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AN INTEGRATED APPROACH TO IDENTIFY SUITABLE AREAS FOR THE LOCATION OF PUBLIC FACILITIES USING MULTI-CRITERIA ANALYSIS BASED ON GIS AND AHP IN THE CITY OF EL KHROUB, ALGERIA

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ABSTRACT

Random and spontaneous urban growth is the result of massive natural population growth, as it is in all developing countries. As for our study air, it also results from the unloading of the mother city of Constantine to the satellite city of El-Khroub, which gave urbanization the power to take over its vast environment, An uneven distribution of public facilities in the city's major districts, as well as traffic jams. This work attempted to determine the suitability of urban land for the location of public facilities in the city. It should be noted that land suitability assessment is a major factor in urban planning and management. Our land adequacy assessment is subject to the AHP model, calculating the weighting of various criteria including physical, socio-economic, environmental and urban. The final adequacy analysis revealed the proportion of land most suitable, estimated at 3.52% of the total area, covering mainly fallow land. The results of this study provide a detailed mapping of urban development potential, integrating both existing data and future projections.

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Introduction.

Public facilities (PF) play a major role in meeting the needs of the service, since urban studies often impose a restrictive definition of public services, restricting them only to facilities and services accessible to the general public (Albe-Tersiguel et al 2008). The PF plays a vital role in city life, and accessibility allows people to access their basic needs (Dembele Samba.2017). The PA provides services to citizens and must be accessible and open to all. They are usually carried out under the responsibility of the state, local authorities or a private establishment (Dubos-Paillard,E et al.2003).

One of the main determinants of quality of life in cities is access to urban PF (Clegg and Garlick 1979; Ali and Rahman 2004). The level of development of states and the availability of basic EPs are linked to a complex relationship, where it is not possible to determine with certainty whether more urbanized states have better access to these states (Ram B. Bhagat, 2010). In some cases, there may be developed countries with a shortage of certain basic services, while less urbanized territories have better availability of these services. Similarly, it cannot be established categorically whether large cities are better off than small ones in terms of availability of basic EPs (Ram B. Bhagat, 2010). We can find large cities with an uneven distribution of services, while we find others with better availability of these public facilities and a better quality of life in general. While basic public services are essential to society, their distribution is marked by flagrant injustice. Although these services are essential to survival and a decent life, we note significant variation in their availability between different geographic units and the individuals themselves (Henderson, et al, 2001; Anderson and Pomfret, 2004; Kenbur and Venables, 2005).

This is why urban planning plays an important role in achieving more just and inclusive societies by ensuring that all individuals, regardless of their social background or income, have equal access to basic public services and facilities such as health and education (Cervero, R. 2001; Murray, A.T. 2001; Maruna, M.et al 2018). Despite their crucial role in the daily lives of communities, access to infrastructure is unevenly distributed across the territory, both in rural and urban areas (Jahangeer A.P et al, 2018; Aderamo A.J. and Aina O.A.2011). The geographical distribution of facilities leads to spatial and social disparities in regions and within cities (Madu, 2007). The development of projects and plans for future development of facilities in a region requires a thorough prior knowledge of their nature and territorial distribution. The accelerated urban development of cities over the past three decades has put considerable pressure on urban social amenities, and the urban planning agency, overtaken by urban expansion, has been unable to adequately respond to needs, this resulted in an unequal distribution of civic infrastructure within cities (Aburas, M.M et al 2015; Zahoor A. et al 2017). Unequal access to urban facilities in southern cities has a negative impact on the physical well-being of populations. Urban growth and rural exodus are global phenomena, particularly marked in developing countries. Many small towns and rural areas are rapidly becoming large conurbations (Jain, K and Subbaiah, Y.V 2007; Mahrous, MS 2009). This exponential population growth is putting a strain on the urban environment and creating a multitude of problems, such as urban sprawl, lack of affordable housing, chronic congestion, a faulty drainage system, Sanitation problems and a glaring lack of other essential services (Liu,Y, and Phinn, S.R,2003; Kunze, A, 2012). Adequacy analysis assesses the extent to which a system meets stakeholders' expectations and needs. The adequacy analysis is the process, the procedures used to establish the adequacy of a system according to the needs of a stakeholder. In this context, it is all the more important to optimize the implementation of public works taking into account the specific needs and constraints of a territory in order to control the inappropriate urban growth and preserve the surrounding space of urban agglomerations (Ullah, K.M. and Mansourian, A, 2015; Kumar, M and Shaikh, V.R.2013, Jafari, S and Zaredar, N). Remote sensing and GIS techniques are used to provide data that will be used for development and research (Saha A and Roy R. 2021; Mallick SK, 2024). Persuading the best approveable geospatial specimens for possible development and planning requires issuing management privileges and using decision support engineering (Martellozzo et al. 2018; Huang et al. 2023). Using Geographic Information Systems (GIS), it is possible to analyse and map various relevant factors such as population density, distribution of existing services, accessibility of transport, socialeconomic and environmental constraints (Malczewski, J. 1999). Land suitability assessment is often based on the combination of GIS and multi-criteria hierarchy (MHM) method. Among these, hierarchical analysis (AHP) and weighted linear combination methods are particularly prevalent in the field of remote sensing (Shang and Luo. 2021, Zhu et al. 2022 and Shang et al. 2023). Assessment of adequacy is essential for informed decision making. The assignment of relative values, or weights, to the various combined factors is the crucial choice that the analyst must face when using this tool (Jallow,A.G, 2020). The GIS-based analytical hierarchy process (AHP) was used as a multi-criteria decision-making model to find an appropriate site for the construction of equipment in the city of El Khroub in northeastern Algeria. The migratory pressure exerted by the metropolis of Constantine on its satellite city, El Khroub, as well as rural migration flows have led to rapid and anarchic urban growth. This accelerated urbanization has undermined environmental balances, physical and social inequalities of access, resulting in overcrowding, sanitation problems, infrastructure shortages and degradation of natural spaces. To address these phenomena and promote sustainable urban development, it is crucial to assess the suitability of land for different uses. This assessment will help guide land use planning choices to meet the needs of the population while preserving ecological diversity.

The academic access feasible for this work are as follows, first of all, this article will be a model convertible to other similar areas, because it deals with the assessment of the suitability of land for the implantation of EPs in order to achieve equitable spatial distribution. This study can be used to enable urban planners to identify, compare and analyse the proper planning and management of urban development sites.

Study area.

Work on the town of El Khroub, which is located south of the Constantine wilaya in northeastern Algeria, between 6° 41' and 6° 43' E longitude, and between 36° 15' and 36° 17' N latitude (National Institute for Cartography and Remote Sensing, 2009). These elevations vary between 600 meters to the west and 750 meters to the east, it is extended on the surface of 968 hectares (hec) (Ahmed Amine Tabet, 2023). Its total population is 179,188 (Census of the commune, 2022). The climate is semi-arid, with annual rainfall varying between 500 and 560 mm (Bouteraa, 2019). The city's infrastructure is quite considerable; towards Guelma by the national road n° 20, towards Tébessa by the RN n° 10 and towards Batna by the RN n° 03 (Hioul, 2002). (Figure1: (Ahmed Amine Tabet, 2023)).

Methods.

Data and material.

