AN AHP-BASED APPROACH TO SELECTING A PRIORITY PUBLIC TRANSPORTATION MODE FOR INVESTMENT

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ABSTRACT

This article presents a new approach to prioritize and select transportation projects using multi-criteria decision-making techniques. It is aimed at organizations responsible for managing and developing transportation modes, and addresses the need for a systematic methodology for selecting which transportation modes to invest in. The proposed methodology is based on the Analytical Hierarchy Process (AHP) and implemented using the ExpertChoice software. This approach involves decision-makers in the process of identifying transportation modes that are potentially profitable and beneficial for the community.

Keywords: transportation modes; project selection; multi-criteria decision support; Analytical Hierarchy Process (AHP); AHP

1. Introduction

Transportation is a critical infrastructure that enables the mobility of people and goods necessary for economic and social activities. As cities expand, it becomes increasingly complex for urban transportation to efficiently connect dispersed populations over large metropolitan areas. Traffic congestion, long commute times, air pollution, and inadequate accessibility are common problems plaguing major urban centers around the world.

In recent years, Algeria has experienced rapid urbanization characterized by the expansion of cities in both size and number. This has led to significant transportation challenges in large cities such as Algiers due to its high population density and strategic location. In particular, Algiers has undergone rapid population growth fueled by a high growth rate and migration. As the economic capital, Algiers has historically attracted migrants. The population increase in Algiers has led to growing demand for transportation, necessitating upgrades in both the quantity and quality of transport infrastructure and facilities. The layout of jobs, businesses, residences, and other urban functions within the city creates transportation needs. Despite the presence of various transportation modes including public transport, private cars, trains, metro, and tramways, the western province of Algiers suffers from a transportation deficit compared to the eastern province. In this context, the state aims to improve the transportation sector in these communities, with sector managers seeking to launch a new project in the region. Therefore, selecting the priority transportation mode for investment is critical to enhance residents' quality of life and spur economic development in the area.

The key research question is: How can the selection of the priority transportation mode for investment in West Algiers be optimized, taking into account relevant criteria and the needs of all stakeholders involved in the transportation process?

The transportation sector in Algeria has undergone significant evolution, transitioning from the absence of public policy to its development and regulation (Mekhalfa & Boubakour, 2021; Bouguelaa, 2017). Significant initiatives have been undertaken to address urban transport issues, including launching significant investment projects and allocating substantial budgets (Santos Rodrigues, Mendes dos Reis, & Sivanilza, 2022).

According to Saaty (1980), project selection in the urban transportation sector is a complex issue, and the use of the Analytic Hierarchy Process (AHP) can provide a systematic approach to decision-making. Saaty's book *Principia Mathematica Decernendi - Mathematical Principles of Decision Making* further discusses the mathematical principles of AHP (Saaty, 2009). In his earlier work *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*, Saaty offers practical guidance on incorporating AHP into decision-making processes (Saaty, 1980). Saaty also explores decision-making skills and case studies in his book *Decision Making for Leaders: The Analytic Hierarchy Process for Decisions in a Complex World* (Saaty, 1999). Additionally, Saaty's book *Models, Methods, Concepts & Applications of the Analytic Hierarchy Process* delves into various applications of AHP, including group decision-making and risk assessment (Saaty, 2005). The AHP is used to systematically organize interdependent factors and provide a relatively straightforward solution to decision-making problems (Skibniewski, 1992).

The current literature encompasses several studies focused on project selection using multicriteria analysis. For example, (Chatterjee, Hossain, & Kar, 2018) have applied AHP in a fuzzy environment to help any company set priorities in terms of investment. Sadi-Nezhad (2017) conducted a study on project selection using multi-criteria decision support techniques and indicated that among many existing techniques, AHP, ANP, and TOPSIS were the most popular methods. The study carried out by Khan and Ali (2020) concluded that the AHP method is more widely preferred by researchers in almost all fields and applications. Saracoğlu (2015) describes an application of the AHP method in the problem of selecting investments of small hydroelectric power stations. Akhrouf (2022) employed the AHP in the healthcare domain to devise a decision support model for selecting the most effective health infrastructure projects. Fenniche (2018) applied the AHP in the financial services sector of commercial banks to establish a more viable system for evaluating commercial bank performance in the local market.

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Using AHP in the transportation sector for project selection involves utilizing the principles and methodology of the AHP to evaluate and prioritize potential projects. By considering various criteria and sub-criteria, the AHP enables decision-makers to weigh the importance of each factor and make informed choices. Several recent studies have utilized the AHP method to address decision-making challenges in the urban transportation sector. Baric and Starcevic (2015) focused on the implementation and analysis of the AHP in solving transportation problems. An (2011) examined various surface guidance systems that organize public transport networks in France. Furthermore, the study by Kumru and Kumru (2014) titled "Analytic Hierarchy Process Application in Selecting the Mode of Transport for a Logistics Company" focused on the application of the AHP in the decision-making process for selecting the mode of transport for a logistics company. The research utilized the AHP method to systematically evaluate and prioritize various transportation modes based on specific criteria. The study provides insights into the use of the AHP as a decision support tool in the logistics industry, aiding in the selection of the most suitable mode of transport for efficient and effective operations (Kumru & Kumru, 2014). The study by Moslem and al. (2023) titled "A Systematic Review of Analytic Hierarchy Process Applications to Solve Transportation Problems: From 2003 to 2019" provides a comprehensive overview of the applications of the AHP method in solving transportation problems. The research conducted a systematic review of studies published between 2003 and 2019 that utilized the AHP in the transportation domain. The study examined the various transportation problems addressed, the specific applications of the AHP, and the outcomes achieved. The research offers valuable insights into the wide-ranging use of the AHP as a decision-making tool in the transportation sector, highlighting its effectiveness in solving complex transportation problems and aiding in informed decision-making processes (Moslem, Saraji, Duleb, & Duleba, 2023).

This article presents a multi-criteria decision analysis using the Analytic Hierarchy Process to select a priority urban transport mode for investment in the case study of west Algiers.

2. Methodology

Multi-criteria decision analysis (MCDA) methods are continuously evolving. As Ben Mena (2000) notes, MCDA procedures seem to better enable moving towards an optimal compromise rather than an outdated single optimum solution. Several MCDA methods have emerged such as the AHP, ELECTRE, MACBETH, SMART, PROMETHEE, UTA and more (Ishizaka & Nemery, 2013; Ishizaka & Labib, 2011). For this study, the AHP was selected to prioritize and choose transportation modes. The AHP is recommended for these types of ranking problems that involve scoring alternatives across multiple criteria (Ishizaka & Nemery, 2013). The AHP provides a systematic and structured approach to decision-making that incorporates multiple criteria for evaluating alternatives (Brunelli, 2015; Chang, 2007). Compared to other MCDA techniques, the AHP provides a structured methodology to break down a complex decision into a hierarchy, make pairwise comparisons between criteria and alternatives, derive ratio scale priorities, and synthesize results to determine the optimal outcome. Its simplicity, flexibility, and power make it well-suited for supporting transportation investment decisions through systematic prioritization of projects based on customized criteria. Additionally, the Expert Choice software was designed by Saaty as a digital version of this technique (Saaty & Forman, 2022). In

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this study, the Expert Choice version 11 was used for modeling the problem, calculating the criteria and the alternatives priorities and for the sensitive analysis.

