USE OF ANALYTIC HIERARCHY PROCESS MODEL FOR SELECTION OF HEALTH INFRASTRUCTURE PROJECTS

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ABSTRACT

This article aims to develop a methodology in which alternative projects are prioritized and selected using appropriate methods of multi-criteria decision-making in organizations responsible for managing and developing health infrastructure. This study addresses a particular gap in implementing a systematic methodology for prioritizing and selecting projects in the health sector. The methodology developed proposes an approach based on the AHP multi-criteria decision support method for decision-makers and stakeholders to prioritize and select projects in the health sector. The problem was modeled using the Expert Choice software which allows a good "integration of the decision-maker" in the decision-making process making it possible to intervene in the research and decisions to identify the most efficient and potentially profitable health projects that are useful to the community

Keywords: project selection; health infrastructure projects; multi-criteria decision support; AHP; Analytical Hierarchy Process

1. Introduction

The selection of projects is considered a crucial component of project portfolio management. Project managers, who are tasked with overseeing projects, face the challenge of having limited resources to carry out a multitude of project ideas. As a result, they must select the most promising projects from the pool of candidates. Project selection is viewed as an evaluation process, where each project concept is assessed and the one with the highest priority is chosen. To make this determination, managers can utilize a single criterion, such as the cost of implementation, to rank the projects. The least expensive projects can then be selected, resulting in a simple single-criteria decision. However, decision-makers often use multiple criteria, such as technical, environmental, social, etc., in their decision-making process. These criteria can be conflicting and subjective, including both tangible and intangible factors. This is referred to as multi-criteria decision-making.

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The selection of projects is a complex decision-making problem that requires a multi-criteria analysis and the use of appropriate methods. It is important to note that there is generally no alternative that is best from all perspectives, and the concept of optimization is not applicable in this context. The development of multi-criteria methods has moved away from aggregating into a single criterion and towards more flexible methods that incorporate interactivity. Several Multi-Criteria Decision Making (MCDM) methods have been developed to support decision-making in this context (e.g., AHP, ELECTRE, MACBETH, SMART, PROMETHEE, UTA, etc.), see also Ishizaka & Labib (2010) and Ishizaka & Nemery (2013).

The literature presents several studies on the selection of projects using multi-criteria analysis. For example, Chatterjee and al. (2018) applied the AHP in a fuzzy environment to help companies set priorities in terms of investment. One study describes an application of the AHP method for the problem of selecting investments in small hydroelectric power stations (Saracoğlu, 2015). Ciptomulyono (2000) proposed a model integrating the AHP and multi-objective programming for the selection of electrical projects. An application based on the AHP for the selection of a production project according to the criteria of sustainable development was developed by Jurı´k, Horňáková, Šantavá, Cagáňová, & Sablik (2022). A study on project selection using multi-criteria decision support indicated that among many existing techniques, AHP, ANP, and TOPSIS were the most popular methods (Sadi-Nezhad, 2017). Khan and Ali (2020) concluded that the AHP method is more widely preferred by researchers in almost all fields and applications. Based on a review of the existing literature on the selection of health infrastructure projects, little research exists that uses the AHP or its extensive forms in this area.

Moreover, the COVID-19 outbreak, declared a pandemic by the World Health Organization (WHO) on March 11, 2020, can be described as the largest multifaceted crisis ever faced by the modern world (Ağaç & Şimşir, 2022). Globally, as of May 25, 2022, 524,339,768 confirmed cases of COVID-19, including 6,281,260 deaths, have been reported to the WHO (OMS, 2022). This pandemic revealed the vital importance of health infrastructure, such as hospitals, health centers, and laboratories, in preserving human life.

Countries worldwide, including Algeria, have launched or relaunched health infrastructure programs and projects to address the shortcomings in the care of COVID-19 patients and other patients affected by communicable and non-communicable diseases. However, decision-makers in the health sector have more potential projects than available resources to implement them.

The economic crisis caused by the COVID-19 pandemic has also resulted in a decrease in financial resources, forcing countries to reduce their budgets. This has a direct impact on public facilities budgets, including health infrastructure projects. Policymakers must adopt policies to rationalize spending and prioritize projects that are most beneficial to the community.

This study aims to develop a methodology for prioritizing and selecting health infrastructure project alternatives using appropriate methods of multi-criteria decision-making in organizations responsible for their management and development.

2. Methodology

The selection of a multi-criteria method to deal with a particular problem is a multi-criteria decision problem with no obvious solution. Opting for one method over another is often done arbitrarily, due to the lack of standard rules (Al-Shemmeri, 1997). The Analytical Hierarchy Process (AHP) has been used to prioritize and select health infrastructure projects. It is recommended for this kind of ranking problem with scores (Ishizaka & Nemery, 2013).

The AHP method has aroused the interest of many researchers mainly because of the good mathematical properties of the method and the fact that the required input data are rather easy to obtain (Triantaphyllou & Mann, 1995). Its simplicity is characterized by comparing pairs of alternatives according to specific criteria (Vargas, 2010). In addition, the method has been popularized and made easy to use by the development of several software programs. The most well-known are Expert Choice (Saaty & Forman, 2022) and Super Decisions (Saaty & Saaty, 2022; Mu & Pereyra-Rojas, 2018). In this study, we used Expert Choice software version 11, which is a decision-making software that is based on multi-criteria decision-making and implements the AHP by computing the relative weight instead of calculating by hand.

2.1 Presentation of the AHP method

The fundamental problem with decision-making is choosing the best alternative from a set of competing alternatives that are evaluated according to contradictory criteria. The Analytical Hierarchy Process (AHP) provides a comprehensive framework for solving such problems. It is a systematic procedure to represent the elements of any problem. It organizes basic rationality by breaking down a problem into its smaller constituent parts and then using simple pairwise comparison judgments to develop priorities in each hierarchy (Saaty, 1986).

The AHP method is one of the most widely used multi-criteria decision-making tools available to decision-makers and researchers (Kumar & Vaidya, 2006). Many notable works have been published based on the AHP including applications in different areas such as planning, selection of a better alternative, resource allocations, conflict resolution, optimization, etc. (Kumar & Vaidya, 2006). Kumar and Vaidya (2006) predicted that the AHP will be widely used for decision-making and that the use of ad-hoc software applications will further address the complexity of integrated applications of AHP and other techniques to represent real-world situations. This generalization is certainly due to the method’s ease of application and the structure of the AHP that follows the intuitive way that managers solve problems. Hierarchical modeling of the problem, the ability to adapt verbal judgments, and consistency checking are major assets of the AHP (Ishizaka & Labib, 2011).

2.2 AHP fundamentals

Three principles can be recognized in problem-solving: decomposition, comparative judgments, and synthesis of priorities (Saaty, 1986). The AHP is a rigorous methodology that is divided into a series of important steps including structuring the hierarchy, setting priorities, and verifying the logical consistency of the analysis.

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2.2.1 Establishing the hierarchical structure

As in all decision-making processes, the facilitator works for a long time with the decision-maker(s) to structure and model the problem. The AHP has the advantage of allowing hierarchical structuring of criteria (Figure 1) which allows users to better focus on specific criteria and sub-criteria when assigning weights. The number of components in each level generally ranges from five to nine (Saaty, 1984).

