European Journal of Applied Sciences – Vol. 12, No. 06
Publication Date: December 25, 2024
DOI:10.14738/aivp.1206.18149.
Guidana, G. F., Kali, A., & Tanone, D. (2024). Using the ELECTRE Tri Method to Categorize Roads: The Case of the Ngaoundéré Town in Cameroun. European Journal of Applied Sciences, Vol - 12(06). 847-859.

Using the ELECTRE Tri Method to Categorize Roads: The Case of the Ngaoundéré Town in Cameroun

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ABSTRACT

A road network is the set of roads that enable people and goods to move from one point to another. It provides access to important infrastructures such as health and education services. In Cameroon, the road network inherited from the colonial era poses major challenges. The case of Ngaoundéré, capital of the Adamaoua region, a transit city between the regions of the far south of Cameroon and the far north, sees its road networks frequently used. Given the increase in traffic, poor user behavior and deterioration, the problem of road safety (assaults, frequent accidents) and the deterioration of the means of locomotion, which contributes most to greenhouse gas emissions (GHG), has arisen. This work involves assigning the various roads to distinct categories in order to highlight potentially dangerous roads requiring special attention. To do this, we'll be building a more or less exhaustive, coherent and non-redundant set of criteria enabling a multi-criteria evaluation of these different roads. Seven relevant and coherent criteria (distance, type, condition, season, infrastructure, behavior and aggression) were selected. We used the ELECTRE Tri method, derived from the AMCD assignment problem, to categorize these roads. After a robustness analysis, this method enabled us to identify at-risk roads in the city of Ngaoundéré from among 42 essential ones. Some 95.24% of Ngaoundéré's roads are poor and 4.76% are hazardous. According to these criteria, the city does not have any roads in the Good or Very Good categories.

Keywords: Road safety, Assignment, ELECTRE Tri, Road, AMCD.

INTRODUCTION

A road network is the set of roads used to move people and goods from one point to another. It provides access to important infrastructures such as health and education services. In Cameroon, the primary objective of road infrastructure was to facilitate the export of natural resources to Germany (1884-1916) and France (1916-1960). After independence, they remain a major development problem, particularly in urban areas [1]. Cameroon records an alarming number of people who lose their lives or are seriously injured in road accidents [2]. Plus de 3000 cas d'accident de la route sont enregistrés au cours de l'année de 2024 [3]. Infrastructure deterioration, traffic jams, traffic accidents and many other problems related to human life are topical issues in cities [4].

THE EXISTING RANKING METHOD

Thus, it is important and very urgent to categorize the road networks of certain cities in order to help the State and the population in the intervention as well as its use. Several studies have been carried out on road networks, highlighting their importance in the connectivity and construction of public space in Cameroon [5], [6]. Similarly, the ELECTRE Tri method was used to prioritize drainage sections and identify the most deteriorated sections in Alsace [7]. The detection of hazardous roads in Khorasan province was carried out using hybrid AMCD methods [8]. In addition, AMCD has been used to assess multimodal accessibility and the contribution of roads to sustainable development [9]. A hybrid multicriteria approach combining three methods and artificial intelligence as well as the notion of fuzzy logic was used to categorize roads in 27, wilaya of Oran, Alsace and Iran [10] [9], [11], [12]. There was also a question of prioritizing road maintenance, in which roads are evaluated and ranked according to various criteria [13]. The evaluation of public road policies in Cameroon was carried out using the matching method in order to reach the most disadvantaged strata [14]. For our study, we chose to use the ELECTRE Tri multicriteria method, recognized for its ability to handle complex problems involving varied and often contradictory evaluation criteria [15], [16] in order to assign the various roads in the city of Ngaoundéré to predefined categories.

MATERIALS AND METHODS

The city of Ngaoundéré, located in the Adamaoua region of Cameroon, with a surface area of 17,196 km^2, is a strategic city linking the various regions of Cameroon from north to south. It is also a commercial crossroads, attracting populations of diverse origins. Despite the importance of its progressive development, its roads have serious infrastructure problems such as a high state of deterioration, frequent traffic jams, insufficient signposting, lack of maintenance and many other problems such as insecurity [17]. We used the urban map of Ngaoundéré, various geographical tools and data collected on the various roads, based on the criteria selected, to draw up a database of Ngaoundéré's essential roads in order to assign them to predefined categories [18].

Evaluation Criteria Used

Multicriteria evaluation consists in assessing or enabling decision-makers to make better, more consistent decisions [19] Thus, the coherent, non-redundant and exhaustive evaluation criteria used in our study are:

- *distance*: research has shown that the longer and more isolated the journey, the higher the number of high-speed accidents [20];
- *type of road* (National, Regional, Urban and Departmental: a criterion for distinguishing roads according to their physical characteristics and the traffic they carry. It also enables the implementation of safety measures adapted to each type of road [21], [22];
- *Road condition* (tarmac, earth, cobblestone): this is a factor contributing to accidents when it is poorly maintained or contains potholes or cracks;

- *Season*: this criterion is important in categorizing roads, as weather conditions vary throughout the year and can have a significant impact on the risk of road accidents [23], [24];
- *Infrastructures* : the lack of road signs, darkness, can progressively increase the risk of accidents [25] and the proximity of a school, market, road signs on each road also explores the importance and relevance in the categorization of roads [26], [27], [28];
- *User behavior* (Prudent, educated, reckless, ...) are the major cause of road accidents [29];
- *Aggression per week*: is an essential element as a criterion when categorizing roads. Physical aggression, harassment and vandalism are all behaviors that can lead to road [30];
- *Accidents case*: It is also important to know whether there have been any accidents on the section in the past. When this is affirmed, it is also essential to know the frequency per week, month or year.

