International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2023, 13(5), 98-107.

Utilizing Industry 4.0 to Overcome the Main Challenges Facing UAE to Achieve the (SDG6.b) Goal of the United Nation Sustainable Development

Amel Alnaqbi, Muataz Al Hazza*

Department of Mechanical and Industrial Engineering, School of Engineering, American University of Ras Al Khaimah, UAE.
*Email: muataz.alhazza@aurak.ac.ae

Received: 26 April 2023 **Accepted:** 28 July 2023 **DOI:** https://doi.org/10.32479/ijeep.14574

ABSTRACT

United Arab Emirates (UAE) is described as a desert country facing significant challenges in managing water resources due to its arid climate and rapid population growth. In recent years, UAE government has prioritized sustainable water management practices. It has made progress towards achieving the Sustainable Development Goal (SDG) 6.b, which aims to "support and strengthen the participation of local communities in improving Water and sanitation management. The main purpose of this research is to investigate the UAE's significant challenges in achieving SDG6.b Goal of the United Nations Sustainable Development Goals for 2030. Concurrently, this research concentrates on overcoming these challenges. As one of the best qualitative methods, Delphi method was used to explore these challenges and how to integrate Industry 4.0 to overcome those challenges. Five experts from various areas linked to and supporting the water field were invited and accepted to be involved in this research. This research involved a comprehensive approach to prioritize the selected challenges, with the aim of achieving high consistency. The implementation of AHP and Delphi Methods incorporating two rounds of evaluation and expert feedback to reach an 80% consistency threshold. The first round was about identifying and evaluating a set of challenges using AHP method, which compares challenges based on their importance. While the second round was implemented to clarify the prioritization of challenges, this iterative process allowed adjustments based on expert insights, which increased consistency in the prioritization results. Achieving 80% consistency by making two rounds of implementation was an important milestone in this research. It ensured that the prioritization results were reliable and consistent.

Keywords: Industry 4.0, SDG6.b, AHP, Delphi
JEL Classifications: D7, D8, L6, L8, R5

1. INTRODUCTION

Water is the most precious resource that covers more than 70% of the planet. It is vital to all lives; Humans, plants, and animals are composed of main Water. All living creatures would die if it were not for Water. From the geographical data, 3/4 of the Earth's surface is covered with Water. All living things need Water to survive as life without Water is not considered. The results are only 1% of Water readily available for human use (Karataş and Karataş, 2023). As per Hossain (2015), Water is used for drinking, washing, cleaning, cooking, growing food, and many other things. A person's daily requirement of Water is around 150-250 gallon. And more Water was used by industries to generate electricity, manufacturing goods etc. Meanwhile, Challenges around water management are already immense. On the other hand, more than a billion of people facing lack of access to the potable Water. Some 2.7 billion-or 40% of the world's population-suffer water shortages yearly for at least a month. The Organization for Economic Co-operation and Development (OECD) estimates that by 2050, around 4 billion people may live in water-scarce areas. From 80% to 90% of the scarce Water in the world's arid and semi-arid river basins is used, and over 70% of the world's major rivers no longer reach the sea these data are as the World Water Council. On the other hand, 2.4 billion people exposed to many diseases due to inadequate sanitation, such as diarrhoeal disease, the third leading cause of death among children under five (McLennan, 2021). Another record shows that 80% of the world faces serious threats to its water security due to water availability, water demand, and pollution (Kakes, 2020). The global risks report issued in 2016 considered the water crisis as one of the three most significant challenges in the world in 2016.

On the other hand, "Water Crises" was listed in the World Economic Forum (WEF) as one of the top 10 global risks impacting the world. Moreover, 4 billion people-two-thirds of the worldwide population-face water scarcity, resulting from another study that sports the previous findings (Mekonnen and Hoekstra, 2016). The health and Security of human people is a priority of all governments, and they are working hard to provide adequate supplies of clean and safe Water (Szabo, 2011). Also, according to Alsharhan and Rizk, (2020) the unequal distribution of water resources, water quality problems, escalating demands and climate change are the main global water challenges.

The 2030 Agenda for Sustainable Development, including Sustainable Development Goal 6 (SDG 6), known as the "Water Goal," was adopted in 2015 by the UN Member States, which states, "Ensure availability and sustainable management of water and sanitation for all." the importance of water cycle aspects in the development was recognized by SDG 6 goal and it was included directly and indirectly in all 17 SDGs (Ortigara et al., 2018). The United Nations mentioned that access to safe water, sanitation, and hygiene is the most basic human need for health and well-being (United Nations (n.d).

Indeed, it is an investment agenda in physical infrastructure (including renewable energy) and human capital to achieve the SDGs (Sachs et al., 2022).

An adverse environmental effect and stress on the water system at regional and global scales may be caused due to human efforts to meet human Water needs locally. Hence, attaining and reaching the Sustainable Development Goals (SDGs)* targets require a broad and in-depth knowledge of global and local water availability and use dynamics. Furthermore, if the actions will not properly pre-designed to consider these inter-linkages, interactions, and trade-offs between different SDG targets may cause sub-optimal or even adverse outcomes (Bhaduri et al., 2016).

2. THE MAIN CHALLENGES FACING UAE

UAE is one of the countries with limited freshwater resources with average annual rainfall fluctuating between 80 and 140 mm. At the same time, the groundwater of both deep and shallow aquifers is about 757.6 km^3 while fresh is <7.5%. The annual groundwater extraction is about 2668 million m^3 compared to recharge i.e., 350 million m^3 (Alam et al., 2017). Thus, the resource of freshwater, which is mostly available as groundwater, is minimal, however water demand keeps growing due to the improvement in the living standard, population increase, and economic growth. This water shortage is aggravated by excessive withdrawal for municipal and agricultural use (Hussein et al., 2021). Furthermore, UAE is considered to have one of the highest levels of water consumption in the world, about 550 L/day, which causes enormous pressure on the government to comply with the high-water demand (Vaidian et al., 2019). The classification of Water resources in the UAE is two different categories, conventional water resources (Surface water and groundwater aquifers), which are in limited quantity due to the country's location being in a dry belt region marked with limited rainfall. Moreover, groundwater resources are the main natural water resource. These resources are split up to renewable resources (shallow aquifers) and non-renewable resources (deeper aquifers) (Vaidian et al., 2019). On the other hand, the groundwater quality in UAE is changing, and salinity is increasing with the elapse of time (Murad, 2008). Maintaining a sustainable freshwater supply is considered one of the main challenges in UAE. The limited conventional water resources can be found mainly in surface water, which is almost absent due to the scarcity of rainfall coupled with arid conditions. At the same time, the groundwater is brackish and non-renewable (Al-Katheeri, 2008).

