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REVIEWING THE SUITABILITY OF THE URBAN GROWTH AREA USING THE AHP METHOD. A CASE STUDY OF THE AIN-TOUTA MASTER PLAN

Abstract: Urban growth is the expansion of cities and towns, both in size and population. It is driven by factors such as population growth, migration, economic development, and land use changes. As populations rise, demand for housing, infrastructure, and services also increases. This leads to expanding urban areas. Selecting urban growth areas is complex due to the overlapping of data and indicators. A multidisciplinary approach is essential. This study uses a Geographic Information System (GIS) to enable data flow and various analysis methods. The paper will explain how GIS supports urban master plan implementation through a digital approach that combines Computer-Aided Design (CAD) and GIS. The objective of this research is to identify areas in Ain Touta suitable for urban growth. The Analytic Hierarchy Process (AHP) supports and improves the urban master plan. AHP uses linear algebra to evaluate each pair-wise comparison. Each criterion receives a weighting based on its perceived importance. A higher weight signals a pivotal role in decision-making. In this context, environmental quality, safety, accessibility, and soil geotechnical considerations are the main factors in selecting sites for expansion.

Keywords: urban planning, decision-making, GIS, CAD, AHP, criteria weight.

Introduction

In Algeria, territory planning is the development of practical solutions for urban, rural, and physical environments within a specific time period. This involves measuring and evaluating spatial phenomena, their spatial relationships, and their distribution patterns using quantitative analysis methods, it aims to highlight the results of the diagnosis, the causes

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for the current situation, and the scientific justification for decisions making, and proposing appropriate future solutions. Urban planning defines the overall organization of the city and specifies general directions such as determining expansion areas, structured facilities, the main road network, industrial areas, easements, protected areas, agricultural lands and wise natural resources management. It also specifies the reference limits for land use plans. Good urban planning can ensure equitable access to public services, adequate housing, and a high quality of life for all city residents. It can also help mitigate environmental impacts by reducing the need for car travel and promoting urban green spaces. The Urban Master Plan is a spatial planning and urban management tool that sets out the fundamental principles for the spatial development of the relevant municipality. (Law No. 90-29). Urban growth areas are determined in urban master plans based on scientific criteria such as soil geotechnics, accessibility, and cost. However, the strength of their influence on decision-making can vary, potentially resulting in inappropriate choices being made. In Algerian cities, the negative impact of ownership is often clearer and stronger than that of other criteria. This research paper will demonstrate the importance of GIS in supporting the implementation of master plans by combining a digital approach with CAD and GIS.

One of the most important goals of digital urban planning is selecting the spatial suitability of urban services and activities using multi-criteria analysis, particularly hierarchical analysis. Spatial suitability is the process of selecting the most appropriate location for a specific service. This location is chosen based on a set of environmental, economic and engineering criteria.These criteria are determined by the scientific background and research on the study area. Analysis hierarchy will be applied in this research to support planned urban development, guiding growth toward areas that contribute to a more arrangement and coherent city structure.

This paper addresses the issue of identifying the most suitable areas for urban growth using GIS. These systems provide a hierarchical analysis process that assists in making multi-criteria decisions, allocating the appropriate weight to each criterion. In order to address this issue, the following questions must be asked:

How are urban growth areas defined in the urban master plan?
How can spatial modelling support decision-making?
How can the analytical hierarchy process be used to select urban growth areas?

In practice, expansion areas in Algerian cities are determined within the master plan using a traditional method involving the evaluation of each factor on a separate AutoCAD map, with no consideration given to the impact or interactions between factors. One disadvantage of this method is that it cannot measure the impact of relationships between factors that contribute to the selection of expansion areas.

Conversely, urban growth planning supported by geomatics technologies such as Geographic Information Systems (GIS), remote sensing, and spatial modelling ensures that land resources are managed optimally, thereby minimising conflicts and promoting sustainable urban development. GIS allows us to create a geographical database organised according to a topological structure, enabling us to weigh up and compare each factor in order to determine spatial suitability. This digital environment facilitates consultation between stakeholders, aids decision-making, and provides a range of analysis and geoprocessing methods that meet the needs of land use planning.

