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Integrated Multiple Attribute Decision Framework for Risk Management of the Grand Ethiopian Renaissance Dam on Egypt

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Abstract - *Many reviews have stated that the construction of Great Ethiopian Renaissance Dam (GERD) could have serious impacts on the water resources in downstream Eastern Nile countries, especially Egypt. However, the present work aims to determine risks of GERD on Egypt, and suggests the management strategies to mitigate these risks. The work tasks were divided into two main phases. In the first phase, the Generic Risk Matrix (GRM) that contains a broad set of categorized risks according to their potential impact and probability of occurrence is developed. While, the second phase involved on developing the Analytic Hierarchy Process (AHP) based on multiple attribute or criteria decision analysis of an integrated technical, environmental, economic and socio-community indicators for weighting various GERD risk management strategies. Then, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was used to produce an overall ranking of alternatives strategies, The findings of this work demonstrated that several promoted sustainable strategies for water resources management in the Eastern Nile countries, especially Egypt can be considered when choosing the most convenient alternative to mitigate the adverse impact following from the building of GERD on downstream countries especially Egypt.*

Key Words: Water Resources, Risk Management, GERD, GRM, AHP, TOPSIS.

1. INTRODUCTION

The Nile River is an important resource for the economy system of East and Northeast Africa. The basin has two basic water supply sources and a basic water user group. The source of water supply is the Easter Nile (Ethiopia), which accounts for 85% of the stream of the Nile, and the Nile in the east of the equator (Nile tropical countries) accounts for 15% of the stream. The water resources accessibility is distributed between the Nile basin countries: Egypt and Sudan are the greatest water users, both countries are almost entirely dependent on water from the Nile and have substantial irrigation (Waterbury, J, 2002).

Hence, the Ethiopian authorities are imposing bold plans and applications for the improvement of hydropower, with a view to substantially decreasing poverty and growing an environment for social change.

GERD is predicted to generate a most of 6000 megawatts of hydroelectric electricity; the figure (1) shows a diagram illustrating the location of GERD. The likely effect of the dam has always been a source of regional disputes. The Egyptian government, a country that depends closely on the waters of the Nile, protested the dam, which it believed would decrease the quantity of water it obtains from the Nile. (Goor, Q et al., 2010).

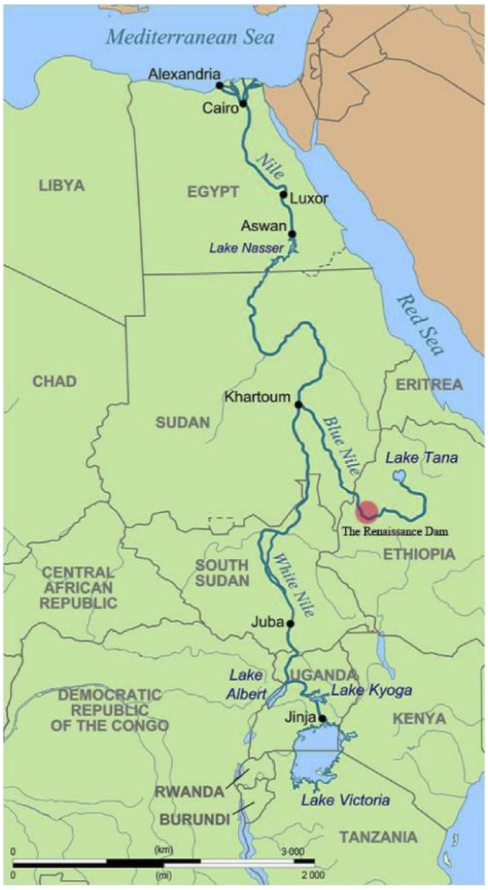

Fig -1: Map of the Nile Basin with Location of GERD (Mobasher, 2016)

1.1. Impact of GERD Project

The international expert panel presented its final determination May 31, 2013, which included the effect of GERD on Egypt and Sudan and the important gaps in GERD project research. The determination found that the primary hazardous effects on Egypt will be the reduction in power generation from the Aswan High Dam (AHD) as a result of the lower water levels of Lake Nasser, and the salinization of agricultural land in Egypt in the Nile Delta, which is attributed to the increased upstream water withdrawal due to GERD operations and the large-scale losses of Sudan's flooding and declining agriculture during GERD's storage and operation period (IPoE 2013).