The non-conventional water resources (desalination, cloud seeding and treated wastewater), in connection with the desalination; there are currently about 33 desalination plants in the UAE. In addition to desalination, treated wastewater is an additional water resource which help to meet the water demand as the available number of wastewater treatment plants is 79 mediums to large sized that produce about 615 million cubic meters, this treated Water is preferred to be used for landscaping and irrigation (Vaidian et al., 2019). Alam et al. (2017) stated that UAE started to transform from deserts into green lands, Urban Landscape of UAE appears difficult to reconcile with the ecological, social, and cultural conditions of the country. By Comparing UAE water consumption to the world, UAE is the highest in grade per capita. Domestic use is only 13%, while 80% of Water is utilized for various greening projects.

A lot of fresh Water is used outdoors for irrigation, washing cars, and filling swimming pools. Beware not to pollute that Water as the chemicals are used for lawns and gardens, and then by watering them with pure Water, the Water will wash the chemicals off the plants and then run down a storm drain and go straight to the sea and streams. This polluted Water can kill fish and wildlife (Hossain, 2015). Over the past three decades, the extra groundwater pumping for irrigation has decreased the groundwater flow by one-tenth. Currently, to achieve sustainable development and to mitigate the present severe groundwater depletion in the area, the extraction rates of the groundwater need to be reduced with at least 25% (Mohamed Alghafli, 2016). According to (Alsharhan and Rizk, 2020), future wastewater reuse is expected to be expanded in use to more than the use for agricultural toward municipal and industrial applications. Concurrently, water management needs to optimize natural water flow, including surface water and groundwater. However, uncertainty over climate change makes management more complex. Most important factor in water management is the groundwater which meets the requirement of most of the world's population (AL-Dabbagh et al., 2020).

United Arab Emirates (UAE) policies prioritize "Water security concerns" as it is particularly acute in the UAE, as the country located in one of the scarcest Drinking Water regions of the world. In line with the UAE Vision 2021 and SDG 6, the UAE Ministry of Energy and Industry (MOEI) developed the UAE Water Security Strategy 2036 to set a roadmap to achieve water security. The strategy will be developed in collaboration with more than 30 water sector entities and built based on an extensive repertoire of previous studies and references. The stress on water resources in UAE is increasing with the increase of the gap between demand and resource amount diverges (Hussein et al., 2021). Water Resources is gradually decline as the demand growing at an unsustainable rate (Al-Katheeri, 2008).

Most crucial water-related problems in UAE are the exhaustion of underground water sources in several areas, saline-water interference and water quality deterioration such as those related to the oil industry or agricultural activities (Rizk and Alsharhan, 2003).

The continuously increasing demand makes sustainable development of water resources a challenging task for managing water scarcity (Ahmed, 2022). In addition, UAE strives to fully comply with SDG 6, especially for groundwater and desalination of seawater, to achieve this goal (AL-Dabbagh et al., 2020). It is important to highlight that pollution of surface water is a problem itself and that may be threat to fresh groundwater resources as both are found hydrodynamically connected (Ahmed, 2022). Some solutions to maintaining cost-effective fresh water supplies are: Promoting wastewater treatment and reuse; Minimizing water leakage and losses; developing more efficient water distribution and irrigation systems; and storing excess fresh Water from desalination plants and treated wastewater using artificial recharge techniques. (Al-Katheeri, 2008). From all the above, it can be concluded with several key challenges that hinder UAE plan towards achieving SDG 6.b, including:

- Location of UAE which located in a region with an extremely high baseline water tension
- The sharp increase of water consumption and demand with the increase of populations
- Climate change which is making water management more complex
- The transformation of UAE from deserts into green lands, Urban Landscape which leads to a significant increase of water consumption
- The limited surface water, which can almost be considered absent due to the scarcity of rainfall coupled with arid conditions
- The change of the quality of groundwater in UAE, and salinity is increasing with the elapse of time
- Water quality deterioration such as those related to the oil industry or agricultural activities.

To address these challenges, UAE implemented various strategies and utilized different technologies that involves enhancing community engagement by establishing the awareness campaigns, improving water management practices, ensuring sustainable urban planning and development and utilizing the industry 4.0 in water management.

3. UTILIZE INDUSTRY 4.0 ON WATER SCARCITY

Looking back at the first industrial revolution, it was started in 1770s as a moving from hands to machines, from farms to first factories using steam and waterpower. After 100 years later, electricity established along with the second industrial revolution that introduce the automation, assembly lines which then triggered the concept of 'factories. While the third industrial revolution is the establishment of computers in 1970s which allowed to automate blue color work and factories, and finally the cyber physical systems where the machines can now talk to each other with increased technology-human interaction, thereby introducing the fourth industrial revolution or Industry 4.0 (Mukhopadhyay and Mukhopadhyay, 2021).

The Fourth Industrial Revolution (FIR) era, also referred to as the "Industry 4.0" has led to digital transformation across different sectors worldwide, such as the water sector (Alabi et al., 2019). It is about encouraging smart production by machines and humans communicating with each other (Ktari et al., 2022).

Industry 4.0 is a strategic approach to the integration of advanced Internet-based control systems that enable people and machines to connect at anytime, anywhere, with anyone and anything in the unique complex system. It is describing the growing integration of the ICT sector into production and service systems, which means that it complements the Lean production principles already established to respond to and meet future customer requirements (Poljak, 2018, May).

For Improving water monitoring and management, the water sector can use artificial intelligence to reach a stable water source during the demand increase, needing future drinking water quality and water distribution systems. Furthermore, artificial neural networks (ANNs) shall be employed more in water treatment applications. This can be developed better using nanocomposites for wastewater and freshwater treatment and management using Industry 4.0 (Uwamungu et al., 2022).