2.1 Steps of the AHP

The AHP method enables the decomposition of a complex problem into its various components, which are then organized in a hierarchical structure. The AHP is based on a systematic approach to structure complex decision problems and incorporate decision-makers preferences. The method involves several key steps (Forman & Gass, 2001). First, the decision problem is defined, followed by the creation of a hierarchy that breaks down the main criteria and sub-criteria. Relative weights are assigned to each criterion through pairwise comparisons. Alternatives are then assessed against each criterion using pairwise comparisons to determine their relative performance. Criteria and alternative priorities are calculated based on the assigned weights and performance evaluations. A sensitivity analysis is performed to test the robustness of the results, and finally, a decision is made based on the calculated priorities.

2.2 Definition of the hierarchy

The decision-making process breaks down the problem into distinct key components, established in a hierarchy that include the goal (objective), the main criteria, secondary criteria (if applicable), and alternatives (see Figure1). This constitutes the essential and innovative part of the decision-making process. The number of components by level generally ranges from five to nine (Saaty, 1984).

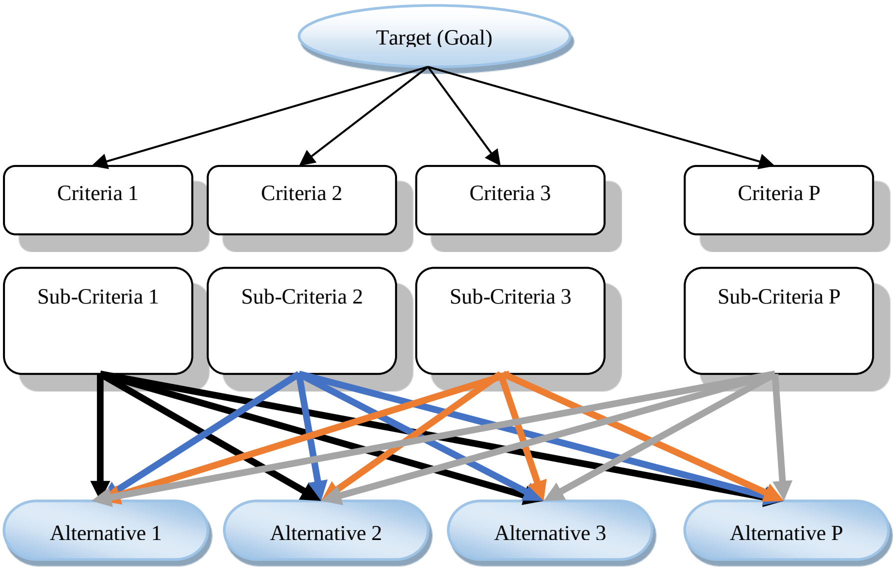

Figure 1 General hierarchy of AHP (Saaty, 1980)

2.3 Pairwise comparisons

Once the structure is set, comparisons are made to evaluate the significance of each element within each level of the structure. For example, decision-makers may be asked to assess two criteria or options at a time and decide which one is more preferred. These evaluations are usually done through the use of rating scales or matrices for comparison. In this scale, participants are presented with pairs of options and asked to select the one they prefer or find more important. These rating scales

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provide a structured way to compare and evaluate different elements or options. Table 1 describes the scale used to make pairwise comparisons.

Table1
Pairwise comparison scale of the AHP method (Saaty, 1980)

Importance level	Definition
1	The importance of both elements is equal. Both elements contribute equally to the property.
3	There is a low level of importance for one item compared to another. Personal experience and appreciation slightly favor one element over another.
5	Personal experience and appreciation strongly favor one element over another.
7	The importance of one element over another is clearly demonstrated. One element is strongly favored and its dominance is evident in practice.
9	The absolute importance of one element over another is undeniable. The evidence strongly supports one element over the other, making it as convincing as possible.
2, 4, 6, 8	There are intermediate values between two neighboring assessments. A compromise is required to reconcile the two assessments.
Reciprocal	If element i is assigned one of the previous digits C_{ij} when compared to element j, thenC_{ji} has the reciprocal value $1/C_{ij}$ when compared to i (the inverse of the number).

2.4 Construction of comparison matrices

The pairwise comparisons are used to construct comparison matrices. A comparison matrix is a structured representation of the relative preferences between elements at each level of the hierarchy. A pairwise comparison matrix is always a square matrix. In fact, they are triangular reciprocal matrices, with the elements to be compared in both rows and columns. The pairwise comparison matrix is structured as follows (Saaty, 2005):

$$A = (a_{ij})_{nxn} = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

With $a_{ij} > 0$ expressing the degree of preference of x_i to x_j, the criterion in row i is preferred over the criterion in column j if the value of the element (i,j) is greater than 1, otherwise the criterion in column j is preferred. Automatically, the inverse of the assigned number is associated with the $(j, i)^{th}$ position according to the following rule (Saaty, 1980):

$$a_{ij} > 0, a_{ji} = \frac{1}{a_{ij}}, a_{ii} = 1 \; \forall i \quad (2)$$

2.5 Calculation of weights

The calculation of weights involves constructing a pairwise comparison matrix, normalizing it, and then multiplying each element by its corresponding weight. The resulting weighted matrix is used to determine the weighted scores for each element or criteria. These scores are then normalized to reflect their relative importance. By following these steps, decision-makers can accurately evaluate and compare different options, enabling informed decision-making based on established goals and criteria.

2.6 Consistency analysis

The Consistency analysis is a vital component of the AHP. Its main objective is to evaluate the consistency of decision-makers' judgments while making comparisons between various options and criteria. The Consistency Index (CI) is computed using the following formula:

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \quad (3)$$

Where λ_{max} is the maximum eigenvalue of the judgment matrix, and n is the number of criteria.

The Consistency Ratio (CR) is derived by comparing the CI value to the Random Consistency Index (RI) by the following formula:

$$CR = \frac{CI}{RI} \quad (4)$$

Where RI is the random coherence index (RI = means CI of 500 randomly filled matrices). The value of RI is associated with the matrix order, which refers to the number of criteria considered, and is obtained from Table 2 (Saaty, 1980). The CR value measures the level of error introduced in the formulation of judgments. Typically, if the CR value is below 0.1, errors are considered relatively low, indicating a high level of relative consistency in responses. In such instances, the final estimation can be accepted. However, if the CR value exceeds 0.1, the decision-maker should carefully examine element comparisons to identify sources of inconsistency.

Table 2
Random Consistency Indices (Saaty, 1980)

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

2.7 Analysis of results

The analysis of the results is conducted after the calculation of weights. These weights are then utilized to assess and compare various decision options. By assigning weighted scores, options can be ranked, facilitating the identification of the optimal choice or enabling informed decisions based on predefined goals and criteria. Once the weights are calculated, they are used to evaluate and compare different decision options. Options can be ranked based on their weighted scores, enabling the determination of the best choice or making informed decisions according to established goals and criteria.