In this study, in order to know the real distribution of public facilities we adopted the method of Kernel density which clearly shows the parts of significant densification of equipment at the city of El Khroub, we also found the need to analyse the distribution trend using the nearest neighbour method, in order to assess the layout of equipment within the city. Then six different types of thematic respectively basic layers were created from different sources, for altitude maps, slope maps were prepared using the digital elevation model (DEM) ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) at a spatial resolution of 30 m downloaded from United States Geological Survey Earth Explorer (earthexplorer.usgs.gov). The map of land use and soil cover is obtained through previous work on automatic extraction of agglomerations from bare ground, whose evaluation values have an overall accuracy of 96.44% and the value of the Kappa (K) coefficient of 95.72% (Ahmed Amine Tabet, 2023). Guided by the zoning of the 2020 Master Plan for Urban Planning and Development, we have mapped out the major neighbourhoods and existing public facilities. In this study, all maps are made using ArcGIS 10.7 software.

AHP model processing.

Submitted by Saaty in (Saaty. T.L, 1977), the analytical hierarchical process (AHP) method consists of breaking down a complex problem into a hierarchical structure. By comparing two-to-two the elements of this hierarchy, it is possible to establish priorities between the different options Saaty, T.L 1977). The evaluation process, which comprises six stages (Saaty, 1980), consists of identifying relevant criteria, prioritising them and assigning weights to them reflecting their importance in the decision to be taken through the hierarchical decomposition of a complex problem, the development of pairs of comparison matrices, the assignment of numerical values to judgements, the calculation of relative weights of criteria, the synthesis and prioritization of criteria and finally the verification of the consistency of the model (Danumah,J.H et al, 2016).

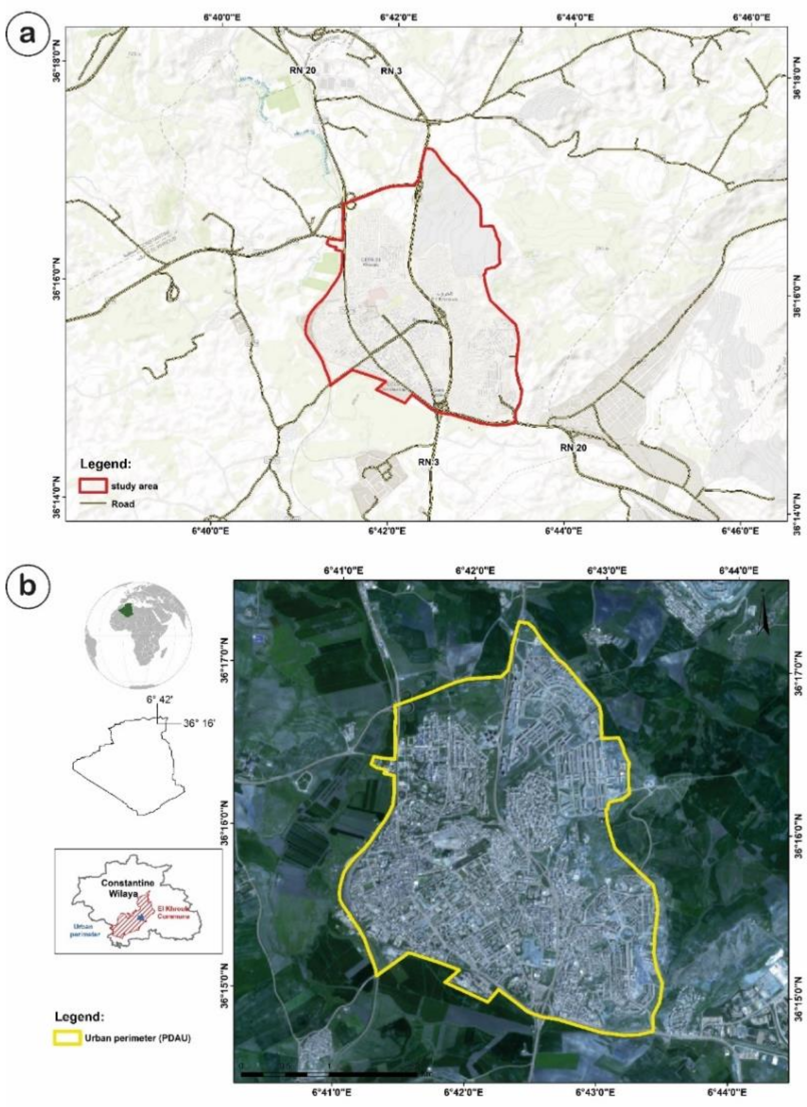


Fig. 1. a) main road. b) geographical location of El Khroub.

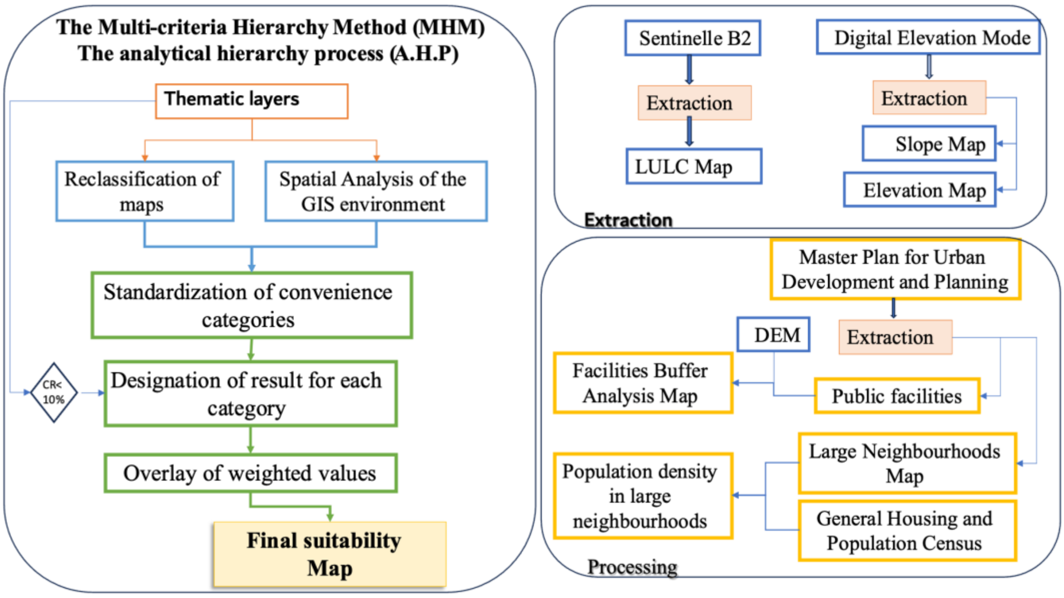


Fig. 2. Flow chart of methodology.

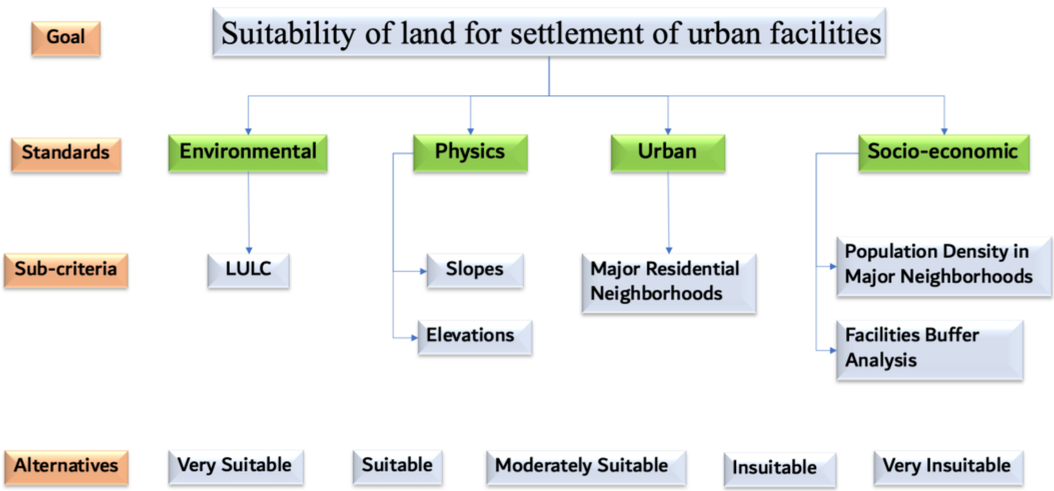


Fig. 3. Utilisation du modèle AHP dans la carte d'implantation des équipements public.