Water 4.0 is the recent concept being invented from the industry 4.0. It is considered as the future of water industry which is also referred to as "Smart Water" or "Digital Water" Industry. Water 4.0 utilize the digitalization and automation in the middle of a strategy for resource-efficient, flexible and highly competitive water management (Alabi et al., 2019).

The "Industry 4.0" program was initiated in 2011. It was established by the integration of new technologies such as: artificial intelligence, the cloud, cyber-physical system, and the Internet of Things (IoT) in the industrial activities (Zengin et al., 2021). The best example for utilizing industry 4.0 to meet SDGs is the implementation of Artificial Intelligence (AI) to address sustainability challenges by using ML Model for predicting and optimizing water resource use in the energy sector to support forecasting and decision-making on energy planning, production, distribution, maintenance, and agriculture for weather prediction, fertilizers, irrigation optimizations, etc. (D'Amore et al., 2022).

Comparing water industry to other industries, Water industry is also enhancing its future competitiveness with the use of automation in smart grids. For better understanding of water management systems, the increased integration of IT, sensors and model applications, opportunities have been created to demonstrate them in production, early warning and decision-making processes.

With the assistance of intelligent hardware and software and of the independent exchange of information from the user to individual, the integration of planning and operating processes becomes more important for resource productivity and efficiency (Bufler et al., 2017).

Artificial intelligence can be used in water sector to improve and monitor water management. AI also can help operators by making sophisticated, intelligent decision-making which can improves the accuracy and dependability of the treatment system. Also, it can deliver intelligent decisions including water quality, leak detection, and water process optimization (Uwamungu et al., 2022).

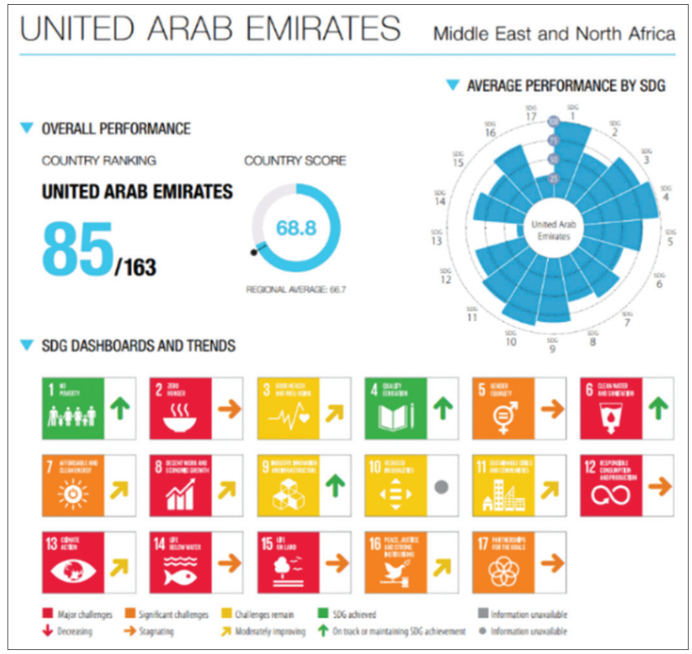
However, it can be summarized that UAE policies are supporting innovations, developing water management, and minimizing water security risks. This was achieved by making a strategic plan for water sustainability by forecasting water demand and consumption for more than 20 years. Overcoming the challenges facing UAE to achieve the united nation goals of SDG6.b (which is summarized in Figure 1 that shows UAE still in a major challenge for the field of SDG6 in SDG dashboard and trends for the year 2022); industry 4.0 shall be adopted to utilize the latest technologies for finding the best practices and opportunities to increase the Water needed to cover the future demand.

4. METHODOLOGY

Overcoming the challenge to achieve the UN goal SDG6.b in UAE and exploring success factors aligned with the UAE 2030 plan to avoid water crises utilizing industry the advantages of industry 4.0 is a complex issue involving considering many factors and decisions. This research will use the integration between Delphi Method and Analytic Hierarchy Process (AHP) prioritizing framework. However, the research methodology is based on sequential feedback loops summarized in Figure 2. The main steps of research can be concluded in eight main steps:

1. Comprehensive literature review of Water scares factors in the UAE and the best alternatives to overcome the challenges to achieve the SDG6.b goal. Moreover, the success factors linked to industry 4.0 will be covered.
2. Select the best expertise (From 3 to 5) in water security in UAE to analyse the challenges and the success factors.
3. Design a specific questionnaire to utilize the pairwise matrix (AHP) method.
4. Implement the Delphi method anonymously.

Figure 1: UAE SDG Dashboard and Trends in 2022 (Sachs et al., 2022)



5. Repeat the Delphi rounds until getting an agreement on all the questions.
6. Creating the pairwise matrix based on the Delphi results.
7. Test the consistency by avoiding bias due to the area of the expertise
8. Develop a suggested main framework that overcomes challenges utilizing Industry 4.0.

Expert people who have been selected as they are influence to water field in Sharjah-UAE were invited to identify what they believe in the factors that affect the UAE goals to minimize water scarcity. The questionnaire was built as per Delphi Method, while the results and findings were analyzed using AHP Method.

Some of the assumption for this research are summarized as follows:

- Assumption 1: UAE infrastructure is working on implementing Industry 4.0 technologies for all sectors. As UAE current and future is to support innovations and technologies in all fields.
- Assumption 2: UAE government and the participation of local communities are the core support for achieving the goal SDG6.b. As it assumes that the communities are aware of the importance of water and sanitation management and are willing to contribute their knowledge, resources, and efforts to achieve SDG6.b.
- Assumption 3: UAE Policies and water management strategies and plan for 2030 to avoid water crises is considering water management practices, including water conservation, demand management, and protection of water resources.
- Assumption 4: Industry 4.0 technologies are the best solution for overcoming the key challenges that the UAE faces in achieving SDG6.b. Example of these technologies are: Internet of Things (IoT), Artificial Intelligence (AI) and automation, which are the core components of Industry 4.0, can be helpful to address the challenges related to water scarcity and inefficient water management in UAE.

4.1. Delphi Method

The Delphi technique was primarily developed by Dalkey and Helmer (1963) at the Rand Corporation in the 1950s. It is one of the generally accepted methods which convers opinions from experts within specific topic areas. Delphi was defined as the method used for data gathering from the subjects within their domain of expertise; its goal is to take the convergence of their opinions about the specific issue (Hsu and Sandford, 2007).