Study area

The city of Ain Touta is located 450 kilometres southeast of Algiers, the capital of Algeria, at an east longitude of between 6°7' and 6°13' and a north latitude of between 35°34' and 35°31'. Situated between two mountain ranges, the city lies at an altitude ranging from 900 to 950 metres.

The city lies at the intersection of several important roads: National Road 3 (RN3), which connects Constantine and Biskra; National Road 28 (RN28), which links M'Sila and Batna; and the Constantine–Biskra railway line (see Fig. 1). The estimated urban agglomeration population for Ain Touta in 2025 is approximately 100,000. According to the 1998 general census of population and housing, the population of Ain Touta is estimated at 44 895 inhabitants. In 2008, the population of the city jumped to become 64 809persons. Ain Touta is the second largest city in the Batna region. It is also the only urban settlement in the region, surrounded by many rural municipalities, which causes a rural exodus towards the city. Therefore, when addressing the issue of urban expansion, it is crucial to consider the needs of both the city and the wider region by calculating growth and migration rates, respectively.

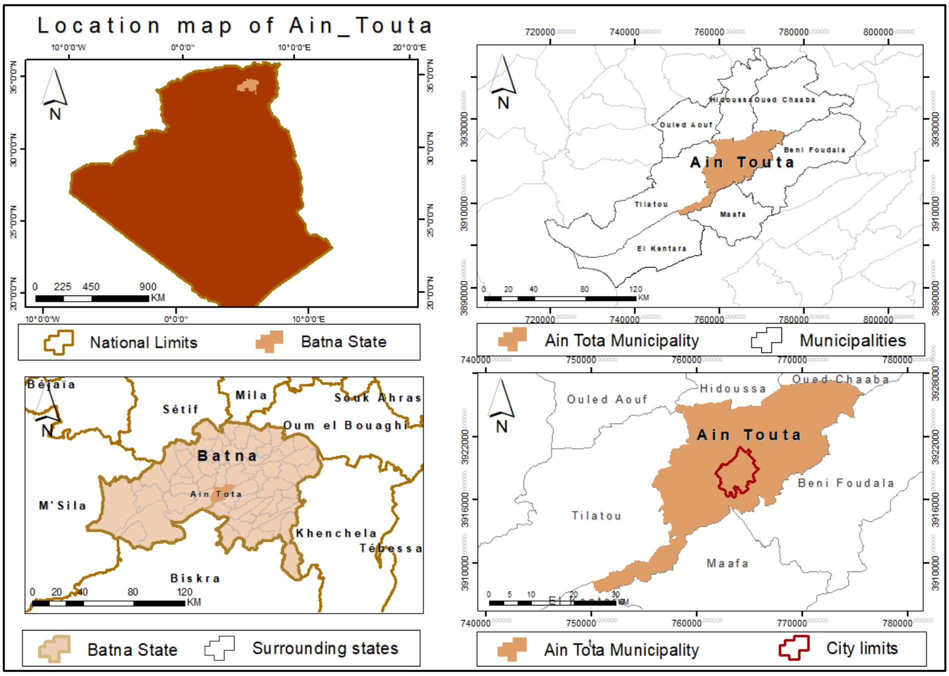

Fig. 1. The study area

Literature reviewer

The master plan has been a critical instrument for shaping the development of cities worldwide (Khadour et al., 2023). Master plans have become powerful tools in the development of large scale complex projects of urban design. It offers a device that is flexible in the articulation of interests in time (Rubén, 2006). In Brazil, the 1988 Constitution mandated cities with over 20,000 inhabitants to develop or revise their master plans, emphasizing their importance in local planning and territorial organization (Lacerda et al., 2005).

Effective implementation of these plans requires integration with land-use planning and collaboration among stakeholders (Villanueva et al., 2011).