These expectations are confirmed by the report submitted by a group of professional in Egypt which issued a recommendation report for its government on the social, economic and political impact of GERD on Egypt in June 2013, which is the consequence of the Ethiopian dam.

The report concludes that the influence will be a decrease in the water allocation of Egypt within the hold and operation of GERD particularly within the drought periods. There is also a possibility of GERD"s saddle dam collapse, which will lead to disastrous outcomes in Sudan and Egypt represented in leaving agricultural lands, water pollution and inundating of captain cities and settlements revealing millions to the threat of death and replacement (GNB 2013).

Numerous studies underlined the adverse impacts of GERD on Egypt. E.g.; Mobasher, 2016 studied the effect of GERD on water supply and hydropower generation from AHD in Egypt. Three, four, five, six, seven and eight years filling period was simulated by considering current operation rules for AHD reservoir (Mobasher, 2016). The findings out of this study can be summarized as follows: -

- For three, four and five years filling period of GERD respectively, Lake Nasser water level upstream AHD will decrease significantly because of GERD filling, and AHD Minimum Operating Level (147 m) will be reached.
- This analysis shows that, Egypt will suffer significant shortfalls relative to historical average releases from Lake Nasser reaches to 3.41 BCM/year for filling period 8 years, the annual deficit might grows and reaches to 10.32 Billion Cubic Meter (BCM)/year for filling period 3 years.
- The annual average energy generation could be 3606, 4134, 5261, 6079, 6412, and 6856 for three, four, five, six, seven and eight years filling period of GERD respectively, compared to 7594 GWh from AHD without GERD. The mean annual energy of AHD will reduce to 53, 46, 31, 20, 16 and 10 % for three, four, five, six , seven and eight years filling period of GERD respectively (Mobasher, 2016).

2. MATERIAL AND METHOD

In this research, General Risk Matrix Method (GRM) is combined with an integrated multi-attribute decision-making framework, including AHP and TOPSIS methods. However, the first phase of study includes risk identification, assessment and analysis with the aid of GRM method. Then, the second phase involved in treatment responses and appropriate risk management strategies. Moreover, AHP is implemented to estimate the relative weights of strategies criteria and sub criteria, while TOPSIS methods was used to rank the risk responses strategies. Figure (2) illustrates the main phases and steps of the study methodology (McInnis, 2001).

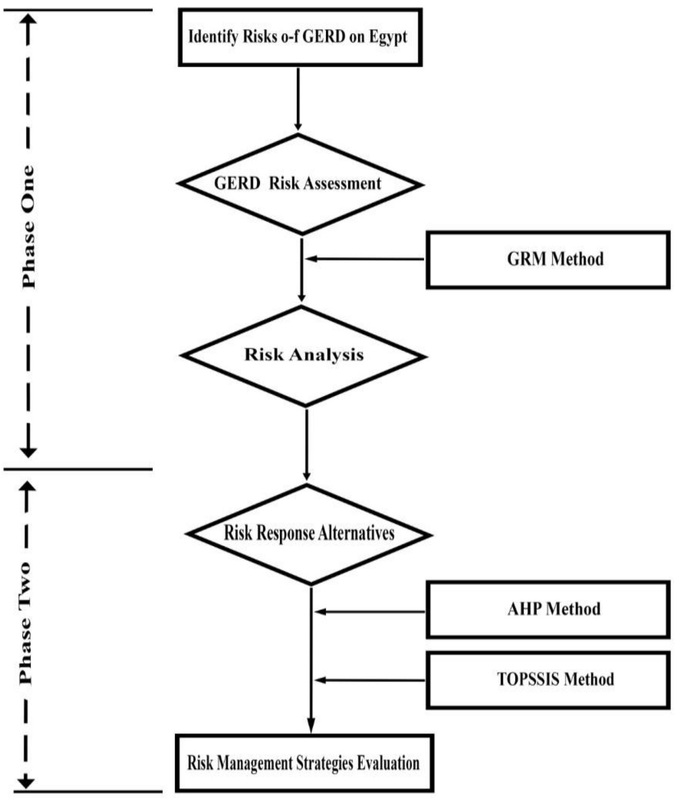

Fig -2: Study Methodology

2.1 Generic Risk Matrix Approach

GRM is a powerful tool to assist the risk analysis process, especially in the case of relatively lack of resources or uncertainty about how to conduct project risk analysis. GRM contains a various range of risks, which are classified and arranged based on their possible influence and general likelihood of occurrence. The risk matrix is created based totally on the input and feedback of 12 professionals considering the impact and possibility of various risks. The focus group of professionals mentioned is composed of engineers with unique backgrounds in the fields of water resources management (McInnis, 2001).

