintenance Cost	9	3	3	9	9	1	3	9	3	9	9	9	9	4.17	8.67	23.70%	7.70%	23.70%	13.00%	13.00%	18.90%	9.74%
12	9	Quantity of Water	3	3	3	9	1	3	3	9	3	1	9	9	9	4.47	9.3	17.90%	32.10%	17.90%	17.90%	3.60%	10.60%	8.04%
13	9	Source Sustainability	3	3	3	9	9	9	3	9	9	3	9	9	9	4.73	9.84	12.40%	37.50%	4.20%	20.90%	4.20%	20.90%	10.61%
		Column Number	1	2	3	4	5	6	7	8	9	10	11	12	#	Technical importance score		0.173	0.262	0.135	0.174	0.061	0.198	1.0032223
		Max Relation ship in column	9	9	9	9	9	9	9	9	9	9	9	9	9	% Importance		17.28	26.12	13.48	17.32	6.074	19.72	100
		Required Weight	428.5	433.2	367.8	761	502	431	297	576	361	##	632	522	#									
		Relative Weight	6.6	6.68	5.67	12	7.73	6.6	4.58	8.88	5.6	8	9.7	8	11									
		Relation ship between requirments:																						

Figure 10: HOQ for Red Sea zone using AHP results

The outcomes of the HOQ model list the alternatives using AHP results for the Red Sea Zone's water resources, which are illustrated in the following table.

Table 11: Importance percentage of the water resources (alternatives) using AHP results for Red Sea zone

Water resources	Nile River	Desalination	Rains	Wastewater Treatment	Agricultural Drainage	Ground Water
QFD results (%Importance)	17.28%	26.12%	13.48%	17.32%	6.07%	19.72%

The optimal choice for the Red Sea zone is evident from Table 11, where Desalination has a significant percentage of 26.12%. The next highest percentage, 19.72%, is attributed to Ground Water, followed by Wastewater Treatment in third place, 17.32 %, Nile River in fourth place, 17.28%, Rain in fifth place, 13.48%, and Agriculture Drainage in last place, 6.07%.

5.5 Integration between AHP results and QFD for the North Coast zone

By implementing the procedures of HOQ (House of Quality), as %AHP results were used in the model in place of Competitive Analysis for North Coast Zone, as demonstrated, the corresponding input and outcomes were obtained and illustrated in Figure 11 in the following section.

The outcomes of the HOQ model, listing the alternatives using AHP results for the North Coast Zone's water resources, were illustrated in the following table.

Table 12: Importance percentage of the water resources (alternatives) using AHP results for the North Coast zone

Water resources	Nile River	Desalination	Rains	Wastewater Treatment	Agricultural Drainage	Ground Water
QFD results (%Importance)	18.47%	27.41%	14.10%	16.20%	5.73%	18.08%

Table 12 clearly shows that desalination is the best option for the North Coast zone, with a significant percentage of 27.41%. Nile River is responsible for the second greatest amount (18.47%), which is followed by Groundwater (18.08 %), the wastewater treatment (16.20 %), rain (14.10%), and the least is agriculture drainage (5.73%).