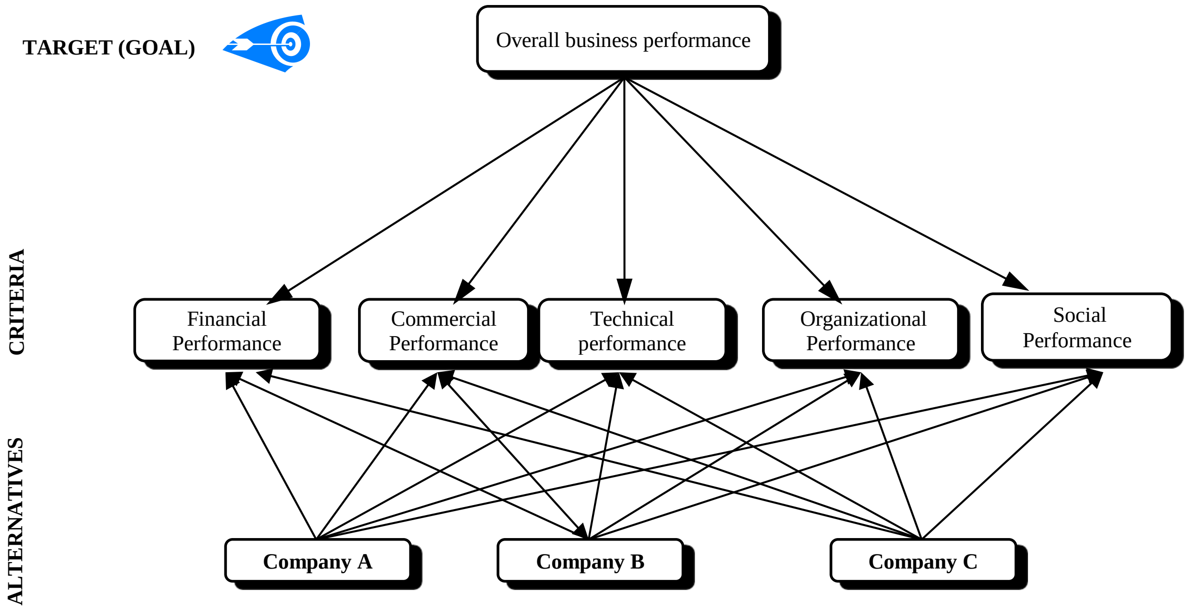

Figure 1 Hierarchy modeling the global diagnostic problem of companies (Akhrouf, 2007)

2.2.2 Prioritization

The first step in prioritizing the different elements that are part of a decision problem is to make binary comparisons of elements at the same level of the hierarchy two by two against a given criterion while combining logical thinking with experience. The matrix presents the most effective framework for making such comparisons.

To approach the process of binary comparisons, one must start at the top of the hierarchy and select the C or property criterion that will be used to perform the first comparison. Then, from the level immediately below, we must consider the elements to compare: A1, A2, A3, etc. Suppose we are dealing with seven elements, we would arrange them on a matrix as shown in Figure 2.

C	A_1	A_2	A_3	•	•	•	A_7
A_1	1	C_{12}	C_{13}	•	•	•	C_{17}
A_2	C_{21}	1	C_{23}	•	•	•	C_{27}
A_3	C_{31}	C_{32}	1	•	•	•	C_{37}
•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•
A_7	C_{71}	C_{72}	C_{73}	•	•	•	1

Figure 2 Binary Comparison Matrix

To fill the matrix of binary comparisons, numbers are used to represent the relative importance of one element to another as a function of ownership. Table 1 describes the scale used to make binary comparisons. C_{ij} represents the relative importance of A_i compared to A_j according to criterion C and C_{ji} is its reciprocal ($C_{ji}=1/C_{ij}$).

Table1
Binary comparison scale of the AHP method (Saaty, 1984)

Degree of importance	Definition	Explanation
1	Equal importance of both elements	Two elements contribute equally to the property
3	Low importance of one item over another	Personal experience and appreciation slightly favor one element over another
5	Strong or decisive importance of one element over another	Personal experience and appreciation strongly favor one element over another
7	Demonstrated importance of one element over another	An element is strongly favored and its dominance is attested in practice
9	Absolute importance of one element over another	Evidence favoring one element over another is as convincing as possible
2, 4, 6, 8	Intermediate values between two neighboring assessments	A compromise is necessary between the two assessments
Reciprocal	If element i is assigned one of the previous digits C_{ij} when compared to element j, then C_{ji} has the reciprocal value1/C_{ij} when compared to i (the inverse of the number).	

The scale defines and explains the values from 1 to 9 assigned to ratings in comparing pairs of similar elements at each level of a hierarchy against a criterion at the next higher level. For example, let the comparison matrix of three elements A1, A2, and A3 concerning criterion C be:

C	A_1	A_2	A_3
A_1	1	9	5
A_2	1/9	1	1/2
A_3	1/5	2	1

Figure 3 Example of a binary comparison matrix

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In line 1 of the above matrix (Figure 3), if A_1 is an element that has absolute importance over A_2, then C_{12}=9 and C_{21}=1/9. In the case that A_2 is a more important element than A_1, then C_{12}=1/9 and C_{21}=9. Finally, if both are of equal importance, the rank would be 1, or C_{12}=C_{21}=1.

2.2.2.1 Calculation of priorities

Calculating the priorities of the elements is equivalent to finding the normalized eigenvector of the matrix as shown in Table 2.

Table 2
Calculation of priorities

C	A1	A2	A3	A1	A2	A3	Sum of rows	Sum of rows divided by the number of items (n=3)
A1	1.00	9.00	5.00	(1/1.31) = 0.76	(9/12) = 0.75	(1/6.5) = 0.77	(0.76 +0.75 +0.77) = 2.28	**(2.28/3) = 0.76 (76%)**
A2	0.11	1.00	0.50	(0.11/1.31) = 0.08	(1/12) = 0.08	(0.5/6.5) = 0.08	(0.08 +0.08 +0.08) = 0.25	**(0.25/3) = 0.08 (8%)**
A3	0.20	2.00	1.00	(0.2/1.31) = 0.15	(2/12) = 0.17	(1/6.5) = 0.15	(0.15 +0.17 +0.15) = 0.47	**(0.47/3) = 0.16 (16%)**
	1.31	12.00	6.50	1.00	1.00	1.00		
Sum of each column (S)				Standardized matrix Sum of each column = 1			Eigenvector	Normalized eigenvector => Priority vector

The priority vector is given by the normalized eigenvector (0.76; 0.08; 0.16). The final classification of the three elements A1, A2, and A3 concerning criterion C is as follows: A1 with a weighting of 0.76 (76%); A3 with a weighting of 0.16 (16%) and finally, A2 with a weighting of 0.08 (8%).

2.2.2.2 Consistency of judgments

The AHP method evaluates the overall consistency of assessments using a consistency ratio. The value of the consistency ratio must be equal to or less than 10%. If it is greater than 10%, the assessments may be somewhat random and require some revisions (Saaty, 1984). Saaty proposed a coherence index (CI) which is linked to the method of the eigenvalues of matrices and is calculated by Equation (1):

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \tag{1}$$

Where n is the dimension of the matrix and λ_{max} (lambda max) is the maximum eigenvalue.

