# Factors Impact on Choice of Suitable Water Resource

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## Abstract.

Water is a crucial factor in economic and sustainable development, with its significance increasing with rising demand. The future is bleak if Egypt fails to effectively develop and execute a water resources management strategy that can effectively address the growing demand for freshwater within restricted supply constraints. Hence, it is imperative to examine the diverse water sources accessible in Egypt and reallocate these resources to other regions within the country to meet the water demand adequately. This study aimed to investigate the many factors influencing the selection of optimal water resources and assess the respective effects of these factors on the decision-making process. The results are derived from prior research studies, expert perspectives, and the completion of questionnaires by professionals. The search results found that the relative weights for factor in water resource selection are 9.84%, 9.30%, and 6.10% for the sustainability of the resource, quantity of water produced, and topography of the city and its surroundings, respectively. The most vital factor in selecting a water resource is its sustainability, followed by the quantity of water produced. The least important factor is the topography of the city and its surroundings.

**Keywords:** Water resource, Egypt, Water resource choice

# 1. Introduction

The water shortage is a pervasive issue that significantly constrains development in numerous nations [11] [16]. One of humanity's paramount challenges is the heightened competition for water resources, particularly with expanding agricultural practices and riverbed water utilization, while simultaneously addressing environmental considerations. Achieving an equilibrium between the water demand and availability in Egypt is essential, as deviating from this equilibrium would result in diminished aspirations. In recent years, Egypt has seen significant challenges related to water scarcity, the inequitable allocation of water, and the improper use of existing water resources [9]. Egypt employs inefficient irrigation systems, significantly contributing to the prevalence of water mismanagement throughout the nation. The per capita allocation of freshwater in Egypt is around 20 cubic meters, with the Nile River serving as a primary water source. Hence, it can not be argued that the Nile River is a fundamental pillar supporting Egypt's industrial and agricultural sectors. The United Nations has issued a warning indicating that Egypt may face water scarcity by 2025 [10].

Egypt's per capita amount of water suffered a fifty percent drop from 1960 to 1990, mostly due to the simultaneous rise in population and insufficient water supply. According to projections, the per capita water allocation is predicted to decrease to 605 cubic meters by 2025 [21]. Based on the latest available statistics from 2015, it has been stated that the per capita allocation of water in the United States amounts to 1,207 cubic meters. Moreover, it is noteworthy that certain nations, such as China, have a comparatively lower per capita water allotment than Egypt. According to the latest available dated 2019, China's per capita water allocation was 413 cubic meters [14]. Hence, the effective management of water resources is a crucial endeavor aimed at achieving an equilibrium between water consumption and the availability of water resources. This entails implementing various measures such as enhancing rainwater harvesting techniques, augmenting groundwater extraction, facilitating wastewater treatment and reuse, employing desalination methods for seawater, and improving its transportation infrastructure. Concurrently, efforts must be made to adapt to water scarcity.

## 1.1 Basic Water Resources

Water sources can be classified into five main categories. Namely, surface water (i.e., lakes, reservoirs, ravers), underground water, atmospheric water (i.e., rainfall, snowfall), and saline waters. Furthermore, each category is subdivided into one or more types of water sources [26].

The primary issue encountered in Egypt pertains to the instability of the water resources system. Consequently, a significant challenge arises in bridging the disparity between the available limited water resources and the escalating demand for freshwater. The water resources in Egypt can be categorized into two main types: traditional and non-traditional [21]. Traditional water resources include prominent examples such as the Nile River, groundwater, and rainfall. Non-traditional water sources encompass the utilization of sewage and the process of saltwater desalination [12].

### 1.1.1 River Nile Basin

The Nile River holds significant importance as a primary water resource in Egypt. Egypt, like numerous other nations, partakes in the utilization of the Nile River's water resources. Moreover, Egypt is situated near the end of the Nile River, resulting in substantial water discharge along its course. In 1959, Egypt entered into a formal agreement with the neighboring country of Sudan. According to the terms of this agreement, Egypt is allocated a water share of 55.5 billion cubic meters per year [20][7] [17].

The flow of the River Nile is influenced by climatic conditions, which in turn contribute to the occurrence of both flood and drought events in Egypt [1]. The maximum annual discharge of stored water behind the High Dam in Egypt is limited to 55.5 billion cubic meters, contingent upon the flood reaching a level that threatens the dam's integrity. This event occurred in 1998 as a result of recurring droughts. The storage of water in Lake Nasser during periods of heavy Nile inflow is of utmost importance.

### 1.1.2 Groundwater

Groundwater is a significant water resource in Egypt, located beneath the earth's surface. It can be accessed through various means such as shelf halls, wells, or natural springs and leaks. Due to its reliability, groundwater is the primary source for irrigation and drinking. Moreover, groundwater has wide applications in public, industrial, commercial, mining, irrigation, and thermal water systems [22]. Groundwater is an indispensable water resource that serves a multitude of uses. Groundwater serves many functions: public, industrial, commercial, mining, irrigation, thermal water systems, and various effluents [25].

### 1.1.3 Reuse Of Agriculture Drainage Water

In 1920, Egypt started an ambitious program for water reuse. The seepage of drainage water may include toxic pollution and chemical elements that cause harm to aquifers. [2]. Agricultural drainage water varies according to its location. For example, in Upper Egypt, wastewater is used indirectly when it returns to the Nile. Reuse of agricultural drainage water mixed with canal water. The total reused water in Egypt is approximately 4.5 billion $m^3$/year [6]. Egypt tends to reuse an additional three billion cubic meters per year for the Al Salam Canal Project and the supply of the Nubaria Canal. Treated sewage and industrial effluent may provide approximately three billion cubic meters annually [3].

### 1.1.4 Rainwater In Egypt

Egypt is well recognized as a predominantly desert nation, characterized by a shortage of rainfall. The average annual rainfall in Egypt seldom surpasses 200 mm, particularly along the northern coastline. As one moves from the coastal areas into the interior regions, the amount of rainfall drops dramatically. In the city of Cairo, rainfall is nearly negligible, approaching non-existence. The sporadic nature of winter precipitation in various regions renders it unreliable for agricultural purposes. The source's reliability is compromised by its spatial and temporal fluctuation [7] [21]. Moreover, it is projected that there will be a decline in the annual precipitation levels across numerous Mediterranean African nations and the northern Sahara region, including Egypt [1].

