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Determining The Optimal Method For Water Management Using Hierarchy Analysis (AHP):A Case Study In The City Of Baghdad

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Abstract:
This research aims to determine the most effective method for water management in the city of Baghdad, by using the hierarchy analysis model (Analytic Hierarchy Process (AHP) This model is considered a scientific tool that supports multi-criteria decision-making in a complex environment facing increasing water challenges, such as the case of the city of Baghdad, which suffers from several challenges, including:Scarcity of resources, deteriorating water quality, and institutional and administrative problemsThe model was developed based on a set of technical and institutional criteria, including: water pricing, water awareness and education, water legislation and laws, water loss, water regulations and standards, intermittent water supplies, and graywater reuse. Three main alternatives have been identified to achieve optimal water management: rationalization of water use, water privatization, and activating water investment.
Data were collected using binary comparison matrices distributed to experts in water-related institutions in Baghdad. The results showed that (rationalization of water use) received the highest priority (6092.88), indicating its effectiveness as a first strategic option for addressing problems of consumption and waste. The model also proved its accuracy through an acceptable consistency rate of (5.59%).
The study recommends the integration of regulatory, awareness-raising, and economic tools to ensure water resource sustainability. It also suggests the potential application of the model to other cities facing similar conditions.
Keywords: *Optimal water method, hierarchy analysis(AHP).*

1. INTRODUCTION:

Water is an essential element for life and represents a vital link between various vital sectors, such as residential, agricultural, and industrial sectors. The availability of water is a prerequisite for meeting the needs of societies and ensuring their sustainability in the future..

The Middle East is witnessing rapid transformations at the social, economic, environmental and political levels, accompanied by high rates of population growth and urban expansion, as well as the effects of climate change, making the region one of the most water-scarce and water-stressed regions in the world.Iraq is among these severely affected regions, suffering from increasing water challenges due to population pressure, urban growth, and declining surface water supplies due to the policies of upstream countries. This is compounded by widespread water scarcity, which negatively impacts various segments of society. Hence, the urgent need to strike an effective balance between water supply and consumption is highlighted, requiring the adoption of precise scientific methodologies that support competent authorities in making rational and effective decisions to manage water resources.

In this context, this research aims to analyze and determine the optimal method for water management in the city of Baghdad, by employing the hierarchical analysis model.Analytic Hierarchy Process (AHP) is a scientific tool to support multi-criteria decision-making. This model provides a systematic approach to identifying appropriate alternatives to address critical water challenges, proposing feasible solutions that contribute to mitigating water stress and scarcity, and ultimately ensuring the sustainability of the water resource for current and future generations in Baghdad.

2. RESEARCH METHODOLOGY

2.1. Research problemBaghdad faces increasing challenges in water management, due to rapid population growth, uncontrolled urban expansion, deteriorating infrastructure, and the negative effects of climate change. These factors have negatively impacted the quantity and quality of available water, highlighting the need to use accurate scientific tools to determine the most appropriate water management approach. Accordingly, the main research question is:

What is the best way to manage water in the city of Baghdad? And how can the hierarchical analysis model be employed?AHP) to identify this method effectively?

3.1. Research objectives: This research aims to achieve the following objectives::

1Determining the optimal method for water management in the city of Baghdad.

2. Building an application framework using the hierarchical analysis model (AHP) to evaluate management alternatives in the water sector.

3. Supporting decision-makers in directing policies towards more sustainable and effective options.

4.1. Research community and sample: The research community consists of experts working in the bodies responsible for water resources management in the city of Baghdad, and they are:

1.Ministry of Water Resources

2. National Center for Water Resources Management

3. Baghdad Water Department, affiliated with the Baghdad Municipality

(30) experts were selected according to their specializations and experiences to fill out the binary comparison matrix for water management standards and alternatives.

3. Theoretical aspect:

1.3 Water management concept:Water management refers to the processes and procedures that regulate the use of available water resources to meet the needs of society in residential, agricultural, and industrial areas, by influencing the quantity and quality of available water (Bouqnour & Gharib, 2021: 1164). Water management focuses on preparing water to increase the quantity of available water (61: 2024). Mhaibes & Yass(2011:344,.Cabrera et al.), through collecting, treating, and distributing water to users. This method has led to a high level of water stress on water resources, so water supply management alone cannot permanently meet water needs. The existence of increasing water stress is not only a result of the continuous increase in consumption by individuals, but also a result of the methods used to manage the water sector, and their inadequacy at the level of the various sectors (Madahhi & Mohammed, 2018: 39). Water management can be divided into two basic dimensions: the first is water supply, which stipulates that water supply is often centralized, meaning that governments or authorities are responsible for the availability of fresh water for the residential, agricultural, and industrial sectors, by making the most of fresh water resources and working to develop them (2005: 2). et al.Baroudy)The second: water consumption, which still has a limited role in water management.672) :2011, Saleth). This is done by using some available methods such as rationalization through its various means, to encourage individuals to change their behavior in using water (52) :2015, Hamad). Due to the presence of many factors such as increasing population growth and climate change that led to the emergence of the problem of water scarcity and the accompanying water stress that affected most countries of the world, this necessitated the development of optimal methods for efficient water management, to address the problem of water stress and ensure the existence of a sustainable water resource for generations now and in the future.

2.3 Water management tools: Tools used in water management:

- Water preparation
- Water consumption

1.2.3 Water Supply: With the decline in water resources and the increase in consumption, in addition to population growth, climatic conditions and other factors that affect supply, the water supply system must ensure that consumers have access to good quality water in sufficient quantities. (2020:2773,. Fernandes et alWater supply is concerned with providing sufficient quantities and acceptable quality of water to meet the needs of various sectors. This includes developing water sources, purifying water, and establishing transportation and distribution networks. With increasing pressure on water resources, focusing on supply alone is no longer sufficient; it must be combined with consumption management tools.:680) 2011, saleh). The concept of water supply refers to the measures affecting the quantity and quality of water as it enters the distribution system. It includes activities that identify the locations of water sources for their utilization and development, i.e., they are directed towards the establishment and development of the water sector (Sweileh, 2014: 58). Water supply faces increasingly worsening challenges represented by increasing water scarcity and climate change, which is expected to have a significant impact on water availability patterns, as well as rapid population growth, which will result in increased water needs for consumers. Therefore, investment plans must be developed to improve the water sector and increase supply, develop infrastructure systems, and introduce modern technologies to provide new water sources (Abdul Qader & Ghrayeh, op. cit.: 19) et al., 2020: 5) Halefom (). Therefore, enhancing water supply is essential to achieving water security, especially in light of increasing consumption and changing patterns of water availability. This requires sustainable infrastructure development and the adoption of innovative technological solutions.