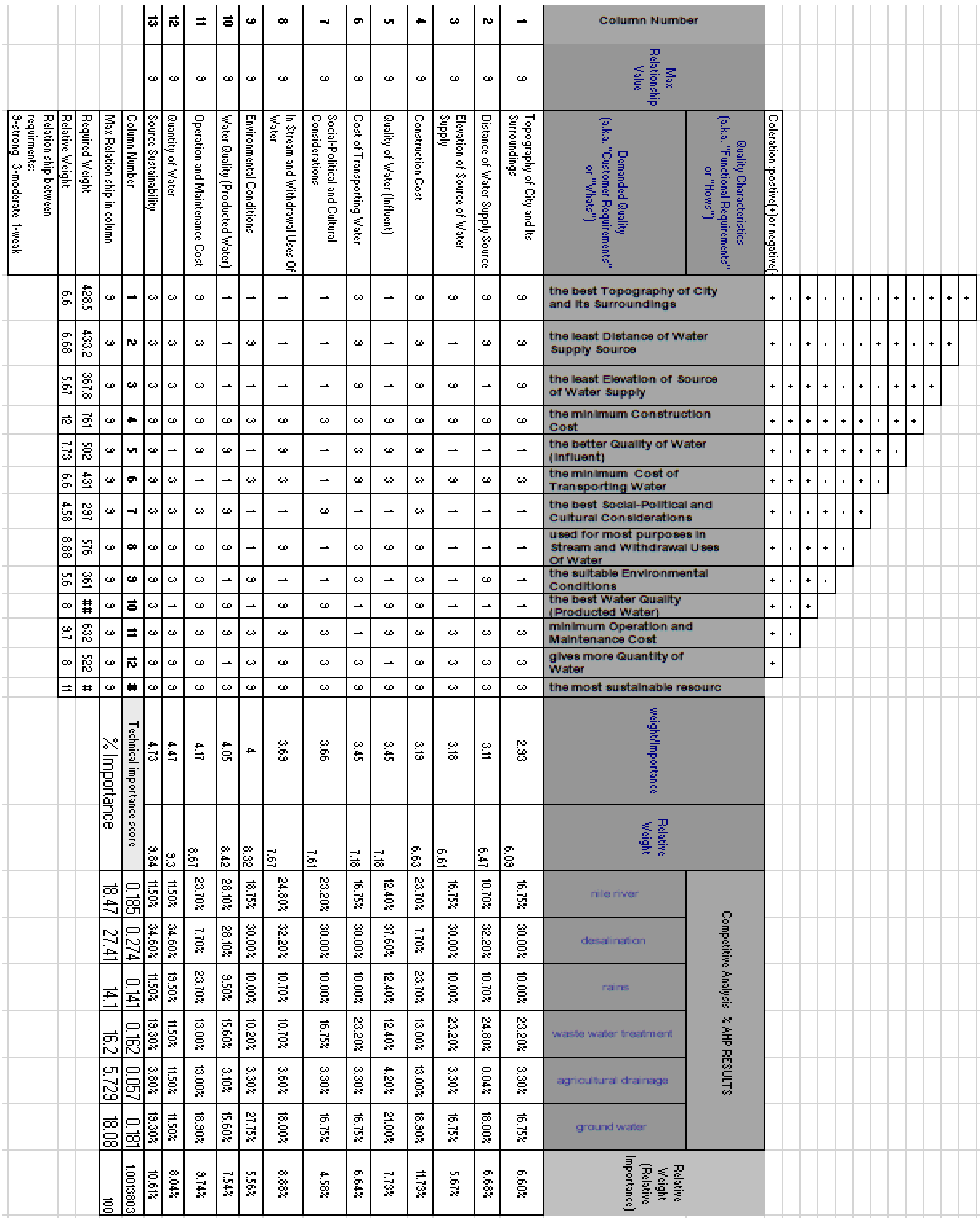

Figure 11: HOQ for North Coast Zone using AHP results

6. Comparison between AHP results and QFD results, and the integration results

In order to determine which water source is best for each region in Egypt a compression between three approaches which are AHP fuzzy analysis and QFD methods and the results of integration between them: the first relies on making matrix between the alternatives for each factor, while the second method uses matrix between the factors each other, and the third the procedures of HOQ (House of Quality) as %AHP results were used in the model in the place Competitive Analysis, in order to produce are more accurate results.

6.1 The Comparison of Upper Nile Zones

By comparing the results from the Nile Delta zone, it was found that, even though a slight difference in percentage between the three approaches, the water resources remained in the same order, where the Nile River being the best source ground water comes after it and desalination being the worst alternative as shown in Table 12 and Figure 12.

Table 13: Results of AHP, QFD methods and their integration for Upper Nile zone

Water resources	Nile River	Desalination	Rains	Wastewater Treatment	Agricultural Drainage	Ground Water
AHP results	31.9%	4.70%	7.1%	14.1%	20.2%	22.0%
QFD results	27.82 %	7.30%	11.01%	14.06%	18.47%	21.35%
QFD results using AHP%	31.25 %	4.96%	8.29%	13.99%	19.56%	21.96%