### 1.1.5 Reuse Of Treated Wastewater

New wastewater treatment facilities are being constructed in Cairo and other towns in response to substantial volumes of wastewater commonly utilized for agricultural purposes. The expected annual volume of reused treated domestic water through the treatment of household wastewater in 2001/2002 was reported to be 2.97 cubic kilometers [15] [6].

### 1.1.6 Desalination Of Seawater

Seawater desalination is a viable method employed in Egypt for the production of freshwater. However, it is essential to note that seawater desalination is associated with significant expenses and requires a substantial energy supply. Seawater desalination is subject to various elements influencing its utilization, including water quality, technological considerations, energy expenditure, plant capacity, and availability. It is worth noting that seawater desalination represents a non-conventional supply of water in Egypt [8]. The application of desalination is observed in various regions, including coastal municipalities, islands, and isolated industrial locations. The desalination capacity in Egypt has increased to around 150,000 cubic meters per day [6].

## 1.2 Factors Affecting The Choice Of Water Resource

Egypt has different water sources (i.e., Nile River, desalination, rain feed, reuse treatment wastewater, reuse agriculture drainage, and groundwater). To compare these sources, the factors affecting the water source selection must be determined. These factors can be summarized into ten main factors based on previous research and experts' opinions [23]. These factors will be discussed in the following section.

### 1.2.1 Quantity Of Water Source

Adequate access to water at its source is essential to fulfill the diverse demands and requirements of the designated population throughout a specific timeframe. The development of ways to get alternative water supplies becomes imperative in situations where existing water resources are inadequate.

### 1.2.2 Quality Of Produced Water

The acceptability of water quality and the appropriateness of its treatment are crucial considerations for a community. When local communities prioritize good hygiene and sanitation services, the advantages of utilizing improved water sources will likely be enhanced. However, it is essential to acknowledge that specific water quality issues, such as elevated fluoride levels, pose challenges in terms of treatment and can have significant health consequences. On the other hand, certain factors, such as turbidity, generally present a higher level of manageability in treatment processes.

### 1.2.3 Distance Of Water Supply Source

The supply source should be located at a close distance to the urban area. Thus, fewer pipelines are needed, leading to enhanced water supply and transmission cost-efficiency. In general, the selection process favors the source that is in the closest distance to the urban area.

### 1.2.4. Topography Of The City And Its Surroundings

There should not be a significant discrepancy in the land between the source supply and the city. In other words, the presence of steep slopes should be avoided due to the challenges they pose during construction and their potential to escalate construction costs and impede the laying of pipes.

### 1.2.5 Elevation Of The Source Of Water Supply

In order to meet the daily water pressure demands of a city, it is necessary for the water source to be situated at an elevation higher than that of the city. In cases where the water supply is situated at a lower elevation than the city, the implementation of pumps becomes necessary to facilitate the water's compression. Consequently, there is a resultant escalation in the workload and expenses associated with the development, operation, and maintenance.

### 1.2.6 Socio-Political And Cultural Considerations

The significance of social and political factors in development should not be underestimated. For instance, in cases where water supplies are culturally insufficient, security challenges may arise, leading to limited accessibility for specific demographic groups, such as women and individuals with disabilities. Under such circumstances, the advantages of the novel system will be constrained.

### 1.2.7 Operation And Maintenance Cost

For the operation and maintenance of the water source and treatment plant. Energy, replacement, and repair costs have been determined to be statistically significant factors for cost recovery and to be inversely associated. It is essential to use caution when selecting individuals to undergo training and assume the responsibility for operating and maintaining the water source production system.

### 1.2.8 Economic Considerations

In order to achieve long-term cost savings, it is imperative to incorporate economic factors into the decision-making process pertaining to the construction and maintenance of the system. [13 and 18]. It is imperative to ascertain the identity of the responsible party for payment as well as the specific method by which payment will be rendered. By whom will the system be managed and maintained? From whence will the resources be obtained, and what measures will be taken to ensure their security?

### 1.2.9 Environmental Condition

Alterations in environmental circumstances can substantially impact the availability and utilization of water resources. The water demand of agriculture can potentially be mitigated through either an increase in rainfall or a decrease in evaporation. The fluctuations in temperature within the vegetation area or biodiversity directly impact the rise in water demand. The degradation of water quality resulting from heightened levels of contamination diminishes the accessible water supply in a manner comparable to that of a drought [24].

### 1.2.10 In-Stream And Withdrawal Uses Of Water

A fundamental differentiation in water utilization characteristics between in-stream and withdrawal water uses can be observed. The transient or ephemeral characteristic of water resources often ensures that particular applications do not hinder the accessibility for subsequent utilization in numerous cases. These applications are generally referred to as in-stream uses. They have minimal impact on the characteristics of water and, thus, do not affect the quality or quantity of water available for following uses. In-stream applications encompass a variety of activities, such as recreational pursuits, the preservation of aquatic habitats and other environmental functions, navigation, and hydroelectric power generation. [24]

## 2 QUESTIONNAIRE

There are different water sources in Egypt (namely, Nile River, desalination, rain feed, reuse treatment waste water, reuse agriculture drainage, and groundwater), as mentioned in section 2. To compare these sources, we must determine the factors affecting source selection.

The factors affecting the choice of suitable water resources based on previous literature and experts' opinions are as follows:

- 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 with drawl uses of water.
- Cost of transporting water.
- Quantity of water produced
- Sustainability of the resource

The importance of each factor in selecting water resources is determined by a questionnaire that is formed in Google form and sent to experts. This questionnaire determines the importance of each factor from 1 to 5, where one is the least effective and five is the most effective.