Pairwise comparison.

The binary scheme is based on the scale recommended by Saaty (Saaty, 1980) for comparative factor analysis in Table 1. Pairwise judgments are the fundamental element of the AHP process. For each criterion, two options are compared at a time and a relative weight is assigned to each on a scale of 1 to 9 (Table 1). This weight expresses the importance of one criterion over the other, and the weights assigned to each pair must be reciprocal. Any rating reveals the extent to which option "X" meets the "Y" criterion.

Table 1. Saaty's Scale.

Scale	Judgment of preference	Description
1	Equally important	Two factors contribute equally to the objective
3	Moderately important	Experience and judgment slightly favour one over the other
5	Important	Experience and judgment strongly important favour one over the other
7	Very strongly important	Experience and judgment strongly important favour one over the other
9	Extremely important	The evidence favouring one over the other is of the highest possible validity
2,4,6,8	Intermediate preference between adjacent scales	When compromised is needed

Summary of the assessments.

It is necessary to synthesize our assessments in order to obtain an overall estimate of the priorities relating to the criteria, this synthesis is made thanks to the establishment of the standardized matrix which allows meaningful comparisons between the elements (Saaty, 1984). This summary provides the percentages of the overall priorities to weight the priority vectors by the weight of the criteria and take the sum in relation to all the weighted priority values corresponding to those of the next lower level and so on. These operations result in an overall priority vector for the lowest level of the hierarchy. If several results are obtained, their arithmetic mean can be taken (Saaty, 1984).

After calculating the weights, it is necessary to calculate the consistency ratio (CR) to check the degree of consistency of the judgments made by any expert (Weldu WG, Deribew IA, 2016). This is an indication provided to justify whether the comparison matrix is consistent or not (Saaty TL, 1977). The formula to obtain the CR value is,

$$\boldsymbol{CR = (CI/RI) * 100}$$

Where CR is the coherence ratio,
CI is the ratio of the coherence index,
RI is the random inconsistency index of a randomly generated pairwise comparison matrix from 1 to 10 (Table 2), calculated by matching random indices using a sample (Saaty, T.L. 2001). In the Consistency Ratio (CR) formula, the CI is calculated by the following equation.

$$\boldsymbol{CI = (\lambda - 1)/(n - 1)}$$

Where CI is the consistency index,
λ is simply the mean of the consistency vector,
n refers to the total number of criteria. The coherence ratio of the hierarchy must be equal to or less than 10% (Saaty, t. l. 1980). If not, the quality of the information should be improved by possibly revising the way in which the questions are asked to make binary comparisons (Saaty, 1984).

Table 4. The random inconsistency value. (Saaty, T.L.1984).

Number of criterion	1	2	3	4	5	6	7	8	9	10
Random Inconsistency	0.00	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Development of sub-criteria maps.

After sorting the criteria for the location of public facilities, various thematic maps were drawn up. Six thematic maps were prepared in a GIS environment, the criteria used being six and most of them are in vector format, where we had to convert them into rasters to succeed in our analysis.

Incorporation of Criteria Maps and Final Suitability Map.

After assigning weights, in the ARCmap and using a weighted overlay tool, we integrated the maps to obtain the final suitability map.

Results and discussion.

At El Khroub, there is a considerable inequality in the distribution of equipment densities (fig.4), the kernel density method clearly shows the condensation points of the equipment. At the city level, there is a strong inequality in the distribution of the density of facilities, which is confirmed by the result of the analysis of the spatial distribution of public facilities. In particular by the method of the nearest neighbour, we can not only locate these facilities but also identify trends of grouping or dispersion within the urban territory (DEMBELE Samba, 2017). The fig.5 illustrates the dispersed nature of the equipment, this examination reinforces the previous one by providing the necessary answers based on reliable statistical indicators (z-score, average distance observed, average distance expected and the ratio of the nearest neighbour).

According to the results of the exit from the p-value program is low close to zero 0.10 we reject the hypothesis of nowhere between the distribution of equipment and space, the ratio is inadequate. Since the Z-score value is estimated to be -1.636, it is less than -1.65, which means that the confidence level is 90%. According to the results, since the value of the NNR is 0.95, it is close to 1, here we judge that the distribution of public facilities in the city has a random distribution.

Almost like all cities in developing countries will grow coincidentally (Arjun S, Ranjan R, 2020). In these cities, although PF is a fundamental pillar of sustainable urban growth, the identification of suitable sites for the establishment of PF is never subject to planning or programming. Conversely, it can be linked to population density, as is the case for the educational PFs of the first three phases. The search for suitable areas was used using six criteria and the integration of these criteria made it possible to identify different suitable locations for the future establishment of PF.

Fig.4. General Equipment Density (Core Density)

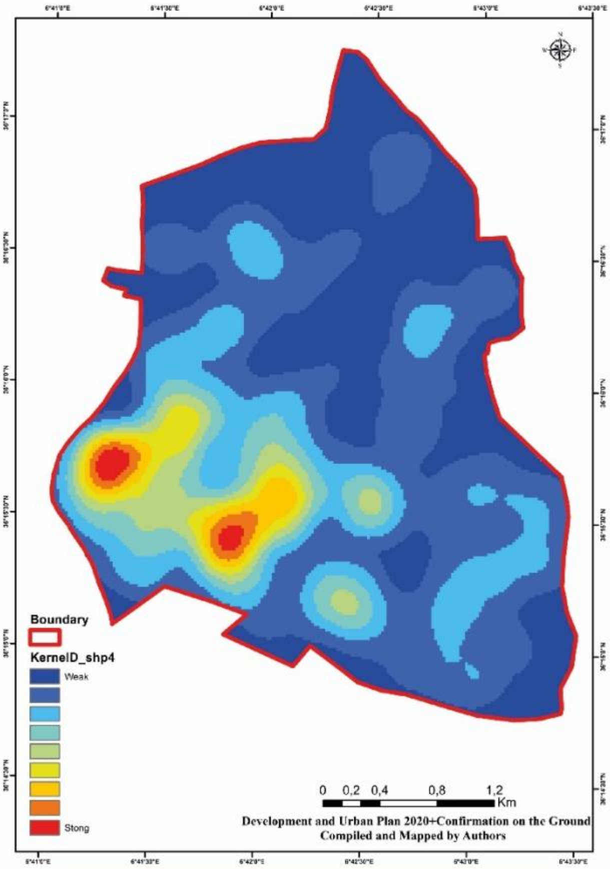
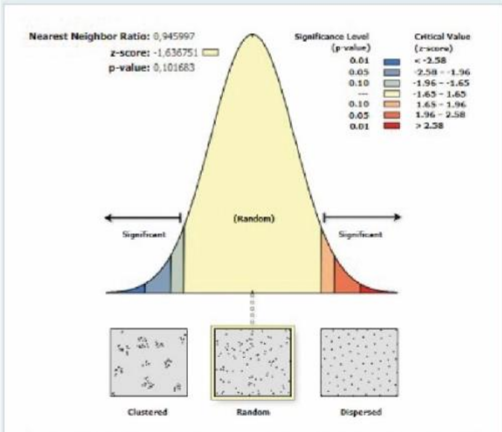


Fig.5. Trend in the distribution of public facilities (nearest neighbour)



Given the z-score of -1.63675099272, the pattern does not appear to be significantly different than random.

