Development of an Importance Scale for Seawater Intake Types Based on Physical Parameters Database

Rim El Masmodi[1*] *and Bouabid* El Mansouri[1]

[1] Laboratory of Natural Resources and Sustainable Development, Ibn Tofail University, Faculty of Sciences, P.O. Box 133. 14 000, Kenitra, Morocco

Abstract. This article presents an advanced Geographic Information Systems (GIS) based interface that innovates coastal water resource management in Morocco, with specific application to the ASSILAH region. This solution integrates spatial analysis with multi-criteria decision support, particularly focusing on the geographical distribution and territorial challenges of the Moroccan coastline, using programming tools such as Excel Visual Basic for Applications (VBA). The methodology combines GIS spatial analysis capabilities with the Analytic Hierarchy Process (AHP) to evaluate complex geographical parameters including bathymetry and coastal infrastructure. The integration of geospatial data provides a clear and precise visualization of potential areas for seawater intake installations, thereby facilitating the understanding of territorial issues for decision-makers. The AHP method, known for its robustness in multi-criteria decision support, allows for choosing the optimal type of seawater intake. The interface, developed through Excel and VBA, transforms complex spatial and analytical data into an accessible decision support tool. The resulting system offers regional planners a comprehensive framework for coastal sustainable infrastructure development in the Assilah coastal region as a pilot case for Morocco's unique geographical context.

Keywords: Decision making tool, seawater intake types, AHP analysis, GIS spatial analysis.

1 Introduction

The choice of the type of seawater intake is a crucial and costly decision that impacts the establishment of desalination plants. Among the three components of seawater desalination (intake, treatment, and concentrate discharge), the location and design of the intake are often the most challenging aspects of the system. This complexity arises due to technical strategy requirements, regulatory hurdles, and public perception issues [3]. Before even determining the location of the desalination plant, it is essential to focus on the choice of the type of the seawater intake, as this decision influences not only the initial and maintenance costs but also the environmental impacts on the chosen area. The capacity of desalination plants worldwide

* Corresponding author: rim.elmasmodi@uit.ac.ma

has more than doubled lately, due to the cost of desalinated seawater compared to traditional freshwater resources [5].

The integration of Multiple Criteria Analysis (MCA) is considered a highly valuable and effective management tool that focuses on integrating different impacts and outcomes of various options into a peerless assessment, making it a valuable aid in decision-making processes [8]. The addition of GIS as a data analysis tool facilitates the identification of the most suitable locations for particular purposes [1]. To simplify this complex decision-making process, we have developed a decision support tool based on multicriteria approach. This article aims to introduce our decision support tool, which based on the discretization and integration of geospatial data and the use of the AHP to rank different criteria according to their importance in various types of intakes. This tool is going to help decision-makers and stakeholders determine the most appropriate type of seawater intake for any coastal region in Morocco, considering a variety of physical, technical and environmental parameters.

2 Methodology

For the development and use of the interface intended for decision-makers and stakeholders, an integrated and iterative approach adopted. It begins with a crucial preparatory phase, encompassing the collection and standardization of geospatial data for the Moroccan coastline. Integration into a GIS was indispensable due to the vast geographical extent of the Moroccan territory. Following this phase, the use of the AHP becomes possible. This initial step lays the solid foundations necessary for creating a robust and reliable decision support tool. The second phase focuses on the technical aspect and the integration of various components. It includes VBA programming and integration with Excel to create an intuitive and efficient user interface. This phase also includes the development and incorporation of financial and environmental analysis models, thereby enriching the tool's evaluation capacity. A rigorous series of tests and validations then conducted to ensure the reliability and accuracy of the interface in real-world scenarios.

The methodology culminates with the deployment of the interface and its practical application. This approach ensures not only the effective adoption of the interface by end-users but also its constant evolution to meet changing needs and new on-the-ground realities.

El Masmodi et al. (2024) showed that to manage the extent and diversity of the Moroccan territory, the coastline was discretized into nearly 500 cells, each 10 km x 10 km. Each cell was analysed based on 20 parameters (different data covering social, qualitative, and quantitative aspects of the area, as well as parameters such as bathymetry, hydrology, hydrogeology, soil nature, coastline nature, geomorphology, topography, groundwater quality, etc.).