- **Water preparation methods are divided into the following:**

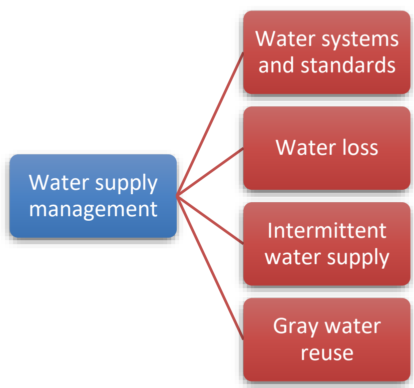

Figure (1) Water preparation methods

1.1.2.3 Water systems and standards: Accurate water measurement and monitoring systems are essential tools for enhancing water use efficiency. Water measurement is essential to effectively and efficiently meet consumers' water needs, and the coverage of systems and meters should be maximized across all sectors.) 16: 2017, Edalat & Abdi (. Metering is considered the most important part of the water supply system, in order to preserve the available water. The presence of meters and water-saving devices enables the provision of more water when used, which means increasing the efficiency of water use (Mas'adia & Al-Wafi, 2023: 100). Metering technology and water-saving devices can be used to monitor changes in individuals' water usage behavior, as well as to test the effectiveness of different interventions to manage users' consumption behavior. These economical uses lead to a reduction in excessive water consumption and significant water savings (274: 2015,Garcia-Valiñas).

2.1.2.3 Water loss: Reducing and controlling water loss in the distribution system can achieve significant water savings and thus avoid the requirements for extending and establishing water supply facilities or reducing water loss by reducing water losses in the distribution system.) 211: 2009, Sharma & Vairavamoothy. Water losses from water distribution systems significantly impact water sustainability and are a closely related indicator of water inefficiency. Controlling water losses promotes the efficient use of water as a valuable natural resource by allowing less water to be withdrawn and collected from the environment. Water losses can be classified into two types: real and apparent losses. Pipe leakage is the major component of real losses. A significant amount of water loss is associated with leakage, which can be caused by several different factors such as aging pipes, poor pipe connections, ground movement, high pressure in distribution networks, and poor pipe construction quality. Consumption represents the second type of apparent water loss (534, 2016: 532, et al. Zyoud). Water losses are unavoidable in distribution systems. Water utilities must strive to deliver water efficiently and effectively by minimizing water losses. Not all water losses are due to poor infrastructure and leaking pipes. These losses often result from weak distribution networks and excessive water use (Edalat & Abdi, 2017: 13).

3.1.2.3 Intermittent water supply: Intermittent water supply is one of the most widely used techniques for addressing the gap between water supply and consumption. It is used in situations of water scarcity and water stress, when there is insufficient supply to meet all demands 24 hours a day, 7 days a week. In conditions of water stress, implementing this approach helps reduce water loss, as restricted supply hours can prevent pipe leaks. It has been widely reported that the majority of water systems in developing countries are intermittent, and it is also widely adopted in developed countries facing water scarcity. (535): 2016,. et al Zyoud).

4.1.2.3 Greywater Reuse (Secondary Grade Water): Water reuse is an artificial practice that aims to treat domestic wastewater and make it reusable.Again. Greywater recycling can help mitigate the increasing consumption of freshwater resources, as the recycled water is used for non-potable purposes, for various end uses including toilet flushing, municipal uses such as firefighting, street cleaning, landscaping, and irrigation (1,317434,: 2019,. et al Taher). Wastewater is divided into two main types: greywater, which is the water resulting from household washing activities such as washing machine, Dishwashers, bathtubs and showers, while the second type is black water: which is the water coming out of toilets, which is more polluted and dangerous in terms of treatment (5.7: 2010,. et al Allen).

2.2.3 Water consumption Water scarcity and water stress are among the most prominent manifestations of the growing gap between water supply and consumption. This is a growing problem in various countries of the world. If appropriate policies are not adopted to control consumption and regulate supply processes, this gap will widen further (671: 2011,Controlling water consumption is considered a pivotal strategy for improving efficiency and ensuring its sustainability, while taking into account the economic, social, and environmental dimensions. This aspect is linked to a set of socio-economic techniques such as analyzing consumer behavior, using water conservation techniques, and reducing excessive water use (Bautista, 2015:11). The concept of water consumption refers to the use of methods and mechanisms aimed at shaping a more efficient consumption pattern among users, through intervention after the water enters the distribution system, i.e., after the processing stage. Managing user behaviors and social norms associated with consumption are key axes in this field (Sweileh, 2014:58). Consumption control strategies focus directly on the quantity and patterns of use, and are concerned with how to direct user behavior towards water rationalization (Russell & Fielding, 2010:1).