The current process for the design of an urban master plan in Algeria cites typically involves a team of urban planners that conceive a number of schemes based on land use zoning with the help of CAD software. Modern planning theories focus on the fact that successful planning decisions should essentially consider all participants.

Without proper planning, rapid urbanization may put significant stress on ecosystems. Unplanned urban expansion has a severe impact on the natural resources and environment and can lead to air pollution, which is a challenging issue for many emerging cities throughout the world (Bose & Chowdhury, 2020). Despite the several studies on hierarchical analysis in Algerian cities, these have not been applied to urban master plan, and their results have not been compared with the CAD, this study fills the gap by providing a comprehensive of spatial suitability, thus contributing valuable reduce spatial weaknesses and improve the degree of suitability areas that contribute to a more arrangement and coherent city structure.

Selection of suitable places for built-up development by maintaining ecological balance has become an inevitable part of proper urban planning (Saha & Roy, 2021).

Economic and ecological considerations and various physical elements significantly impact the choice of a construction location (In Kim et al., 2015).

"Choosing appropriate locations for built-up growth while maintaining natural balance has become necessary for sustainable urban planning (Liladhar Rane et al., 2024).

The site choice largely determines whether a project is successful or unsuccessful. An inappropriate building site is frequently to blame for project failure, especially in developing nations. One of the crucial elements of planning is selecting a construction site (Zhonghao et al., 2024).

Urban growth inevitably decreases the sustainability of land use and the ecosystem. Thus, the application of innovative techniques is urgently necessary to advance the concept of sustainable growth. In recent years, the analytic hierarchy process (AHP) has become one of the most significant modern techniques for land suitability analysis by using a geographic information system (GIS) and a multi-criteria approach (Aburas et al., 2015).

Conducting a land suitability study is the best and most efficient way to identify locations ideal for future urban expansion and urban heat islands direct effect for urban areas (Yin et al., 2023).

In a land suitability study, the potential of the land is divided into components according to how well it can be used for that purpose. A highly appropriate land parcel indicates a good chance of being used for a particular purpose. On the other hand, low suitability denotes that the land has a comparatively low potential to fulfill a specific function. The result of a land suitability study is a map showing potential future land use patterns (Zhao et al., 2023).

Most studies use different criteria for suitability analysis, but some of them have used the expert opinion for the criteria and weighting (Parvez & Islam, 2020).

The suitability techniques analyse the interaction between location, development actions, and environmental elements to classify the units of observation according to their suitability for a particular use (Collins et al., 2001; Kalogirou, 2002.; Keshavarzi et al., 2010; Malczewski, 2004).

Sustainable urban Planning involves integrating geomatics technology into city master plans to raise and improve economic growth, social services, and environmental conservation. It also promotes flexible planning and sustainability in urban areas. The application of quantitative approaches, such as multi-criteria decision making techniques in land suitability procedures has increased, which allows handling heterogeneous data (Mosadeghi et al., 2015).

GIS doesn't have the competencies to include all selection factors related to land suitability valuation on its own, although it has authority in spatial analysis. Rather, it needs to be combined with supplementary assessment and evaluation tools, e. g., AHP Multi-Criteria Decision Analysis methods. AHP Multi-Criteria Decision Analysis has physical appearance and functionalities (Triantaphyllou, 2000).

Geographic Information Systems software provides extensive opportunities for planning studies. In this context, natural and human environmental sub-features were determined, data were collected based on these features, and the contribution of these criteria to urban growth was determined by producing new data sets (Bayar, 2020).

The decision-maker can more effectively choose the best locations for urban development by developing a geospatial evaluation model (Kılıc et al., n.d).

AHP is an MCDM model that uses GIS to compare geographical attributes pairwise and give weights based on the specialist review (Kanak et al., 2023).

GIS technology and multicriteria decision-making (MCDM) are often used to evaluate land appropriateness. Numerous multi-attribute (or multicriteria) evaluation processes, particularly for assessing land suitability, have been used in the RS-GIS context, including the analytical hierarchy method (AHP) and weighted linear combination with its variations (Shang & Luo, 2021).