It is an iterative process to collect and extract the anonymous judgments of experts using a series of data collection and analysis techniques punctuated with feedback. It is suited as a research instrument when there is incomplete knowledge about a problem or phenomenon; however, it is not a method for all types of IS research questions. The Delphi method works especially well when the goal is to improve our understanding of problems, opportunities, solutions, or to develop forecasts (Skulmoski et al., 2007).

After the multiple iterations, each Delphi participant is expected to be very knowledgeable about the problem. Also, the results are supposed to be well explained by the final round as it was reviewed by its author many times, without any pressure application coming from other participants (Hsu and Sandford, 2007).

Generally, Delphi method collects the data using a series of questionnaires delivered by the investigator through multiple iterations looking for the consensus of opinions regarding the discussed issue.

However, there is no fixed percentage of agreement, Ab Latif et al. 2016 said that one criterion recommends that consensus is achieved by having 80% of subjects' agreement. He mentioned as well that the different experts should agree at least 70% of Delphi subjects.

Though, with many questions and multi-direction, it is not easy to have 100% of consensus, especially, if the experts are from different backgrounds. Due to its important usage in the forecasting filed, many people thought that Delphi is a forecasting tool only, while there is a surprising number of other applications can be allocated to it.

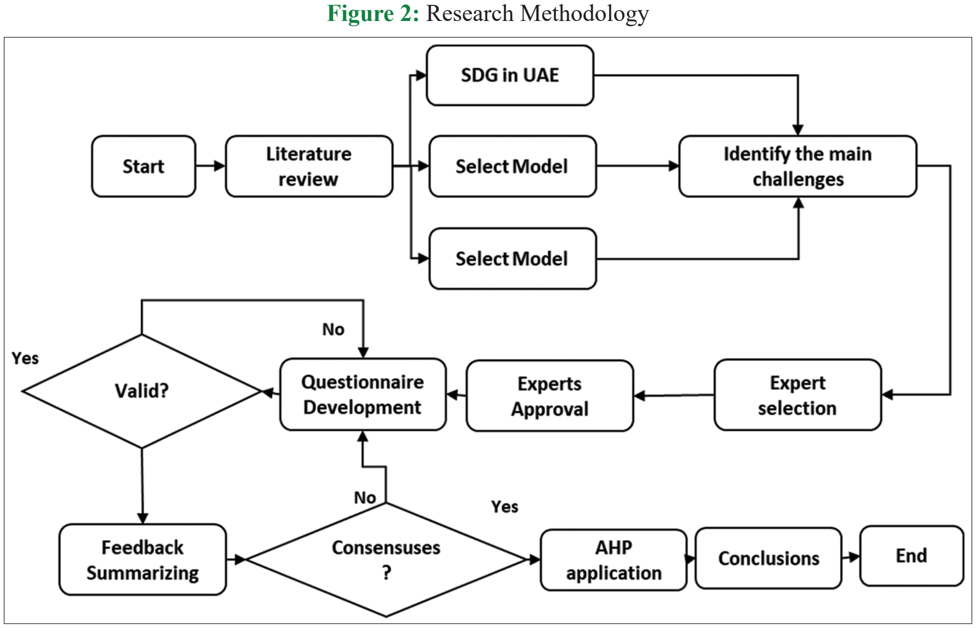
Some of the advantages for using Delphi Method are:

- The anonymity, which can help in reducing the impacts of the dominant persons
- Decrease the bias that is usually found in the normal meetings
- The feedback controlling, by the well-organized summarizing of the data collected in the previous round, letting each expert to add additional information or more illustration to his/her judgments
- The ability of the collected data to be analyzed by many different statistical techniques
- Delphi technique solves the problem of the confidentiality, by using the electronic communication, taking the benefit of the geographic distribution of the experts
- Solving one of the most important problems in group meetings that is known as "the group pressure" which is forcing some members to conform with a specific viewpoint, even if they are opposing it
- Keep the discussion focusing on the desired goal, rather than the noise that happens in the normal meetings and takes the discussion to other side of somebody else interest.

All these attributes help Delphi to overcome the obstacles faced by the old pooling opinions methods. There are also some of disadvantages for using this method such as it is time consuming since the time needed between the interactions is quite delaying the process. Furthermore, it is a bit tiring for the investigator, who must contact all the subjects, and summarize the data collected in each iteration, then built a new questionnaire to be distributed again.

The flowchart in Figure 3 illustrates the working mechanism of Delphi method. Beginning with the experts' selection, then the questionnaire development and distribution, the loop below shows

Figure 2: Research Methodology



the concept of doing multiple iterations until the consensus is obtained (Hsu and Sandford, 2007).

Moreover, Delphi method forms a group communication process to allow a group of individuals to deal with a complex problem and to achieve the best underlying arguments involving different policies or resources allocation alternatives (Linstone et al., 1975).

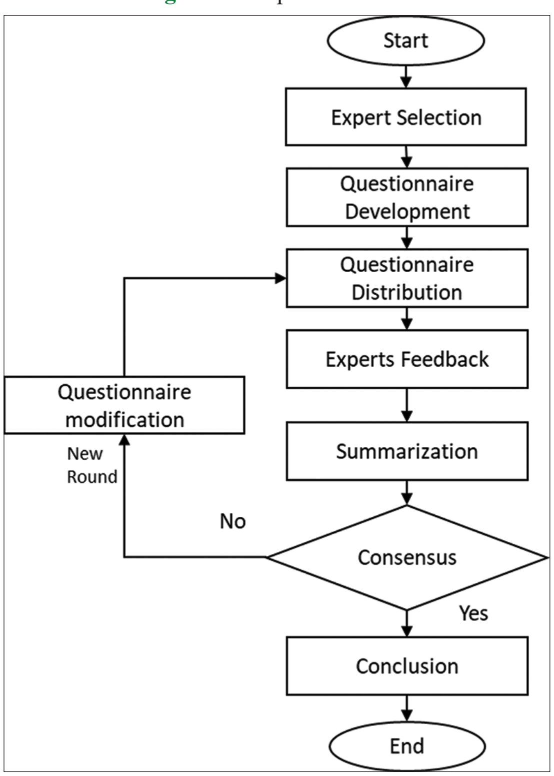
4.2. The DELPHI Subjects (Experts) Selection

The subject selection takes the largest portion of the importance of Delphi methodology, because all the results and analysis are depending on their opinions. In such a way, the participants must be carefully chosen depending on their qualifications to give their judgments within their fields of expertise. The subjects can be either in-domain experts, professional staff members, or decision makers who are possible to use the outcomes of the study. They all can be chosen if they are willing to give their contributions and make the concentrate revision for their opinions.