- **Methods of regulating water consumption are divided into the following:**

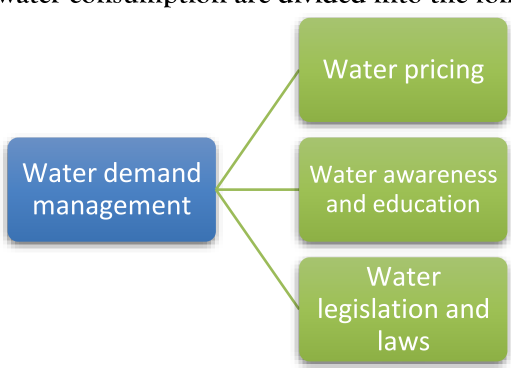

Figure (2) Methods of regulating water consumption

1.2.2.3 Water pricing: Water pricing is one of the most important direct economic tools used to reduce water consumption and ensure financial sustainability in the water distribution sector. It helps generate the revenue needed to cover infrastructure and operating costs and is an effective way to encourage users to use water wisely.(Edalat & Abdi, 2017: 15). An appropriate pricing strategy aims to enhance water consumption efficiency among users, and can be considered one of the future solutions to achieve a balance between supply and consumption (OECD, 2015: 36). Pricing policies are an effective tool for redistributing water among competing uses in a fair and economical manner, as well as providing sustainable financing for infrastructure development and improved water-related services. Implementing progressive pricing or imposing taxes on excessive use is also an effective way to change consumer behavior, encouraging them to adopt more efficient consumption patterns and contributing to achieving optimal levels of water efficiency.(Expósito & Berbel, 2020: 662). Thus, water pricing is not merely a financial instrument, but rather a strategic tool that promotes goals related to sustainable water management in the long term (Iglesias & Blanco, 2008: 2).

2.2.2.3 Water awareness and education: Water awareness and education are essential tools for managing water consumption, as they contribute to raising community awareness of the importance of water and the need to conserve it. They also highlight the importance of individual responsibility in rationalizing its use. These efforts contribute to bringing about positive changes in individual behavior, leading to a reduction in consumption and waste rates (4: 2023,(Bashir & Padder). Educational programs and media initiatives often convey important environmental information to the public, related to the importance of water and ways to conserve it. Studies indicate that increased awareness of environmental issues increases the likelihood that individuals will commit to sustainable practices to protect the environment (273: 2015,et al,.Garcia-Valiñas). Mass media campaigns are an effective means of promoting the importance of water conservation and reducing excessive consumption, as they influence individual decisions and behaviors. These campaigns complement economic and legislative techniques, focusing on behavior change through persuasion rather than coercion, making them a sustainable, long-term option for managing water consumption.

3.2.2.3 Water legislation and laws: The existence of effective laws and regulations is a fundamental pillar of water resources management. They constitute the legal framework that ensures the equitable and sustainable use of water and preserves the rights of individuals and institutions to this vital resource. Continuous updating and development of these regulations is essential to keep pace with environmental, economic, and social changes, in line with current water challenges.(Yildiz, 2023: 4). The regulatory legislative framework provides the necessary guidance and tools for stakeholders in planning, managing, developing, and protecting water resources, enhancing performance efficiency and contributing to achieving sustainability goals. Furthermore, legislative assessment is an essential element in analyzing the current status of the water sector, as it provides an accurate view of the effectiveness and adequacy of applicable laws in addressing the challenges of water scarcity and water stress (Alias et al., 2017).

2.3 Hierarchical analysisAnalysis Hierarchy Process (AHP)

Hierarchical analysis is (AHP is a widely adopted multi-criteria decision-making method. It uses appropriate quantitative methods in the decision-making process to identify the best alternative from a set of available alternatives based on multiple criteria. This theory demonstrates its high efficiency in finding solutions to complex problems and making decisions with multiple criteria (Al-Rashed, 2011: 116). The concept of the Analytic Hierarchy Process (AHP) is referred to as an effective tool for analyzing complex decisions with multiple attributes and is a fundamental approach to the decision-making process. The advantages of this approach are that it reduces complex decisions to a series of discrete and continuous binary comparisons within a multi-level hierarchical structure, creates comprehensive priorities for ranking alternatives, compiles the results as a general theory for measurement methods, and addresses the subjective and objective aspects of the decision-making process. This method is characterized by ranking the available alternatives based on their proximity to the optimal solution. In addition to including useful techniques to verify the consistency of decision-makers' judgments and reduce bias in the decision-making process (Thongngern et aI, 2017:90)) et aI, 2012: 1, 2) (Saaty et aI, 2024:1). (Saleh

2.3 Steps of Hierarchical Analysis There are several steps to making the final hierarchical decision, which are as follows:

1.2.3 Building the hierarchical structure: The hierarchical structure consists of three basic levels arranged in a logical order to help in making decisions in a systematic and effective manner, as follows::23) 2023(Macchiaroil. et aI., (Bozorg et aI., 2021:6) Axelsson et) aI,.2021:27).

Level 1

Main Objective: This level is at the top of the hierarchy and defines the overall goal that the analysis seeks to achieve. The objective is the final outcome or main goal of the analysis process. Objectives can be general or specific. Objectives are determined based on the nature of the problem and the needs of stakeholders, and they guide the entire AHA process.

Level 2

Evaluation Criteria: At this level, the criteria that constitute the main factors influencing the achievement of objectives are identified. These criteria are located in the middle of the hierarchy and are therefore viewed as intermediate between the overall objective and the alternatives. Criteria are the factors or aspects considered in evaluating alternatives. Criteria are ranked based on their importance to the main objective, and relative weights are often assigned to each criterion to indicate its impact.

Level 3

Proposed Alternatives: This level represents the available alternatives or possible solutions to the problem and is evaluated to arrive at the best decision. Alternatives are ranked based on how well they meet the evaluation criteria at Level 2, and each alternative is evaluated using quantitative or qualitative measures to ensure its quality and performance against each criterion.