Average Nearest Neighbor Summary

Observed Mean Distance:	98,0981 Meters
Expected Mean Distance:	103,6981 Meters
Nearest Neighbor Ratio:	0,945997
z-score:	-1,636751
p-value:	0,101683

Dataset Information

Input Feature Class:	equipement
Distance Method:	EUCLIDEAN
Study Area:	10796300,000000
Selection Set:	False

Environmental factors.

The environment and its factors play a critical role in finding suitable locations for connections, although this data is not always available. With improvements in satellite techniques, traditional methods have often been transformed by remote sensing data analysis to monitor changes including land use change. (Sertel & Akay 2015). Land use and operation Fig.6 is mentioned as a fundamental criterion for understanding the distribution of land use in the study area, the land use map was drawn from sentinel data A2 of April 6, 2020. It has been classified as built-up land, green spaces, barren land and asphalt. In the further analysis, sterile land was considered a very appropriate criterion because in the future new constructions could be carried out, including developments, after this sub-criterion we have the sub-criterion of green space, which is considered to be an appropriate standard for locating EPs. Buildings are moderately adapted as they may contain administrative equipment or branches. The last sub-criterion, asphalt (roads), is classified in a category not suitable for such development.

Socio-economic factor.

The highest population density is linked to the location of the EPs, which makes them closer to the citizen’s service. In this work, the densest areas are best suited to the future public establishment in order to bring them closer to the citizen (fig.7). It should be noted that the population densities in force are distributed according to the major areas of the city, which we will discuss later. In our work the reality of PF distribution in the city of El-Khroub is a basic criterion for decision making of the ideal location of these in the future (fig.8), we considered that buffer zones from 0 to 200 m very inadequate for the realization of any public equipment; buffer zones medium adequate is suitable between 200 and 350 meters, while buffer zones adequate is between 350 and 500 meters, and the most suitable site for the implantation of future urban EPs in the city remains for the buffer zones confined between 500 and 650 meters and more than 650 meters.

Urban factor.

For this work, the urban factor is understood to mean all the major neighbourhoods (fig.9), which are part of the revision of the intercommunal master plan (Constantine-El Khroub-Aïn Smara-El Hamma-Didouche Mourad), which has the following designations A, B, C, D, E, F, G, N1 and N2. During the work, we distinguished adequacy according to the availability of PF in the major neighbourhoods, and it is natural that the adequacy be directly proportional to the lack of equipment. The urban standard is classified into four categories: very appropriate, appropriate, average fit and very inappropriate.

Physical factors.

Physical factors, such as elevations and slopes, are the fundamental criteria for building public facilities. A steep slope is not suitable for any type of construction because it requires higher construction costs, is also risky. Topographical characteristics (Fig.10, Fig.11) The criteria for suitability to construct equipment (environmental, physical and social) are classified into three categories: very suitable, appropriate, moderately suitable.

fig.6

LULC

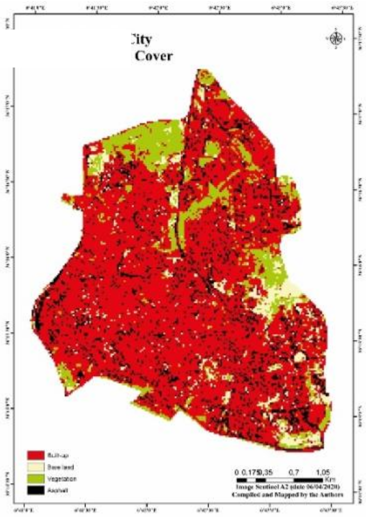


fig.7

Population density

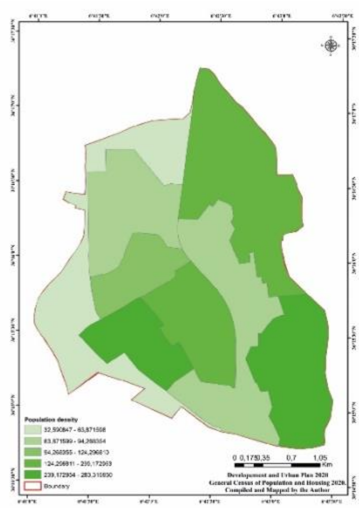


fig.8

Facilities Buffer

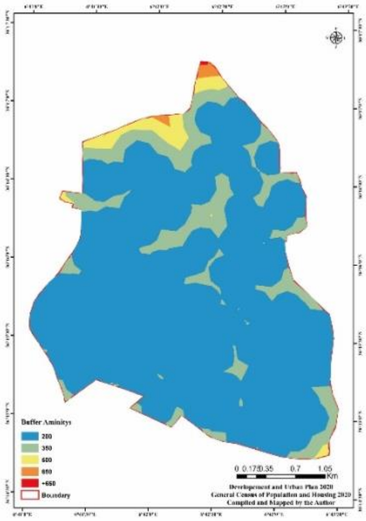


fig.9

Large District

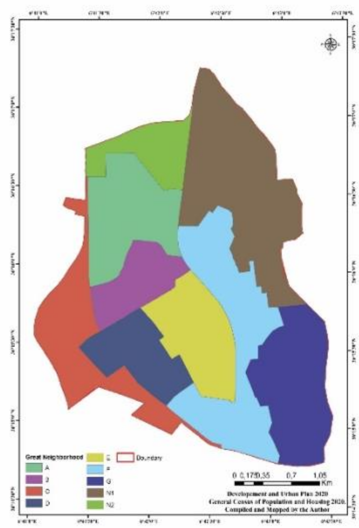


fig.10

Slope

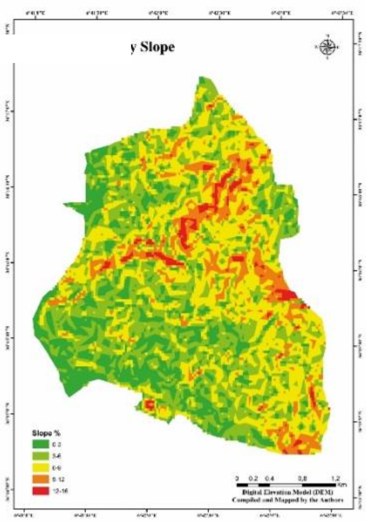
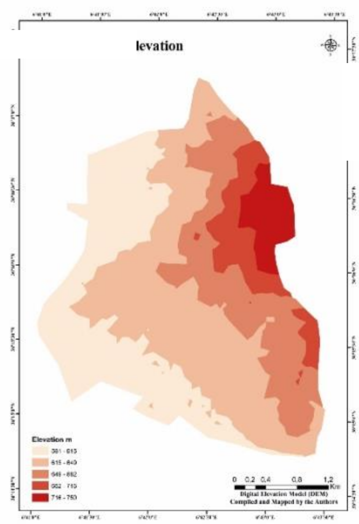


fig.11

Elevation



Pair wise comparison matrix and normalized pair wise comparison matrix.