2.1.1 GRM identification and categorization

In this research, risk identification is accomplished through brainstorming, interviewing individuals and expert groups. Ask the mentioned professionals to list all potential project risks that may occur, regardless of their probability of occurrence. This technique is carried out as a team, because when one person identifies risks, it usually triggers another person to identify other related risks. This technique can be used to initially identify various risks (McInnis, 2001).

Through an extensive literature review, three main categories have been identified. At the same time, the corresponding risks decided for every category, the categories and related risks are as follows: -

A- Social risks (SR): include four risks: -

- **Water supply (SR1):** GERD has established reservoirs that can supply water for a diversity of objectives, containing municipal, manufacturing and farming. Seasonal and annual changes in streams may cause water shortages for people in coastal countries. It is predicted that the living of farmers and other villagers would be significantly affected.
- **Public health (SR2):** Newly established water bodies will produce water-related sicknesses, as for instance malaria and bilharzia, which will have an effect on public health. Some infectious ailments are unfold round the hydroelectric electricity reservoir, particularly in heat climates and heavily populated zones (NBI 2012).
- **Safety and security (SR3):** Dam securities interests are correlated to wrong design or wear of materials used in construction, (FEMA, 2015).
- **Population redistribution (SR4):** After the construction of GERD, due to increased demand in other sectors (such as industry, population increase, etc.), agriculture may be affected by water shortages. Considering that Egypt's water supply to the Nile has decreased, considerations about population redistribution have become important.

B- Environmental risks (ER): involved in eight risks: -

- **Decreasing years of filling period of GERD reservoir (ER1):** Impounding of GERD at mean annual inflow during 3 years will reduce the working zone of Lake Nasser by 25.413 BCM annually, (Ramadan et.al, 2013). However, as a result of reducing of water flows into Lake Nasser, the water levels will reduce from 0.40 to 0.75 m when water flow reduced from 90% to 80% of the mean annual water flows into Lake Nasser (Nada and Fathy, 2014).
- **Decreasing annual Egypt's share of water (ER2):** The continuous storage of GERD for 6 years in the normal flow hydrological stage will lead to water shortage in the downstream, depending on the initial water storage capacity of Lake Nasser. (Ramadan et.al, 2013).
- **Downstream flow regime (ER3):** Vital downstream hydrological modifications can destroy fluvial environments which rely on periodical natural flood, water contamination deterioration within low flow durations, and rise of saltwater intervention near river inlets, (Ledec and Quintero,2003).
- **Water quality (ER4):** as a result of the lowered oxygenation and reduction of contaminants from relatively fixed reservoirs, the flooding of biomass and the resulting underwater decay and/or stratification of reservoirs lacking oxygen in deep lake water will result in severe water quality degradation. (Ledec and Quintero, 2003).
- **Shortage of groundwater storage (ER5):** The groundwater in Egypt is assessed 6.5 BCM yearly, the percentage of shortage of groundwater according to GERD is 2.145BMC yearly that represents a reduction of 33%, (WRIM, 2014).
- **Fisheries (ER6):** Reservoirs have a positive impact on certain fish by increasing the available aquatic habitat area. However, the net impact is usually negative because dams prevent the migration of upstream fish, while downstream passage through turbines or spillways is often unsuccessful, (Ledec and Quintero, 2003).
- **Climatic variability and change (ER7):** Large areas of the basin are susceptible to drought because of the variable rainfall and high evapotranspiration rate. Seasonal water shortages associated with natural climate changes make it complicated to preserve maximum power production capability overall the year and may decrease the long-range economic sustainability of candidate hydropower projects. With global climate change, the negative impact of climate on the power industry is expected to increase significantly (NBI 2012).
- **Cultural assets (ER8):** Cultural properties including historical, archaeological and spiritual places and purposes may be submerged and destroyed by reservoirs (Ledec and Quintero, 2003).