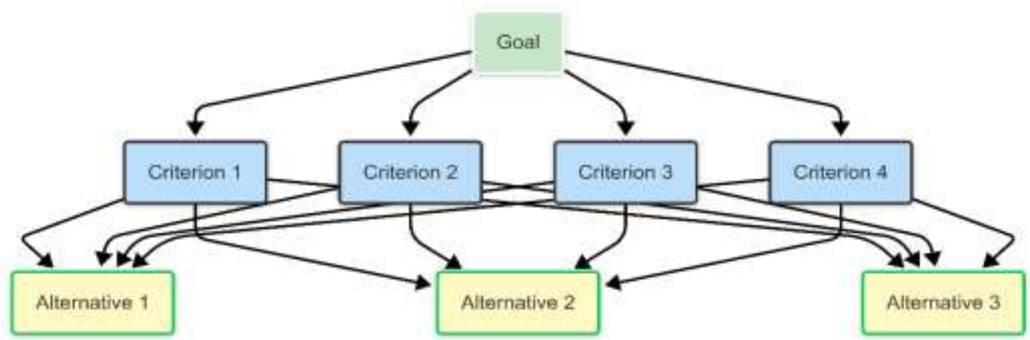

Figure (3) General hierarchical structure

2.2.3 Binary comparison matrix:

The AHS primarily works by comparing criteria and alternatives and formulating priorities to make an overall judgment about the alternatives (overall preference for the final alternative). These comparisons are taken from actual measurements through subjective judgments by decision makers and experts to determine the influence of all factors.(5, 23, 24): 2012 Saaty etaI.,),(((Malhotra, 2001:2)(

We will list in Table (1) the matrix of binary comparisons with its details, as follows:

Table (1) Binary comparison matrix

A n*n = (aij) =

1	a 12	a 13	a 1n
$1/_{a\ 12}$	1	....	a 2n
....	....	1	....
....	....	....	1

Whereas:

The relationship between the values of a binary comparison matrix for two mutually exclusive criteria is as follows:

(A) It is the matrix of binary comparisons, where (aij) represents the binary comparisons between the elements, (i) represents the row elements, (j) represents the column elements, which represents (3.2.1...n), and the matrix is square, meaning that the number of rows equals the number of columns, (n*n).

Binary comparison with the same elements is represented by (1) and is constant (aii = 1). The decision maker fills in the upper triangular matrix based on the Thomas Saaty numerical scale for pairwise comparisons, shown in Table (). The values of the lower triangular matrix are obtained automatically, where the inverse of the lower part of the matrix is used based on the commutative property of the elements.

Table (2) Thomas Saati's numerical scale for binary comparisons

of utmost importance	More than very strong importance	very strong importance	More than strong importance	strong importance	More than moderate importance	Moderate importance	Low importance	equal importance	**Linguistic classification**
9	8	7	6	5	4	3	2	1	**numerical classification**
$\frac{1}{9}$	$\frac{1}{8}$	$\frac{1}{7}$	$\frac{1}{6}$	$\frac{1}{5}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$	1	**Interchange classification**

Source: Prepared by the researcher.

Table (2) shows the verbal, numerical and commutative provisions used in the comparison matrix (A), where the decision maker chooses from his personal perspective one of these importances for the purpose of preferring between the criteria and alternatives (91): Thungngern.et aI.,2017).

3.2.3 Matrix Weight Synthesis

It uses the information in a binary comparison matrix to estimate relative priority (i.e., assigning a weight to each criterion and alternative). Since prioritization is the essence of AHI, the purpose of prioritization is to use it to rank alternatives. To generate priorities, the values in each column of the comparison matrix are summed to derive the total column. A standard matrix is created using an approximation method that works by dividing each criterion in the matrix by the sum of its columns, and using the arithmetic mean of each row to convert the values to ratios.A percentage reflects relative importance, indicating the relative priority required: (Suleimani, 2021: 111-112) (Ben Governance et al., 2019: 1206) (Brestovac et al., 2013: 10). The values of the standard matrix appear in the following equation (1):

$$Kij= (1)\frac{aij}{\sum aij}$$

Since:

(Kij) represents the values of the standard matrix.

Refers to the arithmetic mean of the binary comparison matrix. $\frac{aij}{\sum aij}$

To obtain the standard matrix (A1), shown in Table (3).

Table (3) Standard matrix for binary comparisons

A 1=

K11	....	K1n
....	....	....
Kn1	....	knn

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https://theaspd.com/index.php

Where it represents:
(1A) Standard matrix for binary comparisons.
After extracting the complete standard matrix, the relative priorities (relative weights) are calculated, as shown in Equation (2):

$$Wij=\frac{\sum kij}{N} \qquad (2)$$

Whereas:
Wij refers to relative weights.
$\frac{\sum kij}{N}$ Represents the arithmetic mean for each row.
Thus, the final priorities of the matrix appear as in Table (4):
Table (4) Relative weight structure

Wij=

W1
W2
W3
wn

4.2.3 Eigenvector (Eigenvector):
Eigenvectors, defined as the basic order of preferences (criteria and alternatives), are a fundamental step in extracting the maximum eigenvalue (ʎ$\boldsymbol{max}$) which helps in determining whether the matrix is consistent or not. The eigenvectors of the matrix (A) By multiplying the binary comparison matrix with the extracted relative priorities vector (multiplying each element by the weight in row form), thus forming the eigenvector, which is symbolized by (ʎ), as shown in Table (5): (Ben Government et al., 2019:1206).

Table (5) The unified matrix in the weight vector for extracting eigenvectors

A n*n (aij) =

1	a 12	a 13	a 1n
$^{1}/_{a\ 12}$	1	….	a 2n
….	….	1	….
….	….	….	1

***Wij**

W1
W2
W3
wn

Eyes =vector (A)

ʎ1
ʎ2
ʎ3
ʎn

Since: (ʎ) represents the eigenvector of each criterion.

5.2.3 Maximum eigenvalue (ʎ$\boldsymbol{max}$):
It is used as a basic criterion for calculating the consistency ratio, which makes it an essential tool for ensuring the reliability of the results of hierarchical analysis. The maximum eigenvalue is calculated (ʎ$\boldsymbol{max}$), by adding the eigenvectors and dividing by the number of eigenvectors, to arrive at the final eigenvalue(ʎ$\boldsymbol{max}$) As shown in equation (3): (Ben Government et al.,2019:1206) (8: 2012 Saaty. et aI.,).

$$ʎ\boldsymbol{max}= (\frac{\lambda 1+ \lambda 2+ \ldots \lambda n}{N} 3)$$

Whereas:
(ʎ$\boldsymbol{max}$): Represents the maximum eigenvalue, which is the arithmetic mean of the elements of the eigenvector.

(n): represents the number of eigenvectors.