The data collection aimed to gather relevant geospatial information for the Moroccan coastline, collected and analysed using a GIS. All these parameters constitute the core of our interface, forming the integrated database within an Excel sheet. Fig. 1 below illustrates the methodological process adopted for developing a decision support interface for selecting water intake types along the Moroccan coastline.

This process comprises 9 numbered steps, each corresponding to a specific phase of interface development, allowing at this stage the final choice of the 5 most favorable intake types ranked by compatibility with the chosen region. Key steps in this process include spatial discretization and referencing (step 2), GIS analysis (step 3), data export to Excel (step 4), analysis and standardization of criteria (step 5), weighting and ranking criteria using the AHP method (step 6), creation of a classification dictionary (step 7), cross-referencing database parameters with dictionary records (step 8), and finally selecting the most advantageous intake types (step 9).

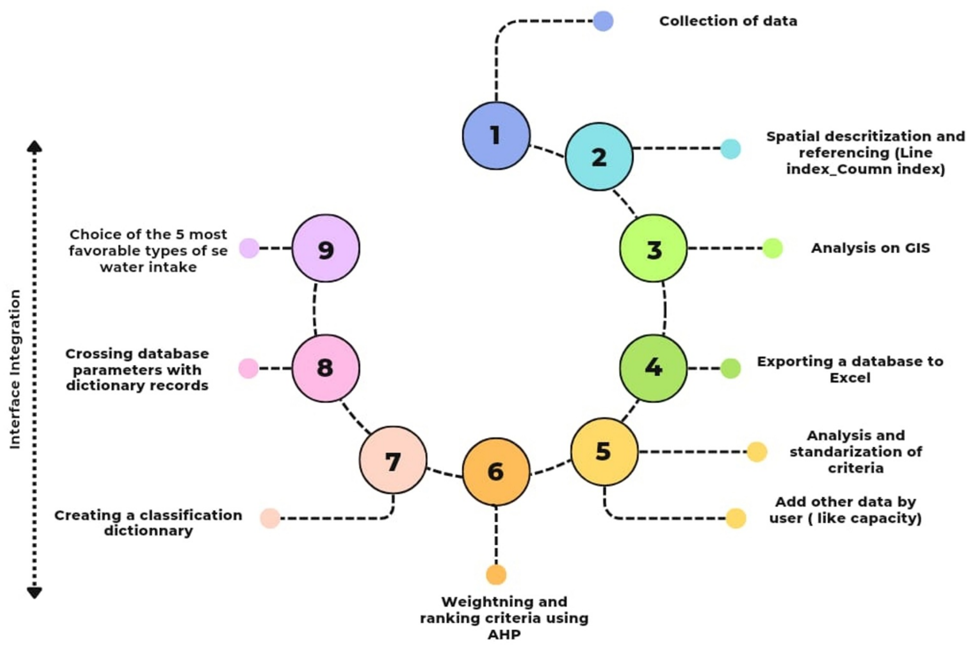

Fig. 1. Global diagram of the process from data collection to decision-making

This methodological approach integrates the various tools and techniques mentioned previously, including GIS, AHP, and the use of Excel, thus offering a comprehensive view of the development process of the decision support interface for regional water resource managers in Morocco.

The AHP, created by Saaty, is a robust multicriteria decision-making tool that has been widely applied across diverse fields. It is a structured method for organizing and analysing complex decisions. The AHP analysis breaks down the decision problem into a hierarchy of more easily understandable elements, and then evaluates the relative importance of these elements through pairwise comparisons, allowing for the calculation of overall scores for each option [6, 7].

To calculate the priorities of each alternative within each sub-criterion, it proposed that the decision-maker uses the alternative considered the most important, or one of the most important, as the basis for comparison within each criterion [4]. Saaty defined a rating scale that measures the importance or difference of one element over another.

The user interface of the platform designed to be user-friendly and easy to navigate, ensuring a smooth user experience.