Since the hierarchical analysis method is a scientific method, i.e., the two-way comparison process, the comparison of couples is the one that reaches the relative weights of factors or Indicators and evaluation. Therefore, spatial decision-making usually includes many Geographic Information Systems (GIS) integrated with the Analytic Hierarchy Process (AHP) have emerged as powerful tools for urban growth suitability analysis. This approach allows for the evaluation of multiple criteria, including physical, socio-economic, environmental, and accessibility factors (Aburas et al., 2015; Shah et al., 2020; C. & N., 2018).

The process involves creating spatial layers for various factors, assigning weights through AHP, and using GIS to perform multi-criteria analysis (Pooja et al., 2020; Kara & Akçit, 2018). This method helps identify areas suitable for sustainable urban development, supporting informed decision-making in urban planning (Aburas et al., 2016). Studies have demonstrated the effectiveness of this approach in different geographical contexts, such as Surat, India (Pooja et al., 2020; Kara & Akçit, 2018) and Setif, Algeria (Khelili et al., 2022).

The integration of GIS and AHP provides a robust framework for addressing the complexities of urban growth while promoting sustainability and optimal resource utilization.

Many studies have been conducted on the evaluation of spatial suitability in various fields. A scientific method of assessing the suitability of spatial areas for urban expansion in cities is proposed by integrating AHP and GIS techniques (Boutaghane et al., 2022). The analytic hierarchy process (AHP) helps in breaking a complex problem into different simple criteria, and the criteria are given weightage according to their relative importance (Ransikarbum, et al., 2021).

That reflects the opinions and decisions of decision-makers, experts, interested parties, and stakeholders to determine the paths of urban expansion (Naser et al., 2021).

Material and methods

Applying spatial suitability to GIS software involves four steps. First, all data is converted from vector to raster. The second step is unifying the values of the categories within the layers through reclassification. The third step is assigning weights to each criterion according to its importance through pairwise comparison. Fourth, a suitability map is developed using the raster calculator tool in the GIS software to multiply each factor by its weight. Therefore, a score could be identified for each pixel. Finally, the maps are combined and overlaid to create the final suitability map.

One of the most important multi-criteria decision-making (MCDM) approaches used by GIS software to determine spatial suitability is the Analytical Hierarchy Process (AHP). Therefore, the aim of this study is to identify areas suitable for urban growth in the Ain Touta municipality using the AHP method. Consequently, this study provides new insights into the integration of GIS tools with MCDM for the practical assessment of urban land suitability in master plans.

The study was conducted to determine areas for future urban expansion in Ain Touta City. Multi-criteria decision-making analysis was employed to derive the results. First, the future population of Ain Touta City was estimated, which was necessary for calculating the area required to accommodate that population in 2045. This estimate was based on the most recent available data and the assumption that the population would continue to grow.

The second step involved selecting criteria to determine the most suitable areas for future urban expansion. Recent research literature was used to inform the selection of these criteria. Six factors were adopted as criteria in this study (see Table 1.).

Table 1. Reclassify Raster's of Criteria

Criterions	Category	Value
	Built up Area	0
Land Use/Land Cover	Bare Land	5
	Forest Lands	1
	Agricultural Lands	1
Easements		0
	public	7
Property	privat	3
	wakf	1
	0-3	2
	3-5	7
Slope	5-8	5
	8-12	3
	12-25	1
	<25	0
	10	0
	20	1
	30	2
	40	3
Distance to stream	<50	5
	unsuitable	1
Accessibility	suitable	5

Weightage by AHP

Selecting the criteria and their sub-criteria is an important step in the AHP process because it affects the judgement by separating the criteria and giving some greater weight than others. Each criterion was ranked by weight based on its level of suitability.

The analytical hierarchy process (AHP) was then used to calculate the weights of each criterion using a pair-wise comparison matrix.

In order to make comparisons, a scale of numbers is needed to show how much more significant or dominant one element is over another with regard to the criterion or property with which they are being compared (See Table 2).