3. Model construction for selection priority transportation mode for investment

When making investment decisions in transportation, a comprehensive consideration of multiple criteria is essential. To begin, we compiled a list of available transport modes and identified both quantitative and qualitative criteria and sub-criteria. This meticulous step ensures that the results obtained are relevant and enables informed decision-making. Considering multiple criteria in transportation investment facilitates informed decision-making by providing a comprehensive evaluation of various aspects. By incorporating quantitative and qualitative factors such as cost, efficiency, environmental impact, capacity, safety, and social impact, decision-makers gain a holistic understanding of potential outcomes and impacts. This approach helps mitigate risks associated with single-factor decision-making, enabling a balanced perspective, trade-off analysis, and identification of synergies. By considering multiple criteria, decision-makers can select transportation modes that align with their goals and priorities, enhancing the quality and robustness of investment decisions.
The AHP model is applied to the selection of the priority transportation mode for investment. It is structured in four levels with six main criteria, thirteen basic sub-criteria and five alternating transportation modes. The result of the hierarchical breakdown is summarized in Table 3.

Table 3
Structuring the problem of selecting health infrastructure projects

Goal (objective)	Selection of proposed transportation modes for investment
Criteria	Geographical; Sociodemographic; Organizational ; Technical; Economic and Financial; Environmental
Sub-criteria	Each criterion was broken down into corresponding sub-criteria
Alternatives	The alternatives represent the various transportation modes candidates for selection.

3.1 Goal identification

The objective or goal is to choose the best and most efficient transportation option to meet the travel requirements of the West-Algiers area in Algeria. The study is focused on providing useful insights and suggestions to support informed decision-making when adopting and utilizing a new mode of transportation, considering various limitations and preferences.

3.2 Criteria and sub-criteria identification

In the context of decision-making, criteria refer to measurable aspects that are used to characterize and quantify alternatives. These criteria play a crucial role in the process of selecting a priority mode of transportation for investment. The criteria for this particular study were carefully chosen based on extensive literature reviews (Abastante, Bottero, & Lami, 2012; Baric & Starcevic, 2015; Bottero, Ferretti, & Pomarico, 2012; Moslem, Saraji, Duleb, & Duleba, 2023; Santos Rodrigues, Mendes dos Reis, & Sivanilza, 2022). The stakeholders who are transport experts in Algiers that were consulted recognized the relevance and completeness of the list of criteria. To identify the evaluation and selection criteria, a comprehensive study involving both qualitative and quantitative research methods was conducted with officials from the Algerian Urban Transport Authority (AOTU-A). The aim was to ensure a thorough understanding of the factors influencing investment projects.

Given the large number of factors to be considered, we selected six main criteria: geographical, sociodemographic, financial and economic, organizational, technical, and environmental. However, in order to enhance the evaluation of investment projects and make more informed selections, each criterion has been further broken down into sub-criteria. This breakdown has resulted in a total of six criteria and thirteen sub-criteria presented in Table 3.

Table 3
Descriptive table of criteria and sub-criteria

CRITERIA	**SUB-CRITERIA**	**DEFINITION**
Geographical		Topographic characteristics or any other relevant geographical element. It is used to assess how a mode of transportation meets the travel needs in a given region, taking into account the specific geographical features of that region.
	Reliefs	The topographic and geographical characteristics of a given area. It is a quantitative sub-criterion that was measured by the maximum slope of the modes.
	Geographical coverage	Indicates the geographic areas served by this specific mode of transport, and it is a quantitative criterion that was measured by coverage radii.
Sociodemographic		Refers to the analysis of the characteristics of the population and society in a given region.
	Population	Directly influences the demand for transportation; the larger the population, the greater the transportation needs.
	Number of travelers	A quantitative measure that represents the number of people using a specific mode of transportation over a specific period. This is a key indicator used to assess the popularity, capacity, and efficiency of a mode of transportation.
Financial and economic		Encompasses elements such as operating costs, fares, required investments, and overall profitability of the mode of transportation.
	Budget	Encompasses costs related to feasibility studies, land acquisition, infrastructure construction, vehicle or equipment purchase, operational expenses, maintenance, as well as other aspects related to the implementation and proper functioning of the mode of transportation.
	Job creation	Jobs created as a result of the introduction of a new mode of transportation. These jobs can be temporary during the construction phase, or sustainable and necessary for the operation, maintenance, and ongoing management of the transportation system.
Organizational		Measures the quality of transportation services.
	Security	Crucial to ensure the safety of users and to mitigate the risks of accidents and injuries.
	Comfort	Has a direct impact on user experience, fatigue reduction, accessibility, space management, as well as the attractiveness and adoption of the mode of transport.
	Frequency	Important to consider when choosing a new mode of transport. It ensures accessibility, reduces waiting times, promotes smooth mobility, meets demand needs, and encourages communal use.
Technical		The set of characteristics of each mode of transport.
	Sustainability	Essential to consider the sustainability of the mode of transport to ensure that this investment will be profitable in the long term and provide better reliability and stability in the continuity of service
	Commercial speed	Directly influences the travel time of passengers
	Carrying capacity	Refers to its capacity to carry a sufficient number of passengers.
Environmental		The action of pollution prevention, which contains only one sub-criterion: pollution risk.

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3.3 Identification of alternatives

In our case, we have a range of alternatives available for transportation. These include five modes: metro, tramway, train, bus-ETUSA, and BHNS as defined in Table 4. Each mode offers unique features and benefits that cater to different transportation needs. By considering these alternatives, we can explore a wider range of options and make informed choices based on our preferences and requirements. Each of these transportation modes offers distinct advantages in terms of speed, accessibility, comfort, and capacity. By considering these details, we can make informed choices about which mode best suits our transportation needs and preferences.

Table 4
Definition of alternatives (modes of transportation)

Transportation modes	Definitions
Metro	The metro system, also known as a subway or underground, is a rapid transit mode typically found in urban areas. It operates on dedicated tracks, either underground or elevated, providing efficient and fast transportation.
Tramway	Tramways, also known as streetcars or trolleys, are light rail systems that operate on tracks embedded in city streets. They offer a convenient and accessible mode of transportation, connecting different neighborhoods and key locations within a city.
Train	Trains are a versatile mode of transportation that can operate within cities and connect different regions. They typically run on a dedicated railway network, offering a high-capacity and efficient means of travel.
Bus-ETUSA	Buses are a common mode of transportation that operate on roads, providing flexible and accessible service. They are available in various sizes and capacities, ranging from small minibuses to large articulated buses.
BHNS	BHNS (Bus with High Level of Service) refers to bus services that are designed to provide a high level of comfort, efficiency, and reliability. These buses often operate in dedicated lanes, separate from regular traffic, ensuring faster and more consistent travel times.