The goal is to enable users, regardless of their technical skill level, to navigate easily through the various functionalities of the tool. This includes access to data, modification of criteria and their weights, as well as the generation of ranking reports for the types of seawater intakes.

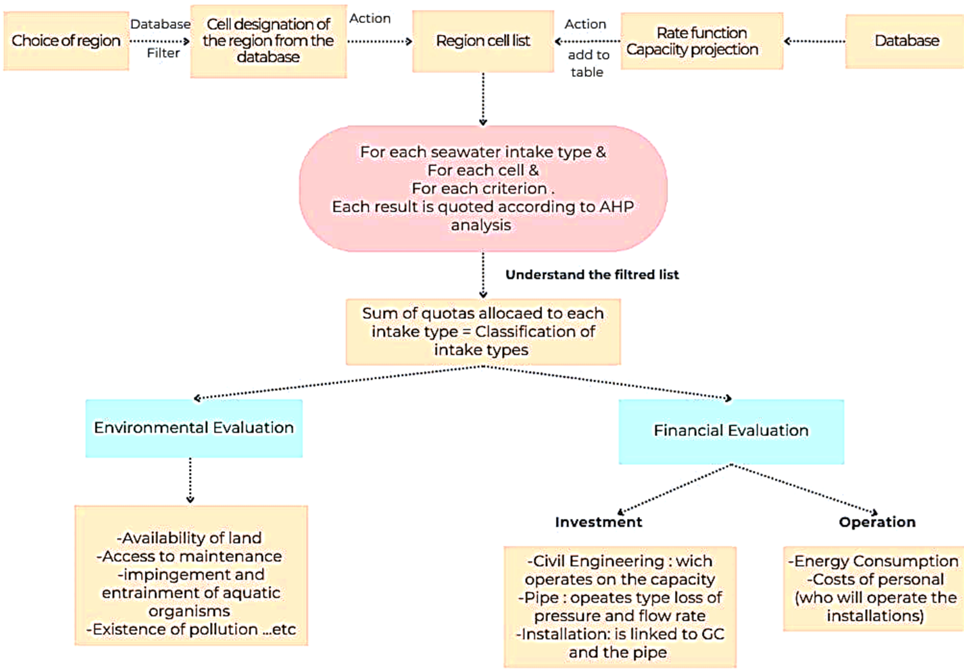

Fig. 2. Detailed steps for integrating an interface

The process begins with the selection of the region of interest, followed by filtering the database and designating the corresponding cells. These preliminary steps allow for the establishment of a list of regional cells, which then enriched by projecting capacity based on user-customized calculations. The core of the process is represented by the central step (shown in pink in Fig. 2), which applies the analysis to each type of seawater intake, for each cell and each criterion. This crucial step integrates the weighting and ranking of criteria, in accordance with the AHP methodology previously described, ensuring an objective and multicriteria evaluation of the options.

The diagram in Fig. 2 concludes with a bifurcation towards two types of complementary evaluations: environmental and financial. The environmental evaluation considers factors such as land availability, access for maintenance, and impact on aquatic organisms. The financial evaluation divided into two aspects: investment (including civil engineering and installation) and operation (covering energy consumption and personnel costs).

This holistic approach, integrating technical, environmental, and financial considerations, reflects the intention to provide regional decision-makers with a comprehensive and nuanced decision support tool, as highlighted in previous discussions on the advantages of the interface for the sustainable management of water resources in Morocco.

One of the major strengths of this tool lies in its customization capability. Users can create their own customized models to meet specific needs. At the city (or region) selection level on the first window (Fig. 3), once this choice made, they can utilize the decision support system to view the results on the second window, which opens automatically (Fig. 4).

