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Optimisation of Housing Search Process in the Major Cities of Cameroon Using the ELECTRE Is Method

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Abstract

In the context of a growing housing deficit, the Cameroonian population is increasingly faced with the problem of access to rental housing. In general, finding quality housing that meets one's needs and resources is a real challenge for many urban families. Households use a variety of strategies and skills in their search for housing in order to gain access to the property they are looking for. The problem identified here is known in the literature as a decision support problem. To solve this type of problem, several methods have been proposed, which can be divided into two categories of methods: multi-objective decision support methods and multi-attribute decision support methods. These two categories of methods have the common limitation of not considering the preferences of multiple actors in the decision process. This means that the multi-actor aspect remains an open problem. In this paper, we use the ELECTRE Is method to improve the housing search process. The resulting process model incorporates the preferences of multiple actors to share the decision making. The proposed model has allowed us to develop a prototype that guides to the best housing in the city of Yaounde according to a set of input criteria.

Keywords: Business Process Optimisation, Business Process Modeling, QoS, Decision Support, ELECTRE Is

Introduction

One household in eight in Cameroon is potentially capable of accessing property without the help of the state. This is one of the findings of the National Institute of Statistics at the end of the study on the supply and demand for social housing and plots of land for housing purposes. The study also shows that only households with a monthly income of at least 200,000 francs are able to finance the purchase of their home. It conditions access to other fundamental rights, notably the right to health, education, work, family life and privacy etc. Cameroon has ratified various instruments in favour of the right to adequate and suitable housing such as the Universal Declaration of Human Rights, the International Covenant on Economic, Social and Cultural Rights and the Vancouver Declaration, to name but a few (Freddy Tsopfack Fofack et al., 2019). At the national level, Cameroon's constitution in its preamble protects the right to property which is an element of the right to housing (Maroi Agrebi, 2018). However, despite urban development and housing policies, the reality is that there is a notorious deficit in both the quality and quantity of housing. The Ministry of Housing and Urban Development estimates that there is a housing deficit of one million five hundred thousand units. The Cameroon National Housing Report (2015) also reveals that the construction of housing by the structures promoting the production of housing, notably the Mission d'Aménagement et d'Equipement des Terrains Urbains et Ruraux, the Société Immobilière du Cameroun, the Mission de Promotion des Matériaux Locaux as well as private real estate promoters, do not always manage to satisfy the demands. The housing problem in the main cities of Cameroon is expressed in terms of demand, availability and prices charged and deficit. Demand is a function of the rate of growth of the urban agglomeration, given that each household needs a dwelling. So this must be added the latent demand, that is, the unsatisfied

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demands accumulated since the creation of the city. When we talk about availability, we are talking about supply linked to demand, and to this end, we emphasise the action of the public and private sectors (Freddy Tsopfack Fofack et al., 2019). In a context where the housing deficit is growing, the Cameroonian population is increasingly faced with the problem of access to rental housing. Generally speaking, finding quality housing that meets one's needs and resources is a real challenge for many families in the city. In Cameroonian cities, access to rental housing for the needy is a difficult exercise and a major challenge, given the precarious living conditions of many families and the inadequacy of housing to accommodate them (Freddy Tsopfack Fofack et al., 2019). Thus, acquiring rental housing at the size of a studio or flat is a real "obstacle course" because it is sometimes necessary to search for a long time to find a dwelling and obtaining a house is generally a decision taken on the basis of less detailed information (Freddy Tsopfack Fofack et al., 2019). Households in their search for housing deploy a range of strategies and skills to access the property they are looking for. Individuals have diverse skills in relation to housing search and the ability to use housing search tools, such as the internet and property networks and advertisements, are a part of strategy for accessing housing. In Cameroon, the reality is different insofar as the above-mentioned tools are not always privileged when it comes to seeking to satisfy the right to housing. In their search for housing, applicants in Cameroonian cities develop various stratégies: The strategy of acquaintance, based on the word-of-mouth method, is one of the most common ways of accessing housing. It is based on the social capital that is fundamental in the acquisition of housing; the network of social relations that the individual uses in a specific field. In the search for housing in the city, Cameroonians mobilise direct or indirect acquaintances such as family members, friends and colleagues. These people, who are scattered throughout the city, use their interpersonal networks, thus maximising their chances of finding accommodation more quickly. Each link in the chain that makes up the applicant's social capital is thus obliged to use its network of acquaintances to help its relative in need. To this end, because the housing seeker is driven by the need to find housing, he or she does not hesitate to remind the network that has been set up on his or her behalf not to lose sight of his or her complaint until he or she obtains satisfaction. Another strategy used to access rental housing in urban Cameroon is the substitution method. It consists, for a person who is already settled or looking for housing and in integrating a house as soon as another person directly or indirectly known to him or her vacates it the negotiated substitution of one tenant by another. This strategy of access to housing would have an individual integrate the dwelling that one of his relatives plans to leave. To do this, he gives notice of his intention to replace him. By doing so, he temporarily secures the flat until the existing tenant leaves. When the tenant is ready to move out, he informs the landlord and the prospective tenant. Real estate agencies are also most often called upon. These are companies specialising in property transactions. They mediate between landlords and tenants or between property sellers and buyers. They receive offers of rental accommodation from some landlords and register applications from the needy. Few housing applicants use estate agencies. This is because the majority of housing owners are themselves involved in finding tenants for their buildings, through posters in the busy streets of the city and through social contacts. Owners and applicants are obliged to pay the real estate agency a registration fee at the outset and a percentage of the value of the property or the rent if the mediation is successful. In view of the above, the majority of landlords manage to rent out their properties without the intervention of an estate agent in order to avoid expenses that they consider incongruous. The other method of acquiring housing consists of scouring the urban arteries in search of housing to rent. Here, the individuals motivated by the need to acquire a home is called upon to make permanent visits to the area in order to find something that can satisfy his or her criteria. The choice of a better dwelling in an urban environment, under various (often conflicting and contradictory) criteria, appears to be a major necessity in urban logistics (Freddy Tsopfack Fofack et al., 2019).