Table 2. The fundamental scale of absolute numbers for AHP

Priority	***Value***
Equal in importance	1
Preferring one standard over another	3
A strong preference for one criterion over another	5
An very strong preference for one criterion over another	7
An absolute preference for one criterion over another	9
Average values are used between the previous weights	2,4,6,8

Source: Saaty, 2008.

Normalized pair wise comparison matrix

Using previous research and expert opinion, the determining factors for suitable urban growth sites were identified. Additionally, this manuscript determined factors based on remarks obtained through interviews with local authorities involved in preparing the master plan. A pairwise comparison was implemented in the matrix for all criteria using a numerical scale of nine points to prioritise the importance of one criterion over another (see Table 3).

Table 3. Selected criteria and priority

Criterions	*Priority*
land use	1
eaisement	1
property	2
slop	2
proximity to stream	3
accessibility	6

Pairwise Comparisons

Once the hierarchy has been established, the decision maker conducts pairwise comparisons to determine the relative importance or priority of the criteria.

Pairwise comparisons involve comparing each element against every other element at the same level in the hierarchy. A scale is used to assign numerical values representing preference or importance. A commonly used scale is Saaty's 1–9 scale, where 1 represents equal importance, 3 a weak preference, 5 a moderate preference, 7 a strong preference, and 9 an extreme preference (see Tables 4 and 5).

Table 4. Pairwise comparison matrix by AHP

Criterions	Land use	Eaisement	property	Slope	Proximity to stream	Accessibility
Land use	1	1	2	2	3	6
Eaisement	1	1	2	2	3	6
Property	0.5	0.5	1	1	1.5	3
Slope	0.5	0.5	1	1	1.5	3
Proximity to stream	0.333	0.333	0.666	0.666	1	2
Accessibility	0.166	0.166	0.333	0.333	0.5	1
Total	3.499	3.499	6.999	6.999	10.5	21

Table 5. Pairwise comparison matrix and computation of criterion weightage

Criterions	Land use	Eaisement	property	Slope	Proximity to stream	accessibility	Wigth
Land use	0.285	0.285	0.285	0.285	0.285	0.285	**0.285**
Eaisement	0.285	0.285	0.285	0.285	0.285	0.285	**0.285**
Property	0.142	0.142	0.142	0.142	0.142	0.142	**0.142**
Slope	0.142	0.142	0.142	0.142	0.142	0.142	**0.142**
Proximity to stream	0.095	0.095	0.095	0.095	0.095	0.095	**0.095**
Accessibility	0.047	0.047	0.047	0.047	0.047	0.047	**0.047**
Total	1	1	1	1	1	1	1

Consistency Ratio of AHP

The CR is important for identifying whether or not the study's comparisons are consistent. Condition 1: ƛ must be equal to or greater than the number of factors used. The value of ƛ in this study = 6.1, which means that it satisfies this condition. Computation of consistency index (CI) done using equation (1):

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

Calculation of consistency ratio (CR):

$$CR = \frac{CI}{CA} = 0.016 = 1.6\% \quad (2)$$

Condition 2: Consistency ratio, CR (0.016) <0.10, refers to the reliable level of consistency in the pairwise comparisons. Thus, the CR value meets the requirement of condition 2, indicating that the weights obtained are accepted.

Results

The last stage of the (AHP) is synthesizing the results to calculate the total priority scores for each alternative, allowing for the chosen of the best area based on their accumulated weights from the criteria. This involves combining the relative value of the criteria with an estimate of each alternative against those criteria, in order to produce a final numerical score for each area of suitability (Fig. 2).