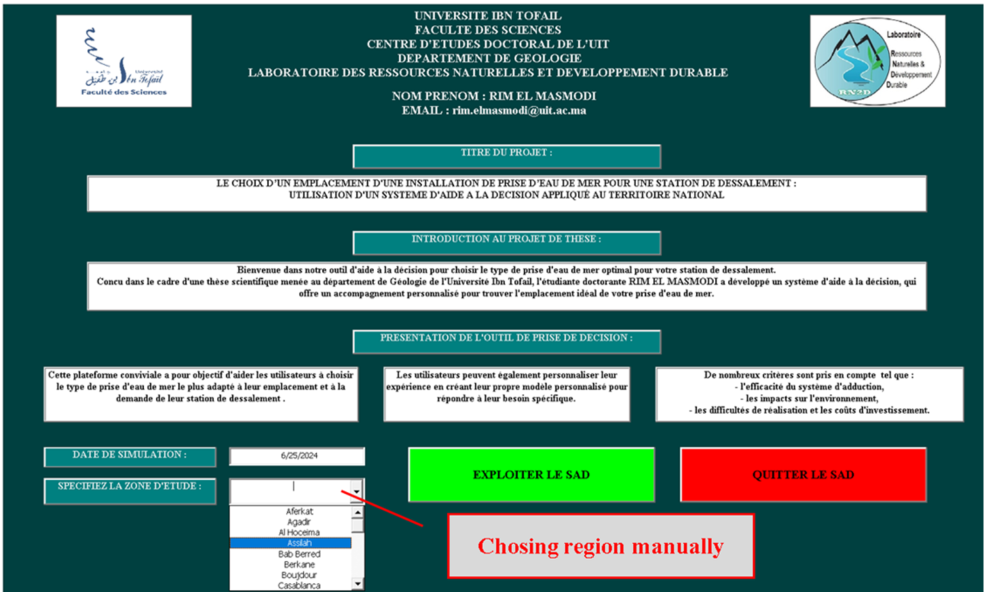

Fig. 3. Homepage of the interface for selecting the study area

The VBA code estimates the forecast capacity of the operation based on the region's population, growth rate, and adjustable parameters. The cells (data recording lines) corresponding to the chosen region are cross-referenced with the possible intake types and the estimated capacity. An environmental and institutional response matrix guides the elimination of unsuitable options. Hydraulic calculations size the intake and seawater conveyance pipes, installations, and civil engineering works.

An evaluation of environmental and institutional criteria, as well as the calculated costs of the financial estimation for investment and operation of the seawater intake, performed to provide a final classification that aids decision-making, optional user intervention allowed to optimize the default configuration by enabling customization.

Table 1. Analysis of criteria and sub-criteria for the 10 types of seawater intakes based on the AHP method [2].

Seawater Intake type N°	**Rock coast**	**Sand coast**	**Dune coast**	**Small Capacity**	**Medium Capacity**	**Large Capacity**	**Shallow Aquifer**	**Deep Aquifer**	**Absent Aquifer**	**Absent Salinity**	**Medium Salinity**	**High Salinity**
Intake 1	12	6	10	7	1	2	9	5	3	4	11	8
Intake 2	11	3	8	7	4	1	12	10	6	2	5	9
Intake 3	11	4	8	9	5	2	12	10	6	1	3	7
Intake 4	2	9	5	7	3	1	12	10	6	4	8	11
Intake 5	1	8	3	9	2	5	12	10	6	4	11	7
Intake 6	11	4	7	8	10	12	1	3	6	9	2	5
Intake 7	7	12	10	8	5	11	1	3	6	9	2	4
Intake 8	10	12	8	4	6	11	3	5	9	1	2	7
Intake 9	11	12	8	6	4	10	7	1	3	9	5	2
Intake 10	6	12	9	4	1	7	11	3	8	10	5	2