It's important to note that these criteria are not exhaustive, and that there are many other factors that can affect road safety. However, these criteria are a good starting point for understanding the causes of road accidents [31].

Data Standardization

In this section, we model categorical or qualitative data as numerical data, thus scaling from 1 to 5 to facilitate calculations and visualization (Table 1).

Tableau 1 : Characterization of evaluation criteria

Criteria	**Type**	Standardized values	**Direction**
Distance	Numeric value	**En Km**	Assending
Type	Enumerated value	National = 1, Regional = 2, Departmental = 3, Urban = 4	Descending
Condition	Enumerated value	Earth = 1, Tared = 2, Paved = 3, Iron = 4	Descending
Season	Enumerated value	Rainy = 1, Dry = 2	Assending
Infrastructures	Boolean	Nil, fair, good, Excellent	Assending
Behavior	Enumerated value	Prudent = 1, Imprudent = 2	Descending
Aggression	Enumerated value	Frequent = 1, Less frequent = 2, never mentioned = 3	Descending
Accident	Enumerated value	Not yet = 6, Rarely = 4, Frequently = 2, very frequently = 0	Assending
Pr4 = very good, Pr3 = Good, Pr2 = Bad, Pr1 = Dangerous			

We present the routes implemented and the evaluation criteria used, along with a detailed description of each route in Table 2.

Table 2: Performance table

Roads	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	Roads description
R_1	0.830	4	2	1	3	2	1		Carrefour Trois-Mala at the Grand marché
R2	0.800	4	2	1	2	2	1		Marhaba in social housing
R3	0.616	4	2	1	2	1	1		The road to Garwa Boullaye

R4	1.000	4	2	1	3	1	1		Av. Rue Ahidjo
R5	0.300	4	2	1	3	1	1		The road from classical high school to shopping mall
R6	1.000	4	1	1	3	1	1		Ngaoundéré public school at the military Camp
R7	1.600	4	2	1	7	1	1		Carrefour Novergien at the Catholic hospital
R8	1.540	4	2	1	4	1	1		Road from Baladji to Beka Housseré
R9	1.700	4	1	1	6	2	1		From Beka technical high school to Beka public school
R10	2.090	4	1	1	3	1	1		From Primary school of Beka to Beka secondary school
R11	1.700	4	2	1	3	1	2		Road from Baladji to the shopping center
R12	2.740	4	2	1	5	2	2		Road by Pass Rd
R13	0.400	4	2	1	3	2	1		Road from the shopping Center to hotel TRANSCOM
R14	1.600	4	2	1	3	1	2		Norvegien Carrefour to Burkina market
R15	0.210	4	3	1	3	1	2		The road from gatehouse to the catholic chaplaincy
R16	1.170	4	1	1	2	1	2		From catholic chaplaincy to protestant chaplaincy
R17	0.300	4	1	1	3	2	1		From catholic chaplaincy to Carrefour Anta-Diop
R18	0.550	4	2	1	2	2	1		The from the gatehouse to ENSAI
R19	0.410	4	3	1	2	1	2		The road from the campus pharmacy to the university
R20	50.560	1	2	1	13	2	1		The road from downtown to the Dang
R21	9.000	1	2	1	3	1	2		National road N15a
R22	16.000	3	2	1	16	1	2		The road from Ngaoundéré to Bélél
R23	2.000	4	2	1	22	2	1		Station road
R24	1.600	4	2	1	17	2	1		Rue du Petit marché
R25	10.000	4	1	1	6	2	1		La route Nationale 20 allant vers Touboro
R26	3.000	4	2	1	5	1	2		Road from Carrefour Marhaba to Beka
R27	3.000	4	1	1	3	2	1		Road from d'Onaref Beka
R28	16.000	1	4	1	1	1	2		The train axis
R29	3.000	4	2	1	3	1	2		Airport road
R30	1.000	4	1	1	4	2	1		The road from Carrefour Bantaï to Regional hospital
R31	0.960	4	1	1	7	1	2		Dang market to the sub-prefecture of ngaoundéré III
R32	1.390	4	2	1	1	2	1		The road from the University to Gada-Dang
R33	1.530	4	2	1	4	1	2		The road from Tradex to Malang church
R34	1.100	4	2	1	2	2	1		Primary school of Bini to Village Universitaire
R35	1.600	4	2	1	3	1	2		The road from Béka Houssére to Bokom
R36	0.920	4	1	1	3	1	2		Carrefour Bamiangua au quartier Haut Plateau
R37	1.570	4	1	1	5	1	2		Haut plateau district to Résidentiel district
R38	1.500	4	1	1	7	1	2		Carrefour Mission to Bamianga market
R39	0.620	4	2	1	4	2	1		The road Regional hospital to large market
R40	1.170	4	2	1	5	2	1		The road from Bantaï market to Sabonguari high school
R41	4.109	4	2	1	9	1	2		Carrefour Bois de Mardock au Carrefour Houssére
R42	1.041	4	2	1	9	1	2		La route allant du Poste à l'Onaref