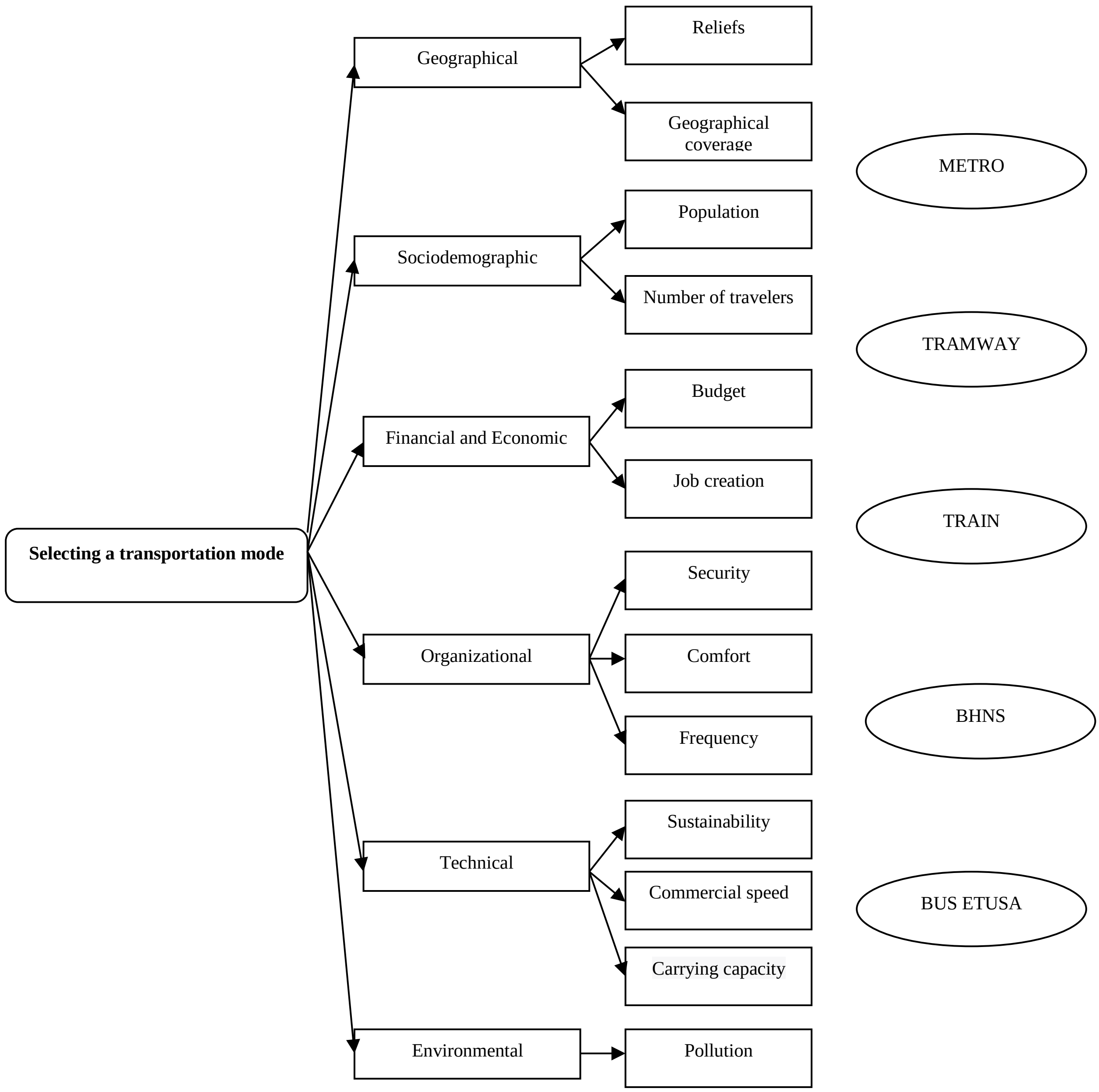

Figure 1 Hierarchical structure for the selection of a priority public transportation mode for investment

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4. Results and discussion

In order to establish a hierarchy and determine the relative weights of criteria and options in urban transportation, experts in the field performed pairwise comparisons. The following individuals were included as respondents in this process:

- Director of Studies and Development at the Urban Transport Authority-Algiers (UTA-A)
- Head of Public and Private Transport Division at UTA-A
- Department Head of Infrastructure at the Urban Transport Study Office (UTSO)
- Department Head of Urban Transportation at UTSO
- Operations Manager at the Algiers Metro Company (AMC)
- Expert in Management-Transport-Logistics

This methodology allows for an objective and systematic approach to evaluating and prioritizing different aspects of urban transportation.

4.1 Evaluation of the relative importance of criteria

The evaluation of the relative importance of criteria in the alternative selection problem involves pairwise comparisons completed by evaluators or experts. To incorporate the information from the group of experts, the average of each response was calculated using the geometric mean to minimize errors. The geometric mean minimizes errors by logarithmically transforming the values and providing balanced weighting, ensuring that extreme values do not disproportionately influence the average response in pairwise comparisons. This approach ensures a comprehensive assessment of the criteria's contribution to the solution of the problem at hand (Ishizaka & Labib, 2011). The resulting relative importance of each criterion can be found in Table 5.

Table 5
Relative weighting of the priority of the main criteria

Ranking	Criteria	Relative weighting
1	Sociodemographic	0.375
2	Financial and Economic	0.196
3	Technical	0.139
4	Organizational	0.131
5	Geographical	0.106
6	Environmental	0.053
Inconsistency ratio = 0.03		

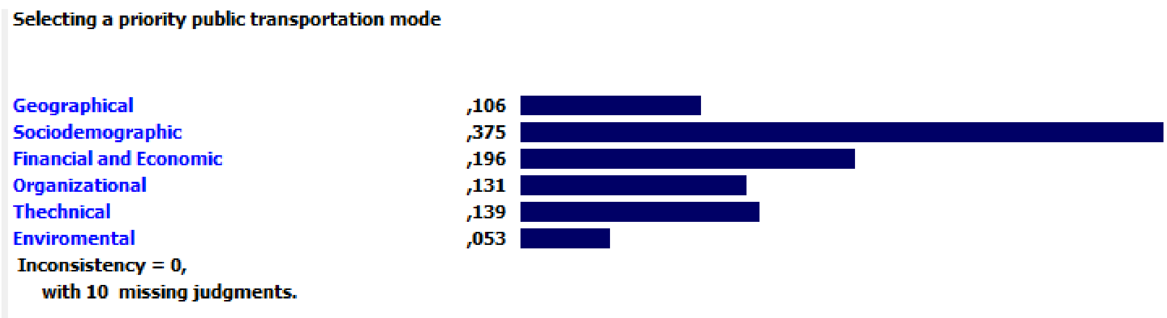

Figure 2 Priorities and weighting of criteria (data provided by Expert Choice software)

In the field of transportation, the sociodemographic criterion is crucial as any study conducted in this domain requires researchers to focus on demographic and social changes. Additionally, transportation experts primarily examine transport demand to determine areas requiring transport development and regulation, as well as locations where it is possible to increase transport services (supply) to meet this demand. Therefore, it is logical that the sociodemographic criterion is the most important for designing a mode of transport, as it obtained a weight of 37.5%. The financial and economic criterion is another necessary factor, which is why it is ranked second with an importance of 19.6%. The environmental criterion ranked last with a rate of 0.053, representing 0.53% importance.

4.2 Analysis of consistency of the entire judgments

Table 6 presents the consistency index of all criteria and sub-criteria.

Table 6
Consistency indices of each level of the hierarchy

Criteria	Sub-criteria	Consistency index
Goal		0.03
Geographical		0
	Reliefs	0.02
	Geographical coverage	0.06
Sociodemographic		0
	Number of travelers	0.05
	Population	0.05
Financial and economic		0
	Budget	0.05
	Job creation	0.00862
Organizational		0.00352
	Security	0.04
	Frequency	0.02
	Comfort	0.04
Technical		0.05
	Carrying capacity	0.07
	Commercial speed	0.07
	Sustainability	0.01
Environmental		_
	Pollution risk	0.01
	Set ratio = 0.04	

In Table 6, it is evident that the inconsistency ratios obtained from the judgments provided by the respondents for each level of the hierarchy are consistent. The overall consistency ratio is 4%, which is below the threshold of 10%. Therefore, it can be concluded that the overall judgments are consistent.