The consistency ratio (CR) is calculated by Equation (2):

$$CR = \frac{CI}{RI} \tag{2}$$

Where RI is the random coherence index (RI = means CI of 500 randomly filled matrices). Random indices are presented in Table 3. If the CR is less than 10%, then the matrix can be considered to have acceptable consistency.

Table 3
Random Consistency Indices (Saaty, 1984)

Matrix dimension	1	2	3	4	5	6	7	8	9	10
Random consistency	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

For the matrix in Figure 3, the maximum eigenvalue is calculated as shown in Table 4.

Table 4
Calculation of the eigenvalue

Eigenvector	A1 (0.76)	A2 (0.08)	A3 (0.16)
Sum (S)	1.31	12.00	6.50
$Maximum\ eigenvalue\ \lambda_{max}$	[(1.31 x 0.76) + (12 x 0.08) + (6.5 x 0.16)] = 2.9956~3		

The dimension of the matrix n=3; λ_{max}=3; then, $CI = \frac{(\lambda_{max} - n)}{(n-1)} = \frac{(3-3)}{(3-1)} = 0$;

thus, RI=0.58; CI=0; CR=0; the CR is less than 10%; therefore, the matrix can be considered to have acceptable consistency.

3. Application of the AHP for the selection of health infrastructure projects

The prototyping approach inspired by the DELPHI method was used in the process of designing and building the multicriteria decision support model. The ideas on the composition and structuring of the model are primarily based on documentary analysis of literature in the research field, personal reflections, and on a practical case study.

In the case study, we conducted on-site investigations through interviews and questionnaires with a group of decision-makers and experts representing stakeholders in the planning and management of health infrastructure projects. Primarily, officials from the Directorate of Studies and Planning (DEP) at the Algerian Ministry of Health, Population, and Hospital Reform (MSPRH) were interviewed. We also worked with officials from the health and population directorates of the district of Tipaza and Bouira. Interviews were organized with officials in charge of the health sector at the General Directorate of Budget (DGB) in the Ministry of Finance. Experts from the National Fund for Equipment and Development (CNED) attached to the Ministry of Finance guided us through the provision of project maturity guides. Some judges from the Court of Auditors (CC) responsible for the health sector were also solicited, and they enriched the study from the perspective of auditors controlling public spending. Interviews were also conducted with researchers from the Higher School of Commerce (ESC) and the School of Health Management (ENMAS).

The AHP model of this study is applied to the selection of health infrastructure projects. It is structured in four levels with seven main criteria, eighteen basic sub-criteria, and three alternating projects. The result of the hierarchical breakdown for the selection of the projects envisaged is summarized in Table 5.

Table 5
Structuring the problem of selecting health infrastructure projects

Purpose (objective)	Selection of proposed health infrastructure projects
Criteria	Political; Geographical; Sociodemographic; Epidemiological; Technical; Economic and Financial; Environmental
Sub-Criteria	Each criterion was broken down into the corresponding sub-criteria
Alternatives	Alternatives represent the various health infrastructure projects (hospitals) candidates for selection.

3.1 Objective (subject)

The desired objective was to select the best health infrastructure projects from a set of candidate projects while respecting several criteria (political, sociodemographic, epidemiological, etc.).

3.1.1 Criteria and sub-criteria

We established the list of criteria based on the objectives set by the national health plan and the suggestions of the various actors in the decision-making process for the selection of Algerian health projects. We also used some criteria from the literature (Vargas, 2010; Şahin, 2019; Vahidnia, 2009; Chatterjee, 2013; Ağaç & Şimşir, 2022; Chatterjee, 2018).

Given the large number of factors to be taken into account, we selected seven main criteria as follows: political, geographical, sociodemographic, epidemiological, technical, economic and financial, and environmental. These criteria were broken down into 18 sub-criteria. The stakeholders recognized the relevance and completeness of the family of criteria we used to evaluate and select health projects from the community's point of view.

3.1.2 Alternatives

In our case, the alternatives represent the different possible health infrastructure projects. Three different projects have been identified and must be prioritized.

- Project 1: Realization of a polyclinic
- Project 2: Realization of an anti-cancer center (ACC)
- Project 3: Construction of a 60-bed hospital

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4. Results and discussion

4.1 Establishing the hierarchical structure

The criteria to be taken into account are schematized hierarchically in Figure 4. To present this hierarchy, which is broken down into eighteen sub-criteria, the sub-criteria were grouped into seven main criteria. The criteria, the sub-criteria, and the alternatives are defined in detail in Table 6.