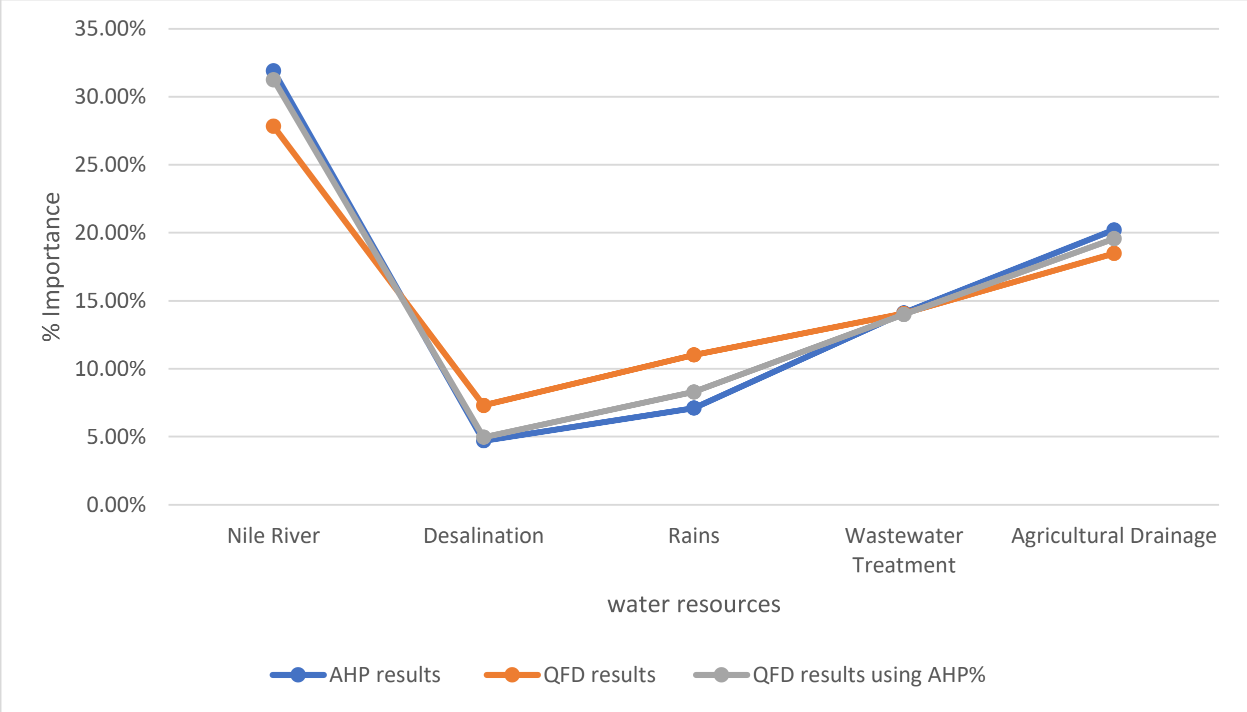

Figure 12: Results of AHP, QFD methods and their integration for Upper Nile zone

6.2 The Comparison of Nile Delta Zones

By comparing the findings obtained from Nile Delta zone, it was discovered that although there was a minor variation in the percent between the three methods, the water resources were still in the same order, where the best source is Nile River coming after it Ground Water, the worst alternative is Desalination as shown in Table 12 and Figure 2.

Table 14 : Results of AHP, QFD methods and their integration for Nile Delta zone

Water resources	Nile River	Desalination	Rains	Wastewater Treatment	Agricultural Drainage	Ground Water
AHP results	32.4%	4.60%	7.0%	13.6%	20.5%	21.8%
QFD results	27.86%	7.13%	10.75%	14.09%	18.66%	21.51%
QFD results using AHP %	31.23%	4.82%	8.18%	13.924%	19.79%	22.053%