The sample size is determined using Tomas Simson's Equation. From equation (1), the chosen simple should be at least 384 experts.

$$n = \frac{N\,P(1-P)}{(N-1)\left[\frac{d}{Z_{1-\alpha/2}}\right]^2 + P(1-P)} \qquad \text{(Eq. 1)}$$

Where,

n is sample size

N is community size, is taken as the number of engineers in the Egyptian engineers syndicate equal to approximately 400000

d is an allowable limited error, taken by 5%

$Z_{1-\alpha/2}$ is the stranded normal distribution at a significant level α, taken equal to 1.96

P is the percentage occurrence of state or condition, Simson prefers when it is unknown to be taken =0.5

## 3 RESULTS

The questionnaire was filled out by 392 experts, and the questionnaire results are discussed below.

Figure 1 illustrates the analysis of the questionnaire results for the first factor (namely, the quantity of water). The analysis shows that most participants see this factor as highly effective in selecting water resources, as most participants give it a rate of 4 and 5, with a total percentage of 84%. While a minor number of the participants (namely, 5%) rated the factor as 1 and 2. Finally, the average rate of the first factor based on questionnaire results equals 4.47.

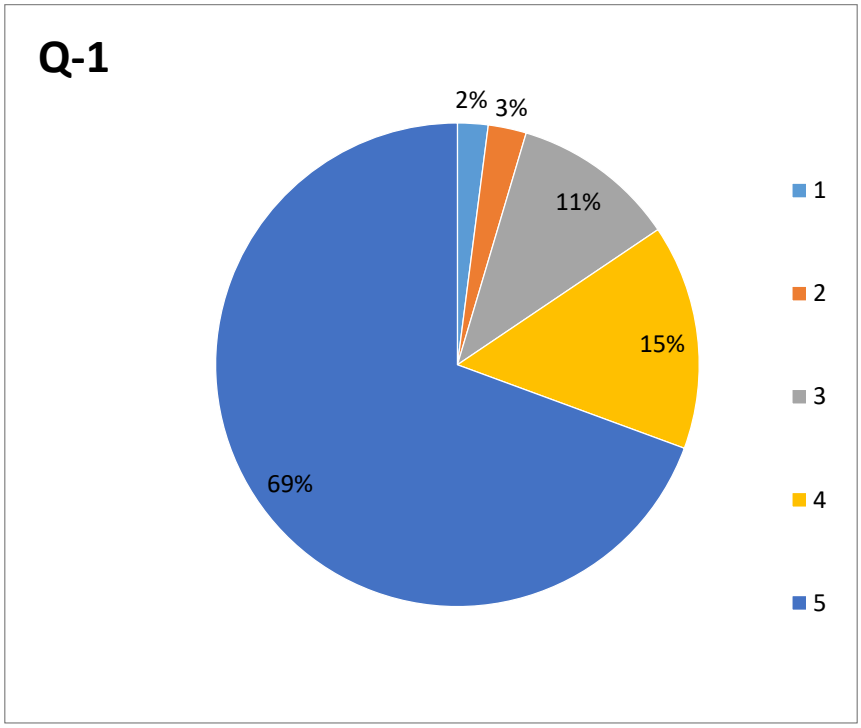


**Figure 1: Questionnaire point 1 (namely, the quantity of water)**

Figure 2 illustrates the analysis of the questionnaire results for the second factor (namely, the Quality of influent water). The analysis shows that most participants see this factor as highly effective in selecting water resources, as most of the participants give it a rate of 4 and 5, with a total percentage of 44%. While some participants (namely, 29%) rated the factor by 1 and 2. Finally, the average rate of the first factor based on questionnaire results equals 3.45.

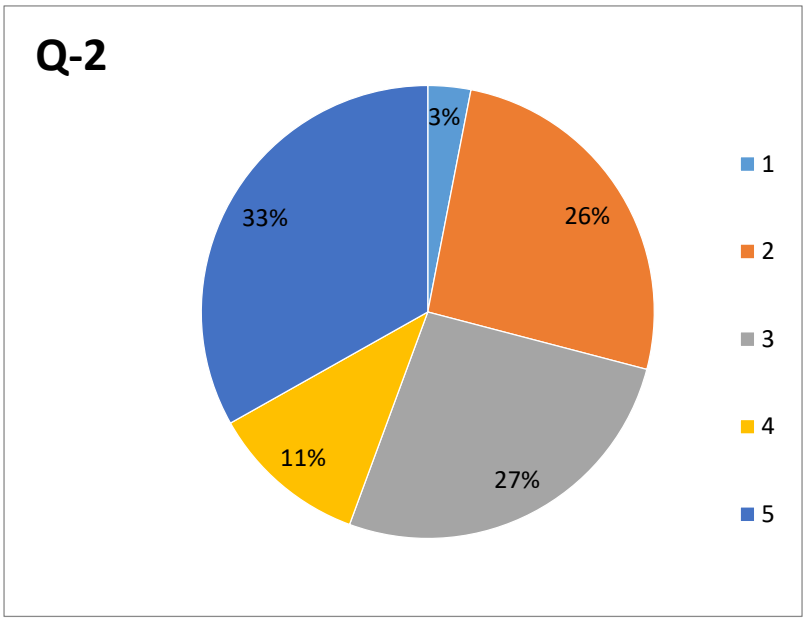


**Figure 2: Questionnaire point 2 (namely, Quality of influent water)**

Figure 3 illustrates the analysis of the questionnaire results for the second factor (namely, the Quality of produced water. The analysis shows that most participants see this factor as highly effective in selecting water resources, as most of the participants give it a rate of 4 and 5, with a total percentage of 69%. At the same time, a minor number of participants (namely,17%) rated the factor by 1 and 2. Finally, the average rate of the first factor based on questionnaire results equals' 4.05.