Jones and Twiss (1978) stated that "the investigators of a Delphi study should select the appropriate individuals through a nomination process." Related to the perfect number of subjects that must be used, it can be said that no specific number is found in the literature, the number is variable, but all agreed that the number must be sufficient to get the consensus required. In this project, five experts are selected to participate in this Delphi who are listed in Table 1:

This process involves a series of rounds of questionnaires, in which the experts were asked to provide their opinions on a range of topics related to SDG 6.b, the questionnaires were containing 3 different types of questions, the first type of questions was built using AHP method and discuss the main challenges facing UAE to achieve SDG6.b. The second question was all about general questions and survey. While the last question was about listing the main success factors that are supporting UAE 2030 plan to avoid Water Crises from expert's point of view.

Figure 3: Delphi Flowchart



4.3. AHP Method

The analytic hierarchy process (AHP), developed by Thomas L. Saaty,1 is designed to address complex multicriteria decision problems. It requires the decision maker to provide judgments regarding the relative importance of each criterion, then to designate a preference for every decision alternative using each criterion. By ranking the decision alternatives, the output of AHP is prioritized based on the overall preferences expressed by the decision maker (Anderson et al., 2012).

It is a method of "measurement through pairwise comparisons and relies on the judgments of experts to derive priority scales" (de FSM Russo and Camanho, 2015). Also, allows the judgements on groups of decision alternatives (DA) to be made and offers a measure of uncertainty in the results. It was developed to aid decision makers to rank or sort information based on several criteria (Beynon, 2002). This method explores every level of the hierarchy on an individual basis utilizing pairwise matrices to compare every possible pair of criteria and determines which criterion has the highest priority (Ahmed, 2022).

Table 1: Experts names and designation

Name	Designation
Expert 1	Water Resources Expert-Water Resource Department, Energy, Water and Future Energy Division
Expert 2	Head of Water Distribution Department-Kalba
Expert 3	Manager
Expert 4	Deputy director of Khorfakkan Branch
Expert 5	Asst. Head of Water distribution (Kalba)

Table 2: The challenges

	Challenges
1	Deterioration of groundwater and reduction of its quality
2	Limited wastewater treatment
3	Use of Water in Landscaping
4	Increasing of population which leads to increase of the demand
5	Use of water in industry

Table 3: Pairwise comparison matrix

	C1	C2	C3	C4	C5
C1	1	4	5	4	5
C2	1/4	1	2	4	3
C3	1/5	1/2	1	2	2
C4	1/4	1/4	1/2	1	3
C5	1/5	1/3	1/2	1/3	1
Total	1.900	6.083	9.000	11.333	14.000

Table 4: Each element of the matrix divided by its column

	C1	C2	C3	C4	C5
C1	0.526	0.658	0.556	0.353	0.357
C2	0.132	0.164	0.222	0.353	0.214
C3	0.105	0.082	0.111	0.176	0.143
C4	0.132	0.041	0.056	0.088	0.214
C5	0.105	0.055	0.056	0.029	0.071

One of the AHP advantages is that it can handle situations where the unique subjective judgments of the individual decision maker represent an important part of the decision-making process.

5. RESULTS AND ANALYSIS

The first round of the Delphi method for this study involved gathering 5 expert's opinions on the challenges facing UAE in achieving SDG6.b through the utilization of industry 4.0. The experts were asked to provide their opinions on selecting and prioritizing the key challenges facing UAE in achieving SDG6.b listed in Table 2 and to list the main critical success factors supporting UAE 2030 plan to avoid Water Crises.

To strives achieving the good decision to select the key challenges facing UAE to Achieve SDG6.b. The experts were invited to prioritize their selection using Saaty scale by comparing two options of the challenges by applying AHP analysis for the results. Pairwise Comparison Matrix were defined as per the results found from the expert's response and the Synthetizations was calculated by first summing the values of each column as shown in Table 3.

Then, each element of the matrix was divided by its column total as shown in Table 4.

Thereafter, the priority was calculated by averaging each element in the row, and the consistency index and the consistency ratio were calculated as illustrated in Table 5.

As the calculations of the Consistency using AHP was to derive the priority weights for the criteria which was carried out as pairwise comparisons and calculation for the above. From the first round and based on the results obtained from the Analytic Hierarchy Process (AHP) analysis, it was found that the level of inconsistency is within the acceptable range. The value of Consistency Ratio was found to be smaller than 10% which was equal to 7.838% which means that the inconsistency is acceptable. The analysis revealed that although there were some minor inconsistencies, the overall findings of the study remain reliable and meaningful. At the same time, from the priority vector results which represent the relative importance of each criterion in the decision-making process. It can be found that the importance of each vector is as shown in Table 6 where the higher values indicate higher priority.

Table 5: The priority and the consistency calculations

Priority	Consistency					Total	
0.490	0.490	0.868	0.618	0.425	0.316	2.717	5.546
0.217	0.122	0.217	0.247	0.425	0.190	1.201	5.533
0.124	0.098	0.109	0.124	0.212	0.127	0.669	5.413
0.106	0.122	0.054	0.062	0.106	0.190	0.535	5.036
0.063	0.098	0.072	0.062	0.035	0.063	0.331	5.227
Lambda	5.351	CI	0.08778	CR	0.07838		

Table 6: Priority vector and importance of each criterion

Criteria	Priority	Level of importance
Deterioration of groundwater and reduction of its quality	0.490	Highest
Limited wastewater treatment	0.217	
Use of Water in Landscaping	0.124	
Increasing of Population which leads to increase of the Demand	0.106	
Use of Water in Industry	0.063	Lowest

From the above, it can be concluded that the Deterioration of groundwater and reduction of its quality has the most significant impact that needs to allocate more focus, time, and resources to overcome this factor in water management and this is supported by numerous studies, which highlight the increasing threats to groundwater quality and its implications for water management as the Groundwater is a critical source of freshwater in UAE required in our life for different uses. Currently, the key issues faced regarding water resources management is the decrease in groundwater level, deterioration of groundwater quality and water scarcity (Maryam Chahwan, 2019). Given that the groundwater is a hidden issue as many countries extract quantities greater than what are being recharged (Tropp and Jagerskog, 2006). According to Abdelfattah et al. (2009), the drop in groundwater levels and the deterioration of the groundwater quality in many areas has set up significant impacts on the existing public water supplies.