METHODOLOGY USED

Solving complex problems is part of the daily life of decision-makers, and decision support is needed to help them better express their choices and preferences with regard to a given situation. Such assistance is based on well-defined methods, and can be single- or multi-criteria

[19]. The ELECTRE Tri de la problématique β method, which solves assignment problems, assigns a set of m action noted $A = \{a_1, a_2, a_3 \ldots . a_m\}$ which the decision is based to well-defined categories. Each action in the set of A will be evaluated by a notated real function $G = \{g_1, g_2, g_3 \ldots . g_n\}$ that takes into account the selected criteria. This is done in relation to the importance of the criteria given by a set of weights $K = \{k_1, k_2, k_3 \ldots . k_m\}$ }. It does not compare the actions that are the subject of the decision with each other, but with profile thresholds of the different predefined categories, noted $C = \{c_1, c_2, c_3 \ldots . c_h\}$. Each alternative will be compared with the profiles of each category, forming a profil $Pr_h = \{Pr, Pr_2, Pr_3 \ldots . Pr_h\}$ [32].

Performance Evaluation

The evaluation of actions consists in quantitatively or qualitatively measuring the performance of criteria in order to assign them to predefined categories (case of the ELECTRE Tri method) [33]. The overall concordance index determines the extent to which an action meets the evaluation criteria. It is calculated by comparing the performance of each action against each criterion with a reference value called a profile. The result is a value between 0 and 1, where 1 is the best match value. The partial match (C_j) for the criterion (g_j) is defined by:

$$\begin{cases} C_j(R, Pr_h) = 0, \ \ if \ g_j(Pr_h) - g_j(R) \geq p_j(Pr_h) \\ C_j(R, Pr_h) = 1, if \ g_j(Pr_h) - g_j(R) \leq q_j(Pr_h) \\ C_j(R, Pr_h) = \sum_{j=1}^{n} K_j * C_j(R, Pr_h) \ if \ note \end{cases}$$

The overall agreement is given by: $C_j(R, Pr_h) = \frac{\sum_{j=1}^{n} K_j * C_j(R, Pr_h)}{\sum_{j=1}^{n} K_j}$

Unlike the concordance calculation, discordance defines the non-membership of a road to a given category. It calculates a global discordance index by taking the maximum of the partial discordances (the higher the index, the more the action is discordant with the class). Partial discordance (Dj) for the criterion (g_j) is defined by:

$$\begin{cases} D_j(R, Pr_h) = 0, \ \ if \ g_j(R) \leq g_j(Pr_h) - p_j(Pr_h) \\ (D_j(R, Pr_h) = 1, if \ g_j(R_h) > g_j(R) + v_j(Pr_h) \\ D_j(R, Pr_h) = 1 - \dfrac{g_j(Pr_h) - g_j(R)}{D_j}, \ \ if \ g_j(R) < g_j(Pr_h \end{cases}$$

Discordance index (D) from the road (R) and the profile Pr_h is defined by:

$$D_j(R, Pr_h) = \{g_j(R, Pr_h)\} \, with \, j = 1, \ldots, n$$

The credibility index is calculated by: $\sigma(R_i, Pr_h) = C(R_i, Pr_h). \, \pi. (1 - d_j(R, Pr_h))/(1 - C(R_i, Pr_h)$ with $\sigma(R_i, Pr_h)$ degree of credibility, $C(R_i, Pr_h)$ the concordance index between R_i, Pr_h and $d_j(R, Pr_h)$ the discordance index for criterion j between roads R_i and profiles Pr_h.

Basic Implementation Parameters

To apply the ELECTRE Tri method in order to categorise the roads in Ngaoundéré, we need to set the values of basic parameters such as the weights, the total sum of which is equal to 1 in our particular preference, indifference, veto and the different profiles (table 3).

Table 3: Basic layout data.

Criteria	**weight(k_j)**	**Preference (p_j)**	**Indifference (q_j)**	**Veto threshold**	**Pr_4**	**Pr_3**	**Pr_2**	**Pr_1**
Distance	0.15	3	0.5	5	0.3	2	5	15
Type	0.10	2	1	3	1	1	4	1
conditions	0.10	2	1	3	2	2	1	10
Season	0.05	2	1	2	2	2	1	1
Infrastructures	0.20	2	1	3	0	5	2	10
behavior	0.25	2	1	5	1	1	2	2
Agression	0.15	1	0.5	1	2	2	1	1
Accident								
Cutting threshold: $\lambda = 0.8$								

Parameters such as criterion weights, concordance and discordance indices, veto, indifference and preference thresholds are defined by the decision-makers.

Suggested Model

In the figure below, we present the approach used to implement the ELECTRE tri method for road allocation [34].