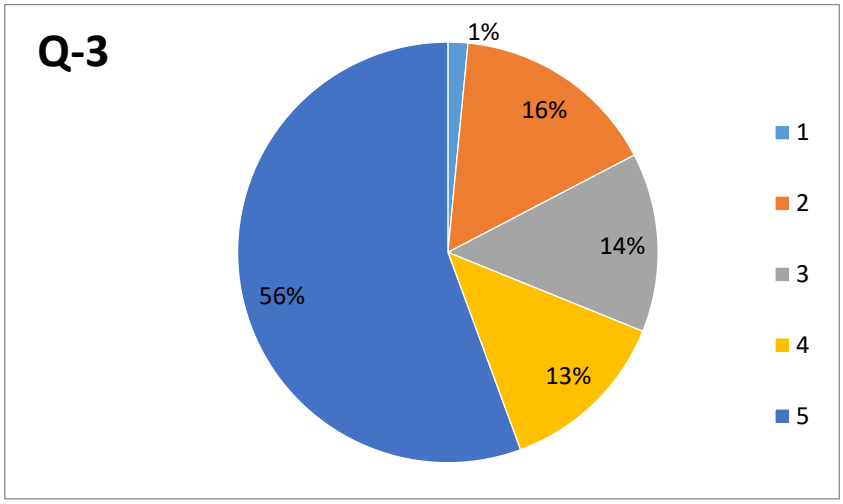


**Figure 3: Questionnaire point 3 (namely, Quality of produced water)**

Figure 4 illustrates the analysis of the questionnaire results for the second factor (namely, the distance of the water supply source). The analysis shows that most participants see this factor as influential in selecting water resources; the participants give it a rate of 4 and 5 with a total percentage of 40% While the participants (namely, 38%) rated the factor with 1 and 2. Finally, the average rate of the factor based on questionnaire results equals' 3.12.

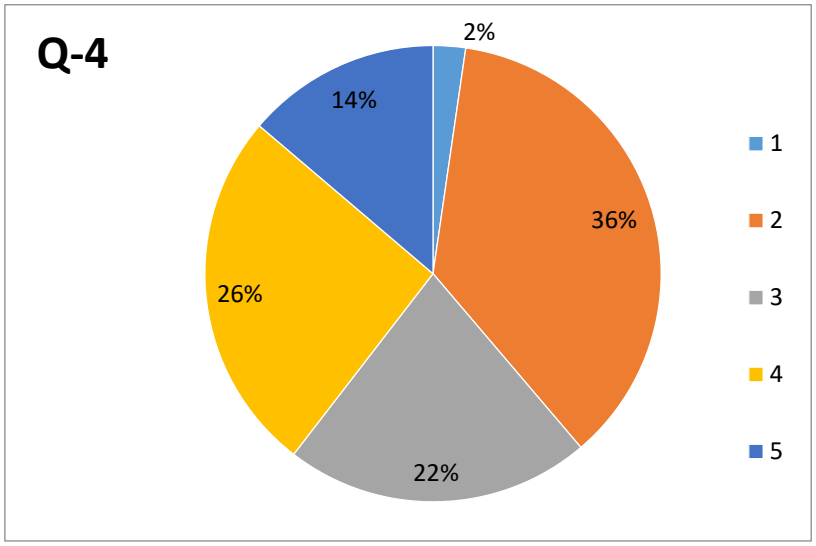


**Figure 4: Questionnaire point 4 (namely, distance of water supply source)**

Figure 5 illustrates the analysis of the questionnaire results for the fifth factor (namely, the topography of the city and its surroundings). The analysis shows that most participants see this factor as having a low influence in selecting water resources as a minor of the participants gives it a rate of 4 and 5 with a total percentage of 25%. While a significant number of the participants (namely, 41%) rated the factor as 1 and 2. Finally, the average rate of the factor based on questionnaire results equals' 2.93.

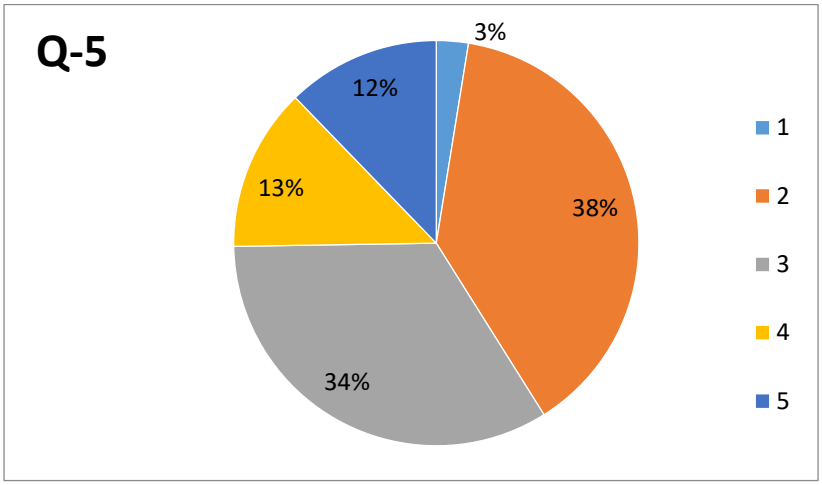


**Figure 5: Questionnaire point 5 (namely, the topography of the city and its surroundings)**

Figure 6 illustrates the analysis of the questionnaire results for the sixth factor (namely, the elevation of the source of water supply). The analysis shows that most participants see this factor as influential in selecting water resources as the participations give it a rate of 4 and 5 with a total percentage of 38%. The participants (namely, 33%) rated the factor by 1 and 2. Finally, the average rate of the factor based on questionnaire results equals' 3.18.