Meanwhile, to gain more justifications from the experts regarding the prioritization of the factors (Challenges) in the Analytic Hierarchy Process (AHP) survey, a second round was initiated as Delphi method is an iterative method which allows for the integration of feedback and revisions, leading to more strong recommendations. The second round aimed to obtain more detailed explanations and insights and gather additional information from the experts regarding their rankings and choices for various factors under examination.

To conclude, the expert's opinions on the key challenges and the AHP results, and the acceptable level of inconsistency are considered as a valuable input in the decision-making process. The results for question 1 was as 60% of the response were strongly agree while 40% selected to be as agree. For the question 2, 40% were strongly agree at the same time 40% also were agree while the remaining 20% selected to be Disagree. On the other hand, the results for question 3 was 60% as strongly agree but 20% were for agree and neither agree nor disagree. Conversely, question 4 results were the same for neither agree nor disagree and agree with 40% response and for strongly agree was 20%. Finally, for question 5, 60% selected to answer as strongly agree while the remaining was 20% for both agree and neither agree nor disagree.

In summary, it worth to mention that most of the experts were agreed to all points highlighted in the questions except one expert who did not express a clear agreement or disagreement and selected "Neither agree nor disagree." Based on the consensus among the experts, it can be concluded that the following points derived from the survey are commonly agreed upon as valuable additions to the research. And these findings can be used to enhance future research and serve as important references for further studies:

- It is important that everybody in the country must be aware about the present situation of water security in UAE, as the country is facing a critical Water management level.
- The water consumption management has high priority than finding new resources for water supply.

- The public support for any water reuse initiatives is a critical aspect for success.
- The industry 4.0 is the best solution to manage the water scarcity.
- Shifting to a Smart City is the best solution for Water Management (with the integration of IT, sensors and model applications, early warning, and decision-making processes,… ets.).

5.1. Description Questionnaire Results (Success Factors Supporting UAE 2030 Plan)

The last question in the survey was open-ended, encouraging the experts to provide a descriptive response by listing the main critical success factors supporting the UAE 2030 plan to avoid water crises based on their experience and perspective.

The Success factor criteria can be defined by their potential impact, temporal association, the scale of the population reached, and agreement between stakeholders that they are indeed a success factor (Herschan et al., 2020).

It seems to have work collaboratively for achieving outcomes, some influencing factors for example knowledge and experience on data gathering, could increase the collection of reliable water quality data and how knowledge affects the quality of data also depended on supporting mechanisms (e.g., initial training) and the feedback culture (Capdevila et al., 2020).

The development of technical capacity, community engagement and monitoring and verification are some of the important success factors. Also, adaptability, international collaboration, the role of pilot studies, knowledge sharing, and stakeholder involvement also applicable factors (Herschan et al., 2020).

Based on the survey results, the feedback from the experts regarding the success factors considered to be a valuable addition to this topic and it is presented in Table 7 and the qualitative priority in Table 8.

The survey findings revolve around the success factors identified by the experts, as UAE's 2030 plan aims to address water scarcity by implementing comprehensive strategies to reduce water consumption, increase water management efficiency, and promote alternative water sources. These success factors can be briefly summarized in a list of key factors, as shown below:

- Smart Water Network (optimize water usage and reduce waste)
- Water Conservation Program
- Preserving groundwater
- Building more efficient desalination plants
- Sustainable Agriculture
- Seawater desalination and its widespread use
- TSE (Sewerage Treated Effluent), grey water reuse and use it for agricultural work
- Awareness campaigns to guide the use of Water
- Injecting Dead or high salinity wells with rainwater after collecting it
- Strategic linkage between neighboring countries for other energies
- Diversification of water Sources (Wastewater reuse, desalination, and groundwater).

These findings can serve as a good tool to evaluate the effectiveness of UAE's water management strategies and identify areas for improvement.

Table 7: Expert's list of success factors

Name	List the main success factors that are supporting UAE 2030 plan to avoid water crises
Expert 1	1-Focusing on the SDGs that enable access to clean energy 2-Do Not Pour Fat and Grease Down the Drain 3-Building more efficient desalination plants 4-Sustainability will make Planet Earth survive longer and will allow us all to live an easier life.
Expert 2	1-Integrated water resources management 2-Smart Water Network 3-Water Conservation Program 4-TSE (Sewerage Treated Effluent), Grey water reuse
Expert 3	1-Preserving groundwater 2-Seawater desalination and its widespread use 3-Recycle and use wastewater and use it for agricultural work 4-Awareness campaigns to guide the use of Water
Expert 4	1-Injecting Dead or high salinity wells with rainwater after collecting it 2-Strategic linkage between neighboring countries for other energies 3-Build more underground reservoirs 4-Spread more awareness regarding these topics
Expert 5	1-Smart water management (optimize water usage and reduce waste) 2-Diversification of water Sources (Wastewater reuse, desalination, and groundwater recharge) 3-Sustainable Agriculture 4-Public Awareness and Education

Table 8: Priority vector and importance of each criterion

Criteria	Priority
Deterioration of groundwater and reduction of its quality	0.490
Limited wastewater treatment	0.217
Use of water in Landscaping	0.124
Increasing of Population which leads to increase of the Demand	0.106
Use of water in Industry	0.063

6. CONCLUSION

In conclusion, it is clear to note that UAE has made considerable strides in water management during the past decade by developing different innovative technologies and policies. However, there are still considerable challenges facing UAE to achieve SDG6.b. that need to be tackled, which are summarized as following from the highest impact to lowest according to their priority calculation from AHP analysis: Deterioration of groundwater and reduction of its quality with priority (0.490), Limited wastewater treatment (0.217), Use of Water in Landscaping (0.124), Increasing of Population which leads to increase of the Demand (0.106) and Use of Water in Industry (0.063). Therefore, based on the consensus among the experts, the following points provide important insights about potential solutions and strategies that can help mitigate water challenges and improve overall water management practices:

- The current water security situation in UAE is critical, and it is crucial that everyone in the country to be aware of it
- The water consumption management has high priority comparing to finding new resources for water supply
- The public support for any water reuse initiatives is a critical aspect for success, by investing in education and awareness-raising activities at the community which will increase the understanding of the importance of water and sanitation management practices
- Implementing Industry 4.0 solutions, such as smart sensors and AI in water management systems, the organizations can effectively monitor and optimize water usage, reduce waste, and enhance overall efficiency in water management
- Shifting to a Smart City is the best solution for Water Management (with the integration of IT, sensors and model applications, early warning, and decision-making processes,… etc.).