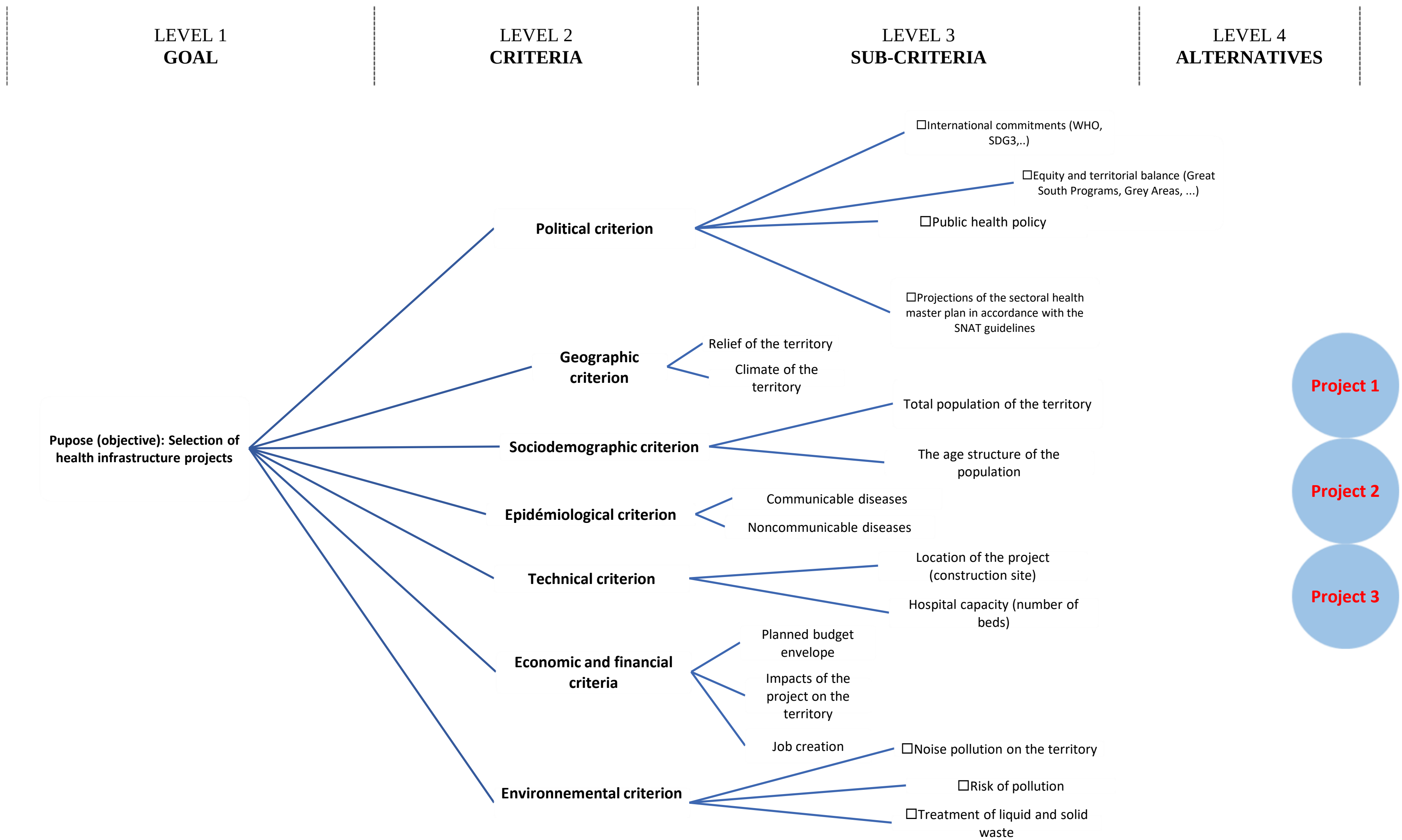

Figure 4 Hierarchical structure for the selection of health infrastructure projects

Table 6
Descriptive table of criteria, sub-criteria, and alternatives

CRITERIA	**SUB-CRITERIA**	**DEFINITION**
Political criterion		Political criteria are related to political and strategic considerations to be considered before integrating studied projects into the national or regional economy.
	International commitments (WHO, MDGs, ODD3, RSI, etc.)	This criterion is evaluated on a qualitative scale reflecting the degree of contribution of a health project to achieving these strategic objectives, particularly Sustainable Development Goals SDG3 relating to health.
	Health public policy	This criterion is evaluated on a qualitative scale reflecting the degree of contribution of the project to the implementation of the public health policy in Algeria.
	Equity and territorial balance (Great South Programs, Shadow Zones, etc.)	This criterion is evaluated on a qualitative scale reflecting the significance of its potential for economic-social-sanitary growth effects throughout the territory.
	Projections of the health sector master plan in accordance with the SNAT guidelines	This criterion is evaluated on a qualitative scale reflecting the coherence of the project with the national master plan for the development of health services and infrastructure.
Geographical criterion		Geographical criteria are related to climatic considerations and the terrain of the areas where the studied projects are to be located.
	Relief of the territory	The terrain of a project's location influences the choice of new health infrastructure projects. It can determine the nature and type of infrastructure to be developed and the health services that will be integrated.
	Territory climate	The climatic conditions of a project's location also influence the choice of a new health facility project.
Sociodemographic criterion		Sociodemographic criteria are related to sociological and demographic considerations of the areas where the studied projects are to be located. They are considered as factors of demand for health care, as defined by World Health Organization.
	Territory total population	The total population of the area is a determining factor for the number of hospital beds, size, and capacity of a health facility project. This sub-criterion can be easily evaluated quantitatively (numerical value) from demographic studies on the population basin by the project owner.
	Population age structure	The population's age structure also determines the nature of health services to be integrated into a project. This sub-criterion can be easily evaluated quantitatively (numerical value) from demographic studies on the population basin conducted by the project owner concerned.
Epidemiological criterion		Epidemiological criteria are related to epidemiological considerations that characterize the areas where the studied projects are to be located, particularly in preventing and controlling communicable and non-communicable diseases.
	Communicable Diseases	It is difficult to determine the contribution to the fight against communicable diseases for health projects in the Algerian context, which is why it is evaluated qualitatively by expert estimation.
	Non-Communicable Diseases	It is difficult to determine the contribution to the fight against non-communicable diseases for health projects in the Algerian context, which is why it is evaluated qualitatively by expert estimation.

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CRITERIA	SUB-CRITERIA	DEFINITION
Technical criterion		Technical criteria are related to technical considerations that characterize the studied projects, particularly in terms of hospital bed capacity and the project's location.
	Project location (construction site)	The choice of project location is made by comparing identified advantages and disadvantages. The geographical location is important as perceived by decision-makers and health sector planners.
	Hospital capacity (number of beds)	Hospital capacity refers to the number of hospital beds planned for the health infrastructure project, which can vary from ten beds for a polyclinic to a hundred beds for a university hospital center. This sub-criterion can be easily evaluated quantitatively (numerical value) from technical feasibility studies conducted by the project owner concerned.
Economic and Financial criterion		Economic and financial criteria are related to the economic and financial effects caused by the integration of the studied projects into the national or regional economy.
	Planned budget envelope	The importance of investment projects included in the State budget implies measuring the impact on public finances of the initial investment costs (first establishment expenses) as well as the operating costs of the infrastructure to be carried out. This sub-criterion can be easily evaluated quantitatively (monetary value) based on the financial feasibility studies carried out by the project owner concerned
	Project impacts on the territory	This criterion measures the expected impact on the economic development of a territory and the implementation of a hospital equipment location.
	Job creation	This criterion concerns the evaluation of the number of direct, indirect, and secondary jobs created by a health project.
Environmental criterion		Considering the importance in the context of a comparative environmental assessment of proposed projects, we have only referred to this criterion qualitatively.
	Noise pollution on the territory	Noise pollution can have harmful effects on citizens' health. For this reason, "noise nuisance" is included as an environmental sub-criterion for the selection of healthcare infrastructure projects
	Pollution risk	This criterion concerns any project activity that has a potential impact on air pollution and the climate conditions of the planet. They are mainly caused by greenhouse gas emissions. The measures affected by this criterion are determined by environmental experts.
	Liquid and solid waste processing	In order to neutralize the effects of harmful waste on the environment, it is necessary to verify the proposed systems for storage, removal, treatment, and discharge for each project.
ALTERNATIVES		The alternatives represent the various health infrastructure projects (hospitals) candidates for selection
	Project 1: Realization of a polyclinic	A polyclinic is a healthcare facility that provides a range of medical services, including primary care, specialized care, and diagnostic services. It is usually larger than a traditional clinic and offers more comprehensive healthcare services.
	Project 2: Realization of an anti-cancer center (ACC)	An anti-cancer center is a specialized medical facility that provides diagnosis, treatment, and care for individuals with cancer. These centers often offer comprehensive services, including chemotherapy, radiation therapy, and surgery, as well as support services such as nutrition counseling and psychological support.
	Project 3: Construction of a 60-bed hospital	A general hospital with 60 beds is a medical facility that provides a range of basic and specialized healthcare services to patients. It typically has a variety of departments and staff, including physicians, nurses, and other healthcare professionals, who work together to provide comprehensive care to patients.

4.2 Prioritization

Each of the criteria and sub-criteria belonging to the same level of hierarchical decomposition do not have the same importance in their ability to contribute to the resolution of the project selection problem. Evaluators or experts were asked to compare the relative importance of all elements of the criteria with a pairwise comparison.