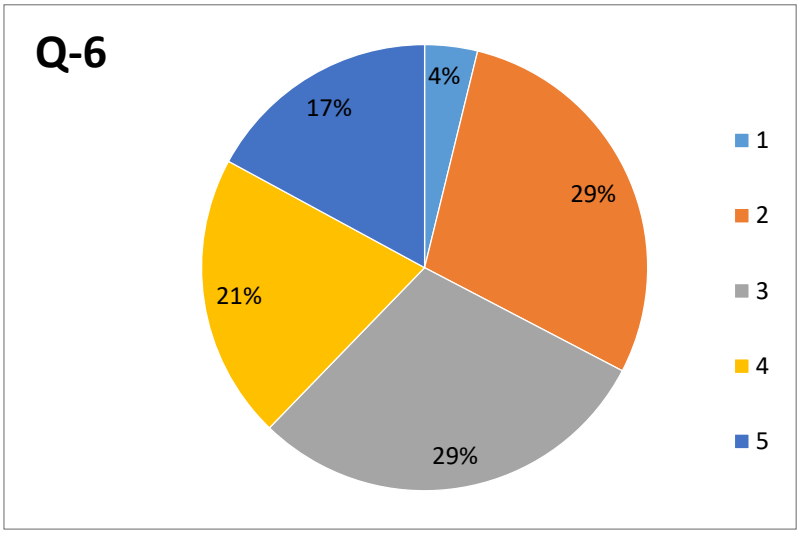


**Figure 6: Questionnaire point 6 (namely, the elevation of the source of water supply)**

Figure 7 illustrates the analysis of the questionnaire results for the seventh factor (namely, Socio-political and cultural considerations). The analysis shows that most participants see this factor as highly effective in selecting water resources, as most of the participants give it a rate of 4 and 5, with a total percentage of 56%. While a minor number of the participants (namely, 17%) rated the factor as 1 and 2. Finally, the average rate of the factor based on questionnaire results equals' 3.66.

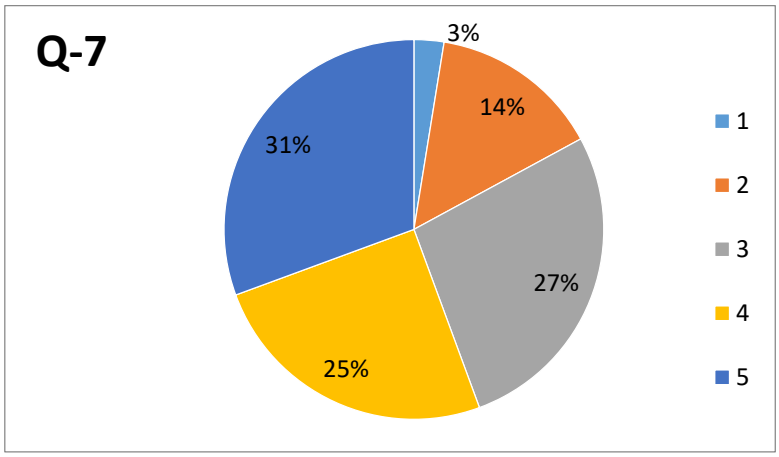


**Figure 7: Questionnaire point 7 (namely, Socio-political and cultural considerations)**

Figure 8 illustrates the analysis of the questionnaire results for the eighth factor (namely, Construction cost). The analysis shows that most participants see this factor as influential in selecting water resources as the participations give it a rate of 4 and 5 with a total percentage of 44%. While the participants (namely, 40%) rated the factor by 1 and 2. Finally, the average rate of the factor based on questionnaire results equals 3.19.

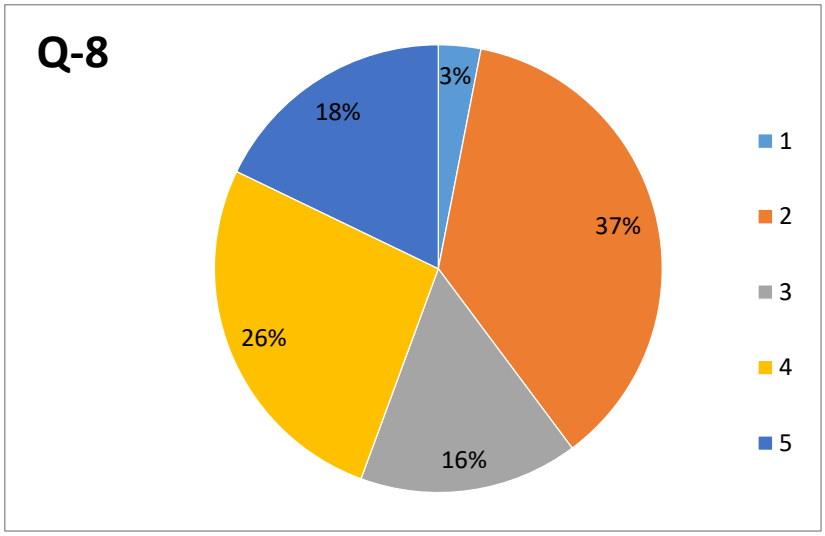


**Figure 8: Questionnaire point 8 (namely, Construction cost)**

Figure 9 illustrates the analysis of the questionnaire results for the ninth factor (namely, Operation and maintenance cost). The analysis shows that most participants see this factor as highly effective in selecting water resources, as most of the participants give it a rate of 4 and 5, with a total percentage of 76%. While a minor number of the participants (namely, 12%) rated the factor as 1 and 2. Finally, the average rate of the factor based on questionnaire results equals 4.17.

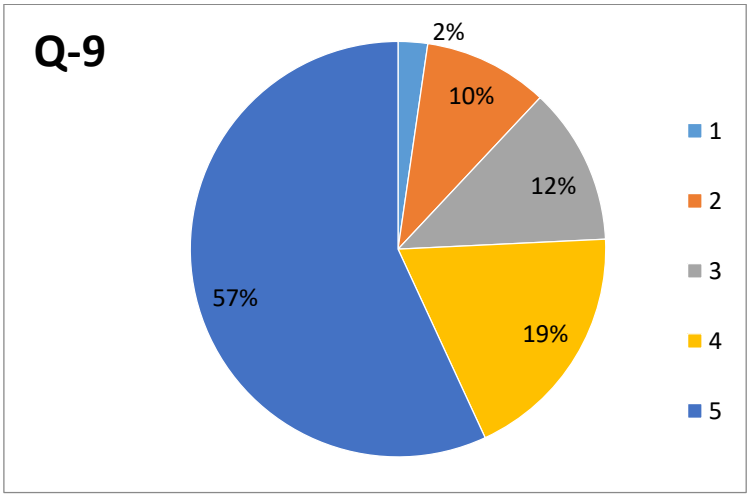


**Figure 9: Questionnaire point 9 (namely, Operation and maintenance cost)**

Figure 10 illustrates the analysis of the questionnaire results for the tenth factor (namely, Environmental Conditions). The analysis shows that most participants see this factor as highly effective in selecting water resources, as most of the participants give it a rate of 4 and 5, with a total percentage of 72%. While a minor number of the participants (namely, 11%) rated the factor by 1 and 2. Finally, the average rate of the factor based on questionnaire results equals 4.