The previous section shows the difficulties encountered in Cameroonian cities in securing housing. These difficulties are not unique to Cameroon. Indeed, the problem of finding housing is known in the literature as a decision support problem. To solve this type of problem, several solutions are proposed in the literature. These solutions can be grouped into two categories (Maroi Agrebi, 2018). Multi-objective decision support methods (MODM) they aim to find the best alternative by considering the different interactions between the constraints of the problem at hand. This alternative is the one that best satisfies all the objectives. The limitations of these methods are that they are unable to include criteria of a quantitative nature in the decision-making process and they are very complex with the addition of new criteria and are not in this case easy to use Multi-attribute decision support methods. In this family of methods, usually the problem to be addressed has a limited number of predetermined alternatives. These alternatives satisfy each objective at a given level. The decision-maker chooses the best solution(s) among all the alternatives according to the priority of each objective and the interaction between them. The advantage of this method is that it is able to take into account quantitative and qualitative criteria, but its main limitation is the choice of alternatives. This is based on maximising (giving greater importance to) some criteria and minimising others.

From the above, it appears that the existing solutions have a common limit relating to the consideration of the preferences of the actors involved in the decision-making process. This means that for a choice problem, the selection of a better alternative by several actors remains an open problem. In other words, how can the preferences of several actors are taken into account in decision support algorithms for a better choice?

To answer the above question, we propose a multi-attribute, multi-actor model based on the ELECTRE Is method. The model allows integrating not only one but several actors in the choice process; this allows each actor to assign a preference on the selected criteria.

The rest of the article is organised as follows: In addition to this introductory part, we present in Section 2 a review of the literature on decision support methods and more particularly on multicriteria methods. Section 3 presents the development of the proposed model. Section 4 describes the experimental implementation of our model and finally, Section 5 concludes this work by presenting a detailed account of the research project highlighting the contribution of this work in relation to previous research.

Literature Review on Decision Support Approaches

Concept of Multi-Criteria Decision Support

Multi-criteria decision support is an analysis that aims to make explicit a coherent family of criteria for understanding the different consequences of an alternative (Maystre et al., 1994). On the other hand, multi-criteria decision support aims to provide a decision-maker with tools enabling him to progress in the resolution of a decision problem where several points of view, often contradictory must be taken into account (Vincke, 1992). Elsewhere, authors add that multi-criteria decision support is developed to deal with different decision problems (choice, sorting, description and ranking, etc.) while taking into account a set of criteria (attributes), often conflicting and non-commensurable and seeking to model the preferences and values of the decision-maker(s) as well as possible (Pohekar & Ramachandran, 2006).