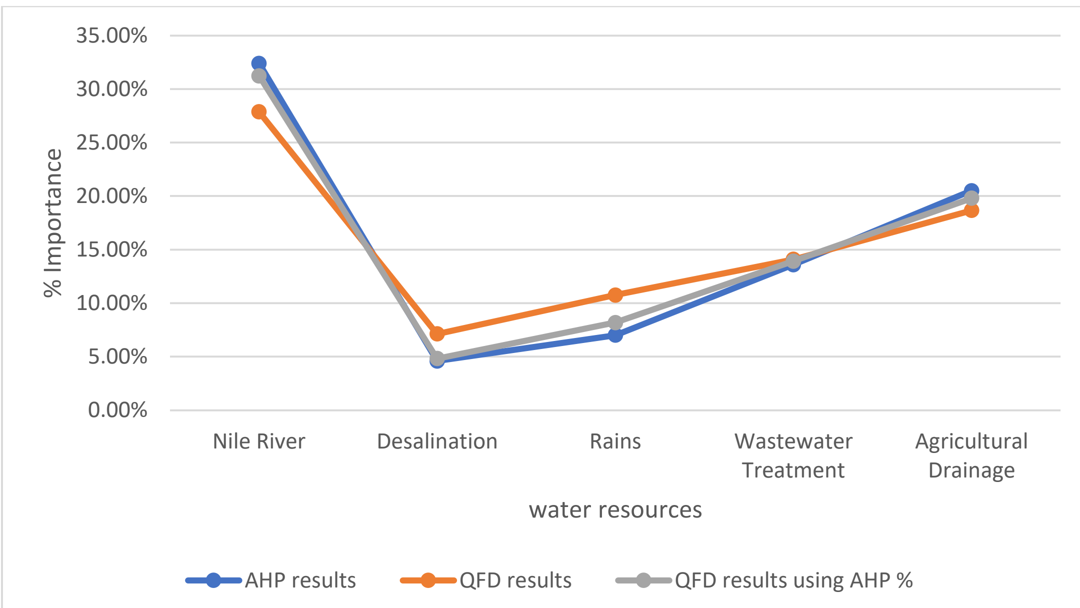

Figure 13: Results of AHP, QFD methods, and their integration for the Nile Delta zone

6.3 The Comparison for Western Desert zones

By comparing the results from the Western Desert zone, it was found that, even though a slight difference in percentage between the three methods, the water resources remained in the same order, where the Ground Water being the best source Rain comes after it while the Desalination being the worst alternative as shown in Table 15and Figure 14.

Table 15: Results of AHP, QFD methods their integration for Western Desert zone

Water resources	Nile River	Desalination	Rains	Wastewater Treatment	Agricultural Drainage	Ground Water
AHP results	9.0%	6.60%	23.0%	8.30%	15.9%	37.2%
QFD results	13.02%	8.63%	21.70%	12.22%	15.51%	28.93%
QFD results using AHP%	9.95%	6.63%	23.35%	8.49%	15.53%	36.04%

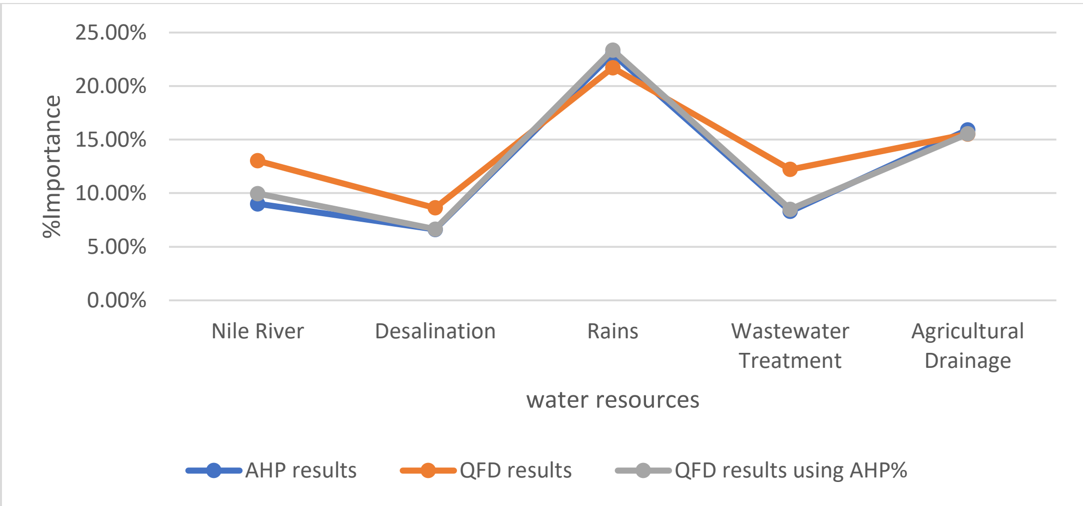

Figure 14: Results of AHP, QFD methods and their integration for Western Desert zone

6.4 The Comparison for Red Sea zones

By comparing the results from the Red Sea zone, it was found that, even though a slight difference in percentage between the three methods, the water resources remained in the same order, where the Desalination being the best source Ground Water comes after it while the Agriculture Drainage being the worst alternative as shown in Table 16 and Figure 15.