4.3 Summary of alternatives' overall priorities

The rankings of the five transport modes, based on all the criteria, provided by the ExpertChoice software, are depicted in Figure 4.

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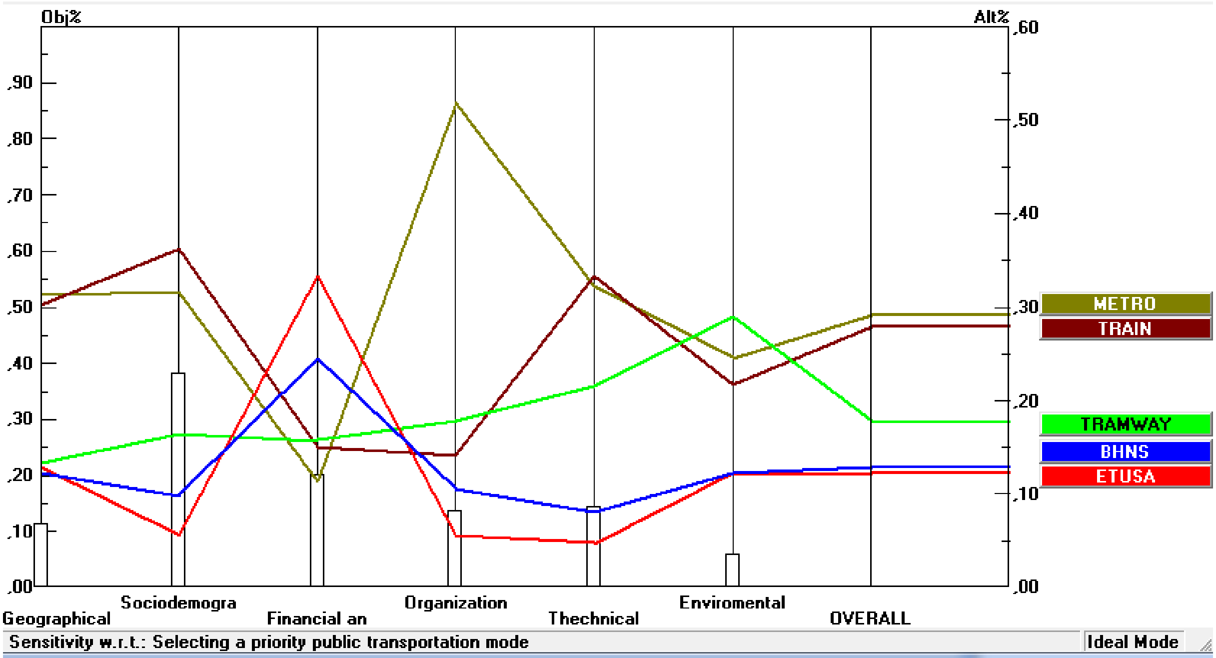

Figure 4 Overall ranking of transport modes concerning main criteria

The ranking result shows that the metro is the transport mode that achieved the highest level of alignment in selecting priority transport modes for investment. Table 7 presents the summary of overall mode priorities.

Table 7
Overall mode priorities

Ranking	**Transportation mode**	**Relative weighting**
1	METRO	0.292
2	TRAIN	0.279
3	TRAMWAY	0.177
4	BHNS	0.129
5	Bus-ETUSA	0.122
Inconsistency ratio =0.04		

The ranking results of the alternatives are summarized in Figure 5.

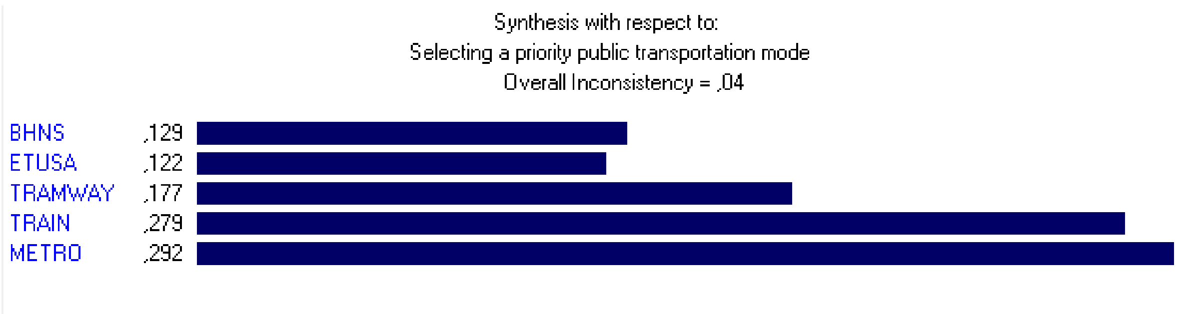

Figure 5 Overall summary of transport modes priorities

In conclusion, the results reveal that the metro ranks in the first position with a percentage of 29.2%, closely followed by the train with 27.9% and the tramway with 17.7%. On the other hand, the BHNS and Bus-ETUSA obtained similar percentages, estimated at 12.9% and 12.2% respectively.

4.4 Sensitivity analysis

A sensitivity analysis of the ranking of transport modes was conducted using ExpertChoice v.11 software. This analysis aimed to understand how changing the weights of the main criteria would affect the mode ranking. The analysis focused on varying the relative weights of certain criteria in different ways. Larger variations were applied to the weights of sociodemographic, technical, economic, and financial criteria, as they are more relevant to the overall objective. Smaller variations were used for the weights of the organizational, geographical, and environmental criteria.

Six different scenarios were considered in the sensitivity analysis. Scenario 1 focused on the sociodemographic criterion, while Scenario 2 examined the financial and economic criterion. Scenario 3 analyzed the impact of varying the weights of the technical criterion. The organizational criterion was the focus of Scenario 4, while Scenario 5 explored the sensitivity of the ranking to changes in the geographical criterion. Lastly, Scenario 6 investigated the effect of altering the weights of the environmental criterion. Conducting this sensitivity analysis provides valuable insights into how different criteria weights influence the ranking of transport modes. Table 8 shows the variations in relative weights of the main criteria for each scenario.

Table 8
Sensitivity analysis scenarios (data provided by Expert Choice software)

Criteria	Initial	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Sociodemographic	**0.375**	**0.501**	0.296	0.158	0.082	0.041	0.021
Financial and Economic	0.196	0.156	**0.501**	0.268	0.138	0.07	0.035
Technical	0.139	0.111	0.066	**0.501**	0.259	0.131	0.066
Organizational	0.131	0.105	0.062	0.033	**0.501**	0.254	0.127
Geographical	0.106	0.085	0.050	0.027	0.014	**0.501**	0.251
Environmental	0.053	0.042	0.025	0.013	0.007	0.004	**0.501**
Transportation Mode weighting results							
BHNS	0.129	0.123	0.173	0.130	0.118	0.120	0.122
ETUSA	0.122	0.109	0.201	0.129	0.094	0.111	0.117
TRAMWAY	0.177	0.175	0.168	0.190	0.184	0.159	0.224
TRAIN	0.279	0.296	**0.237**	**0.282**	0.214	0.258	0.238
METRO	**0.292**	**0.297**	0.222	0.269	**0.390**	**0.352**	**0.299**

Table 8 reveals that when the weight of one criterion is increased, the weights of the other criteria tend to decrease. This observation can be easily understood by considering that the total sum of the weights always equals 1 (Saaty, 1980). For instance, if the weight of the sociodemographic criterion is increased more than the other criteria, the reduction of the weights in the other criteria is proportional. This balance ensures that the total weight distribution remains consistent and reflects the relative importance of each criterion in the overall ranking.