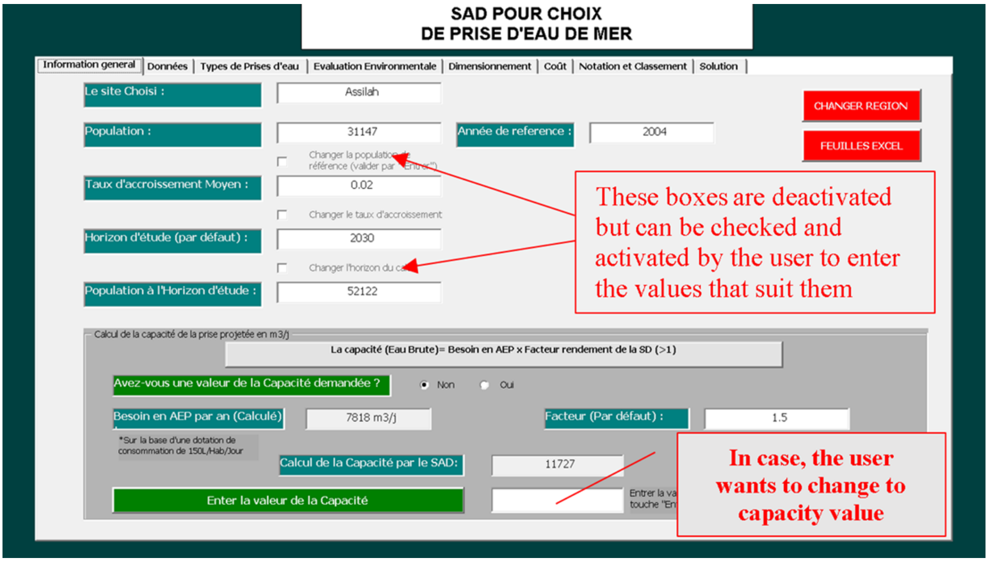

Fig. 4. General information window gathered from the database

A pre-established scale used to derive the scores obtained through the AHP analysis (Table 1). This scoring system allows for ranking the 10 different types of seawater intakes based on their performance, evaluated against the 12 detailed criteria and sub-criteria [2]. The first results of this analysis visualized in Fig. 4.

The objective of the analysis is to determine the types of seawater intakes that are feasible and favorable for installation along the coastline of the city in question. This selection process among the 10 studied intake types is crucial as it eliminates those unsuitable for this specific area, retaining only the seawater intake types that have received the highest ratings from the ranking analysis based on AHP results. This preliminary analysis based on a VBA code that considers the ranking and weighting of the studied criteria.

3 Results and Discussion

The current development of this interface enables the implementation of this analysis across all coastal cities of the kingdom. The resulting example elaborated for the city of Assilah, where four types of seawater intakes are highlighted by our interface (shown in green on Fig. 5), indicating these are the most suitable types for the region (city) of Assilah. Three of these types are direct seawater intakes, while the fourth type is an indirect seawater intake. Further detailed analysis will determine the most favorable feasibility of one of these seawater intake types based on their optimal alignment with defined criteria, thereby assisting decision-makers in selecting the most suitable type of intake for their specific needs.

Results obtained after extensive spatial and hierarchical analysis of parameters and selection criteria, the tool classifies for each cell, five degree of choices of seawater intakes as the most favorable of every region chosen in Assilah. These results are recorded in ranking tables from 1 to 12 (1 being the most favorable ranking and 12 the least one) to create a scale of importance for seawater intake types. This offers a clear visualization of available options and their respective ratings, facilitating planning and projection clarity