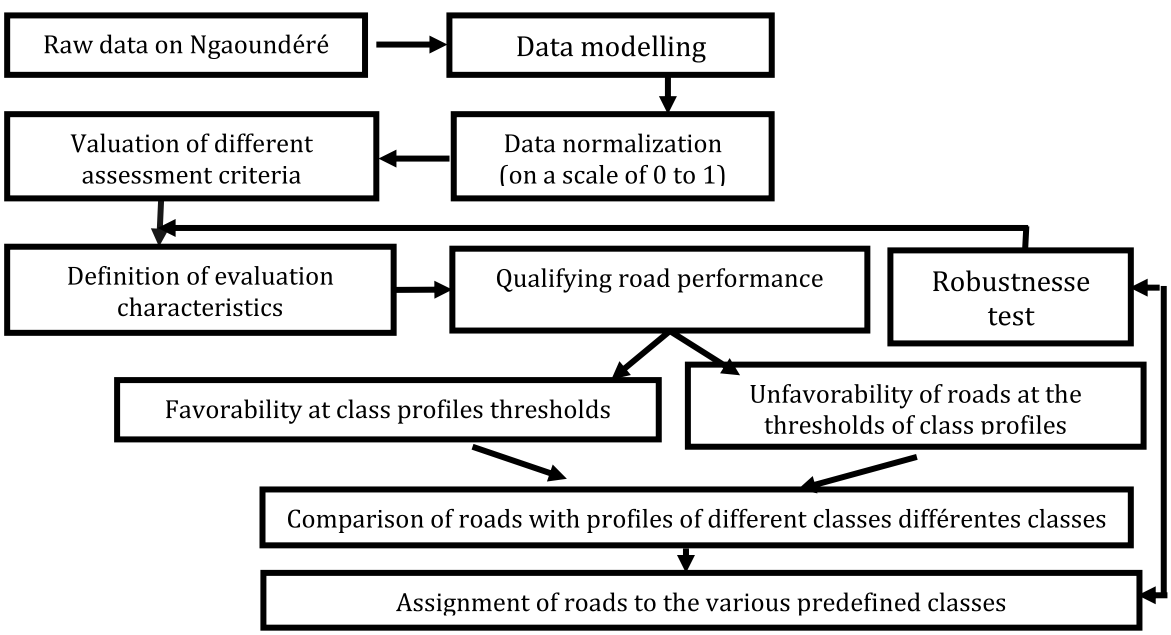

Figure 1: approach to implementing the ELECTRE Tri method for assigning roads [34].

This is in fact the approach we're going to use to assign the various roads to the categories we've predefined.

RESULTS

Global Concordance Matrix

The global concordance matrix summarizes the results of all the local concordance matrices, providing an overall score for each road in relation to each profile. These scores are calculated by multiplying the local concordance values by the weights associated with the criteria, then normalizing the result.

Table 4: Global concordance matrix

Roads	Pr_4	Pr_3	Pr_2	Pr_1	Roads	Pr_4	Pr_3	Pr_2	Pr_1
R1	0.55180	0.90000	1.00	0.90	R22	0.65000	0.65000	0.65	0.68
R2	0.90000	0.90000	1.00	0.90	R23	0.62200	0.70000	0.80	0.70
R3	0.90000	0.90000	1.00	0.90	R24	0.59800	0.70000	0.80	0.70
R4	0.56200	0.90000	1.00	0.90	R25	0.55000	0.55000	0.85	0.90
R5	0.70000	0.90000	1.00	0.90	R26	0.68200	0.58000	1.00	0.90
R6	0.56200	0.90000	1.00	0.90	R27	0.68200	0.78000	1.00	0.90
R7	0.59800	0.70000	1.00	0.90	R28	0.85000	0.85000	0.75	0.88
R8	0.59440	0.90000	1.00	0.90	R29	0.68200	0.78000	1.00	0.90
R9	0.60400	0.70000	1.00	0.90	R30	0.56200	0.90000	1.00	0.90
R10	0.62740	0.90000	1.00	0.90	R31	0.55960	0.70000	1.00	0.90
R11	0.60400	0.90000	1.00	0.90	R32	0.78540	0.90000	1.00	0.90
R12	0.66640	0.56440	1.00	0.90	R33	0.59380	0.90000	1.00	0.90
R13	0.70000	0.90000	1.00	0.90	R34	0.76800	0.90000	1.00	0.90
R14	0.59800	0.90000	1.00	0.90	R35	0.59800	0.90000	1.00	0.90
R15	0.70000	0.90000	1.00	0.90	R36	0.55720	0.90000	1.00	0.90
R16	0.77220	0.90000	1.00	0.90	R37	0.59620	0.70000	1.00	0.90
R17	0.70000	0.90000	1.00	0.90	R38	0.59200	0.70000	1.00	0.90
R18	0.90000	0.90000	1.00	0.90	R39	0.70000	0.90000	1.00	0.90
R19	0.90000	0.90000	1.00	0.90	R40	0.57220	0.70000	1.00	0.90
R20	0.65000	0.65000	0.65	0.65	R41	0.55000	0.64654	0.80	0.90
R21	0.65000	0.85000	0.85	1.00	R42	0.56446	0.70000	0.80	0.90

Roads with high scores (close to 1) compared to Pr_1 *and* Pr_2, such as R_2, R_3 *and* R_5, are considered very good or good. This means they exceed expectations in terms of safety and quality, which is essential for the road network.