Scenario 1: Sensitivity analysis regarding the sociodemographic criterion

When the weight of the sociodemographic criterion is progressively increased to reach a value representing 50% of the relative importance to the objective, the ranking of the transport modes remains unchanged compared to the initial scenario. The metro continues to hold the first position with a priority of 29.7%. This suggests that the sociodemographic criterion, despite its increased weight, does not significantly alter the ranking of the transport modes. Other criteria may have a more prominent influence on the overall ranking, and their weights need to be adjusted accordingly to observe any significant changes.

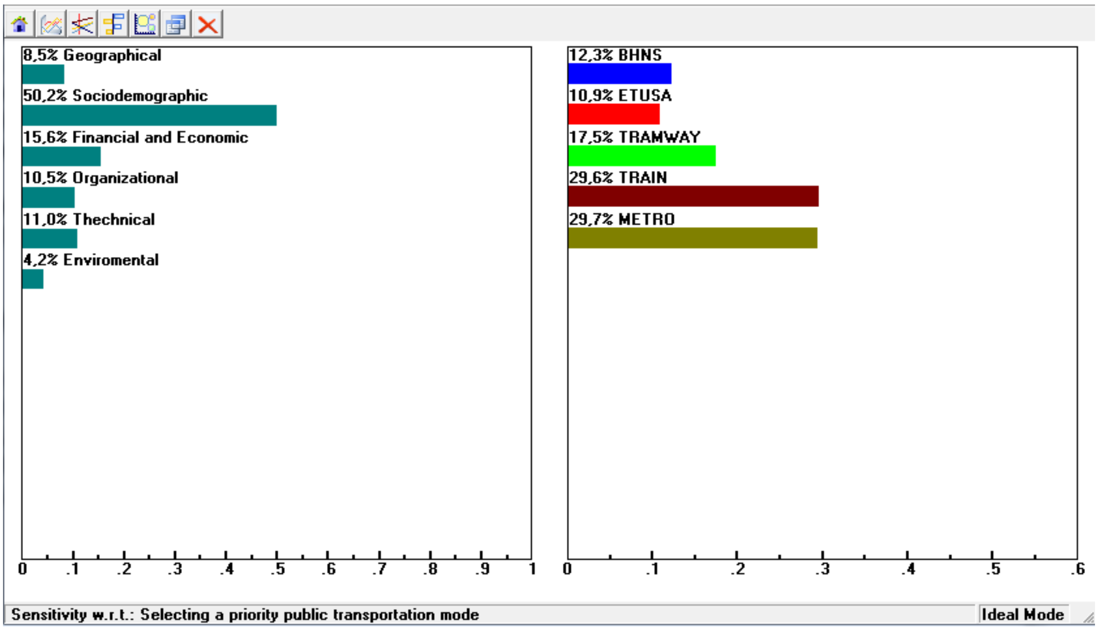

Figure 6 Sensitivity analysis - Scenario 1 (data provided by Expert Choice software)

Scenario 2: Sensitivity analysis concerning the financial and economic criterion

When the weight of the financial and economic criterion is progressively increased to represent 50% of the relative importance to the objective, a change in the ranking of transport modes is observed compared to the initial scenario. The train now occupies the first position with a priority of 23.7%, surpassing the metro which falls to the second position with a priority of 22.2%. This indicates that the financial and economic criterion plays a significant role in influencing the ranking of modes of transport. As the weight of this criterion increases, its impact on the overall ranking becomes more pronounced, leading to a shift in the prioritization of transport modes based on their financial and economic aspects.

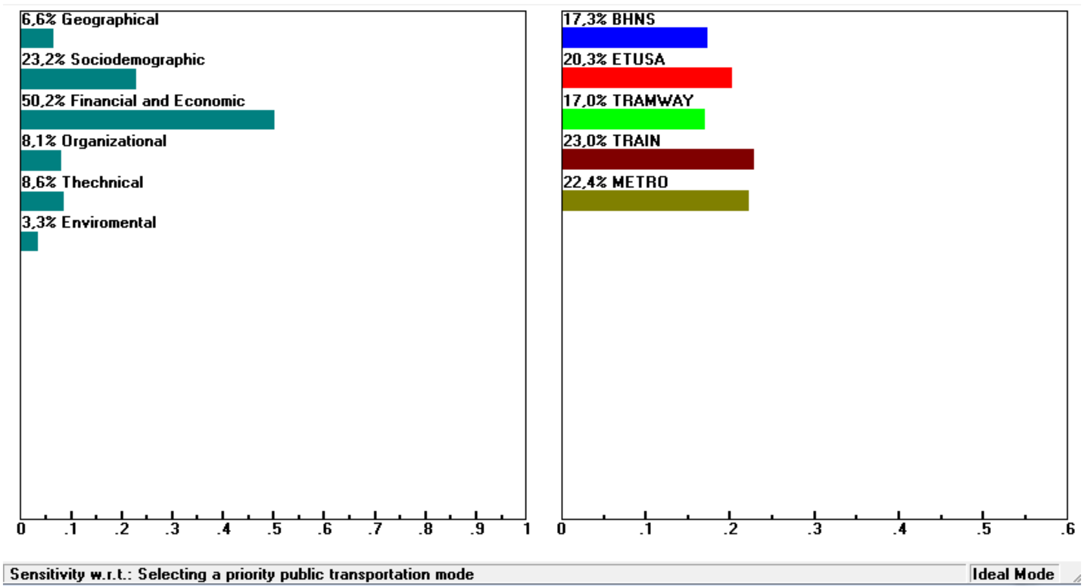

Figure 7 Sensitivity analysis - Scenario 2 (data provided by Expert Choice software)

Scenario 3: Sensitivity analysis concerning the technical criterion

When the weight of the technical criterion is progressively increased to represent 50% of the relative importance to the objective, a change in the ranking of transport modes is observed compared to the initial scenario. The train now holds the first position with a priority of 28.2%, surpassing the metro which falls to the second position with a priority of 26.9%. The other modes of transport retain the same ranking as in the initial scenario. This indicates that the technical criterion has a significant impact on the ranking of modes of transport. As its weight increases, the importance of technical factors such as capacity, speed, and lifespan become more prominent, leading to a reshuffling of the rankings based on these technical considerations.