Table 16: Results of AHP, QFD methods, and their integration for Red Sea zone

Water resources	Nile River	Desalination	Rains	Wastewater Treatment	Agricultural Drainage	Ground Water
AHP results	17.3%	26.30%	12.60%	17.70%	6.00%	20.10%
QFD results	17.60%	24.11%	14.88%	17.75%	7.83%	17.82%
QFD results using AHP%	17.28%	26.12%	13.48%	17.32%	6.07%	19.72%

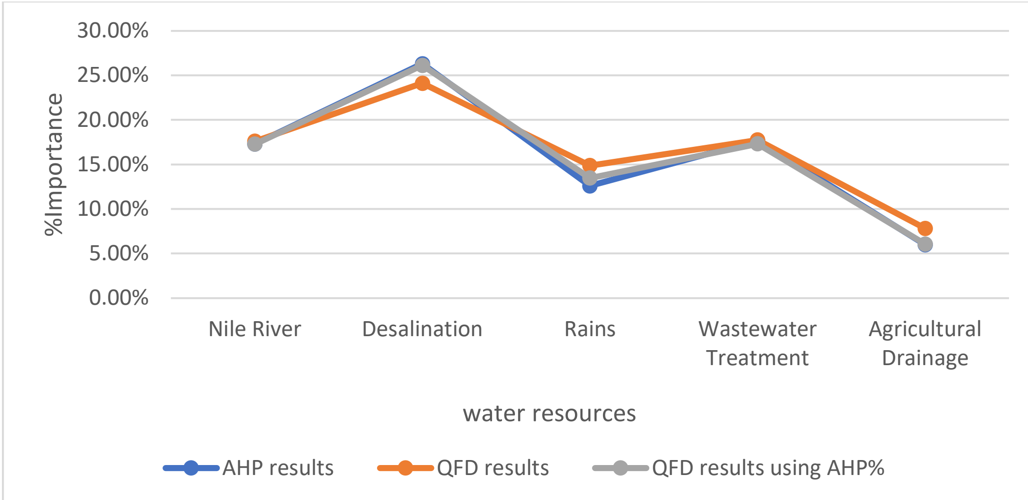

Figure 15: Results of AHP, QFD methods, and their integration for the Red Sea zone

6.5 The Comparison for North Coast zones

By comparing the results from the North Coast zone, it was found that, even though a slight difference in percentage between the three methods, the water resources remained in the same order, where the Desalination being the best source Nile River comes after it while the agriculture drainage being the worst alternative as shown in Table 17and Figure 16.

Table 17: Results of AHP, QFD methods and their integration results for North Coast zone

Water resources	Nile River	Desalination	Rains	Wastewater Treatment	Agricultural Drainage	Ground Water
AHP results	18.30%	28.20%	13.40%	16.30%	5.70%	18.10%
QFD results	18.59%	24.39%	14.96%	16.83%	8.012%	17.21%
QFD results using AHP%	18.47%	27.41%	14.10%	16.20%	5.73%	18.08%

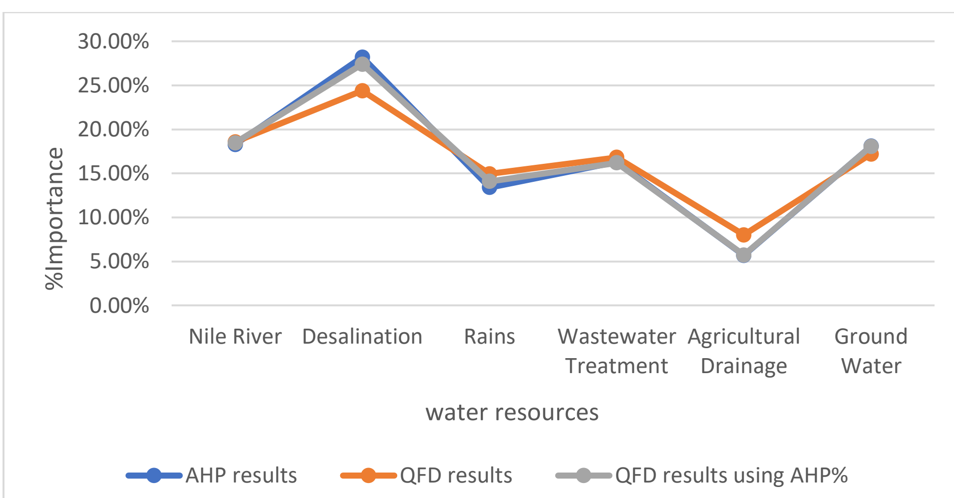

Figure 16: Results of AHP, QFD methods and their integration results for North Coast zone