Roads with lower ratings, such as those up to Pr_3 or Pr_4, indicate poor or unsafe performance. For example, if a road has a low index of Pr_4, this suggests that it could be classified as unsafe and requires urgent attention to remedy the problems identified. The matrix can be used to quickly identify which roads need attention. Roads classified as “very good” or “good” can be prioritized for regular maintenance, while those classified as “poor” or “dangerous” should be targeted for immediate improvement. The concordance matrix, by integrating the profiles Pr_1at Pr_4, offers a clear and structured assessment of the performance of Ngaoundéré's roads. It facilitates not only sorting and evaluation, but also informed decision-making on road network improvement. Using this information, authorities can better allocate resources and improve the safety and quality of road infrastructure.

Global Discordance Matrix

This matrix (Table 5) presents the basic result of discordance between Ngaoundéré's roads, thus reviving the disagreement over the concordance indices (Table 4).

Table 5: Global discordance matrix

Roads	Pr_4	Pr_3	Pr_2	Pr_1	Roads	Pr_4	Pr_3	Pr_2	Pr_1
R1	1.0	1.0	0.0	1.0	R22	1.0	1.0	1.0	1.0
R2	1.0	1.0	0.0	1.0	R23	1.0	1.0	1.0	1.0
R3	1.0	1.0	0.0	1.0	R24	1.0	1.0	1.0	1.0
R4	1.0	1.0	0.0	1.0	R25	1.0	1.0	1.0	1.0
R5	1.0	1.0	0.0	1.0	R26	1.0	1.0	0.0	1.0
R6	1.0	1.0	0.0	1.0	R27	1.0	1.0	0.0	1.0
R7	1.0	1.0	0.0	1.0	R28	1.0	1.0	1.0	0.0
R8	1.0	1.0	0.0	1.0	R29	1.0	1.0	0.0	1.0
R9	1.0	1.0	0.0	1.0	R30	1.0	1.0	0.0	1.0
R10	1.0	1.0	0.0	1.0	R31	1.0	1.0	0.0	1.0
R11	1.0	1.0	0.0	1.0	R32	1.0	1.0	0.0	1.0
R12	1.0	1.0	0.0	1.0	R33	1.0	1.0	0.0	1.0
R13	1.0	1.0	0.0	1.0	R34	1.0	1.0	0.0	1.0
R14	1.0	1.0	0.0	1.0	R35	1.0	1.0	0.0	1.0
R15	1.0	1.0	0.0	1.0	R36	1.0	1.0	0.0	1.0
R16	1.0	1.0	0.0	1.0	R37	1.0	1.0	0.0	1.0
R17	1.0	1.0	0.0	1.0	R38	1.0	1.0	0.0	1.0
R18	1.0	1.0	0.0	1.0	R39	1.0	1.0	0.0	1.0
R19	1.0	1.0	0.0	1.0	R40	1.0	1.0	0.0	1.0
R20	1.0	1.0	1.0	1.0	R41	1.0	1.0	1.0	1.0
R21	1.0	1.0	0.5	0.0	R42	1.0	1.0	1.0	1.0

The matrix is organized with each row and column representing a road ($R_1$to R_{42} and values indicating the index of discordance in relation to the four profiles ($Pr_1\ to\ Pr_4$). Values range from 0 to 1, where 1 indicates total disagreement between road performance on the criteria evaluated. The majority of roads show discordance indices of 1.0 for Pr_4, $Pr_3\ and\ Pr_1$, which means that they do not perform worse on these criteria than the other alternatives. This indicates a homogeneity in the perceived quality of roads for these levels. Some roads, such as R_{21}, show a partial mismatch (0.5 out of Pr_2), suggesting that they may compare favorably with other alternatives on some criteria, but not on all. This could indicate specific weaknesses requiring attention.

Credibility Matrix Between Roads and Profiles

The credibility matrix combines concordance and discordance scores to assess the reliability of the evaluations. Values range from 0 to 1: where 1 represents maximum credibility, the road meets the criteria well with no significant disagreement, 0 represents minimum credibility, the road does not meet the criteria or the disagreement is too high. Intermediate values indicate varying levels of credibility.

Table 6: Credibility matrix between roads and profiles.