C- Economical risks (CR): contain three risks

- **Energy production (CR1):** After the construction of GERD, it is estimated that AHD can reduce the power generation by 20-30% every year. (CU, 2003).
- **Irrigation and desertification of agricultural land (CR2):** The reduction in the releases from AHD reduced Egypt's agricultural land by 46.24%. Egypt's arable land area was 3.9×10^{10} m^2, and Egypt's agricultural land was deserted to 1.8×10^{10} m^2 (18 billion square meters).
- **Navigation (CR3):** dams create obstacles to upstream and downstream navigation and the flow of fish and other organisms. Dams can also greatly modify the water releases and the transportation of sediments, nutrients and food, thereby providing water to the downstream aquatic ecosystems and estuaries. The impact usually extends to hundreds of kilometers downstream (Krchnaket et al., 2009). The lower water level will adversely affect tourism and boating downstream of the river. With the increase in the amount of sediment transported, serious changes have taken place in the waterways and ports.

2.1.2 GRM probability and impact assessments

After risks identification, a total of 12 useable expert responses were used in the risks arising from the building of GERD by identifying the possibility of incident, the impact and risk factors.

In this study, for the development of GRM, appropriate impact and probability values were selected. At the same time, the risk factor is estimated as the outcome of probability and impact value. Therefore, the corresponding risk categories (high, medium and low) are determined. Table (1) illustrates the impact, probability scale and risk factor category (PMBOK, 2008).

The risk factor values that fall into the upper right cells of the matrix (shaded in red) are the highest priority. However, these High-Risk categories (HR) should receive majority of the risk management resources within response delineation and risk observation/ monitoring. The Medium Risk category (MR) that fall into the middle diagonal unit (yellow shaded) has second priority. At any time, the Low Risk category (LR) that falls into the lower left cell (shaded in green) has the lowest priority.

Table -1: Impact, probability scales and indicated risk factor

Probability	Risk Factor				
0.90	0.05	0.09	0.18	0.36	0.72
0.70	0.04	0.07	0.14	0.28	0.56
0.50	0.03	0.05	0.10	0.20	0.40
0.30	0.02	0.03	0.06	0.12	0.24
0.10	0.01	0.01	0.02	0.04	0.08
Impact	**0.05**	**0.10**	**0.20**	**0.40**	**0.80**

2.1.3 Analytic Hierarchy Process (AHP)

AHP is a coordinated approach used to organize and analyze complicated judgements referring to mathematics and sensibility. This study uses the AHP method of multi-attribute decision-making to weight various response strategies. AHP is involved in the creation and utilization of a hierarchy of goals, standards and alternatives.

The proposed hierarchy composed of four main criteria and ten sub-criteria. The steps for the use AHP are as follows (Saaty TL 1990; Okada et al. 2008; Sun et al. 2017):-

Step 1: Develop a hierarchical form which is split into criteria (standards), objective and attribute levels.

Step 2: Develop the comparison matrix An×n and designate each part aij in conformance with the five-scale technique. The concept of assignment by the five-scale technique is revealed in Table (2).

Step 3: Calculate the significance ranking indicator ri as the following way:

$$r_i = \sum_{j=1}^{n} a_{ij} \quad (i = 1, 2, \ldots, n) \tag{1}$$

Where r_i is the significance ranking indicator, and a_{ij} is the part of the comparison matrix $A_{n\times n}$.

Table -2: Concept of assignment by the five-scale technique

Intensity of significance	Definition
1	The factor i is similarly as significant as factor j
2	The factor i is lightly significant related to factor j
3	The factor i is noticeably significant related to factor j
4	The factor i is intensely significant related to factor j
5	The factor i is tremendously significant related to factor j
Reciprocal	The factor i is compared with factor j as a_{ij}. Later, comparison among factor j and i is $a_{ji} = 1/a_i$