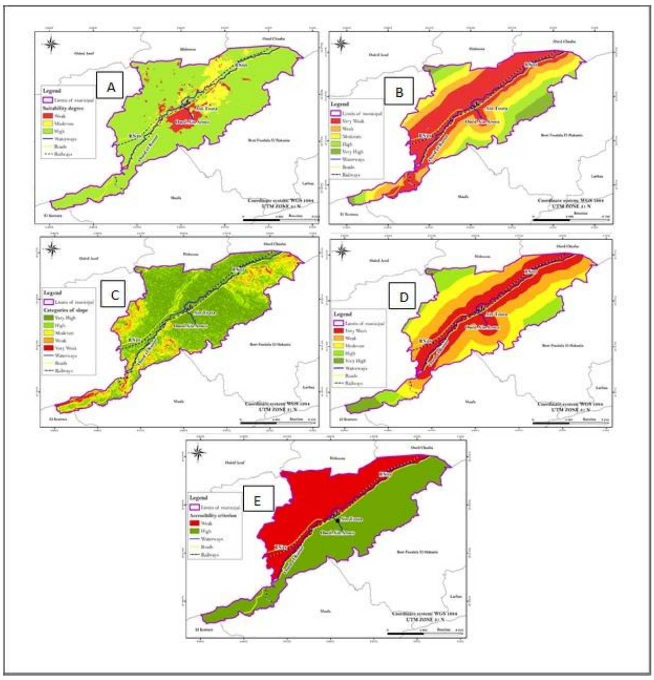

Fig. 2. Maps of criteria. (Source by authors2025). (A) Land use (B) Eaisement (C) slop (D) proximity to stream (E) accessibility

Generation of final Suitability Map

At this part, using the following formula:

Urban growth equation =(Land use × 0.285) + (Easement × 0.285) + (property × 0.142) + (Slope × 0.142) + (proximity to stream × 0.095) + (accessibility × 0.047) (3)

All factor maps were converted into raster format. We relied on the previous weights and the Raster Calculator in ArcMap software to multiply each factor by its weight. Therefore, a score could be identified for each pixel. Then, all maps were combined and overlaid to generate a final urban growth map (see Fig. 3).

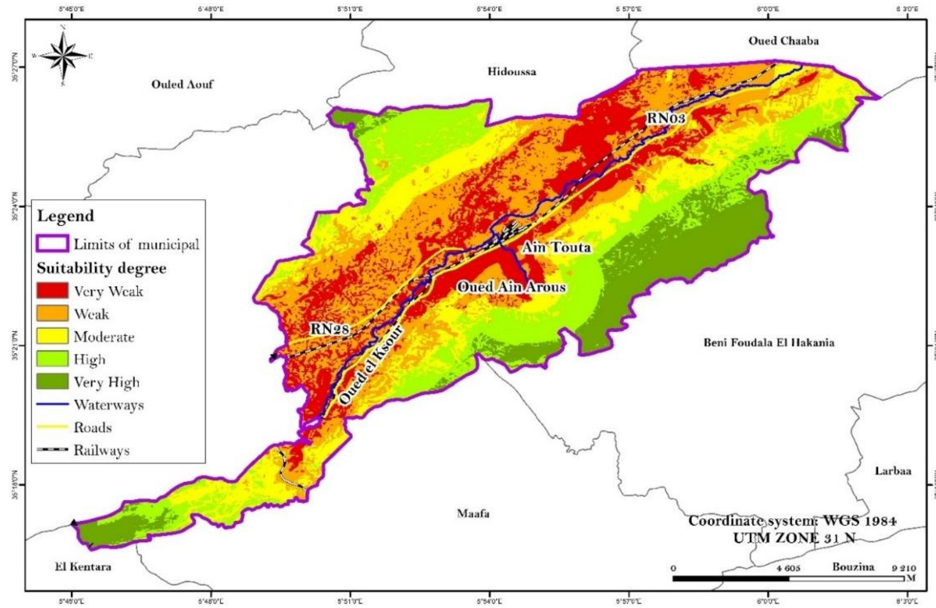

Fig. 3. Ain Touta Municipality, expansion areas using AHP

The results indicated that areas with high spatial suitability are concentrated in the south-east and west, covering 250 hectares and representing 75% of the total area. This area is considered sufficient to meet future spatial requirements, estimated at 160 hectares in 2045. Areas with acceptable spatial suitability extend from the northwest to the south-east and cover 83 hectares (25%). Finally, areas with low spatial suitability are concentrated in the north of the city.