Roads	Pr_4	Pr_3	Pr_2	Pr_1	Roads	Pr_4	Pr_3	Pr_2	Pr_1
R1	0.0	0.0	1.00	0.00	R22	0.0	0.0	0.00	0.00
R2	0.0	0.0	1.00	0.00	R23	0.0	0.0	0.00	0.00
R3	0.0	0.0	1.00	0.00	R24	0.0	0.0	0.00	0.00
R4	0.0	0.0	1.00	0.00	R25	0.0	0.0	0.00	0.00
R5	0.0	0.0	1.00	0.00	R26	0.0	0.0	1.00	0.00
R6	0.0	0.0	1.00	0.00	R27	0.0	0.0	1.00	0.00
R7	0.0	0.0	1.00	0.00	R28	0.0	0.0	0.00	0.88
R8	0.0	0.0	1.00	0.00	R29	0.0	0.0	1.00	0.00
R9	0.0	0.0	1.00	0.00	R30	0.0	0.0	1.00	0.00
R10	0.0	0.0	1.00	0.00	R31	0.0	0.0	1.00	0.00
R11	0.0	0.0	1.00	0.00	R32	0.0	0.0	1.00	0.00
R12	0.0	0.0	1.00	0.00	R33	0.0	0.0	1.00	0.00
R13	0.0	0.0	1.00	0.00	R34	0.0	0.0	1.00	0.00
R14	0.0	0.0	1.00	0.00	R35	0.0	0.0	1.00	0.00
R15	0.0	0.0	1.00	0.00	R36	0.0	0.0	1.00	0.00
R16	0.0	0.0	1.00	0.00	R37	0.0	0.0	1.00	0.00
R17	0.0	0.0	1.00	0.00	R38	0.0	0.0	1.00	0.00
R18	0.0	0.0	1.00	0.00	R39	0.0	0.0	1.00	0.00
R19	0.0	0.0	1.00	0.00	R40	0.0	0.0	1.00	0.00
R20	0.0	0.0	0.00	0.00	R41	0.0	0.0	0.00	0.00
R21	0.0	0.0	0.85	1.00	R42	0.0	0.0	0.00	0.00

Matrix of credibility between routes and profiles (table 6): the matrix is organized with each row representing a route ($R_1$to R_{42}) and each column corresponding to a performance profile (Pr_1 *to* Pr_4). Values range from 0 to 1, where: 0 indicates that the route does not outperform the corresponding profile. 1.00 indicates that the route completely outperforms the profile. Intermediate values indicate a degree of shared credibility between the criteria. Pr_1 (Very good): The majority of roads display an index of 1.00 for Pr_1, meaning that they are considered very good according to the evaluation criteria. This indicates optimum performance for these roads on this profile. Pr_2 (Good): Some roads, such as R_{21}, show an index of 0.85, suggesting that they are generally perceived as good but may have weak points that prevent them from reaching the higher category. Pr_3 (Bad) and Pr_4 (Dangerous): The indices for these profiles are predominantly at 0.00, indicating that most roads are not considered bad or dangerous. This reinforces the idea that the road network is relatively safe and in good condition. Some roads $R_{22}, R_{23}, R_{24}, R_{25}, R_{40}, R_{41}, R_{42}$: have scores of 0.00 on all profiles, meaning that they do not meet any of the evaluation criteria. This could indicate that they require urgent attention or complete rehabilitation. Road R_{28}: With an index of 0.88 for, this road appears to perform acceptably in some respects, but may also present risks that require further assessment. Roads with high indices can be prioritized for regular maintenance, while those with low indices should be targeted for urgent rehabilitation.

Credibility Matrix Between Profiles and Roads

This credibility matrix (Table 7) is an essential tool in the evaluation of roads in relation to reference profiles, facilitating decision-making and providing a sound basis for assigning roads to the respective categories.

Table 7: Credibility matrix between profiles and roads.

Profiles	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14
Pr_1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pr_2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pr_3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Pr_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Profiles	R15	R16	R17	R18	R19	R20	R21	R22	R23	R24	R25	R26	R27	R28
Pr_1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pr_2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pr_3	1.0	1.0	1.0	1.0	1.0	0.0	0.42	0.0	0.0	0.0	0.0	1.0	1.0	0.0
Pr_4	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.88
Profiles	R29	R30	R31	R32	R33	R34	R35	R36	R37	R38	R39	R40	R41	R42
Pr_1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pr_2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pr_3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0
Pr_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 7 presents a credibility matrix between profiles and roads: all indices for Pr_1 are at 0.0, meaning that no road reaches the "very good" level. This may indicate that all routes require significant improvement to reach this standard. Similarly, at Pr_2, all indices 0.0. This suggests that the roads are not considered "good" according to the evaluation criteria, reinforcing the idea that there is a need for improvement throughout the road network. All indices for Pr_3 are at 1.0 for most roads (R_1 *to* R_{39}), indicating that these roads are perceived as "poor". This raises significant concerns about the overall condition of the road network, and may require immediate attention to remedy the problems identified. The indices for Pr_4 are all 0.0, except for R_{21} *and* R_{28}, which are 1.0 and 0.88 respectively. This suggests that the majority of roads are not considered hazardous, but there are notable exceptions that require further assessment. With an index of 1.0 for R_{21} and 1.0 for Pr_4, this road is classified as "bad" and "dangerous". This indicates that it requires urgent attention to improve its safety and quality. R_{28} with an index of 0.88 for Pr_4, this road is close to the critical threshold and could be considered dangerous, which also justifies rapid intervention.

Roads Allocation (Pessimistic Approach)

Assign the stock to a category so that it outperforms the lower reference stock associated with that category.

The pessimistic approach is too strict, and uses alternatives that have minimal potential to match the profile of the higher category. This approach is designed to minimize the risks of over-optimistic assessment, often leading to lower upgrades.

The pessimistic assignment procedure is used to categorize Ngaoundéré's essential roads. It involves assigning roads to the lowest class according to their total score.