Primarily, officials from the Directorate of Studies and Planning (DSP) at the Algerian Ministry of Health, Population, and Hospital Reform (MHPHR) were interviewed, but we also worked with officials from the health and population directorates of the district of Tipaza. Two judges from the Court of Auditors (CA) responsible for the health sector were also solicited, and they enriched our study from the perspective of auditors controlling public spending.

4.2.1 Prioritization of criteria and sub-criteria

Respondents or decision-makers provided judgments on the relative importance of the primary criteria of the first hierarchical level and the sub-criteria of the second level to assess their contribution to the selection of projects. These judgments collected on a numerical scale can be in the form of matrices of comparisons. From there, we calculated the weights of the relative importance or the percentages of the relative importance to each of these elements in the first hierarchical level. The Expert Choice software automatically calculated the relative importance of the first-level criteria according to the overall objective pursued (see Figure 5).

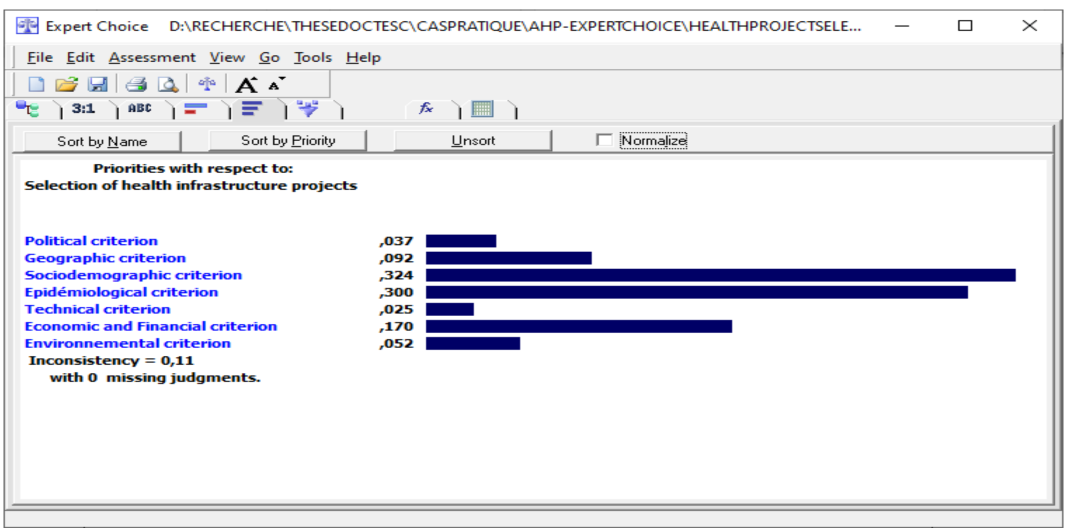

Figure 5 Priorities and weighting of criteria (data provided by Expert Choice software)

Since the demand for healthcare and services comes mainly from the population, which is a necessary determinant of any health policy, it is logical that the sociodemographic criterion would be the most important for evaluating a health project. Thus, the sociodemographic criterion obtained a weight (relative importance) of 32.4%. The epidemiological criterion is also considered another determining factor in the demand for the healthcare of the population and therefore ranked second in the order of priority with a value of 0.3 or 30% relative importance. The technical criterion ranked last with a value of 0.025 or 2.5%. These rankings currently express the preference of the criteria used for the evaluation of health infrastructure projects in Algeria.

The overall relative priorities assigned to the criteria and sub-criteria considered by the relevant respondents were adjusted to obtain the overall relative priorities of the selection criteria set for each proposed project as presented in Table 7.

Table 7
Overall relative priorities of all project selection sub-criteria (data provided by Expert Choice software)

Ranking	Project selection criteria	Overall relative priorities
1	Total population of the territory	0.162
2	Age structure of the population	0.162
3	Communicable diseases	0.150
4	Noncommunicable diseases	0.150
5	Impacts of the project on the territory	0.078
6	Planned budget envelope	0.078
7	Relief of the territory	0.046
8	Climate of the territory	0.046
9	Noise pollution on the territory	0.017
10	Risk of pollution	0.017
11	Treatment of liquid and solid waste	0.017
12	Location of the project (construction site)	0.013
13	Hospital capacity (number of beds)	0.013
14	Job creation	0.013
15	Projections of the sectoral health master plan following the SNAT guidelines	0.012
16	Public health policy	0.012
17	Equity and territorial balance (Great South Programs, Grey Areas, etc.)	0.012
18	International commitments (WHO, MDGs, SDG3, ISR, etc.)	0.002

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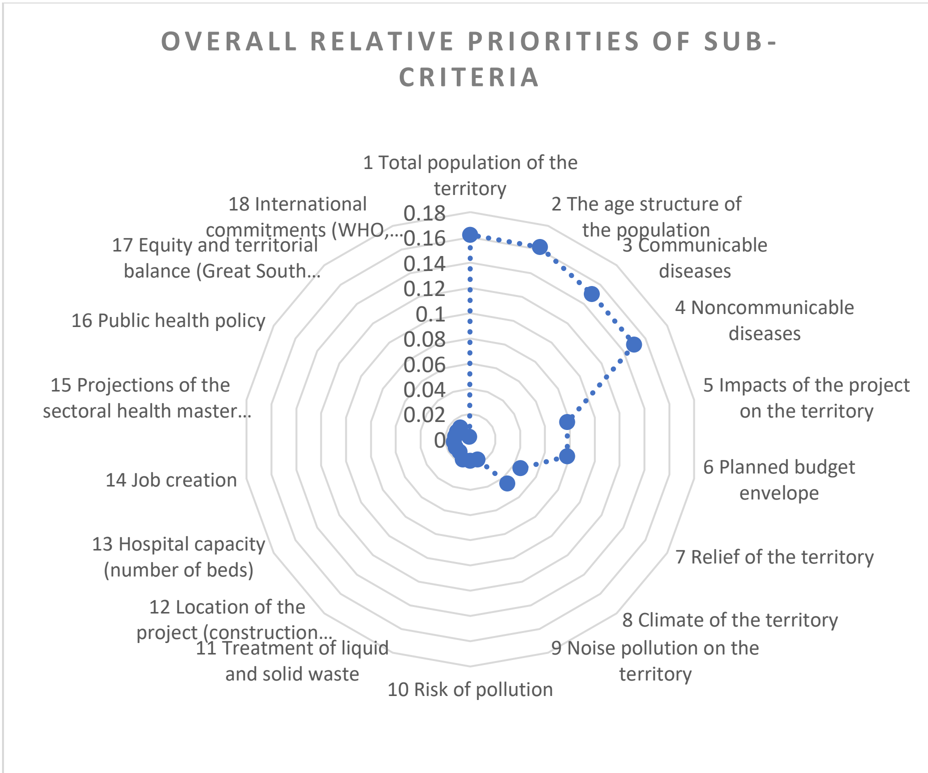

Figure 6 Overall relative priorities of the sub-criteria (Excel software graph)

Table 6 and Figure 6 show the sociodemographic sub-criteria “total population of the territory” and “age structure of the population” are the most important criteria for selecting health infrastructure projects in Algeria. This is followed by the epidemiological sub-criteria “communicable diseases” and “noncommunicable diseases” in second place. This order of preference fits perfectly with the practice of selecting health projects in Algeria, as they are considered to be important and determining factors in the demand for healthcare for the population.