Step 4: Calculate the decision matrix $B_{n\times n}$, and each matrix part is b_{ij} as the following way:

$$b_{ij} = \begin{cases} \frac{r_i - r_j}{r_{\max} - r_{\min}} \times (k_m - 1) + 1 & r_i \geq r_j \\ \left[\frac{|r_i - r_j|}{r_{\max} - r_{\min}} \times (k_m - 1) + 1 \right]^{-1} & r_i < r_j \end{cases} \quad (i, j = 1, 2, \ldots, n) \tag{2}$$

where b_{ij} is the part of the decision matrix $B_{n\times n}$, r_i is the significance ranking indicator of indicator i, r_j is the significance ranking indicator of indicator j, r_{max} is the maximum amount of the significance ranking indicator, and r_{min} is the minimum amount of the significance ranking indicator. k_m is defined as the following way:

$$k_m = \frac{\max\{r_i\}}{\min\{r_i\}} \quad (i = 1, 2, \ldots, n) \tag{3}$$

Step 5: Calculate the optimum transferal matrix $C_{n\times n}$, and each matrix part is c_{ij}, as the following way:

$$c_{ij} = \frac{1}{n} \sum_{k=1}^{n} \left(\lg \frac{b_{ik}}{b_{jk}} \right) \quad (i, j = 1, 2, \ldots, n) \tag{4}$$

Where c_{ij} is the part of the optimum transferal matrix $C_{n\times n}$, and b_{ij} is the part of the decision matrix $B_{n\times n}$.

Step 6: Calculate the quasi-optimum consistent matrix $D_{n\times n}$, and every matrix part is d_{ij} as the following way:

$$d_{ij} = 10^{c_{ij}} \quad (i, j = 1, 2, \ldots, n) \tag{5}$$

Where d_{ij} is the part of the quasi-optimum consistent matrix, and c_{ij} is the part of the optimum transferal matrix $C_{n\times n}$.

Step 7: Calculate the eigenvector of the maximum eigenvalue for matrix $D_{n\times n}$. Later, the weight ω_i of apiece factor can be gotten after standardization. The weight vector that is combined of the weight of every factor is as the following way:

$$\omega = (\omega_1, \omega_2, \ldots, \omega_n)^T \quad (6)$$

Where w is the weight vector.

2.1.4 Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS is a multi-attribute decision analysis method based on the following concept: the elected alternate should have the smallest geometric dimension from the Positive Ideal Solution (PIS), and the geometric regularity should have the Lengthy dimension from the Negative Ideal Solution (NIS). TOPSIS is utilized to categorize the eight recommended management strategies, and then find the most convenient strategy to achieve the goal of moderating the effect of risks. The steps to implement TOPSIS are as the following way (Karahalios 2017; Wang and Chang 2007; Wang et al. 2009):

Step 1: Structure the original assessment matrix $P_{m\times n}$, and every matrix part is p_{ij}.

Step 2: Structure the regularized determination matrix $N_{m\times n}$, and every matrix part is n_{ij} as the following way:

$$n_{ij} = p_{ij} \Big/ \sqrt{\sum_{i=1}^{m} p_{ij}^2} \quad (i = 1, 2, \ldots, m; j = 1, 2, \ldots, n) \quad (7)$$

Where n_{ij} is the regularized amount of p_{ij}, and p_{ij} is the amount of the j evaluation index for the i determination unit.

Step 3: The weighted regularized determination matrix $V_{m\times n}$ is calculated as the following way:

$$V_{mxn} = N_{mxn} W_{nxn} \quad (8)$$

Where $V_{m\times n}$ is the weighted regularized determination matrix, $N_{m\times n}$ is the regularized determination matrix, and $W_{n\times n}$ is a weight matrix composed of ω_j.

Step 4: Calculate the positive ideal solution V^+ and the negative ideal solution V^- calculated as the following way:

Where V^+ is a positive ideal solution and V^- is a negative ideal solution. I is a advantage index, and I* is a cost index.

Step 5: Calculate the dimension of the objective amount from the positive/negative ideal solution as the following way:

$$V^+ = \{v_1^+, v_2^+, \ldots, v_n^+\} = \{(\max v_{ij} | j \in I), (\min v_{ij} | j \in I^*)\}$$
$$V^- = \{v_1^-, v_2^-, \ldots, v_n^-\} = \{(\min v_{ij} | j \in I), (\max v_{ij} | j \in I^*)\} \quad (9)$$
$$(i = 1, 2, \ldots, m; \ j = 1, 2, \ldots, n)$$
$$(i = 1, 2, \ldots, m; j = 1, 2, \ldots, n)$$

Where V^+ is a positive ideal solution and V^- is a negative ideal solution. I is a advantage index, and I* is a cost index.