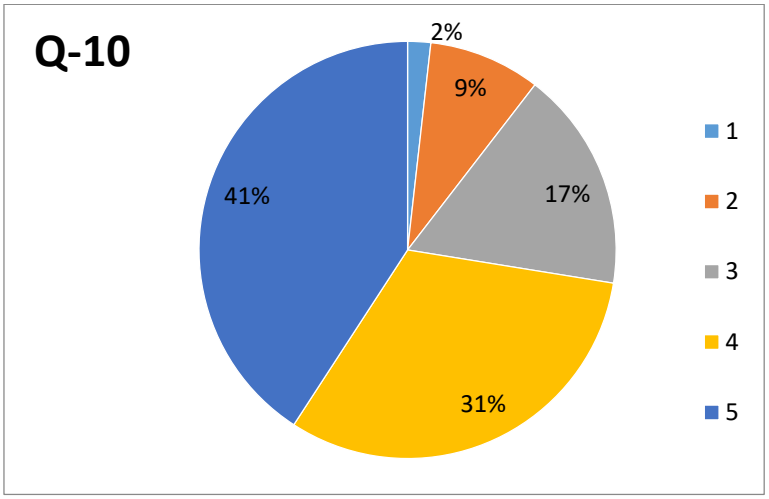


**Figure 10: Questionnaire point 10 (namely, Environmental Conditions)**

Figure 11 illustrates the analysis of the questionnaire results for the eleventh factor (namely, in-stream and withdrawal uses of water). The analysis shows that most participants see this factor as highly effective in selecting water resources, as most of the participants give it a rate of 4 and 5, with a total percentage of 58%. While a minor number of the participants (namely, 17%) rated the factor as 1 and 2. Finally, the average rate of the factor based on questionnaire results equals 3.69.

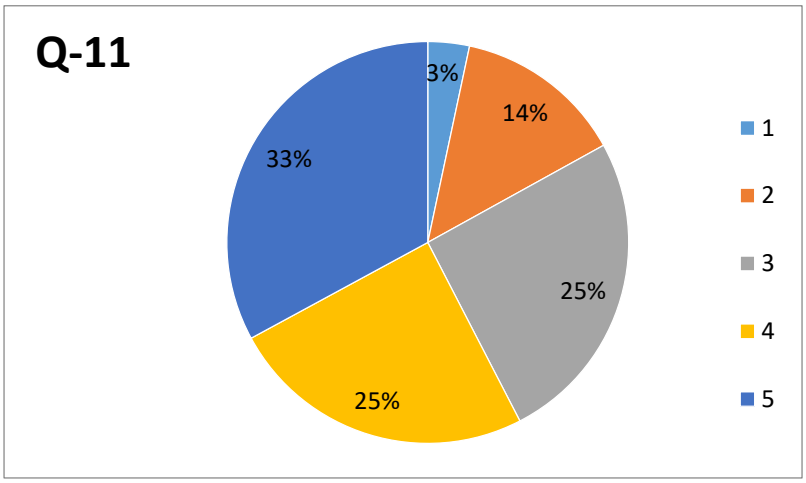


**Figure 11: Questionnaire point 11 (namely, in-stream and withdrawal uses of water)**

Figure 12 illustrates the analysis of the questionnaire results for the twelve factors (namely, cost of transporting water). The analysis shows that most participants see this factor as influential in selecting water resources as the participations give it a rate of 4 and 5 with a total percentage of 50%. While the participants (namely, 34%) rated the factor with 1 and 2. Finally, the average rate of the factor based on questionnaire results equals 3.45.

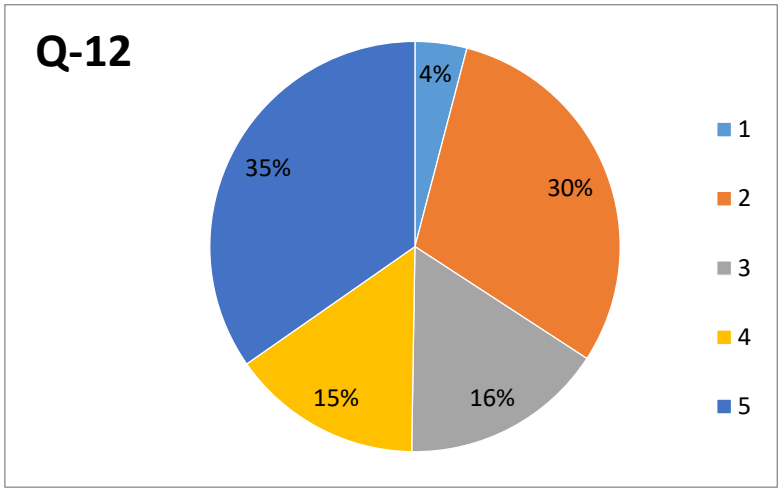


**Figure 12: Questionnaire point 12 (namely, cost of transporting water)**

Fig. 13 illustrates the analysis of the questionnaire results for the thirteenth factor (namely, Source Sustainability). The analysis shows that most participants see this factor as highly effective in selecting water resources, as most of the participants give it a rate of 4 and 5, with a total percentage of 93%. While a minor number of the participants (namely, 1%) rated the factor as 1 and 2. Finally, the average rate of the factor based on questionnaire results equals 4.73.