Table 8: Road assignment.

Profiles	Roads
Very good (Pr_4)	No road meets the minimum requirements of this class
Good (Pr_3)	No road meets the minimum requirements of this class
Bad (Pr_2)	R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, R1, R12, R13, R14, R15, R16, R17, R18, R19, R20, R22, R23, R24, R25, R26, R27, R29, R30, R31, R32, R33, R34, R35, R36, R37, R38, R39, R40, R41 et R42
Dangerous (Pr_1)	R21 et R28

Robustness Test

To assess the robustness of the results obtained, we carried out a sensitivity analysis by adjusting the cut-off point, or favorability percentage λ, in the interval of]0.6, 1]. The results show that for λ = 0.61 or 0.62, all roads except R_{28} are classified as poor (Pr_2). When λ is set to 0.80, roads R_{21} and R_{28} move to the hazardous category (Pr_1), while the other roads remain in the poor category (Pr_2). Finally, at λ = 1, all roads except R_{21} are also classified as poor (Pr_2). These variations underline the robustness of the proposed approach to categorizing roads with a view to improving road safety levels.

DISCUSSION

Multicriteria analysis was carried out to assess the condition and performance of 42 key roads in Ngaoundéré, using criteria such as distance, type, condition, season, infrastructure, user behavior and aggressiveness. The results obtained make it possible to establish ranking relationships between roads according to predefined profiles (Very Good, Good, Bad and Dangerous). It is recommended that local authorities pay particular attention to infrastructure, taking into account their "limited" resources. It is also crucial to monitor and evaluate road maintenance, to set up a daily program of awareness-raising and user education on potential road hazards and good driving practices, while rigorously enforcing penalties for offenders. In addition, it is essential that road users comply fully with traffic regulations in order to improve road safety levels. Detailed tables complete this analysis: Table 3 presents baseline implementation data and preference indices, Table 4 summarizes performance scores, Table 5 highlights discrepancies requiring improvement, and Table 7 assesses road credibility. Together, these elements contribute to informed decision-making for improving the level of road safety.

CONCLUSION

Road safety remains a major challenge requiring targeted, effective interventions to protect the lives of road users. In this study, we chose to use the ELECTRE Tri multi-criteria method, recognized for its ability to manage complex problems involving varied and often contradictory evaluation criteria. Thanks to this study, based on data extracted from the Ngaoundéré urban map and field studies, it was possible to identify potentially dangerous roads with a view to prioritizing maintenance and development work. The results obtained aim not only to reduce the number of accidents, but also to minimize material damage, injuries and fatalities, thus contributing to a significant improvement in road safety and the well-being of users in the region.

References

[1] N. N. N. C. Owona, "Les politiques publiques des transports des transports au Cameroun de 1884 à 2017," Yaoundé Cameroun, 2022.

[2] D. Cameroun, "datacameroun.com," juin 2024. [Online]. Available: https://datacameroun.com/accident-de-la-route-plus-de-3-mille-cas-enregistres-au-premier-semestre-2024/..

[3] J. Lebledparle.com, "Cameroun: plus de 3000 cas d'accidents de la route depuis le debut d'année.," 15 juillet 2024. [Online]. Available: https://www.lebledparle.com/cameroun-plus-de-3000-cas-daccidents-de-la-route-depuis-le-debut-dannee/.

[4] M. Simeu-Kamdem, " Les métropoles camerounaises à l'épreuve des inondations. Villes et risques hydrométéorologiques en Afrique subsaharienne," p. 213, 2022.

[5] H. A. BAMELA, "Corridors des échanges routiers nord camerounais et structuration des territoires traversés," Bulletin de la Société Géographique de Liège, vol. 82, no. 1, pp. 169-184, 2024.

[6] K. Joseph, "La formation d'un espace public camerounais à l'épreuve de la construction des réseaux routiers de la communication," Africa Developpement, vol. 35, no. 3, pp. 179-205, 2010.

[7] N. A. a. W. Caty, "Aide à la décision multicritère pour la hiérarchisation de tronçons d'assainissement dans le cadre d'une gestion patrimoniale," Canadian Journal of Civil Engineering, vol. 36, no. 7, pp. 1207-1220, 2009.

[8] B. M. A. a. S. S. a. B. Hengameh, "Identifying the factors affecting road accidents and providing multi-criteria hybrid decision-making methods for ranking hazardous points," International Journal of Transportation Engineering, vol. 9, no. 1, pp. 439-458, 2021.

[9] S. S. a. B. M. Ali, "Propoing a new hybrid multi-criteria decision-making approach for road maintenance prioritization," International Journal of Quality & Reliability Management, vol. 38, no. 8, pp. 1661-1679, 2021.

[10] K. J. S. a. V. R. J. a. G. A. a. S. Amit, "Optimization of Highway Performance and Safety by Decicsion-Making Techniques," Intertional Journal of Pavement Research and Technology, pp. 1-17, 2024.

[11] A. M. a. M. A. H. a. H. N. a. A. Bouchenak, "Élaboration d'un système d'aide à la décision spatiale application à la dangerosité de l'infrastructure routière," Journal of Decision Systems, vol. 16, no. 3, pp. 369-391, 2007.