Since we adopted six criteria for the analysis, a total of 15 subjects were constituted in the questionnaire that was prepared by five experts according to the Saaty scale. In the pairs comparison matrix (table 5), there are 36 boxes and we filled 36 boxes based on the value we get from the questionnaire. The diagonal value will always be 1 because the impact between identical criteria will be equal, and the rest of these reciprocal values.

The standardized pair comparison matrix (Table 6) is the second step to obtain the final weighting of each criterion. The normalized value was calculated by dividing each value of a matrix table by pair by their respective total column value. To determine the weight of each criterion, the arithmetic mean method was used line by line. Population density is the most important influence criterion (31.46%), followed by large neighbourhoods (19.45%), slope (19.41%) and public facilities (14.71%), while land use and land cover has the lowest influence on the location of public equipment, with only 3.83% weighting. Through this matrix, it is clear that socio-economic factors are the most important factors in decision making for the establishment of new public facilities.

Table 5. Pair wise comparison matrix by AHP.

Pair comparison matrix						
Criteria	SP	EL	LULC	EF	LD	PD
SP	1	3	7	1	1	0.33
EL	0.33	1	2	1	1	0.33
LULC	0.14	0.5	1	0.2	0.14	0.2
EF	1	1	5	1	1	0.33
LD	1	1	7	1	1	1
PD	3	3	5	3	1	1
Sum	6.47	9.5	27	7.2	5.14	3.2

SP Slope, *EL* Elevation, *LULC* Land use land cover, *EF* Existing Facilities, *LD* Large District, *PD* Population density.

Table 6. Normalized pair wise comparison matrix and computation of criterion weightage.

Normalised pair wise comparison matrix							weights (%)	Rank
Criteria	SP	EL	LULC	EF	LD	PD		
SP	0.15	0.31	0.25	0.13	0.19	0.1	19.45	2
EL	0.05	0.1	0.074	0.13	0.19	0.1	11.14	5
LULC	0.02	0.05	0.03	0.02	0.02	0.06	3.83	6
EF	0.15	0.1	0.18	0.13	0.19	0.1	14.71	4
LD	0.15	0.1	0.25	0.13	0.19	0.31	19.41	3
PD	0.46	0.31	0.18	0.41	0.19	0.31	31.46	1
Sum	1	1	1	1	1	1	100	

SP Slope, *EL* Elevation, *LULC* Land use land cover, *EF* Existing Facilities, *LD* Large District, *PD* Population density.

Calculation of the consistency ratio.

It is essential to examine the level of consistency in the assessments. Before calculating the CR value, it is necessary to calculate the value of the coherence index (CI) and λ. Table 7 illustrates the calculation of the coherence vector. The outcome of the consistency report (CR) is less than 10%, therefore the judgment is consistent, further analysis is allowed.

CI = (λ-n) / (n-1) = (6,378-6) / (6-1) = 0.075

CR = (CI/RI) * 100 = (0,075/1,24) * 100 = 6,11%

Tableau 7. Calcul du vecteur de cohérence.

Criteria	Weighted Sum Vector	Consistency Vector
SP	(1*0,235950454) +(2*0,144255116) +(0,5* 0,401770127) +(3* 0,125017301) +(6* 0,032360229) +(5*0,060646773)	6.389
EL	(0,5*0,235950454) +(1*0,144255116) +(0,33*0,401770127) +(0,5*0,125017301) +(7*0,032360229) +(4*0,060646773)	6.274
LULC	(2*0,235950454) +(3,03030303*0,144255116) +(1*0,401770127) +(6*0,125017301)+(6*0,032360229)+(8*0,060646773)	6.314
EF	(0,33333333*0,235950454)+(2*0,144255116)+(0,16666667*0,401770127)+(0,2*0,125017301)+(1*0,032360229)+ +(0,25*0,060646773)	6.415
LD	(0,16666667*0,235950454)+(0,14285714*0,144255116)+(0,16666667*0,401770127)+(0,2*0,125017301)+(1*0,032360229)+ +(0,25*0,060646773)	6.334
PD	(0,2*0,235950454) +(0,25*0,144255116) +(0,125*0,401770127)+(0,5*0,125017301)+(4*0,032360229)+(1*0,060646773)	6.544

Analysing final suitability map.

The overlay of the adequacy maps for the above sub-criteria (fig.12) (land use and occupation, population density, spatial sacredness of public facilities, metropolitan areas, slopes and elevations) enabled us to create a Geographic Information System (GIS) for the complete adequacy of suitable land for the correct location of PF throughout the urban area of the city of El Khroub (fig.13). This model, based on a weighted index system, generated a land suitability map for urbanization, classified into five categories ranging from 'highly adapted' to 'very unadapted' (table 8). The mapping of this capability is shown in the following figure. The areas of the different suitability areas are listed in Table 9. Approximately 3.52% of the total area, equivalent to 38 hectares (hec), is classified as very suitable area. The percentage is the lowest compared to the rest of the percentages in the various categories. This means that any new equipment can be installed in this area which includes sterile land, and will be at an appropriate height and slope and will be in service at a higher population density. Very few plots meet all the criteria, which also proves that this area is now in the best position thanks to its integrated features. The favourable areas, which account for 6.20% and are located in the north of the city, are characterized by a steep slope conducive to recreational facilities or public spaces. The appropriate median areas occupy 26.48% of the total area, most of which are located east of the city (east of National Highway 3), where population concentration is extremely high. The extreme northwest of the city. Inappropriate areas occupy an area of 422 (hec), or 39.07% of the total area. They are located in the northern part of the city and in its southernmost part, due to the availability of facilities. The category characterized by absolute lack of adequacy covers an area of 267 hectares, or 24.72%, and is the heart of the city with a significant concentration of facilities.