7. Conclusions

In this research, we have used decision-making methods to choose the appropriate water source for each zone, where we divided Egypt into five zones according to the populated areas and the methods that have been used are the Quality Function Deployment (QFD) and this method is known as it takes the opinions of customers into account and here is meant by those Responsible For Decision-Making, The Second Method Is Analytical Hierarchy Process (AHP) Is a method of decision-making based on the relationship between alternatives for each factor.

In order to make a suitable decision on the appropriate alternative for each region, we made a comparison and integration between the two methods, and their results were as follows:

7.1 Conclusion of integration between AHP and QFD

For more accurate results, we combined the two methods, where we used the House of Quality (HOQ) model, but we replaced the consumer's place with the ratios of alternatives that appeared in the method AHP, where the results include the relationship between the alternatives for each factor from AHP method and the relationship between the factors to each other from QFD method. as in Upper Nile zone the best alternative is Nile River with important percent 31.25%, underground water comes after it with important percent 21.96%, where the last alternative is desalination with important percent 4.96%. In the Nile Delta zone, the best alternative is the Nile River with an important percentage of 31.23%, underground water comes after it with an important percentage of 22.05%, and the last alternative is desalination with an important percentage of 4.82%. In the Western Desert zone, the best alternative is groundwater with an important 36.04%, rain comes after it with an important percent 23.35%, where the last alternative is desalination with an important percentage 6.63%. In the Red Sea zone, the best alternative is desalination with an important percentage of 26.12%, groundwater comes after it with an important percentage of 19.72%, and the last alternative is agriculture drainage, 6.07%. In the North Coast zone, the best alternative is desalination with an important percentage of 27.41%, the Nile River comes after it with an important percentage of 18.47%, and the last alternative is agriculture drainage with an important percentage of 5.73%.

7.2 Conclusion of the comparison between AHP and QFD and their integration results

By comparing them, we found that although the two methods showed slightly different percentages of importance, but the order of alternatives from the most important to the least is similar in the three methods for all zones. As in the Upper Nile zone, the best alternative is the Nile River with an important percentage of 31.9%for the AHP method and 27.82% for the QFD method, 31.25%for their integration. Underground water comes after it with an important percentage of 22.0%for the AHP method and 21.35% for the QFD method, and 21.96% for their integration, where the last alternative is desalination with an important percentage of 4.70%for the AHP method and 7.30% for the QFD method 4.96%for their integration. In the Nile Delta zone, the best alternative is the Nile River with an important percentage of 32.40%for the AHP method and 27.86% for the QFD method, and 31.23% for their integration. Underground water comes after it with an important percentage of 21.8%for the AHP method and 21.51% for the QFD method, 21.96%for their integration, where the last alternative is desalination with an important percentage of 4.60%for the AHP method and 7.130% for the QFD method, 4.82% for their integration. In the Western Desert zone, the best alternative is groundwater with an important percentage of 37.20%for the AHP method and 28.93% for the QFD method, 36.04% for their integration. rains comes after it with important percent 23.0%for AHP method and 21.70% for QFD method 23.35% for their integration, where the last alternative is desalination with important percent 6.60%for AHP method and 8.63% for QFD method 6.63% for their integration. In the Red Sea zone, the best alternative is desalination with an important percent 26.30%for the AHP method and 24.11% for the QFD method, and 26.12% for their integration. Groundwater comes after it with an important percentage of 20.10%for the AHP method and 17.82% for the QFD method, 19.72% for their integration, where the last alternative is agriculture drainage with an important percentage of 6.0%for AHP method and 7.83% for QFD method, 6.07% for their integration. In the North Coast zone, the best alternative is desalination with important percent 28.20%for the AHP method and 24.39% for the QFD method 27.41% for their integration. Nile River comes after it with an important percentage of 18.30%for AHP method and 18.59% for the QFD method, 18.47% for their integration, where the last alternative is agriculture drainage with an important percentage of 5.70%for the AHP method and 8.012% for the QFD method, 5.73% for their integration.

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