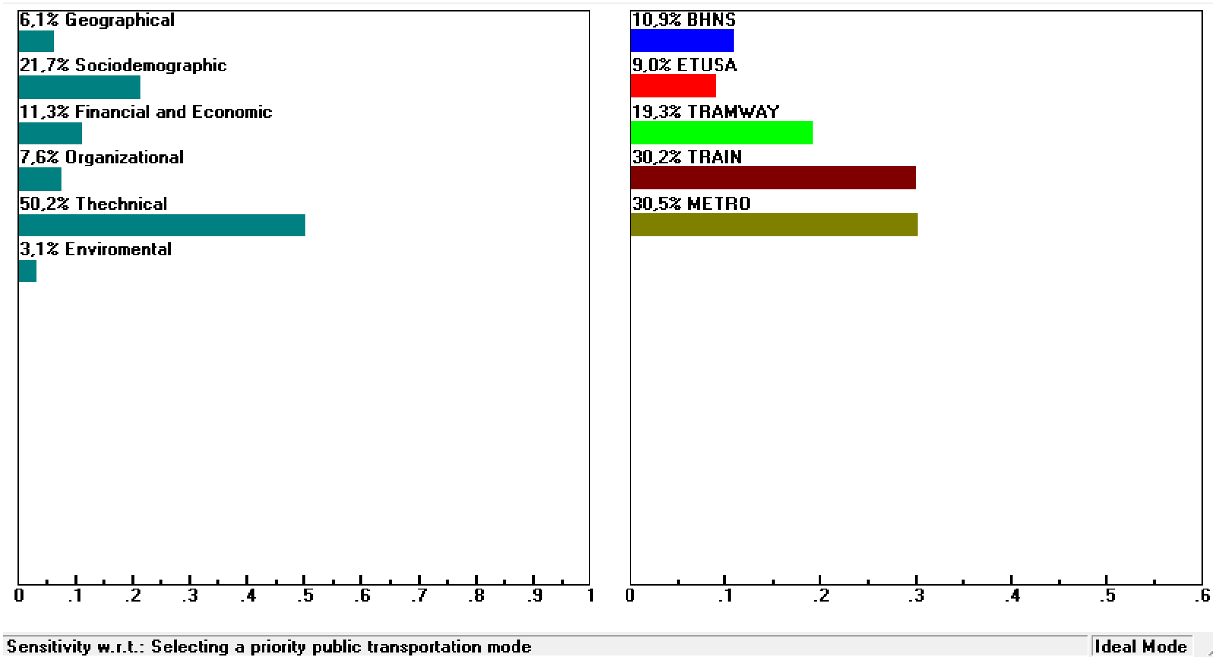

Figure 8 Sensitivity analysis - Scenario 3 (data provided by Expert Choice software)

Scenario 4: Sensitivity analysis concerning the organizational criterion

When the weight of the organizational criterion is progressively increased to represent 50% of the relative importance to the objective, it is observed that the ranking of transport modes remains unchanged compared to the initial scenario. The metro continues to hold its first position with a priority of 39%. This suggests that the organizational criterion, even with an increased weight, does not significantly alter the ranking of transport modes. Other criteria may have a stronger influence on the overall ranking, and their weights need to be adjusted accordingly to observe any significant changes.

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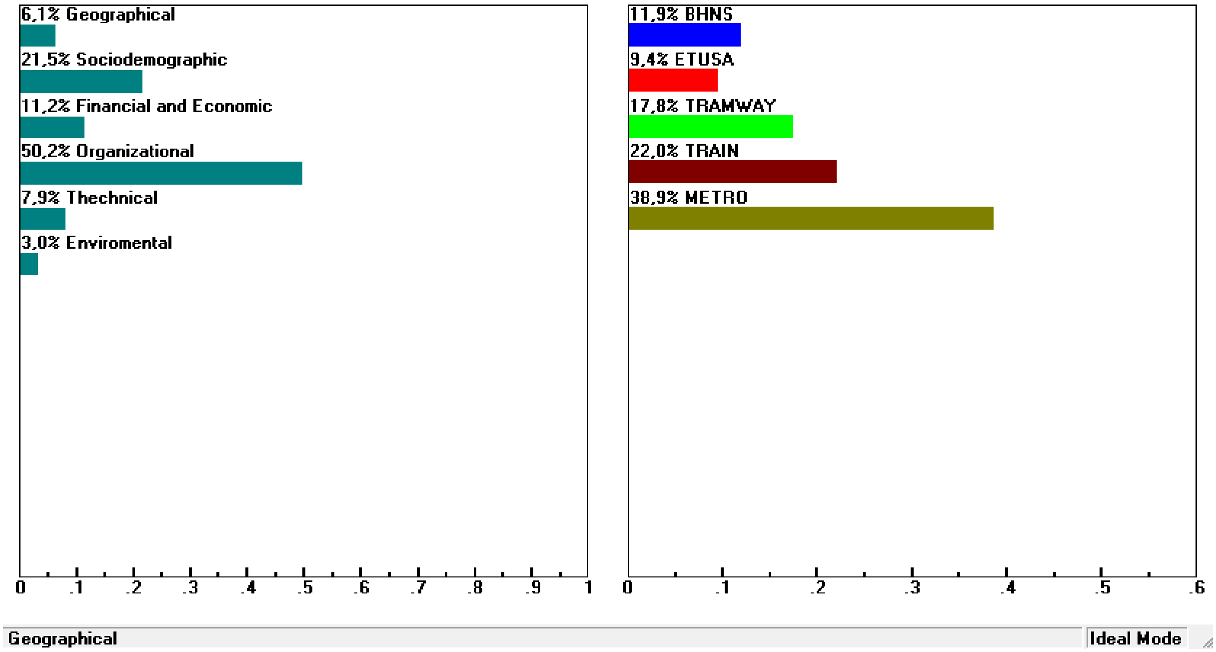

Figure 9 Sensitivity analysis - Scenario 4 (data provided by Expert Choice software)

Scenario 5: Sensitivity analysis concerning the geographic criterion

When the weight of the geographic criterion was increased to represent 50% of the relative importance to the objective, it was found that the ranking of transport modes did not change from the initial scenario. The metro retained its first-place position with a priority of 35.2%. This indicates that the geographic criterion, despite its increased weight, did not significantly impact the ranking of transport modes. Other criteria may have a stronger influence on the overall ranking, and their weights need to be adjusted accordingly to observe any significant changes in the prioritization of modes of transport.