Discussion

The master plan was developed using AutoCAD software. This software is classified as a computer-aided design (CAD) approach, which is used for all urban planning in Algerian cities. It has several advantages:

All versions of AutoCAD work with Covadis to develop topographic elevation plans using a planimeter and an altimeter. For this reason, a topographic survey plan can be imported with high precision, enabling land use and network planning without significant errors.

However, the drawbacks of computer-aided design include a lack of geographic reference, topological dimension, network analysis, and data updating. Therefore, the aim of this research paper is to use the AHP method to support the master plan developed using the CAD approach.

Computer-aided design (CAD) is one of the tools that relies on computers for drafting in layers. This technology is used in many fields, including urban planning, architecture, and civil engineering. It is characterised by the precision of the final plans and models, as well as the variety of 2D and 3D drawings.

Computer-aided design (CAD) software has significantly improved engineering design by improving the accuracy of drawings and simplifying geometric calculations related to volume and area.

CAD drawings are stored as points, lines, and polygons layered using a mathematical coordinate system that records the start and end points of each shape, while the relationships between all drawing elements remain constant.

CAD files can be easily used by many Desktop software offline, with most urban developers in Algeria relying on AutoCAD software in DXF format (see Fig. 4).

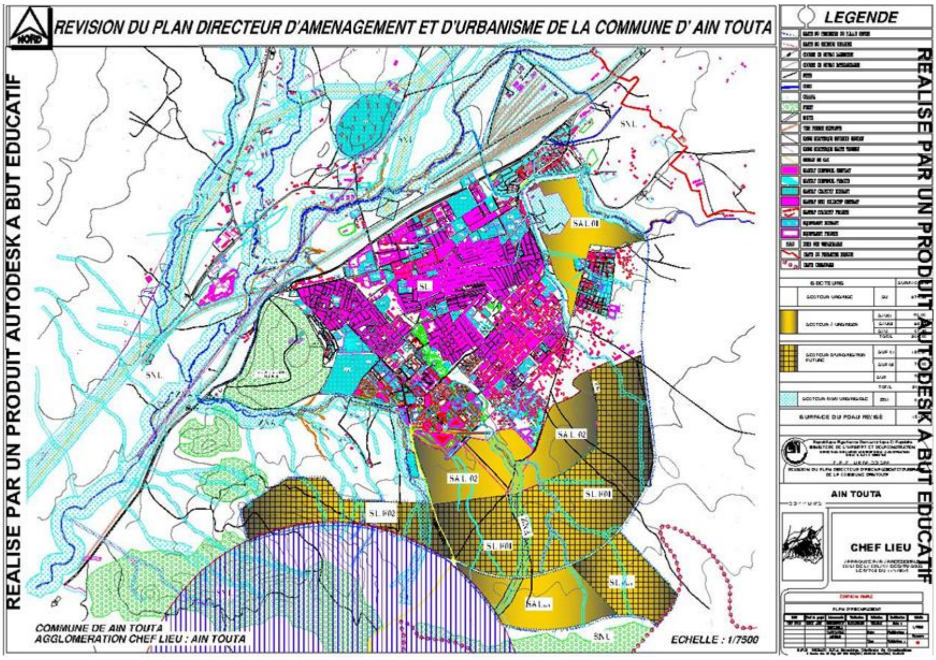

Fig. 4. Urban master plan: expansion areas using CAD approach. Source: Urban Master Plan of AIN TOUTA Municipality

In practice, the expansion areas of Algerian cities were identified in the master plan using a classical method that relied on several criteria presented in the form of AutoCAD desktop layers. The most important of these criteria are land geotechnical characteristics, distance from natural and technological hazards and protected areas, proximity to the city, poor agricultural land, good accessibility and network connectivity, and the nature of real estate ownership. These criteria fall into two categories:

Technical factors of soil criteria in the first stage: The output of this stage is the classification of land as buildable or not.