6.2.3 Consistency ratio (stability of judgments):

The consistency ratio is examined to ensure the stability of the overall judgments of decision makers and to verify the accuracy of binary comparisons. This measure is necessary to know whether the comparisons are correct and logical, which is not present in many quantitative methods used in decision making. The consistency ratio (reliability ratio) is calculated by extracting the consistency index (CI) and the average random consistency index (RI) to reach the final consistency ratio (CR) and this is as follows: (Jawhar, 2015: 60), ((Zyoud et aI 2016: 536.

-Calculating the Consistency Index (CI): The consistency index, which is symbolized by the symbol (CI), is calculated using equation (4): :92)2017 Thungngern.et aI., (.

$$CI=\frac{\lambda\, max - N}{N-1}$$

Since:

(CI) represents the consistency index.

-Average random consistency index (RI): The average value of the stochastic consistency index, which is symbolized by the symbol (RI), is obtained by the average stochastic consistency values of Thomas Saati, which are fixed values based on the size of the matrix (n*n), and are shown in Table (6)::91) 2017Thungngern et aI.,) Anagnostopoulos et aI., 2005:5)).

Table (6) Average random consistency values for Thomas Saati

10	9	8	7	6	5	4	3	2	1	(N)
1.49	1.45	1.40	1.35	1.25	1.11	0.89	0.52	0	0	(RI)

Source: Prepared by the researcher

After extracting (CI) and (RI), the final formula for the consistency ratio can be calculated as in the following equation (5):

$$CR = \frac{CI}{RI} \qquad (5)$$

Since:

(CR) represents the overall consistency ratio.

(RI) represents the average random consistency index.

After performing the equation and arriving at the consistency percentage, this percentage must be within the acceptable limits, as in Table (7):

(21: Previous sourceMacchiaroli and others.

Table (7) Acceptable consistency ratios for Thomas Saati

greater than 4	4	3	Array size (n)
10%	9%	5%	Acceptable consistency ratio

Source: Prepared by the researcher

If the consistency ratio is outside the acceptable limits, the matrix is inconsistent and needs to be re-evaluated by the manufacturers.

The decision is to review its own judgments (i.e., the arbitration and the steps of the hierarchical analysis are repeated until the consistency rate is reached to ensure the reliability of the analysis), since the hierarchical analysis depends on the knowledge and experience of the decision makers regarding the case under study.Brestovac & Grgurina, 2013:9:5) Anagnostopoulos.et aI., 2005).

7.2.3 Prioritization of criteria and alternatives:

To make a hierarchical decision, the process of combining or combining the priorities of the criteria with the priorities of the alternatives relative to the criteria is carried out, by multiplying the priorities of the criteria with the priorities of a specific alternative, to arrive at the final priority for each alternative, and the hierarchical decision is made based on the alternative with the highest value.

4.Applying optimal water management tools using hierarchy analysisApplying optimal water management tools using hierarchical analysis

1.4. Practical aspect: Baghdad is considered the heart of the Iraqi capital and the center of the Republic of Iraq. Due to the diverse aquatic environment surrounding it, the data and information required for the research were obtained from various bodies specialized in water resources management in Baghdad, to ensure the accuracy and diversity of the data and information used in the study area. These bodies were:

(Iraqi Ministry of Water Resources - National Center for Water Resources Management - Baghdad Water Department affiliated with Baghdad Municipality)

2.4.Study data:

Data were collected using a binary comparison matrix, distributed exclusively to the relevant experts in the water sector in the city of Baghdad, as listed below:

Table (8) Competent authorities for standards and alternatives

Number of participating experts	Competent authorities
14	Ministry of Water Resources
5	National Center for Water Resources Management
11	Baghdad Water Department
30	the total

After obtaining the required data and information from the experts, a binary comparison matrix is created for each of the criteria.Water pricing - Water awareness and education - Water legislation and laws - Water loss - Water regulations and standards - Intermittent water supplies - Greywater reuse), as well as creating a binary comparison matrix for the proposed alternatives,Rationalization of water use - water privatization - activating water investment), a value analysis of the weights is carried out, which means the process of converting the binary comparison matrix from a verbal formulation represented by the basic importances of the AHI model to a numerical formulation represented by the required weights, according to each importance and its own weight. Thomas Al-Saati is considered the world specialist in this model who formulated these importances, as shown below:

table(9) Relative importance of hierarchical analysis

of utmost importance	More than very strong importance	very strong importance	More than strong importance	strong importance	More than moderate importance	Moderate importance	Low importance	equal importance	verbal formulation
9	8	7	6	5	4	3	2	1	Digital formula