Therefore, it is important to emphasize some suggested key solutions and success factors which will contribute effectively to achievement the SDG6.b (which focuses on supporting and strengthening the participation of local communities in improving water and sanitation management). These factors serve as essential supports to the overall success of SDG6.b. and UAE's 2030 plan which are:

- Smart Water Network (optimize water usage and reduce waste)
- Water Conservation Program
- Preserving groundwater to ensure the long-term sustainability of water resources by regulating groundwater extraction and promoting the use of alternative water sources
- Building more efficient desalination plants
- Practicing sustainable agriculture to ensure water security by minimizing the Water demanded for agricultural activities
- Soil moisture sensing equipment for irrigation purpose so that it will promote efficient water usage and prevent overwatering
- Seawater desalination and its widespread use
- TSE, grey water reuse and use it for agricultural work
- Conducting awareness campaigns which can play a crucial role in guiding people for responsible water usage. Such campaigns can highlight the importance of water conservation, highlight the impacts of water scarcity, and provide practical tips and guidelines for efficient water usage in daily life
- Recharging dead or high salinity wells. This can be achieved by collecting and injecting rainwater into them which can be an effective method for filling groundwater reserves. In this process rainwater can be captured and directed into the wells, which will help to dilute the high salinity levels
- Establishing strategic partnerships and collaborations between neighboring countries can facilitate the exchange and utilization of alternative sources of energy
- Diversifying water sources is vital for ensuring water security to increase the demand and limited resources such as wastewater reuse, desalination, and groundwater. This will help the countries to reduce their reliance on a single source and ensure a more sustainable water supply.

Overall, UAE's successful experiences in water management are valuable examples for other arid regions worldwide. It has implemented sustainable and innovative water management practices and continues to provide safe water supply for its growing population and contribute to the global effort to achieve water security for all. Additionally, UAE implemented policies and regulations that encourage water conservation, such as developing water reuse regulations, establishing water-saving standards for buildings, and promoting sustainable agriculture practices. At the same time, UAE has engaged in international efforts to address water scarcity, including through partnerships and collaborations with other countries and organizations and international Summits.

It was noted that the subject of utilizing Industry 4.0 in water management in UAE is a relatively new field, and there are few studies on the topic. Thus, there are some limitations that was encountered while doing this research as follows:

1. The effectiveness of Industry 4.0 in water management needs to be studied in further details to be sure whether it was fully implemented or still it faces certain lack of data availability.
2. Using Industry 4.0 can face resistance from some stakeholders if they are unfamiliar with the technologies.
3. There are some external factors that may affect water management in UAE like: climate change and geopolitical events which should be considered in the study.
4. This type of research needs to focus also on some statistical data (previous, current, and forecasted data) for different period so that it will reflect all states of Water.
5. Lack of references related to Success Factors related to Water Crises which leads to mainly depend on the response from the experts.

All in all, a study about Industry 4.0 in water management in UAE should closely consider these limitations to ensure that the findings have been achieved.

7. ACKNOWLEDGMENT

We would like to thank the Research Management Center, American University of Ras Al Khaimah, for their support in conducting our research. The research under Seed Grant (ENGR/001/23): Utilizing Industry 4.0 to overcome challenges in achieving some SGDs in the Middle East countries: A framework development.

REFERENCES

Ab Latif, R., Mohamed, R., Dahlan, A., Nor, M.Z.M. (2016), Using Delphi technique: Making sense of consensus in concept mapping structure and multiple choice questions (MCQ). Education in Medicine Journal, 8(3), 89-98.

Abdelfattah, M.A., Dawoud, M.A.H., Shahid, S.A. (2009), Soil and Water Management for Combating Desertification-Towards Implementation of the United Nations Convention to Combat Desertification from the UAE Perspectives. In: Proceedings of the International Conference on Soil Degradation, Riga, Latvia, pp17-19.

Ahmed, I. (2022), Application of principal component analysis and analytical hierarchical process in surface water quality assessment in hatta catchment, emirate of Dubai, UAE. In: Computational

Modelling in Industry 4.0: A Sustainable Resource Management Perspective. Singapore: Springer Nature Singapore. pp349-366.

Alabi, M., Telukdarie, A., Van Rensburg, N.J. (2019), Industry 4.0: Innovative Solutions for the Water Industry. In: Proceedings of the International Annual Conference of the American Society for Engineering Management. USA: American Society for Engineering Management (ASEM). p1-10.

Alabi, M.O., Telukdarie, A., van Rensburg, N.J. (2019), Water 4.0: An Integrated Business Model from an Industry 4.0 Approach. In: 2019 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM). United States: IEEE. p1364-1369.

Alam, H., Khattak, J.Z.K., Ppoyil, S.B.T., Kurup, S.S., Ksiksi, T.S. (2017), Landscaping with native plants in the UAE: A review. Emirates Journal of Food and Agriculture, 29 (10), 729-741.

AL-Dabbagh, R., Darwish, A.S., Alnaser, N.W. (2020), Management practices of conventional and non-conventional water resources: Study case in emirate of Sharjah, UAE. Arab Gulf Journal of Scientific Research, 38(3), 149-171.

Al-Katheeri, E.S. (2008), Towards the establishment of water management in Abu Dhabi Emirate. Water Resources Management, 22(2), 205-215.

Alsharhan, A.S., Rizk, Z.E. (2020), Water resources and integrated management of the United Arab Emirates. Vol. 3. Germany: Springer Nature.