Suitability criteria are considered in a second stage, taking into account accessibility, obstacles and easements, slope, and land use.

One disadvantage of this method is the inability to integrate and identify the mutual influence of the factors that contribute to the selection of expansion areas. In contrast, GIS enables us to develop a geodatabase based on several criteria, allowing us to weigh up each factor alongside the others. This research paper compares the results of the master plan with those of the Analytical Hierarchy Process (AHP), which represents the decision-making process (MCDM).

The master plan identified an area of 300 hectares as an expansion area, but did not detail or specify the differences between the buildable areas.

The hierarchical analysis identified a total area of 333 hectares (see Table 6) and classified it into five categories that differ in their degree of suitability for development.

The results of the two methods are 90% identical, with most areas of difference and mismatch occurring in areas of weak and medium suitability. To take advantage of areas with medium and low suitability, we can use hierarchical analysis to identify criterions that contribute to low suitability, and then intervene to reduce spatial weaknesses and improve the degree of suitability.

As a result, the hierarchical analysis improves the options and results of the master plan and provides scientific justification for expansion through multi-criteria analysis. It also allows us to consult with stakeholders to make appropriate decisions. Knowing the most influential factor and the different degrees of suitability will help us to choose the most appropriate type of land use and building. Consequently, combining the CAD and AHP methods provides support and improvement to the master plan.

Table 6. Comparison AHP results with master urban plan

Methods	Total area of expansion	Spatial division	Combining CAD/GIS
CAD	300	short, medium and long term	spatial suitability with time period
AHP	333	degree of suitability	

The consistency rate in identifying growth areas strongly justifies the usefulness of hierarchical analysis in supporting and improving the results of the master plan for Ain Touta. The study recommends generalising the use of hierarchical analysis, provided the criteria and their weights are determined according to each region's local characteristics. Additionally, several spatial suitability models have been developed using GIS software, such as the Suitability Modeler in ArcGIS Pro, to identify the best location and facilitate decision-making. Applying any model requires knowledge of the relevant criteria and weights for the topic and study area. Using several suitability models and comparing them also produces better results.

Conclusions

Urban expansion is influenced by factors related to the site, such as slope and the geotechnical report, as well as external factors including accessibility, adjacent land uses, and the city's internal structure. Therefore, this manuscript recommends determining the spatial suitability of urban growth within a digital environment that enables the study of expansion within the city's overall organisation to achieve the strategic planning objectives, followed by the urban design stage for residential neighbourhood units in the form of land use plans. This digital method enables data to be exchanged and coordinated between planning and urban design, eliminating conflicts between the two levels in terms of area accuracy and land use boundaries.

Studying expansion areas in a digital environment improves understanding of master plan trends and supports the planning process. One of the most important outcomes of masterplan analysis is that users cannot understand the factors influencing expansion selection and their degree of suitability. In contrast, hierarchical analysis is more accurate and transparent, providing a clearer rationale for the choice of expansion. Using the AHP/GIS approach to support and improve the results of the master plan produced significant results.

-The topological rules enabled us to monitor the urban area effectively. For example, the topological report highlights any chaotic building or overlapping land use.

-Network analysis enables proximity searches, service area identification, and location allocation, while geostatistical analysis determines distribution patterns.

-Statistical analysis involves exploring data to examine the distribution of attribute values. It is useful to display entity class information on a map, curve, or diagram, and it is also used to summarise data. This is done for categories to calculate the total surface area of each object category.

-Sectoral plans, such as land surveys, can be imported to improve communication and coordination between stakeholders.

-Using geomatics generally facilitates consultation, coordination, decision-making, project implementation, updates, and plan reviews.

GIS and computer-aided design (GIS/CAD) helped us to develop a more credible and transparent urban development plan. This research confirmed that AHP and GIS technologies play a crucial role in helping decision-makers identify suitable areas for future expansion, thereby reducing the randomness of urbanization and creating a sustainable environment for future urban development.

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