4.2.2 Prioritizing alternatives

After establishing the priorities of the criteria, it is now possible to determine how each of the candidate projects is assessed against the selected criteria. In the same way that the prioritization of the criteria was made, the candidate projects are compared in pairs (two to two), taking into account all the established criteria. For our case, three different projects have been identified and must be prioritized. The overall project priorities are illustrated in Figure 7.

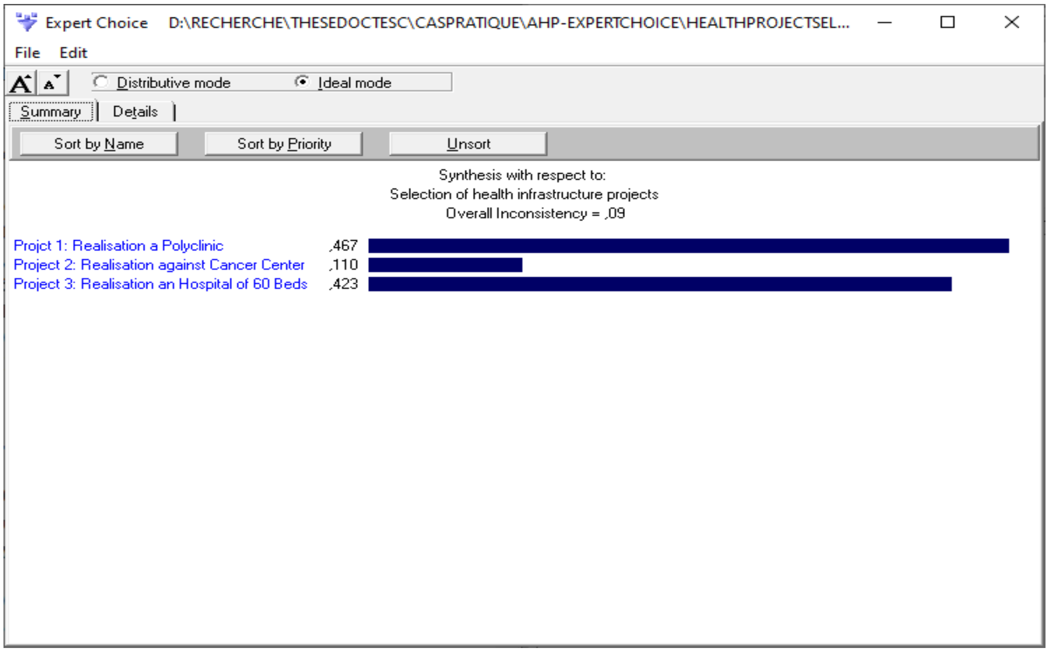

Figure 7 Overall project priorities (data provided by Expert Choice software)

The results show that project 1, "realization of a polyclinic" obtained the highest level of adherence to the objective of selecting projects for the realization of health infrastructure. This project contributes 46.7% (0.467) to the overall target and is followed by project 3, "realization of a hospital with 60 beds" with a contribution of 42.3% (0.423). At the bottom of the ranking is project 2 "realization of a cancer center (CAC)" with a contribution of 11% (0.11) compared to the overall objective of selecting projects for the realization of health infrastructure.

This result of the final ranking of health infrastructure projects perfectly reflects the public health policy followed by the public authorities in Algeria. This observation can be confirmed by the current Algerian Minister of Health who states that "70% of patients admitted to the hospital can be treated at polyclinics. Work is underway as part of the sector's plan to direct, at least, half of this rate to local structures to relieve pressure on hospitals, which will allow them to carry out the missions assigned to them" (Ministre de la Santé, 2021).

4.2.3 Consistency of judgments

The Expert Choice software provides an automatic and interactive inconsistency ratio test for each level of hierarchical decomposition. Table 8 shows the inconsistency ratios for the criteria and sub-criteria, respectively, given by relevant respondents in this search.

The inconsistency ratio for all judgments is 0.0932 (9.32%), lower than the 10% threshold set by Saaty (1984). This indicates that inconsistencies in respondents' preferences are not significant. There is no need to revise the content of the comparison matrices.

Table 8
Indices of consistency of all judgments (data provided by Expert choice software)

	Criteria	Consistency Index
Level 1: Purpose	Selection of health infrastructure projects	0.1135
Level 2: Criteria	Political criterion (L: .037 G: .037)	0.0000
	Geographic Criterion (L: .092 G: .092)	0.0000
	Sociodemographic criterion (L: .324 G: .324)	0.0000
	Epidemiological criterion (L: .300 G: .300)	0.0000
	Technical criterion (L: .025 G: .025)	0.0000
	Economic and Financial Criterion (L: .170 G: .170)	0.0000
	Environmental criterion (L: .052 G: .052)	0.0000
Overall Inconsistency Ratio (Global)		0.0932

4.2.4 Sensitivity analysis

The final priorities of the alternatives will be strongly influenced by the weightings given to the respective criteria. It is useful to perform an analysis of “what would happen if” to see how the final results would be changed if the weights of the criteria had been different. (Mu & Pereya-Rojas, 2018).

The sensitivity analysis of the classification of alternatives (health projects) was carried out using the Expert Choice software. This analysis is helpful for understanding the effect of changing the weights of the main criteria on the ranking of projects. To this end, it was decided to vary the relative weights of certain criteria differently as follows:

- Using larger variations around the weights of the socioeconomic, epidemiological, economic, and financial criteria since these are more relevant to the overall objective.
- Using smaller variations around the weight of political and technical criteria.

Starting from the initial scenario shown in Figure 8, the scenario’s sensitivity analysis concerning changes in criteria weights was achieved by changing the weight of a given criterion at a time as shown in Table 9.

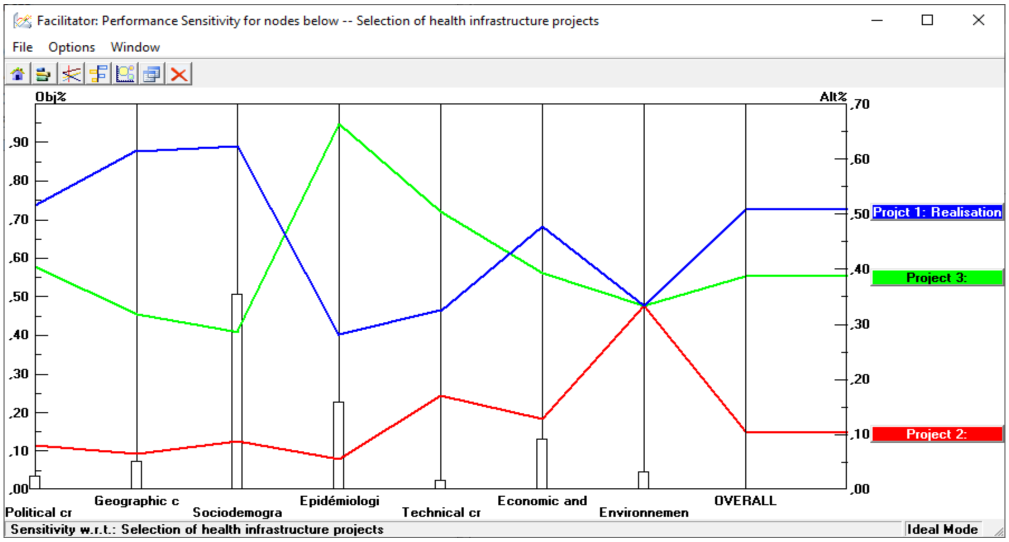

Figure 8 Sensitivity analysis – initial scenario (data provided by Expert Choice software)