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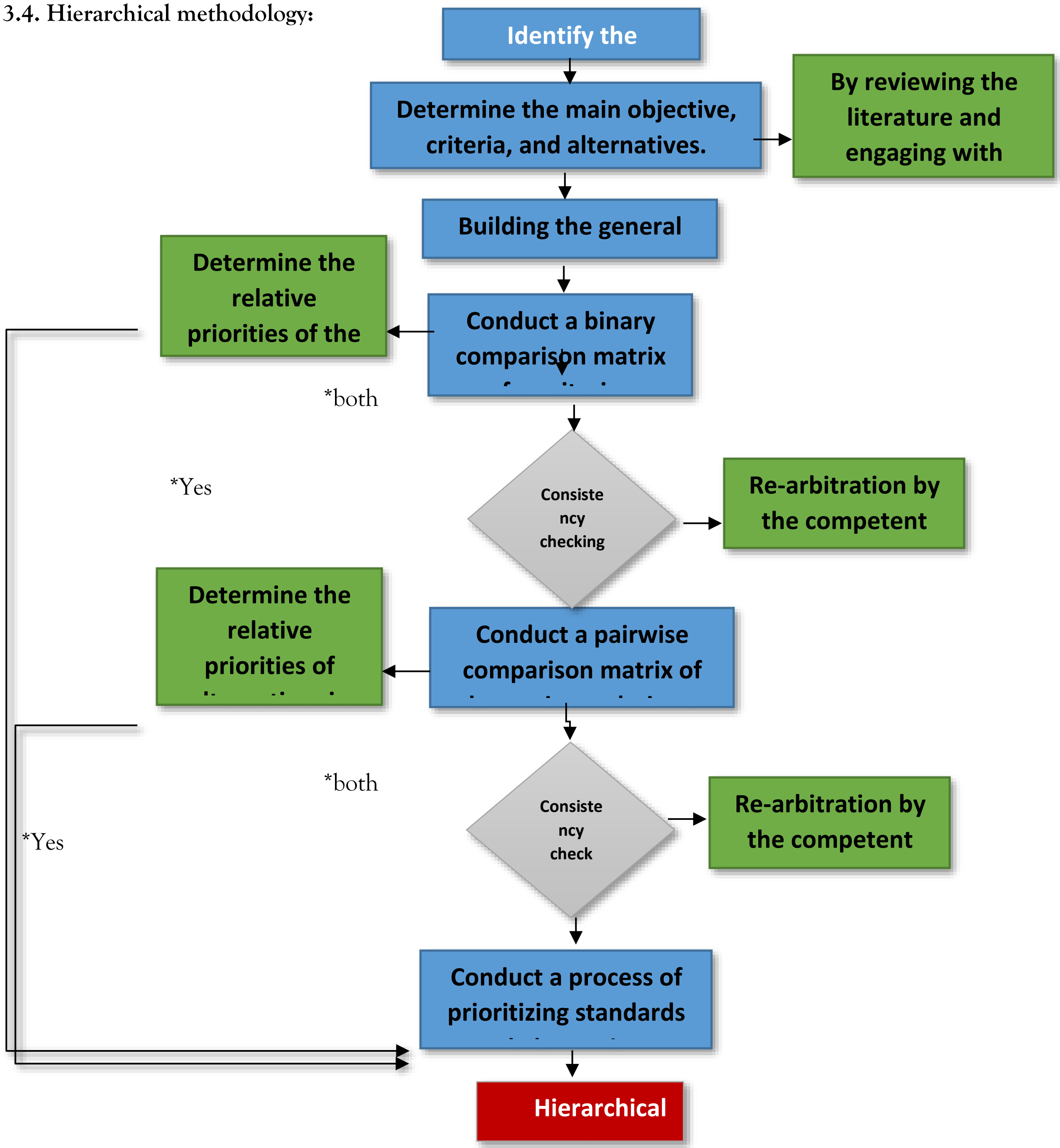
After processing the matrix weights, a unified matrix is created for the final criteria and alternatives, by taking the average of the weights of all criteria to arrive at the final unified matrix.Also, the programs (AHP Online System - AHP-OS) to match the results.

3.4. Hierarchical methodology:

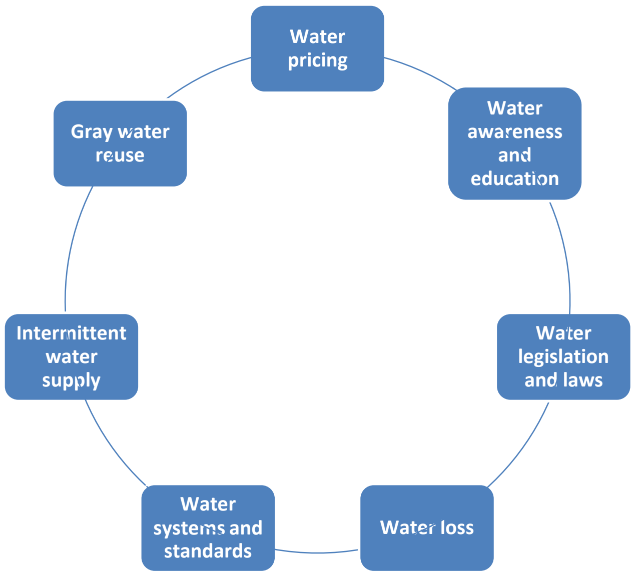


Source: Prepared by the researcher, using the programCanva.

4.4. Determine the main objective, evaluation criteria, and proposed alternatives:

Main objective: The main objective of the research is how to determine an optimal method for water management in the city of Baghdad, as shown in the figure (7).

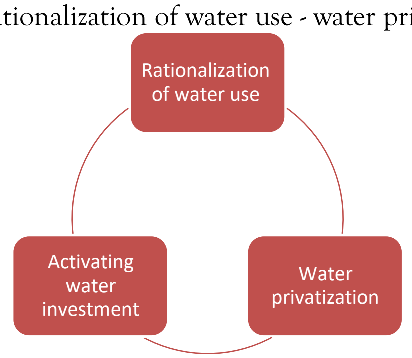
Evaluation criteria: These standards were adopted through the efforts and cooperation of specialists and decision makers in water management in the city of Baghdad. These standards illustrate a set of tools that have been used in different countries around the world. The standards used consist of several tools represented by (7) diverse tools specialized in water supply and consumption, and the goal of the standards is to evaluate alternatives to reach the optimal method for water management, and the alternatives are represented by: (water pricing - water awareness and education - water legislation and laws - water loss - water systems and standards - intermittent water supplies - gray water reuse). As listed:



appearance (5) Water evaluation criteria.

Proposed alternatives (Alternatives)

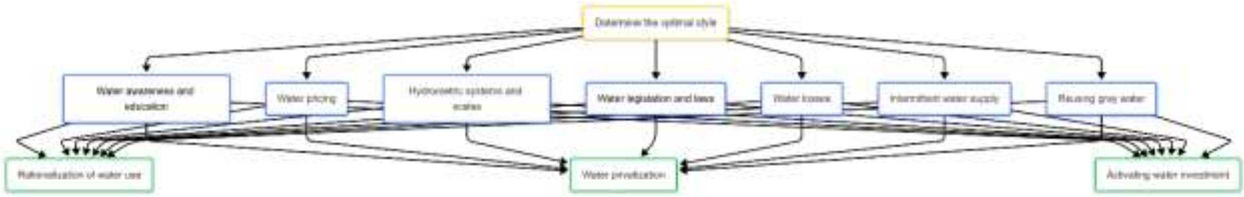
These are methods or procedures taken by water management authorities to improve water efficiency and effectiveness and find applicable solutions on the ground for the development and exploitation of water resources. The model's basic evaluation criteria are:(Water pricing - water awareness and education - water legislation and laws - water waste - water systems and standards - intermittent water supplies - greywater reuse) In order to reach the optimal method for water management in the city of Baghdad, the following alternatives were proposed (rationalization of water use - water privatization - activation of water investment):



Shape (6) Proposed water alternatives

A unified matrix of alternatives (rationalization of water use - improvement of infrastructure) was created in relation to all basic criteria (water pricing - water awareness and education - water legislation and laws - water waste - water systems and standards). After that, a priority matrix was calculated for the weights of the criteria and the weights of the alternatives, in order to arrive at the best alternative in light of these criteria.