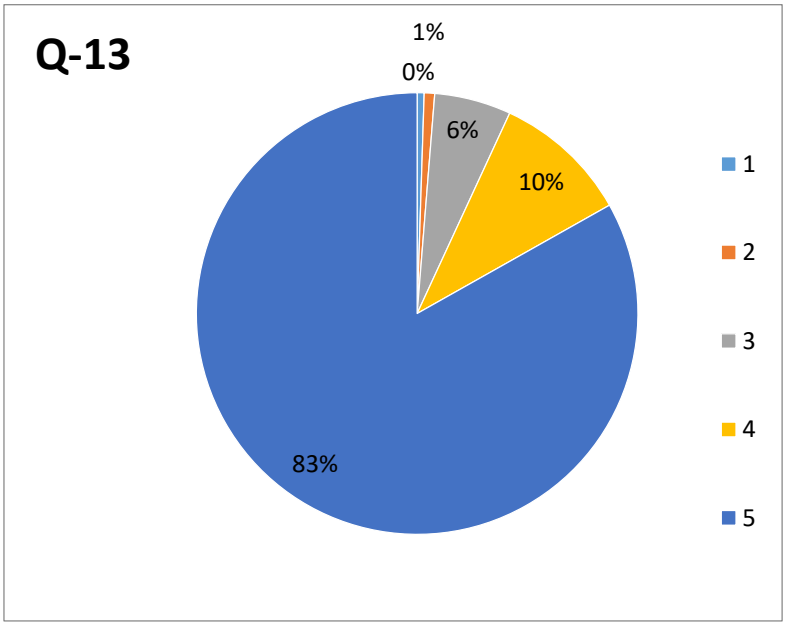


**Fig. 13: Questionnaire point 13 (namely, Source Sustainability)**

From the questionnaire results, the average of the questionnaire rates for each factor was calculated and used to determine the relative weight for each factor using Equation (2). Then, the factors are ranked from highest to lowest to know each factor's weight in the water resource selection, as illustrated inTable (1),
Figure 14, and
Figure 15.

Relative weight = (average /sum of all averages) x100 (Eq. 2)

A summary of research results is depicted in Table (1) and visually represented in
Figure 14 and
Figure 15, displaying the various factors under consideration, organized in descending order of effectiveness. The analysis of the graphs indicates that sustainability is the most influential factor in determining the choice of water source, with a relative weight of 9.84%. This is due to the necessity of having a continuous and readily available water supply. The second most significant factor is the quantity of water, which must be sufficient to meet the region's water demands, with a relative weight of 9.30%. The third factor, operation and maintenance cost, holds a relative weight of 8.68% and emphasis. It is evident that several aspects substantially influence the determination of the water source, and it is imperative to consider each factor without disregard. This is clearly shown as the difference between the most effective and lowest effective is limited to 3%.

**Table (1) Average Rate and Relative Weight Of Factors Affecting The Choice Of Suitable Water Resources Based On Questionnaire Results.**

| Factors Influencing Water Resource Selection | Average | Relative Weight |
|---|---|---|
| Source Sustainability | 4.73 | 9.84% |
| Quantity of Water | 4.47 | 9.30% |
| Operation and Maintenance Cost | 4.17 | 8.68% |
| Environmental Conditions | 4.00 | 8.32% |
| Water Quality (Produced Water) | 4.05 | 8.42% |
| In-Stream and Withdrawal Uses of Water | 3.69 | 7.68% |
| Socio-Political and Cultural Considerations | 3.66 | 7.61% |
| Cost of Transporting Water | 3.45 | 7.18% |
| Quality of Water (Influent) | 3.45 | 7.17% |
| Elevation of the Source Of Water Supply | 3.18 | 6.61% |
| Construction Cost | 3.19 | 6.63% |
| Distance of Water Supply Source | 3.11 | 6.48% |
| Topography of The City and Its Surroundings | 2.93 | 6.10% |
| Sum | 48.08 | 100% |

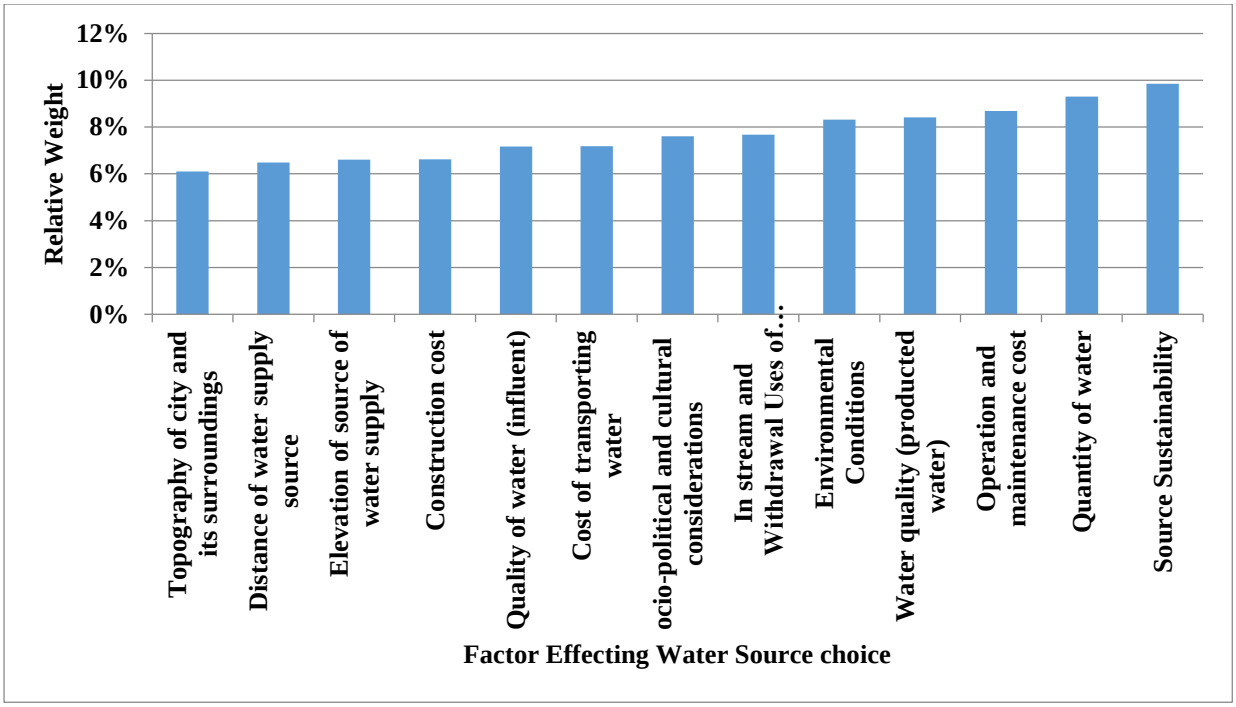


**Figure 14: Based on questionnaire results, the relative weight of factors affecting the choice of suitable water resources.**