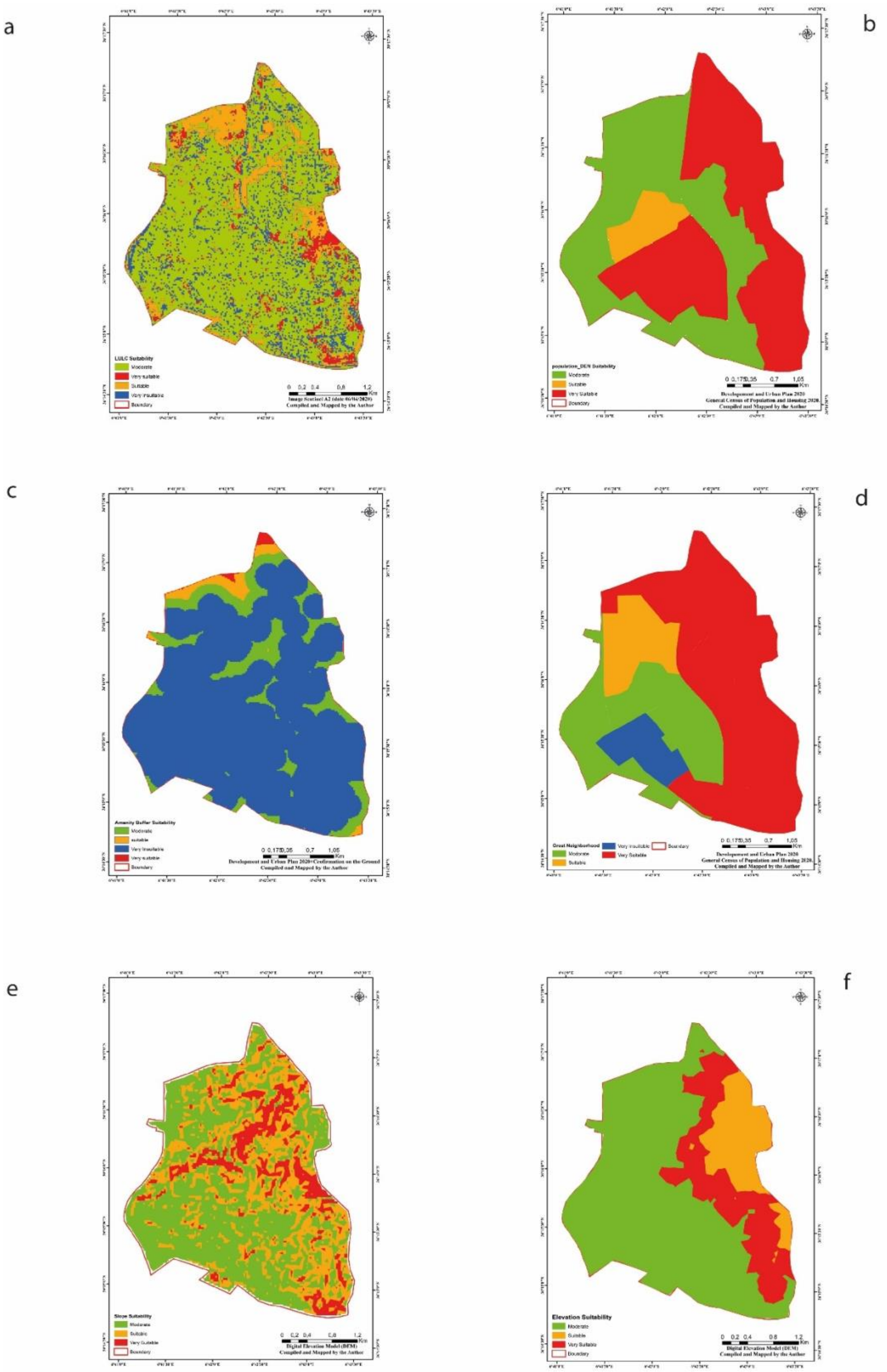


Fig.12. Adequacy maps for sub-criteria: a) LULC suitability, b) Population density suitability, c) Existing Facilities suitability, d) Large District Suitability, e) Slope suitability, f) Elevation suitability.

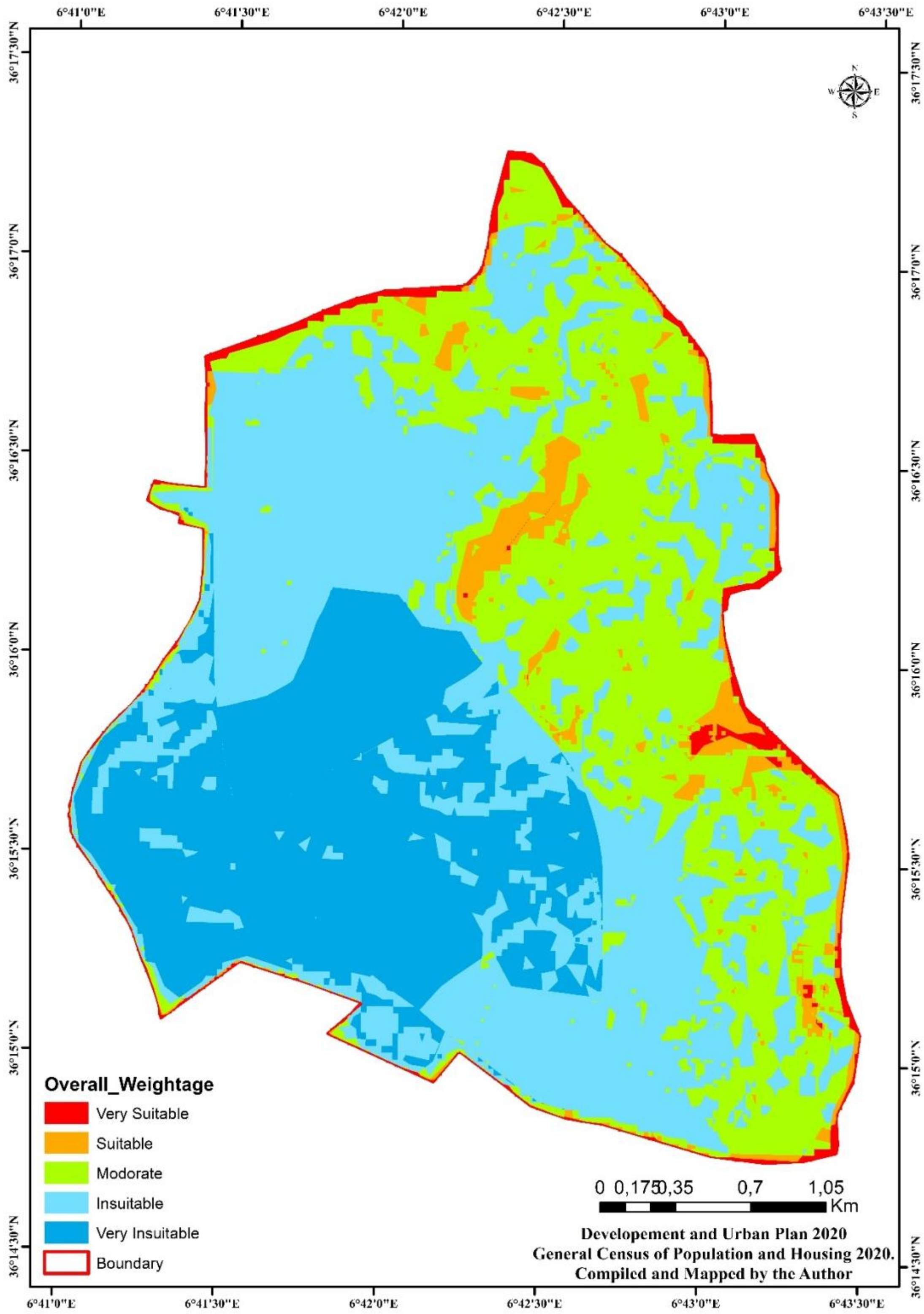


Fig.13. Suitability map for location of public facilities in El Khroub.

Table 8. Summary of criteria, sub-criteria, level of adequacy, subcriteria classification and weighting of criteria.

Criteria	Sub-criteria	Level of Suitability	Weightage (%)	Ranking
Population density	32,59-63,87	Modorate	4.78	3
	63,87-94,26	Modorate	4.78	3
	94,26-124,29	Suitable	14.05	2
	124,29-239,17	Very Suitable	38.20	1
	239,17-283,31	Very Suitable	38.20	1
Large District	N2	Very Suitable	20.54	1
	C	Modorate	3.30	3
	A	Suitable	6.32	2
	F	Very suitable	20.54	1
	B	Modorate	3.30	3
	E	Modorate	3.30	3
	N1	Very Suitable	20.54	1
	D	Suitable	1.59	4
	G	Very Suitable	20.54	1
Land use land cover	Built-up	Modorate	7.35	3
	Bare land	Very Suitable	52.47	1
	Vegetation	Suitable	36.12	2
	Asphalt	Insuitable	4.06	4
Elevation	581 - 615	Modorate	5.77	3
	615 - 649	Modorate	5.77	3
	649 - 682	Very Suitable	43.66	1
	682 - 716	Suitable	22.40	2
	716 - 750	Suitable	22.40	2
Slope	0% - 3%	Modorate	8.69	3
	3% - 6%	Modorate	8.69	3
	6% - 9%	Suitable	12.83	2
	9% - 12%	Very Suitable	34.89	1
	12% - 16%	Very Suitable	34.89	1
Existing amenity buffer	0-200	Insuitable	3.28	4
	200-350	Modorate	8.17	3
	350-500	Suitable	15.48	2
	500-650	Very Suitable	36.54	1
	>650	Very Suitable	36.54	1

Tableau 9. Different suitability categories and their area.