We selected five different scenarios:

- Scenario 1: Sensitivity analysis concerning the sociodemographic criterion
- Scenario 2. Sensitivity analysis concerning the epidemiological criterion
- Scenario 3: Sensitivity analysis concerning the economic and financial criterion
- Scenario 4: Sensitivity analysis concerning the technical criterion
- Scenario 5: Sensitivity analysis concerning the political criterion

Table 9 shows the changes in the relative weights of the main criteria. Generally speaking, each scenario (1 to 5) corresponds to a system of relative weights of the project selection criteria that we can obtain in an interactive way using the Expert Choice software.

Table 9
Sensitivity analysis scenarios (data provided by Expert Choice software)

		Change in weights to consider					
		Initial scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
CRITERIA	Political	0.037	0.028	0.018	0.023	0.019	**0.501**
	Geographical	0.092	0.068	0.044	0.055	0.047	0.048
	Sociodemographic	**0.324**	**0.501**	0.321	0.195	0.166	0.168
	Epidemiological	0.300	0.221	**0.501**	0.180	0.153	0.155
	Technical	0.025	0.019	0.012	0.015	**0.501**	0.013
	Economic and Financial	0.170	0.125	0.08	**0.501**	0.087	0.088
	Environmental	0.052	0.038	0.025	0.031	0.027	0.027
Total weights		1	1	1	1	1	1

Project weighting results

PROJECTS	Project 1: Realization of a polyclinic	**0.467**	**0.508**	0.426	**0.471**	0.398	**0.490**
	Project 2: Construction of a 60-bed hospital	0.110	0.104	0.087	0.117	0.139	0.096
	Project 3: Creation of an anti-cancer center (ACC)	0.423	0.388	**0.487**	0.412	**0.463**	0.414

An examination of Table 9 shows that when the weight of one criterion is increased the majority of the weights of the other criteria decrease. It is easy to understand that, for example, if the weight of the sociodemographic criterion increases more than the other criteria, the reduction of the other weights would be proportional because the total sum of the weights is always equal to 1 (Saaty, 1984).

Scenario 1: Sensitivity analysis for the sociodemographic criterion
By varying the weight of the sociodemographic criterion to reach a value of 50% of the relative importance to the objective, we found that the ranking of the projects remained invariable compared to the initial scenario. Project 1 was still ranked first with a priority of 50.8% followed by Project 3 with a priority of 38.8% and Project 2 with a priority of 10.4% (see Figure 9).

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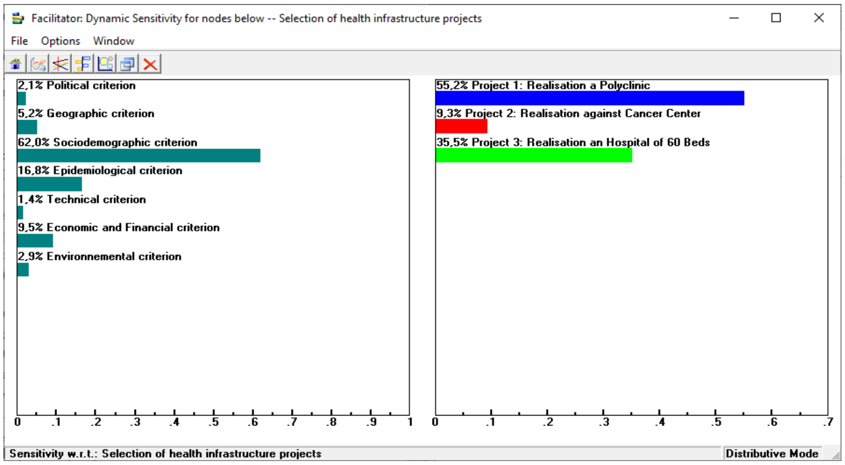

Figure 1 Sensitivity analysis - Scenario 1 (data provided by Expert Choice software)

Scenario 2. Sensitivity analysis for the epidemiological criterion
By varying the weight of the epidemiological criterion to reach a value of 50% of the relative importance to the objective, we saw a change in the ranking of projects compared to the initial scenario. Now, project 3 was ranked first with a priority of 48.7%, followed by project 1 with a priority of 42.6% and project 2 with a priority of 8.7% (see Figure 10).

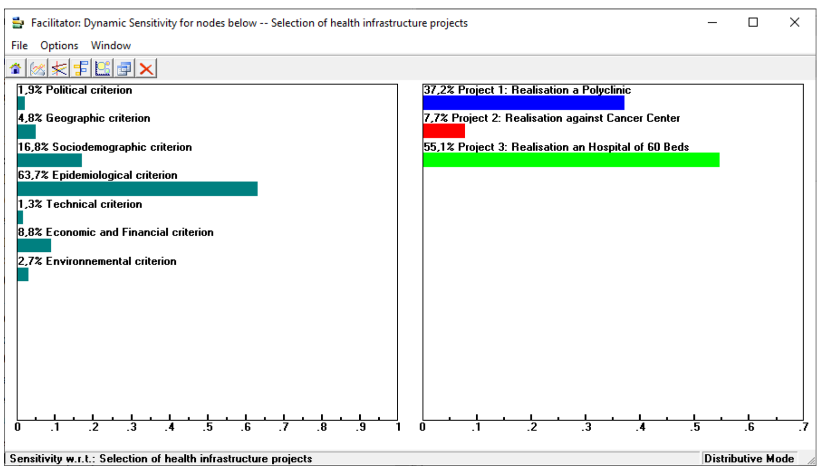

Figure 2 Sensitivity analysis- Scenario 2 (data provided by Expert Choice software)

Scenario 3: Sensitivity analysis for the economic and financial criterion
By varying the weight of the economic and financial criterion to reach a value of 50% of the relative importance to the objective, we found that the ranking of projects remained invariable compared to the initial scenario. Project 1 was still ranked first with a priority of 47.1%, followed by Project 3 with a priority of 41.2% and Project 2 with a priority of 11.7% (see Figure 11).