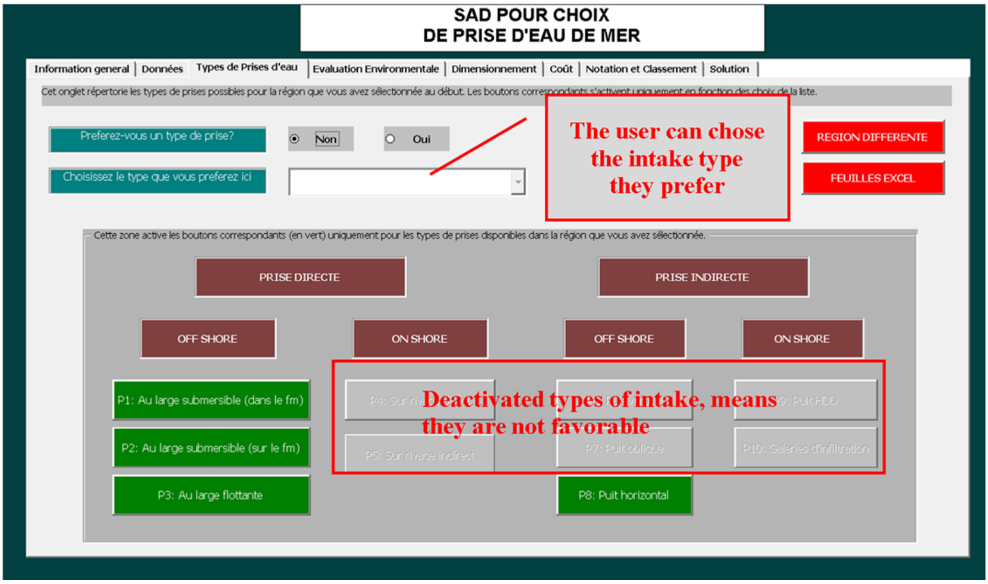

Fig. 5. Visualization of optimal seawater intake types for the selected region (favorable options highlighted in green, unfavorable options grayed out)

4 Conclusion

The developed interface represents and innovative tool for the optimal selection of seawater intake types along the Moroccan coastline. By combining GIS technologies, decision analysis, and programming, it provides regional decision-makers with comprehensive support for informed and sustainable choices. The ongoing integration of financial and environmental analyses promises to enrich further this tool, positioning it as an invaluable resource for the sustainable management of water resources in Morocco.

Future developments could enhance the system through the integration of real-time oceanographic data monitoring, advanced sensitivity analysis capabilities, and scenario modeling of climate change. The potential for extending this methodology to other coastal regions and incorporating stakeholder feedback mechanisms further emphasizes its value as a foundation for sustainable desalination planning. This comprehensive decision support system not only addresses current planning challenges but also establishes a robust framework for future sustainable desalination projects in the region, contributing significantly to Morocco's water security objectives.

Funding
The authors declare that they received no funding for this research and there are no any potential conflicts of interest in this paper.

Author Contribution
All authors (Rim El Masmodi, Bouabid El Mansouri) reviewed and approved the final manuscript, R.El Masmodi contributing to study design, methodology, and the draft manuscript, B.El Mansouri providing supervision, reviewing and interpreting the data.

Ethics approval and consent to participate
Not applicable.

Consent for publication
All the authors have agreed to publish this article.

Competing interests
The authors declare that they have no competing interests.

Acknowledgement
The authors would like to express their gratitude to E3S Web of Conferences for providing a platform to publish this research work and for their professional support throughout the publication process.

References

1. E. Grubert, A. Stillwell, & M. Webber, "Where does solar-aided seawater desalination make sense? a method for identifying sustainable sites", Desalination, vol. 339, p. 10-17, 2014. https://doi.org/10.1016/j.desal.2014.02.004
2. R. El Masmodi, B. El Mansouri, & A. Mridekh, "Multicriteria characterization of feasibility parameters, implementation of seawater intake selection along the moroccan coastline", E3S Web of Conferences, vol. 489, p. 02002, 2024. https://doi.org/10.1051/e3sconf/202448902002
3. E. Mackey, N. Pozos, W. James, T. Seacord, H. Hunt, D.L. Mayer, Assessing Seawater Intake Systems for Desalination Plants (2011)
4. J. Leal, "Ahp-express: a simplified version of the analytical hierarchy process method", MethodsX, vol. 7, p. 100748, 2020. https://doi.org/10.1016/j.mex.2019.11.021
5. M.M. Roux, Investigation of marine components of large direct seawater intake & brine discharge systems for desalination plants, towards development of a general design approach (2010)
6. R. Saaty, "The analytic hierarchy process—what it is and how it is used", Mathematical Modelling, vol. 9, no. 3-5, p. 161-176, 1987. https://doi.org/10.1016/0270-0255(87)90473-8
7. N. Tsiourtis, "Criteria and procedure for selecting a site for a desalination plant", Desalination, vol. 221, no. 1-3, p. 114-125, (2008). https://doi.org/10.1016/j.desal.2007.01.073
8. Y. Chen, J. Yu, & S. Khan, "Spatial sensitivity analysis of multi-criteria weights in gis-based land suitability evaluation", Environmental Modelling &Amp; Software, vol. 25, no. 12, p. 1582-1591, (2010). https://doi.org/10.1016/j.envsoft.2010.06.001