Step 5: Calculate the dimension of the objective amount from the positive/negative ideal solution as the following way:

$$d_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^+\right)^2} \quad (i = 1, 2, \ldots, m; \ j = 1, 2, \ldots, n)$$
$$d_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2} \quad (i = 1, 2, \ldots, m; \ j = 1, 2, \ldots, n) \quad (10)$$

Where d_i^+ is the dimension among the objective amount and the positive ideal solution, d_i^- is the distance between the objective amount and the negative ideal solution, v_{ij} is the weighted regularized amount of p_{ij}, v_j+ is the positive ideal solution, and v_j^- is the negative ideal solution.

Step 6: Calculate the coefficient of nearness as the following way:

$$r_i^* = d_i^- / \left(d_i^+ + d_i^-\right) \quad (i = 1, 2, \ldots, m) \quad (11)$$

Where r_i^* is the coefficient of nearness of each solution, d_i^+ is the dimension among the objective amount and the positive ideal solution, and d_i^- is the distance between the objective amount and the negative ideal solution.

3. RESULTS AND DISCUSSION

3.1 GRM Results

Table (3) illustrates the developed GRM that mainly used in this study for quantitative risk analysis. However, the key benefit of GRM is it is important for treatment responses and appropriate risk management strategies can be considered.

Table -3: Generic Risk Matrix

Risk Code	Risk Probability	Risk Impact	Risk Factor	Risk Category	Risk ranking from the most to the least important
SR1	0.7	0.4	0.28	HR	4
SR2	0.3	0.4	0.12	MR	5
SR3	0.5	0.8	0.4	HR	3
SR4	0.3	0.1	0.03	LR	7
ER1	0.7	0.8	0.56	HR	2
ER2	0.9	0.8	0.72	HR	1
ER3	0.7	0.4	0.28	HR	4
ER4	0.5	0.2	0.10	MR	6
ER5	0.7	0.2	0.14	MR	5
ER6	0.5	0.2	0.10	MR	6
ER7	0.7	0.4	0.28	HR	4

ER8	0.3	0.1	0.03	LR	7
CR1	0.7	0.8	0.56	HR	2
CR2	0.9	0.8	0.72	HR	1
CR3	0.3	0.1	0.03	LR	7

It can be noted from the developed GRM that there are seven different social, environmental and economic risks, and threats can be assessed in the high-risk category. However, these risks will require active management measures to treat and mitigate their effects. The intermediate risk category includes four risks that can be considered as second priority. Finally, the low-risk categories that focus on the lowest priority may not require quick action to completely eliminate their threats.

3.2 Risk Response Alternatives

The results of the developed GRM will be used as a baseline for developing the required response. However, for the purpose of decreasing the risk of GERD in Egypt, the following eight alternative solutions and proposed strategies have been proposed:-

3.2.1 Water saving techniques (St1)

Since agriculture is the main consumer of Nile water in Egypt, water-saving technologies are indispensable, such as: irrigation improvement projects, the use of modern irrigation systems, the change from shallow irrigation to trickle irrigation, and changes in planting methods (Abdin and Gaafar, 2008 year).

3.2.2 Optimum use of water resources (St2)

Applying multi integrated methods such as desalination of sea water and new agricultural projects by using ground water source.

3.2.3 Continues improvement of National Water Resources Plan (NWRP) for Egypt (St3)

The Egyptian governmental institution represented by Ministry of Water Resources and Irrigation (MWRI) must continue in the updated processes of NWRP to care the country's improvement to ensure increasing water use efficiency and water quality protection.

3.2.4 Improvement and enforcement of legislation (St4)

This policy sets more important weight on four important spots

- Increase the fines for users who leak or cause waste in different regions.
- Encourage participation at lower levels through water user associations on new and old lands, and participation at higher levels of water supply channels through the establishment of water federations.

3.2.5 Institutional Reform Egypt (St5)

In order to create an irrigation area that contains all the above fields, and implement truly integrated water resources management.

3.2.6 Participatory Irrigation Management (St6)

Emphasis on improving the entire irrigation process, such as providing strong support services to farmers through the private shop and the public sector.