Suitability categories	Area in sq. km	Area in percentage
verry suitable	38	3,52
suitable	67	6,2
Moderate suitable	286	26,48
insuitable	422	39,07
Verry insuitable	267	24,72

Conclusion.

The work on the provision of public facilities in the city of El Khroub indicates that urban facilities are not distributed in a homogeneous and regular manner between the different districts of the city, on the contrary, they are distributed randomly. Thus, the need to choose suitable sites for proper urban planning is necessary in order to control the problem of non-proactive urban management. To address this challenge, the GIS-based analytical hierarchy process is a lucrative technique that determines multiple suitability classes. In the city of El Khroub, the old neighborhoods are very inappropriate for installing new public facilities because this is where the equipment is concentrated; In contrast, most neighbourhoods on the east side of the city are classified as suitable mid-range. The appropriate and very suitable areas are located south of the large N1 district, north of the G and f; they are compatible with wasteland and urban wasteland. On the other hand, this kind of land-use planning research would be fruitful for policymakers, planners, etc., ensuring that they could identify areas where comprehensive development programmes can be implemented in a proactive, far-sighted and effective manner.

REFERENCES

1. Séverine Albe-Tersiguel, Emmanuel Blum, Corinne de Berny-Riche, Carole Delaporte-Bollérot, Stéphanie Lesellier, Catherine Mangeney, Agnès Parnaix, Claire Peuvergne (2008). Exploratory approach for a hierarchy of equipment in the Île-de-France region. Institut paris region. 141p.(in French).
2. DEMBELE Samba, 2017. Socio-spatial dynamics of the city of Bamako and surroundings. PhD in Geography. University of Caen Normandy. P 77-78. (in French).
3. Dubos-Paillard, E., Guermond, Y., and Langlois, P. (2003). Analyse de l'évolution urbaine par automate cellulaire. Le modèle SpaCelle. L'espace Géographique 32, p. 357–378.
4. Clegg, E.J. and J.P. Garlick (1979) "The Ecology of Disease in Urban Societies", Cultent Ant.ropo10gy 20, pp. 798-799. https://www.journals.uchicago.edu/doi/pdf/10.1086/202382.
5. Ali, Osman, Z.M. and Rahman, M.R.A. (2004). The Effect of Urbanisation on the Health of Urban Residents', Akademika, 65, pp. 111-124.
6. Ram B. Bhagat. (2010). Urbanisation and Access to Basic Amenities in India. URBAN INDIA vol. 31 no.1, January - June 2011.
7. Henderson, J. V., Shalizi, Z., & Venables, A. J. (2001). Geography and development. Journal of Economic Geography, 1(1), 81–105.
8. Anderson, K. and Pomfret R. (2004). Spatial inequality and development in Central Asia. Research Paper No. 2004/36. Helsinki: United Nations University World Institute for Development Economics Research.
9. Bouteraa, O. A. (2019). Groundwater quality assessment using multivariate analysis, geostatical modeling, and water quality index (WQI): a case of study in the Boumerzoug -El khroub valley of Northeast Algeria. . Acta Geochimica, 38(6), 796-814.
10. Ravi Kanbur, Tony Venables. Introduction (2005). Inegalites spatiales et developpement avoir acces fleche Journal of Economic Geography, Volume 5, numéro 1, janvier 2005, pages 1–2, https://doi.org/10.1093/jnlecg/lbh059.
11. Cervero, R. (2001). Integration of urban transport and urban planning. In The Challenge of Urban Government: Policies and Practices; World Bank Publications: Washington, DC, USA, 2001; pp. 407–427.
12. Marija Maruna, Danijela Milovanovic Rodic and Ratka Colic (2017). Remodelling urban planning education for sustainable development: the case of Serbia. International Journal of Sustainability in Higher Education. Vol. 19 No. 4, 2018 pp. 658-680 Emerald Publishing Limited 1467-6370. doi 10.1108/IJSHE-07-2017-0102.
13. Parry, Jahangeer A.; Ganaie, Showkat A.; Sultan Bhat, M. (2018). GIS based land suitability analysis using AHP model for urban services planning in Srinagar and Jammu urban centers of J&K, India, Journal of Urban Management, ISSN 2226-5856, Elsevier, Amsterdam, Vol. 7, Iss. 2, pp. 46-56, http://dx.doi.org/10.1016/j.jum.2018.05.002.
14. Ignace Ani Madu (2007). The Underlying Factors of Rural Development Patterns in the Nsukka Region of Southeastern Nigeria. Journal of Rural and Community Development. www.jrcd.ca. ISSN: 1712-8277. Pp 110-121.
15. Alan T. Murray (2001). Strategic analysis of public transport coverage, Socio-Economic Planning Sciences, Volume 35, Issue 3, 2001, Pages 175-188, ISSN 0038-0121, https://doi.org/10.1016/S0038-0121(01)00004-0.
16. Adekunle J. Aderamo and O.A. Aina (2011). Spatial Inequalities in Accessibility to Social Amenities in Developing Countries: A Case from Nigeria. Australian Journal of Basic and Applied Sciences, 5(6): 316-322, 2011 ISSN 1991-8178. https://ajbasweb.com/old/ajbas/2011/june-2011/316-322.