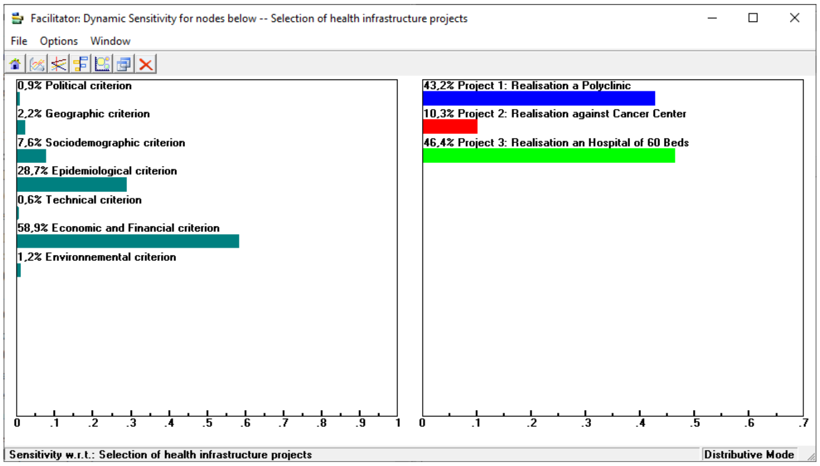

Figure 3 Sensitivity analysis - Scenario 3 (data provided by Expert Choice software)

Scenario 4: Sensitivity analysis for the technical criterion
By varying the weight of the technical criterion to reach a value of 50% of the relative importance to the objective, we saw a change in the ranking of projects compared to the initial scenario. Project 3 was ranked first with a priority of 46.3%, followed by Project 1 with a priority of 39.8% and Project 2 with a priority of 13.9% (see Figure 12).

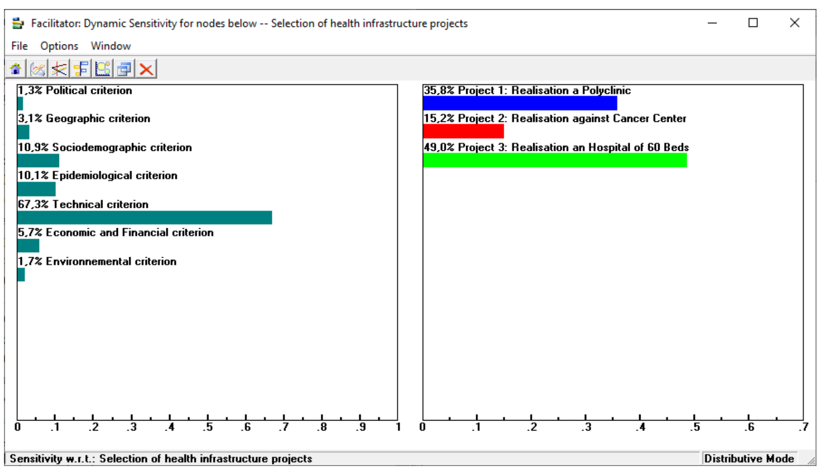

Figure 12 Sensitivity analysis- Scenario 4 (data provided by Expert Choice software)

Scenario 5: Sensitivity analysis for the political criterion
By varying the weight of the political criterion in the range of values [0.0001... 0.94991] from the relative importance to the objective, we found that the ranking of projects remained invariable compared to the initial scenario. Project 1 was always ranked first with a priority that varied between 45.75% and 50.99%, followed by project 3 with a

priority close to project 1 that varied between 44.42% and 40.77% and project 2 with a priority that varied between 9.82% and 8.22% (Figure 13).

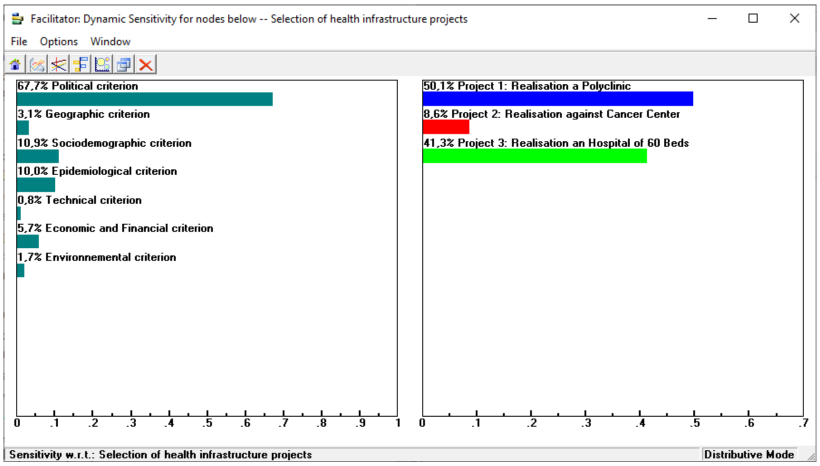

Figure 13 Sensitivity analysis- Scenario 5 (data provided by Expert Choice software)

4.2.5 Decision-making

Once the above steps are completed, it is now possible to make a decision. This is the final step in the AHP analysis. This requires a comparison of the overall priorities achieved and an assessment of whether the gaps are large enough to make a clear choice. It is also necessary to analyze the results of the sensitivity analysis. From this analysis, we can express our final recommendation. If the importance of the sociodemographic criterion is greater than 50% of the overall importance of the criteria in the decision, the best alternative is project 1"realization of a polyclinic"; however, if the importance of the sociodemographic criterion is well below 50%, in other words, the importance of the epidemiological criterion is greater than 50%, in this case, project 3 "realization of a hospital with 60 beds" is the best decision.

4.3 Practical implications of the study

The methodology developed in this article proposed an approach based on the AHP multi-criteria decision support method for decision-makers and stakeholders to prioritize and select projects in the health sector.

The results obtained regarding the importance of the sociodemographic and epidemiological criteria for the selection of health projects as well as the relative importance of polyclinic projects are in line with the current trends that dominate and regulate health projects in Algeria. The AHP offers flexibility for the selection of health infrastructure projects and uses several qualitative and quantitative criteria.

4.4 Originality and value of the study

This is the first study that implements the AHP in the process of prioritization and selection of projects in the healthcare sector. As a first implementation, the study provides decision-makers with a methodology that takes into account both qualitative criteria such as "contribution to the fight against communicable and non-communicable diseases" or "equity and territorial balance", and quantitative criteria such as "planned budget envelope" or "number of jobs created" to evaluate alternatives and gives importance to the ranking of experts related to the criteria and performance values of alternatives for criteria.

5. Conclusion

The study focuses on the problem of selecting public health sector projects while trying to simultaneously achieve a variety of objectives and satisfy selection criteria. A multi-criteria decision support model based on the Analytical Hierarchy Process (AHP) was offered to assist in the selection of projects that meet multiple criteria. This approach allows for a sensitivity analysis to select the most satisfactory projects and provides decision-makers with important information. The AHP method takes into account all criteria for evaluating projects, both qualitative and quantitative, and facilitates communication between the decision-makers and experts to increase the amount of information available.

The study focuses on the selection of health infrastructure projects in Algeria and the decision-making elements are grouped into seven main criteria, including political, geographical, sociodemographic, epidemiological, technical, economic and financial and environmental criteria. The sensitivity analysis provided insights into the solidity of the results and the importance of the different parameters involved. The approach developed can be applied to other problems in selecting social infrastructure projects or economic investment projects. Further studies may consider integrated multi-criteria decision-making approaches and the integration of artificial intelligence techniques with AHP. The decision support model can also be improved to take into account multiple decision-makers.

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