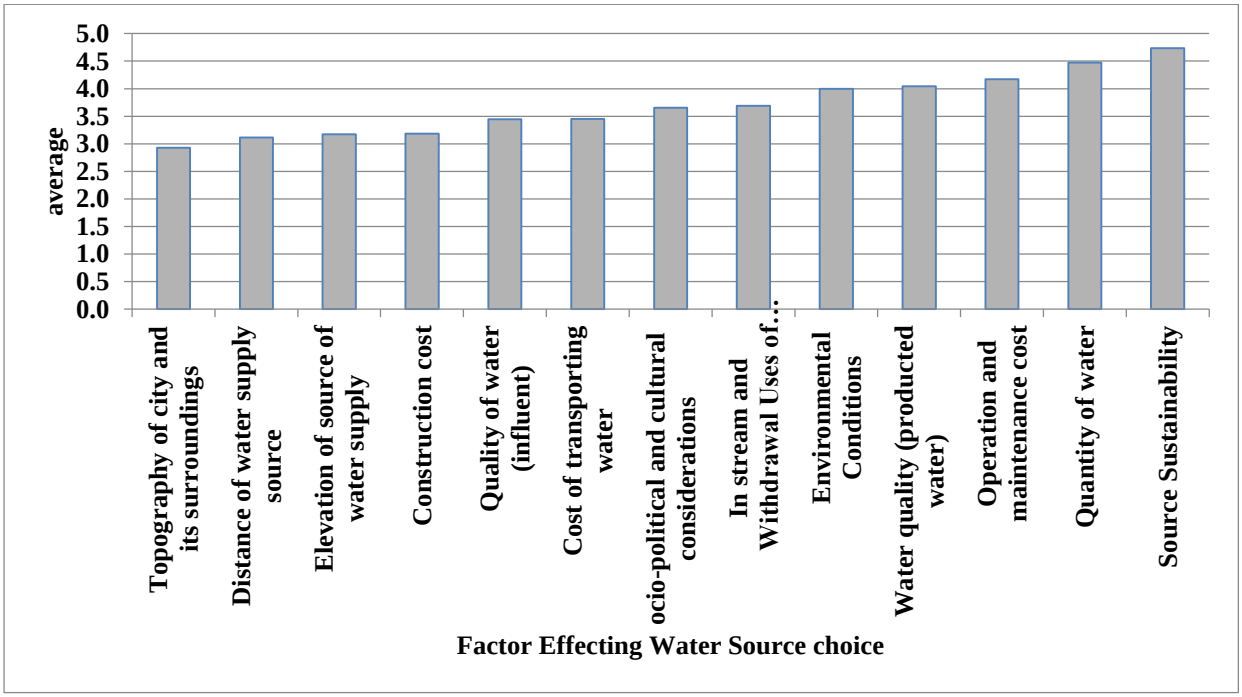


**Figure 15: Average rate of factors affecting the choice of suitable water resources based on questionnaire results.**

## 4 CONCLUSIONS

The main conclusions of the present research may be summarized in the following points:

1. The disparity in weight between the most effective and least effective factors is around 3%, indicating that all of these parameters hold significance in selecting appropriate water sources.
2. The most essential factor in selecting an appropriate water resource is its sustainability, with a relative weight of 9.84%. Water resource sustainability is paramount as it pertains to its consistent availability throughout the year or its limited availability during specific seasons.
3. The quantity of water comes in second place after sustainability with a relative weight of 9.30% since the appropriate supply must be available at all times, and the quantity must cover the intended usage.
4. The least effective factor is city topography, with a relative weight of 6.10%, which may cause some difficulty in water transportation while only having a minor impact on the water in the purpose area.
5. One of the striking contradictions in these results is that the factor related to the distance of the resource of water weight is low compared with other factors where the distance of the resources is significant in the choice. As the resource distance increases, the reliance on this source decreases, but this can be explained as mentioned before: the disparity in weight between the most effective and least effective factors is around 3%, which indicates that all factors are nearly important. Otherwise, the results are all convincing.

## 5 CONSENT FOR PUBLICATION

Not applicable.

## 6 FUNDING

None.

## 7 CONFLICT OF INTEREST

The authors declare no conflicts of interest, financial or otherwise.

## 10. ACKNOWLEDGMENTS

Declared none

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# 9 APPENDIX (I) QUESTIONNAIRE

## Factors affecting water sources selection

This questionnaire presents the factors that affect the choice between different water sources. The importance of each of these factors based on the extent of its influence on the selection, provided that the evaluation is from 1 to 5,

*where 1 is the least influential and 5 is the highest.*

**يقدم هذا الاستبيان العوامل التي تؤثر على الاختيار بين مصادر المياه المختلفة. تعتمد أهمية كل من هذه العوامل على مدى تأثيرها على الاختيار ، بشرط أن يكون التقييم من 1 إلى 5**

*حيث 1 هو الأقل تأثيرًا و 5 هو الأعلى*

1. Quantity of water *

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

2. Quality of water (influent) *

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

3. Water quality (Effluent) *

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

4. Distance of water supply source *

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

5. Topography of city and its surroundings *

- 1
- 2
- 3
- 4
- 5

6. Elevation of source of water supply *

- 1
- 2
- 3
- 4
- 5

7. Socio-political and cultural considerations *

- 1
- 2
- 3
- 4
- 5

8. Construction cost *

- 1
- 2
- 3
- 4
- 5

9. Operation and maintenance cost *

- 1
- 2
- 3
- 4
- 5

10. Environmental Conditions *

- 1
- 2
- 3
- 4
- 5

12. Cost of transporting water *

- 1
- 2
- 3
- 4
- 5

13. In the case of any other factors that may affect the selection of water source. Please mention it in the following box

في حالة وجود اية عوامل اخري من الممكن ان تؤثر على اختيار مصدر المياه. يرجى ذكرها في الخانة التالية

Enter your answer