3.2.7 National Water Quality Monitoring Program (St7)

The main goal of the plan is to cover Egypt through a water quality network to evaluate water use decisions, strengthen human resource capacity building and unify standards.

3.2.8 Increase the roles of the Private Sector (St8)

Encourage the private sector to invest in water infrastructure.

3.3 Risk Management Strategies Evaluation

3.3.1 AHP Results

The relative weights of the four main criteria and ten sub-criteria were considered in the risk response strategy are shown in Figure 3. Based on these weights, it seems that the most important environmental standards are social, community and financial standards. The least important criterion seems to be the triple constrains.

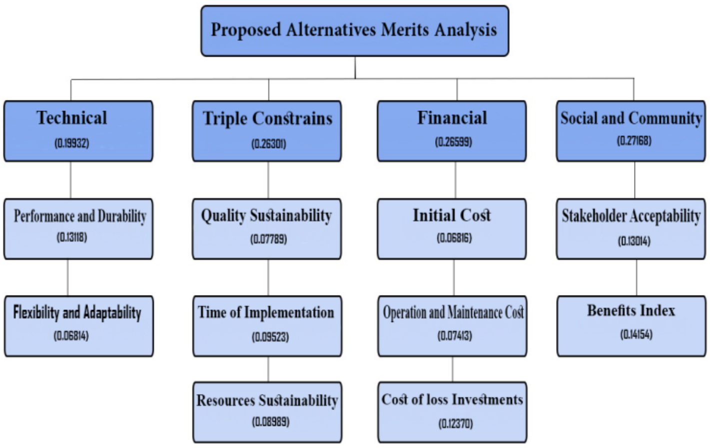

Fig -3: The hierarchical structure of main and sub-criteria and their relative weights

The achieved consistency index (CI) is 0.07852. This number is divided by the random consistency index (0.9) to get the consistency ratio (CR). The consistency ratio obtained is 0.08724. The amount of the consistency ratio (CR) is lower than 0.1, which indicates that the judgment made is consistent and reliable.

3.3.2 TOPSIS Results

The weightages obtained above from AHP are used in giving weights to different criteria's used in TOPSIS method to produce an overall ranking of response strategies alternatives. However, table (5) clarifies the regularized weighted determination matrix that developed based on regularized determination matrix, (Table 4). Then, the positive and negative ideal solutions were calculated as follow:-

A^+ = {0.07379, 0.03717, 0.03934, 0.01163, 0.04875, 0.00839, 0.0886, 0.01489, 0.07415, 0.08846}.

A^-= {0.01476, 0.00743, 0.01574, 0.04654, 0.00975, 0.04195, 0.03544, 0.07446, 0.01483, 0.01769}.

Table -4: Regularized Determination Matrix

Strategy/ Criteria	Technical Criteria		Triple Constrains Criteria			Financial Criteria			Social and community Indicators	
	Performance and durability	Stakeholders acceptability	Cost of loss investments	Operation/ Maintenance cost	Initial cost	Resources Sustainability	Time of Implementation	Quality Sustainability	Flexibility and adaptability	Performance and Durability
St(1)	0.11251	0.10911	0.20203	0.12217	0.10847	0.12309	0.23905	0.12039	0.11396	0.12500
St(2)	0.56254	0.54554	0.40406	0.48868	0.54233	0.36927	0.47809	0.48154	0.34188	0.50000
St(3)	0.45004	0.43644	0.40406	0.36651	0.43386	0.49237	0.47809	0.36116	0.34188	0.37500
St(4)	0.33753	0.32733	0.50508	0.48868	0.32540	0.36927	0.35857	0.36116	0.56980	0.25000
St(5)	0.45004	0.43644	0.50508	0.48868	0.54233	0.61546	0.47809	0.60193	0.45584	0.62500
St(6)	0.22502	0.32733	0.20203	0.12217	0.10847	0.12309	0.23905	0.24077	0.34188	0.25000
St(7)	0.22502	0.21822	0.20203	0.24434	0.21693	0.12309	0.11952	0.12039	0.22792	0.12500
St(8)	0.22502	0.21822	0.20203	0.24434	0.21693	0.24618	0.23905	0.24077	0.22792	0.25000