17. Ahmed Amine TABET, Gihen Rym ABDAOUI, Hafid LAYEB (2023). Automatic extraction of build-up areas from bare land using Sentinel 2A imagery in El Khroub city, Algeria. Bulletin de la Société Royale des Sciences de Liège. Volume 92 - Année 2023, Numéro 1, http://doi : 10.255118/0037-9565.11175.
18. Zahoor A. Nengroo, M. Sultan Bhat, Nissar A. Kuchay, (2017). Measuring urban sprawl of Srinagar city, Jammu and Kashmir, India, Journal of Urban Management, Volume 6, Issue 2, 2017, Pages 45-55, https://doi.org/10.1016/j.jum.2017.08.001.
19. Maher Milad Aburas, Sabrina Ho Abdullah, Mohammad Firuz Ramli, Zulfa Hanan Ash'aari (2015). A Review of Land Suitability Analysis for Urban Growth by using the GIS-Based Analytic Hierarchy Process. Asian Journal of Applied Sciences (ISSN: 2321 – 0893) Volume 03 – Issue 06, December 2015.
20. Kamal Jain and Y. Venkata Subbaiah, 2007. Site Suitability Analysis for Urban Development Using GIS. Journal of Applied Sciences, 7: 2576-2583. URL: https://scialert.net/abstract/?doi=jas.2007.2576.2583.
21. Ashraf MS Mahrous (2009). Application of GIS to describe historical urban development of Kharga City, Egypt. https://www.geospatialworld.net/article/application-of-gis-to-describe-historical-urban-development-of-kharga-city-egypt.
22. Kunze, A., Burkhard, R., Gebhardt, S., Tuncer, B. (2012). Visualization and Decision Support Tools in Urban Planning. In: Arisona, S.M., Aschwanden, G., Halatsch, J., Wonka, P. (eds) Digital Urban Modeling and Simulation. Communications in Computer and Information Science, vol 242. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-29758-8_15.
23. Yan Liu, Stuart R. Phinn (2003). Modelling urban development with cellular automata incorporating fuzzy-set approaches. Computers, Environment and Urban Systems 27 (2003) 637–658. Elsevier Ltd. http://doi:10.1016/S0198-9715(02)00069-8.
24. Kazi Masel Ullah and Ali Mansourian (2015). Evaluation of Land Suitability for Urban Land-Use Planning: Case Study Dhaka City. Transactions in GIS. © 2015 John Wiley & Sons Ltd. http://doi: 10.1111/tgis.12137.
25. Hioul, s. (2002). Mutations fontionnelles d'un village colonial dans la logique de la croissance urabines de Constantine: le cas d'El khroub. Magister, Université de Constantine 1.
26. Manish Kumar, Vasim Riyasat Shaikh. (2013). Site Suitability Analysis for Urban Development Using GIS Based Multicriteria Evaluation Technique. J Indian Soc Remote Sens 41, 417–424 (2013). https://doi.org/10.1007/s12524-012-0221-8.
27. Jafari Sudabe and Zaredar Narges (2010). Land Suitability Analysis using Multi Attribute Decision Making Approach. International Journal of Environmental Science and Development, Vol.1, No.5, December 2010 ISSN: 2010-0264. https://www.ijesd.org/papers/85-D490.pdf.
28. Malczewski, Jacek. (1999). GIS and Multicriteria Decision Analysis (pp. 182–187). New York, États-Unis: Wiley.
29. MALCZEWSKI, Jacek.(1999). GIS and multicriteria decision analysis. 1999, 392 pages, ISBN 0-471-32944-4. New York: John wiley & sons, 1999. https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1538-4632.2002.tb01077.x.
30. Frederick Steiner, Laurel McSherry, Jill Cohen, (2000). Land suitability analysis for the upper Gila River watershed, Landscape and Urban Planning, Volume 50, Issue 4, 2000, Pages 199-214, ISSN 0169-2046, https://doi.org/10.1016/S01692046(00)00093-1.
31. Adama Gassama Jallow, Djim M. L Diongue, Huguette C. Emvoutou, Daouda Mama, Serigne Faye (2020). Groundwater Recharge Zone Mapping Using GIS-based Analytical Hierarchy Process and Multi-Criteria Evaluation: Case Study of Greater Banjul Area. American Journal of Water Resources. 2020; 8(4):182-190. doi: 10.12691/ajwr-8-4-4.
32. Mallick SK, Rudra S, Maity B. 2024. Land suitability assessment for urban built-up development of a city in the Eastern Himalayan foothills: a study towards urban sustainability. Environ Develop Sustain. 26:3767–3792. doi: 10.1007/s10668-022-02857-8.
33. Saha A, Roy R. 2021. An integrated approach to identify suitable areas for built-up development using GIS-based multi-criteria analysis and AHP in Siliguri planning area, India. SN Appl Sci. 3(4):1–17. doi: 10.1007/s42452-021-04354-5.
34. Huang H, Huang J, Wu Y, Zhuo W, Song J, Li X, Li L, Su W, Ma H, Liang S. 2023. The improved winter wheat yield estimation by assimilating GLASS LAI into a crop growth model with the proposed Bayesian posterior-based ensemble Kalman filter. IEEE Trans Geosci Remote Sens. 61:1–18. doi: 10.1109/TGRS.2023.3259742.
35. Martellozzo F, Amato F, Murgante B, Clarke KC. 2018. Modelling the impact of urban growth on agriculture and natural land in Italy to 2030. Appl Geogr. 91:156–167. http://doi: 10.1016/j.apgeog.2017.12.004.
36. Thomas L Saaty, (1977). A scaling method for priorities in hierarchical structures, Journal of Mathematical Psychology, Volume 15, Issue 3, 1977, Pages 234-281, ISSN 0022-2496, https://doi.org/10.1016/0022-2496(77)90033-5.
37. Saaty, T. L. (1980). The Analytic Hierarchy Process: Planning, Priority setting, Resource allocation, Mc Graw-Hill, New York, 19.

38. Saaty, Thomas. L. Decision making (2004) . the Analytic Hierarchy and Network Processes (AHP/ANP). J. Syst. Sci. Syst. Eng. 13, 1–35 (2004). https://doi.org/10.1007/s11518-006-0151-5.
39. Jean Homian Danumah, Samuel Nii Odai, Bachir Mahaman Saley, Joerg Szarzynski, Michael Thiel, Adjei Kwaku, Fernand Koffi Kouame and Lucette You Akpa (2016). Flood risk assessment and mapping in Abidjan district using multi-criteria analysis (AHP) model and geoinformation techniques, (Cote d'Ivoire). Geoenvironmental Disasters (2016) 3:10. DOI 10.1186/s40677-016-0044-y.
40. Min Shang and Ji Luo (2021). The Tapio decoupling principle and key strategies for changing factors of Chinese urban carbon footprint based on cloud computing. Int J Environ. Res. Public Health 2021, 18, 2101. https://doi.org/10.3390/ijerph18042101.
41. Sertel, Elif., & Akay, Semih Sami. (2015). High resolution mapping of urban areas using SPOT-5 images and ancillary data. International Journal of Environment and Geoinformatics, 2(2), 63-76. https://doi.org/10.30897/ijegeo.303545.
42. Zhu G, Yong L, Zhao X, Liu Y, Zhang Z, Xu Y, Sun Z, Sang L, Wang L. (2022). Evaporation, infiltration and storage of soil water in different vegetation zones in the Qilian Mountains: a stable isotope perspective. Hydrol Earth Syst Sci. 26(14):3771–3784. doi: 10.5194/hess-26-3771-2022.
43. Shang Y, Song K, Lai F, Lyu L, Liu G, Fang C, Hou J, Qiang S, Yu X, Wen Z. (2023). Remote sensing of fluorescent humification levels and its potential environmental linkages in lakes across China. Water Res. 230:119540. doi: 10.1016/j.watres.2022.119540.
44. SAATY L. Thomas (1984). Deciding in the face of complexity. A multi-criteria analytical approach to decision support. modern university-enterprise collection EME. (in French).
45. Weldu WG, Deribew IA (2016). Identification of potential sites for housing development using GIS-based multi-criteria evaluation in Dire Dawa city Ethiopia. International Journal of Sciences: Basic and Applied Research (IJSBAR). ISSN 2307-4531.
46. Saaty, TL (1977). A scaling method for priorities in hierarchical structures. Journal of Mathematical Psychology, 15(3), 234–281. https://doi.org/10.1016/0022-2496(77)90033-5.
47. SAATY, Thomas L., and Miguel H. BELTRAN .1980. "Architectural design by the Analytic Hierarchy Process." Journal of the DMG, April 1980.
48. Saaty, T.L. (2001). Fundamentals of the Analytic Hierarchy Process. In: Schmoldt, D.L., Kangas, J., Mendoza, G.A., Pesonen, M. (eds) The Analytic Hierarchy Process in Natural Resource and Environmental Decision Making. Managing Forest Ecosystems, vol 3. Springer, Dordrecht. https://doi.org/10.1007/978-94-015-9799-9_2.
49. Arjun Saha Ranjan Roy. 2020. An integrated approach to identify suitable areas for built-up development using GIS-based multi-criteria analysis and AHP in Siliguri planning area, India. SN Applied Sciences (2021) 3:395 | https://doi.org/10.1007/s42452-021-04354-5.