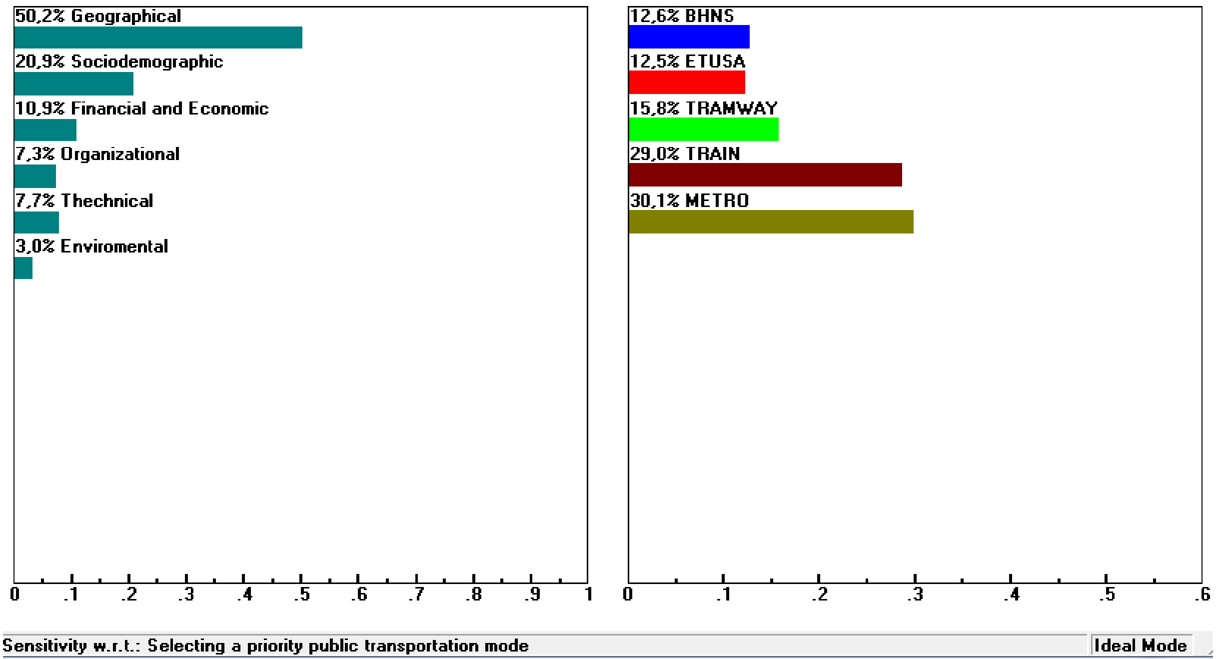

Figure 10 Sensitivity analysis - Scenario 5 (data provided by Expert Choice software)

Scenario 6: Sensitivity analysis concerning the environmental criterion
When the weight of the environmental criterion is increased to represent 50% of its relative importance to the objective, it is observed that the ranking of modes of transport remains the same as in the initial scenario. The metro continues to hold its top rank with a priority of 29.9%. This suggests that the environmental criterion, even with an increased weight, does not significantly alter the ranking of transport modes. Other criteria may have a stronger influence on the overall ranking, and their weights need to be adjusted accordingly to observe any significant changes in the prioritization of modes of transport.

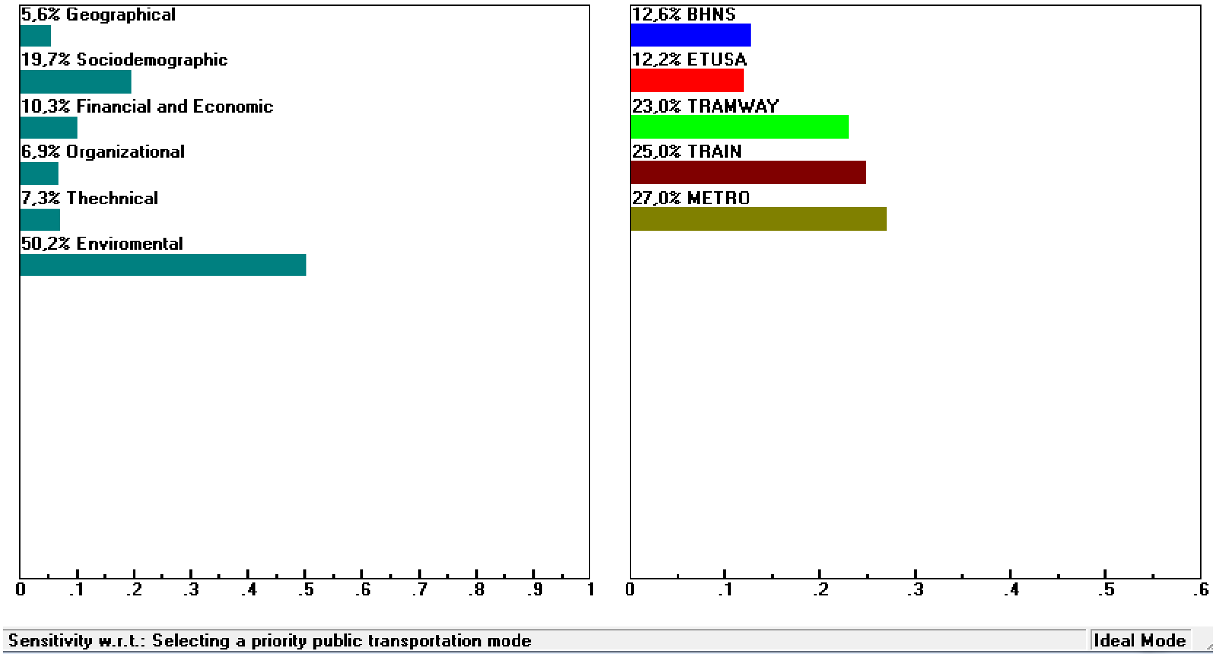

Figure 11 Sensitivity analysis - Scenario 6 (data provided by Expert Choice software)

In summary, the sensitivity analysis revealed that the rankings of the transport modes remained mostly consistent with the initial assessment. However, two notable changes were observed in specific scenarios. In Scenario 2, where the weight of the financial and economic criterion was increased, the metro did not maintain its top position due to its high cost. Instead, BHNS and Bus-ETUSA emerged higher in the rankings due to their more cost-efficient nature. In Scenario 3, which focused on the technical criterion, there was a slight switch between the train and the metro in the rankings, but the overall order remained unchanged. These findings highlight the importance of considering different criteria and their relative weights when evaluating transport modes, as they can significantly impact the final rankings.

5. Conclusion

This study demonstrates the effectiveness of using the Analytic Hierarchy Process (AHP) method for selecting priority transportation projects in West Algiers, Algeria. By structuring the decision problem into a hierarchy with criteria, sub-criteria, and alternatives, the AHP enabled a systematic evaluation of the different transportation modes. The results reveal that the metro is the top priority transportation mode for investment in West Algiers, with a weighted score of 29.2%. The metro's high capacity, speed, and coverage make it well-suited to meet the transportation needs of this densely populated area. The train and tramway also emerge as sound investments, scoring 27.9% and 17.7% respectively. On the other hand, BHNS and bus systems are less preferred options based on the criteria.

The sensitivity analysis provides valuable insights into how changes in criteria weights impact the rankings. Increasing the weight of financial and economic or technical criteria leads to some reprioritization, indicating their significant influence. However, the metro remains the priority mode in most scenarios.

This AHP model offers an effective decision support tool for transportation authorities in West Algiers. By considering multiple criteria and stakeholder perspectives, it enables informed, data-driven decision making. The approach and findings could guide investments in transport infrastructure to maximize benefits for the region. Further analyses of all transportation modes are recommended to optimize the network.

In addition to the AHP, other MCDA methods like TOPSIS, PROMETHEE, ELECTRE, and VIKOR can provide valuable insights to enhance transportation mode selection. TOPSIS considers the similarity to ideal solutions, PROMETHEE evaluates positive and negative aspects, ELECTRE eliminates alternatives and ranks the rest based on preference, and VIKOR determines the compromise solution. These methods can be used in conjunction with the AHP or independently to support informed decision-making and provide a comprehensive analysis for transportation mode selection. Additionally, artificial intelligence techniques, such as machine learning, genetic algorithms, expert systems, and reinforcement learning, can be applied to enhance the selection and choice of transportation modes. These techniques utilize historical data, optimize combinations, incorporate human expertise, and adapt choices based on real-time data to provide comprehensive insights for transportation mode selection.

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