Table -5: Weight Regularized Determination Matrix

Strategy/ Criteria	Technical Criteria		Triple Constrains Criteria			Financial Criteria			Social and community Indicators	
Strategy	Performance and durability	Stakeholders acceptability	Cost of loss investments	Operation/ Maintenance cost	Initial cost	Resources Sustainability	Time of Implementation	Quality Sustainability	Flexibility and adaptability	Performance and Durability
St(1)	0.01476	0.00743	0.01574	0.01163	0.00975	0.00839	0.01772	0.01489	0.01483	0.01769
St(2)	0.07379	0.03717	0.03147	0.04654	0.04875	0.02517	0.03544	0.05957	0.04449	0.07077
St(3)	0.05904	0.02974	0.03147	0.03490	0.03900	0.03356	0.03544	0.04468	0.04449	0.05308
St(4)	0.04428	0.02230	0.03934	0.04654	0.02925	0.02517	0.02658	0.04468	0.07415	0.03539
St(5)	0.05904	0.02974	0.03934	0.04654	0.04875	0.04195	0.03544	0.07446	0.05932	0.08846
St(6)	0.02952	0.02230	0.01574	0.01163	0.00975	0.00839	0.01772	0.02978	0.04449	0.03539
St(7)	0.02952	0.01487	0.01574	0.02327	0.01950	0.00839	0.00886	0.01489	0.02966	0.01769
St(8)	0.02952	0.01487	0.01574	0.02327	0.01950	0.01678	0.01772	0.02978	0.02966	0.03539

Table (6) illustrates the separation of each strategies alternative from the ideal solution. While, the comparative nearness to the ideal solution and the stated strategies alternatives in the order of preference are shown in table (7).

Table -6: Separation from Ideal Solution

Strategy	dj+	dj-
St(1)	0.12269	0.07878
St(2)	0.07387	0.10168
St(3)	0.07301	0.08238
St(4)	0.08361	0.08432
St(5)	0.08422	0.10735
St(6)	0.09087	0.07928
St(7)	0.10485	0.08069
St(8)	0.09578	0.06623

Table -7: Comparative Nearness and Strategies Ranking

Strategy	r*	Rank
St(1)	0.39102	8
St(2)	0.57920	1
St(3)	0.53014	3
St(4)	0.50210	4
St(5)	0.56038	2
St(6)	0.46596	5
St(7)	0.43488	6
St(8)	0.40879	7

It can be noted from TOPSIS results for strategies final evaluation that: -

- The second strategy (St2) involving the optimal use of water resources has a high responsiveness and long-term influence in dealing with the impact of the above priority risk categories on Egypt's water resources, so it is generally higher in the final overall ranking level.
- The strategies with low total final rank could be considered as temporary strategy and could be implemented in parallel with the other high priorities and permanent strategies.
- Encourage the private sectors to share in building and developing of water contamination treatment plans. The private sectors will make a profit from the project within circulation of table water; they will guarantee that everybody in the country has access to water.
- The implementation of any of these options would require collective effort from the government and the private sectors.

4. CONCLUSIONS

- The construction of GERD is causing main changes in the river's water consumption, which will severely affect Egypt's water supply.
- This paper targets to resolve the water scarcity produced by GERD and proposes many management measures and strategies to ensure Egypt's water demand. These management measures and policies are adjusted from issued studies to provide comprehensive solutions to the water scarcity caused by the building of GERD.
- In the GRM method, the custom of fifteen unlike risk zones can be a primary stage to standardization of risk determination procedure in an organization. This decreases the subjectivity in describing risks and more significantly can support consultations about risks about GERD project. The GRM method tries to decrease the subjectivity and stay easy to application by restricting information to either high, medium, or low risks.
- This study discussed eight options and strategies for evaluating their comparative advantages. It also gives recommendations for effective use of water efficiency by reducing physical losses, reusing drainage and municipal water, and reducing irrigation waste.
- The Egyptian government has to support the role of scientific function to develop affordable new desalination technologies and introduce new agricultural seeds with high production, high disease opposition and low water consumption. Advance the decentralization process of water management to the district level, but it should be accompanied by a serious capacity building plan. Establish a well-coordinated information system to support decision makers to conduct effective water resources management on an ecologically sound root.

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