[12] S. E. N. a. S. M. Alavi, "An integrated fuzzy hierarchy risk assessment and multiple criteria decision-making model for rural road hotspot ranking," Accident Analysis & Prevention, 2023.

[13] S. S. a. M. A. Beheshtinia, "Proposer une nouvelle approche décisionnelle hybride multicritère pour la priorisation de l'entretien des routes," pp. 1661-1679, 2021.

[14] A. Nafi, "Unité Mixte de Recherche Cemagref-Engees en Gestion des Services Publics," no. 03.88.24.82.93, 2010.

[15] M. M. a. T. V. a. S. K. a. B. Roy, "Contribution de la méthode ELECTRE TRI à la hiérarchisation de zones à risque induit par la présence d'ouvrages miniers abandonnés. Application au bassin ferrifère lorrain," Revue française de la Géotechnique, pp. 111-120, 2004.

[16] R. H. a. R. E. a. R. a. J. Rasolomamonjy, "Contribution de la méthode Electre Tri à la hiérarchisation des gisements de carrières de roches massives entre Port-Bergé et Djangoa," Madamines, vol. 1, pp. 15-29, 2010.

[17] H. A. B. a. J. P. Ndame, "Accessibilité routière et mutation des activités économiques au Nord-Cameroun," pp. 173 - 182, 2023.

[18] A. B. Bamana, "réalisation de la base de données urbaines (BDU) de Ngaoundéré," Ngaoundédé, 2010.

[19] B. R. a. B. Denis, Aide Multicritère à la Décision : Méthodes et Cas, Paris: Economica, 1993.

[20] S. S. a. B. A. M. a. A. Morteza, "A Rural Road Accident Probability Model Based on Single-Vehicle Hazard Properties including Hazard Color and Mobility: A Driving Simulator Study," Journal of Advanced Transportation, vol. 2020, no. 1, p. 88266374, 2020.

[21] C. B. a. P. L. a. L. P. a. P. Jean-Marc, "Catégorisation des voies urbaines et sécurité routière," 1997.

[22] M. d. T. Publics (MINTP), "Plan stratégique pour l'entretien des routes nationales et régionales.," MINTP, Yaoundé, 2020.

[23] Z. M. J. a. M. H. M. I. a. R. S. a. S. V. Wong, "An Exploration of Weather threats to Road Safety in Tropical Country," Vehicle Safety & Biomechanics Research Centre, 2009.

[24] M. L. a. Z. D. a. W. Y. a. Y. P. a. W. Y. a. Y. Z. a. B. P. a. D. L. a. S. Y, "Short-term effects of ambient temperature and road traffic accident injuries in Dalian, Northern China: A distributed lag non-linear analysis," Accident Analysis & Prevention, vol. vol. 153, no. 106057, 2021.

[25] K. Joseph, "L'espace public camerounais à l'épreuve de la construction des réseaux routiers de communication," Polis/R.C.S.P./C.P.S. R, 2008.

[26] L. V. a. G. M. Line, "La sécurité des infrastructures, une analyse et des recommandations par le comité des experts au Conseil National de Sécurité Routière," Revue Générale des Routes et de l'Aménagement, vol. 76, no. 935, pp. pp-18, 2016.

[27] P. A. a. P. S. a. S. Latif, "The Effect of Road Infrastructure on Traffic Accidents," in APTE 2018, 2019.

[28] A. H. a. S. X. a. J. C. a. R. Thapa, "Application des règles d'association pour enquêter sur les modèles d'accidents mortels et blessés chez les piétons dans différentes conditions d'éclairage," Dossier de recherche sur les transports, vol. 2676, no. 6, pp. 659-672, 2022.

[29] C. Pérez-Diaz, "Théorie de la décision et risques routiers," Cahiers internationaux de sociologie, vol. 114, no. 1, pp. 143-160, 2003.

[30] H. a. a. Benoi, "Mobilité et aménagement urbain: La ville en toute sécurité," 08 Aout 2010. [Online].

[31] X. R. a. Z. S. a. X. P. a. L. A. Y. a. M. Jiaqi, "Towards Better Driver Safety: Empowering Personal Navigation Technologies with Road Safety Awareness," in 2022 IEE 25th International Conference on Intelligence Transportation Systems (ITSC), Macau, China, 2022.

[32] L. Y. Maystre, "Méthodes multicritères ELECTRE: description, conseils pratiques et cas d'application à la gestion environnementale," 1994.

[33] M. S. Ben, "Introduction aux méthodes multicritères d'aide à la décision," BASE, 2000.

[34] J. P. J. s. Lucien Yve Maystre, Méthodes multicritères ELECTRE: description, conseils pratiques et cas d'application à la gestion environnementale, Presses Polytechniques et universitaires Romandes, 1994.

[35] Z. Y. a. N. B. S. Benzar, "A hybrid multi-criteria decision making approach for road safety assessment and prioritization," Transportation Research Procedia, pp. 17-28, 2014.

[36] "Région de l'Adamaoua," 24 Octobre 2024. [Online]. Available: Région de l'Adamaoua.

[37] "GEOSOFT," 01 Juin 2024. [Online]. Available: https://www.geo-soft.fr/.