Anderson, D.R., Sweeney, D.J., Williams, T.A., Camm, J.D., Cochran, J.J. (2012), An Introduction to Management Science: Quantitative Approach. United States: Cengage Learning.

Beynon, M. (2002), DS/AHP method: A mathematical analysis, including an understanding of uncertainty. European Journal of Operational Research, 140(1), 148-164.

Bhaduri, A., Bogardi, J., Siddiqi, A., Voigt, H., Vörösmarty, C., Pahl-Wostl, C., Osuna, V.R. (2016), Achieving sustainable development goals from a water perspective. Frontiers in Environmental Science, 4, 64.

Bufler, R., Clausnitzer, V., Vestner, R., Werner, U., Ziemer, C. (2017), WATER 4.0-An Important Element for the German Water Industry. Berlin: German Water Partnership.

Capdevila, A.S.L., Kokimova, A., Ray, S.S., Avellán, T., Kim, J., Kirschke, S. (2020), Success factors for citizen science projects in water quality monitoring. Science of the Total Environment, 728, 137843.

D'Amore, G., Di Vaio, A., Balsalobre-Lorente, D., Boccia, F. (2022), Artificial intelligence in the water-energy-food model: A holistic approach towards sustainable development goals. Sustainability, 14(2), 867.

Dalkey, N., Helmer, O. (1963), An experimental application of the Delphi method to the use of experts. Management Science, 9(3), 458-467.

De FSM Russo, R., Camanho, R. (2015), Criteria in AHP: A systematic review of literature. Procedia Computer Science, 55, 1123-1132.

ESCAP, U. (2018), SDG 6: Clean Water and Sanitation: Ensure Availability and Sustainable Management of Water and Sanitation for All. Thailand: ESCAP.

Herschan, J., Rickert, B., Mkandawire, T., Okurut, K., King, R., Hughes, S.J., Pond, K. (2020), Success factors for water safety plan implementation in small drinking water supplies in low-and middle-income countries. Resources, 9(11), 126.

Hossain, M.Z. (2015), Water: The most precious resource of our life. Global Journal of Advanced Research, 2(9), 1-11.

Hsu, C.C., Sandford, B.A. (2007), The Delphi technique: Making sense of consensus. Practical Assessment, Research, and Evaluation, 12(1), 10.

Hussein, K.A., Alsumaiti, T.S., Ghebreyesus, D.T., Sharif, H.O., Abdalati, W. (2021), High-resolution spatiotemporal trend analysis of precipitation using satellite-based products over the United Arab Emirates. Water, 13(17), 2376.

Kakes, E.T.M. (2020), The Protection of the Human Right to Safe Drinking Water in the Context of Climate Change: Considering Lessons from the Water Crisis in the City of Cape Town.

Karataş, A., Karataş, E. (2023), Environmental education as a solution tool for the prevention of water pollution. Journal of Survey in Fisheries Sciences, 2023, 61-70.

Ktari, J., Frikha, T., Hamdi, M., Elmannai, H., Hmam, H. (2022), Lightweight AI framework for industry 4.0 case study: Water meter recognition. Big Data and Cognitive Computing, 6(3), 72.

Linstone, H.A., Turoff, M., editors. (1975), The Delphi Method. Reading, MA: Addison-Wesley. p3-12.

Maryam Chahwan, (2019), Water Resource Challenges in the United Arab Emirates, Innovation Arabia 12 Proceedings. p27-44.

McLennan, M. (2021), The Global Risks Report 2021 16th ed. Cologny, Switzerland: World Economic Forum.

Mekonnen, M.M., Hoekstra, A.Y. (2016), Four billion people facing severe water scarcity. Science Advances, 2(2), e1500323.

Mohamed Alghafli, S.S. (2016), Challenges to the Governance of Water Security in the UAE. Master of Public Policy (MPP), Available from: https://scholarworks.uaeu.ac.ae/all_theses/449

Mukhopadhyay, B.R., Mukhopadhyay, B.K. (2021), Industry 4.0. Leveraging the Fourth Industrial Revolution. Tripura: Tripura Times.

Murad, A.A. (2008), Challenges Facing the Sustainability of Conventional Water Resources in the United Arab Emirates (UAE), In: International Conference on Water Scarcity, Global Changes, and Groundwater Management Responses. p1-5.

Ortigara, A.R.C., Kay, M., Uhlenbrook, S. (2018), A review of the SDG 6 synthesis report 2018 from an education, training, and research perspective. Water, 10(10), 1353.

Poljak, D. (2018), Industry 4.0: New Challenges for Public Water Supply Organizations. In: Proceedings of the 3rd International Scientific Conference LEAN Spring Summit. p51-8.

Rizk, Z.S., Alsharhan, A.S. (2003), Water resources in the United Arab Emirates. Developments in Water Science, 50, p245-264.

Sachs, J., Kroll, C., Lafortune, G., Fuller, G., Woelm, F. (2022), Sustainable Development Report 2022. United Kingdom: Cambridge University Press.

Skulmoski, G.J., Hartman, F.T., Krahn, J. (2007), The Delphi method for graduate research. Journal of Information Technology Education: Research, 6(1), 1-21.

Szabo, S. (2011), The water challenge in the UAE.

Tropp, H., Jagerskog, A. (2006), Water scarcity challenges in the Middle East and North Africa (MENA). Human Development Report, 1-26.

United Nations. (n.d.), Sustainable Development Goals. Available from https://www.un.org/sustainabledevelopment/water-and-sanitation [Last accessed on 2023 Mar 31].

Uwamungu, J.Y., Kumar, P., Alkhayyat, A., Younas, T., Capangpangan, R.Y., Alguno, A.C., Ofori, I. (2022), Future of water/wastewater treatment and management by industry 4.0 integrated nanocomposite manufacturing. Journal of Nanomaterials, 2022, 5316228.

Vaidian, I., Azmat, M., Kummer, S. (2019), Impact of Internet of Things on Urban Mobility. In: Proceedings of the Innovation Arabia 12, Dubai, United Arab Emirates.

Zengin, Y., Naktiyok, S., Kaygin, E., Kavak, O., Topçuoğlu, E. (2021), An investigation upon industry 4.0 and society 5.0 within the context of sustainable development goals. Sustainability, 13(5), 2682.