5.4. Building the general hierarchical structure:



appearance (7) Water pyramid structure
Prepared by the researcher, usingMermaid Chart

6.4. Unified Binary Comparison Matrix:

1.6.4 Create a unified binary comparison matrix:

After determining the hierarchical structure, knowing the three basic levels, identifying the relevant authorities, and taking their opinions on the relative importance (criteria and alternatives),The experts' judgments for the criteria and alternative matrices are unified separately, to arrive at a unified judgment. This is done by using the arithmetic mean, so that the unified matrix is formed with different levels of importance for binary comparisons.

1.1.6.4. Unified Binary Benchmarking Matrix:

After standardizing the evaluation criteria, a binary comparison matrix is created for the criteria, with each main criterion showing a level of importance when compared with the other criteria. Water pricing is indicated by a symbol.C1, water awareness and education with the code C2, water legislation and laws with the code C3, water loss with the code C4, and water systems and standards with the code C5, as shown in the table for the binary comparison matrix of the standards:

Table (10) Matrix of binary comparisons of standards

C	C1	C2	C3	C4	C5	C6	C7
C1	1	1	4	5	1	4	3
C2	1	1	5	6	5	4	7
C3	0.25	0.20	1	1	1	4	3
C4	0.20	0.16	1	1	1	3	2
C5	1	0.20	1	1	1	3	3
C6	0.25	0.25	0.25	0.33	0.33	1	4
C7	0.33	0.14	0.33	0.50	0.33	0.25	1
∑	4.03	2.95	12.58	14.83	9.66	19.24	23

2.1.6.2. Combining criteria weights:

In this step, we will generate evaluation criteria priorities by creating a standard matrix. A standard matrix is created using an approximation method, which divides each criterion in the matrix by the sum of its columns. The arithmetic mean of each row is then used to convert the values of each criterion into percentages that reflect the relative importance of each criterion, indicating the required relative priority. The standard matrix with relative priorities appears as shown below:

Table(11) Standard matrix of criteria

(criterion	C1	C2	C3	C4	C5	C6	C7	∑	M $\frac{Cn}{N}$	W*100 %
C1	0.2481	0.3390	0.3180	0.3411	0.1035	0.2078	0.1304	1.6879	0.2411	24.1

C2	0.2481	0.3390	0.3975	0.4093	0.5176	0.2078	0.3043	2.4236	0.3462	34.6
C3	0.0620	0.0678	0.0795	0.0682	0.1035	0.2078	0.1304	0.7192	0.1028	10.3
C4	0.0496	0.0542	0.0795	0.0682	0.1035	0.1558	0.0870	0.5978	0.0854	8.5
C5	0.2481	0.0678	0.0795	0.0682	0.1035	0.1558	0.1304	0.8533	0.1219	12.1
C6	0.0620	0.0847	0.0199	0.0225	0.0342	0.0519	0.1739	0.4491	0.0642	6.4
C7	0.0819	0.0475	0.0262	0.0337	0.0342	0.0130	0.0435	0.2799	0.0399	4

After knowing the relative importance, the consistency ratio must be verified, and this requires knowing the maximum eigenvalue, which was (λmax) by the amount of (7.443), and the consistency index (CI) appeared at (0.0738), and the average random consistency ratio based on the presence of 7 criteria amounted to (1.32), and the consistency ratio (CR) equation is applied to determine the percentage of consistent judgments as follows:

$$CR = \frac{0.0738}{1.32} = 5.59\% \quad (6)$$

The consistency ratio was (5.59%), which is an acceptable percentage in this model.

3.1.6.4. Binary comparison matrix of alternatives relative to criteria:

Alternatives are compared in terms of one of the evaluation criteria at the second level of importance. Since the number of criteria used is (7), there will be (7) pairwise comparisons of alternatives in relation to the criteria.Rationalization of water use is indicated by the symbol A1, water privatization by the symbol A2, and activation of water investment by the symbol A3, as shown in the table () below:

Table (12) Binary comparison matrix of alternatives relative to criteria

C1	A1	A2	A3	C2	A1	A2	A3	C3	A1	A2	A3
A1	1	3	5	A1	1	2	5	A1	1	2	4
A2	0.333	1	2	A2	0.50	1	2	A2	0.50	1	2
A3	0.20	0.50	1	A3	0.20	0.50	1	A3	0.25	0.50	1
∑	1.53	4.5	8	∑	1.7	3.5	8	∑	1.75	3.5	7
C4	A1	A2	A3	C5	A1	A2	A3	C6	A1	A2	A3
A1	1	3	5	A1	1	2	5	A1	1	2	4
A2	0.33	1	2	A2	0.50	1	2	A2	0.20	1	2
A3	0.20	0.50	1	A3	0.20	0.50	1	A3	0.25	0.20	1
∑	1.53	4.5	8	∑	1.70	3.50	8	∑	1.45	3.20	7
C7	A1	A2	A3								
A1	1	3	3								
A2	0.33	1	2								
A3	0.33	0.50	1								
∑	1.66	4.50	6								

4.1.6.4. Combining weights for alternatives relative to criteria:

In this step, we will generate priorities for the alternatives by creating a standard matrix, as shown:

Table (13) Standard matrix of alternatives relative to criteria

C1	A1	A2	A3	W	C2	A1	A2	A3	W	C3	A1	A2	A3	W
A1	0.652	0.667	0.625	0.648	A1	0.588	0.571	0.625	0.595	A1	0.571	0.571	0.571	0.571
A2	0.217	0.222	0.25	0.230	A2	0.294	0.286	0.25	0.277	A2	0.286	0.286	0.286	0.286
A3	0.131	0.111	0.125	0.122	A3	0.118	0.143	0.125	0.129	A3	0.143	0.143	0.143	0.143
C4	A1	A2	A3	W	C5	A1	A2	A3	W	C6	A1	A2	A3	W
A1	0.654	0.667	0.625	0.649	A1	0.588	0.571	0.625	0.595	A1	0.69	0.625	0.571	0.629
A2	0.216	0.222	0.25	0.229	A2	0.294	0.286	0.25	0.277	A2	0.138	0.312	0.286	0.245
A3	0.131	0.111	0.125	0.122	A3	0.118	0.143	0.125	0.129	A3	0.172	0.062	0.143	0.126
C7	A1	A2	A3	W										
A1	0.602	0.667	0.500	0.590										
A2	0.199	0.222	0.333	0.251										
A3	0.199	0.111	0.167	0.159										

The final consistency ratio of the alternatives relative to the criteria was(CR) respectively by (.40%)(.60%)(0%)(.40%)(.60%)(-0.3%)(0.4%).

7.4. Setting final priorities:

The process of combining or merging the priorities of the criteria with the priorities of the alternatives relative to the criteria is carried out, to make the final hierarchical decision. This is done by multiplying the priorities of the criteria with the priorities of a specific alternative, to arrive at the final priority for each alternative, and the hierarchical decision will be made based on the alternative with the highest value.

Table (14) Priority calculation matrix for the first alternative

	1	2	3	4	5	6	7
Criteria weights	**24.6**	**35.1**	**10.2**	**8.6**	**11.8**	**5.9**	**3.9**
Alternative weights 1	**64.8**	**59.5**	**57.1**	**64.8**	**59.5**	**57.1**	**59.4**

*Priority calculation for the first alternative:

The

= 24.6 * 64.8 + 35.1 * 59.5 + 10.2 * 57.1 + 8.6 * 64.8 + 11.8 * 59.5 + 5.9 + 57.1 + 3.9 * 59.4 =6092.88✓

Table (15) Priority calculation matrix for the second alternative

	1	2	3	4	5	6	7
Criteria weights	24.6	35.1	10.2	8.6	11.8	5.9	3.9
Alternative weights 2	23	27.6	28.6	23	27.6	28.6	24.9

*Priority calculation for the second alternative:

= 24.6 *23+ 35.1 * 27.6 + 10.2 * 28.6 + 8.6 * 23 + 11.8 * 27.6 + 5.9 + 28.6 + 3.9 * 24.9 =2615.61

Table (16) Priority calculation matrix for the third alternative

	1	2	3	4	5	6	7
Criteria weights	24.6	35.1	10.2	8.6	11.8	5.9	3.9
Alternative weights 3	12.2	12.8	14.3	12.2	12.8	14.3	15.7

*Priority calculation for the third alternative:

= 24.6 * 12.2 + 35.1 * 12.8 + 10.2 * 14.3 + 8.6 * 12.2 + 11.8 * 12.8 + 5.9 + 14.3 + 3.9 * 15.7 =1296.82

8.4. Hierarchical decision making:

The model results confirm that rationalizing water use is the optimal solution to address the challenges of water scarcity and water stress in Baghdad, as it contributes to achieving sustainable and effective water resource management. Among the most prominent advantages of this approach are::

- Ensuring optimal use of water through fair distribution and rationing consumption in all sectors.
- Increasing the efficiency of the water system, by modernizing the infrastructure and reducing network losses..
- Promoting water sustainability, by protecting groundwater and surface resources from depletion.
- Reducing water waste, through the application of modern irrigation techniques and consumer awareness.
- Adapting to climate change such as drought and reduced rainfall, through solutions such as rainwater harvesting.

Implementing this strategy will contribute to reducing pressure on water resources, ensuringProtecting water resources from depletion, meeting the needs of current and future generations, and reducing social conflicts caused by water scarcity. Water conservation is not just an option, but an absolute necessity to ensure Baghdad's water security in light of climate challenges and population growth.

5. CONCLUSIONS AND RECOMMENDATIONS

1.5 Conclusions:

1. The results of applying the hierarchical analysis model showed that:(AHP) The three proposed administrative alternatives for water management in Baghdad received varying relative weights. The

option of (rationalizing water use) ranked first with a high relative weight of (6092.88), reflecting experts' awareness of its importance as a key strategic option for addressing water-related challenges. In second place came (water privatization) with a relative weight of (2615.61), followed by (activating investment in the water sector) with a relative weight of (1296.82).

2. The results showed that the criteria influencing the evaluation process were not equal in relative importance. Water awareness and education and water pricing received the highest weights, highlighting the importance of both behavioral and economic dimensions in regulating consumption and achieving sustainability.
3. The internal consistency check of the matrices showed that the consistency ratio for all comparisons was within acceptable limits.CR < 10%), where the total percentage reached (5.59%), which enhances the reliability of the judgments provided by the experts and confirms the validity of the results extracted from the model.

1.5 Recommendations: Based on the findings, the research recommends the following::

1. Adopting (rationalization of water use) as a main option within general water management policies, by integrating behavioral, technical, and institutional approaches..
2.Updating water-related legislation and laws to ensure the effective implementation of water policies and support sustainable management options, with the need to activate oversight and accountability mechanisms.
3. Launch comprehensive awareness campaigns targeting all segments of society, using media and school curricula, to spread the culture of rationalization and enhance awareness of the importance of water. In addition to designing a gradual and fair water pricing system linked to consumption levels, while ensuring the protection of low-income groups, with the aim of reducing waste and providing self-financing sources for the development of the sector.
4. The possibility of generalizing the adopted analytical model to other cities facing similar water conditions, taking into account local specificities when preparing alternatives and standards.

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