Classification of Decision Problems

Decision problems can be seen as the direction of investigation we adopt for a given problem. Thus, they express the terms in which the decision-maker poses the problem and translate the type of prescription he or she wishes to obtain (Ayadi, 2010; Bouyssou, 2000). Four problems can be distinguished (Roy, 2013): the choice, sorting, ordering and prescription problem (Roy & Bouyssou, 1993).

Classification of Decision Support Approaches

Decision support is an activity based on evaluation models that explicitly or formally represent reality. In the literature, there are several approaches based on these models, three of which are cited below (Deparis, 2012):

- *Normative Approach:* Given the preferences of the decision maker, which decision is optimal? What rules should a rational agent follow? Which decision models can follow these rules?
- *Descriptive Approach:* How do real decision-makers behave? How do they use their preferences when making a decision? How do they build a model to reflect these observations?
- *Perspective Approach:* How can we help a decision maker who aspires to make a relational choice despite his cognitive limitations? How can we collect his preferences? How can we build recommendations so that he makes a decision in accordance with his points of view?

Multi-Criteria Decision Support Process

The multi-criteria decision support process consists of four basic steps as follows (Maroi Agrebi, 2018; Eduardo Natividade-Jesus et al., 2006):

Step 1: Definition of the Problem and the Object of the Decision: The definition of the problem is based on the precision of the nature of the problem to be dealt with by formulating it either as a choice, sorting, and ordering or description problem. For the determination of the object of the decision, this consists of identifying the potential alternatives on which the decision will be based.

Step 2: Analysis of Consequences and Determination of Criteria: In this step, the consequences of the alternatives must be identified and measured. An alternative usually has several consequences according to a given criterion. The following table summarises the different situations that can arise when comparing two alternatives (Jacquet-Lagrèze et al., 1980).

Step 3: Choice of a Multi-Criteria Decision Support Method: The choice of a multi-criteria decision support method depends on the type of problem posed.

Step 4. Performance of Alternatives: When the analysis of the consequences of potential alternatives is based on several criteria, it is the multi-criteria analysis that provides an answer to the problem posed by the use of for example the preference, indifference and veto thresholds in certain methods.

Multi-Criteria Decision Support Methods

Multi-criteria decision support is a combination of two families of decision support, namely multi-attribute decision support and multi-objective decision support (Maroi Agrebi, 2018).

Study of Multi-Objective Decision Support Methods (MODM)

MODM aim to find the best alternative by considering the different interactions between the constraints of the problem at hand. This alternative is the one that best satisfies all the objectives. The methods proposed to solve multi-objective decision support problems are numerous in the literature. For example, we cite Goal programming the Lexicographic method L-P metrics Geoffrion's method STEM Goal programming and the adaptive search method, etc.

Study of Multi-Attribute Decision Support Methods

In this family of methods, usually the problem to be addressed has a limited number of predetermined alternatives. These alternatives satisfy each objective at a given level. The decision maker chooses the best solution(s) among all the alternatives according to the priority of each objective and the interaction between them. There are several methods for solving multi-attribute decision support problems. These include the Hierarchical Analysis Process, the Technique for Preference Ordering by Ideal Solution Similarity (TOPSIS) and the outranking methods including the Preference Ranking Organisation Method for Enrichment Evaluations (PROMETHEE) and the Elimination and Choice Translating Reality (ELECTRE).

State of the Art on Decision Support Methods

In their work entitled a multi-criteria decision support system (DSS) for housing evaluation, the authors Freddy Tsopfack Fofack et al. (2019), conduct a study in the context of access to social housing in urban areas, in fact, faced with an increase in the demand for quality housing due to the lack of multidimensional and specialised knowledge that should be involved in the evaluation of a house, the space available to build new housing is becoming scarce and urban environmental conditions are deteriorating, so the question arises as to how to carry out a systematic evaluation of housing in urban areas from different perspectives (consumers, authorities and developers) according to the multiple evaluation criteria. Faced with this problem, the idea of their solution is to set up a DSS integrating a problem editor, a database management module, a set of multi-criteria decision support methods and a Human Machine Interface (HMI) aiming at reducing the cognitive effort required from the users, with the aim of helping the different stakeholders to make decisions by assigning houses to predefined classes. Thus the DSS will be able to allow:

- Designers to assess the influence of their options on the final quality of housing;
- Government and financing entities to define lending policies according to quality levels in order to promote the construction and acquisition of quality housing;
- Developers to adapt projects to consumer profiles;
- Local/municipal agencies to characterise the housing stock and/or to prioritise repair or renovation interventions;
- Consumers to choose a house.

The authors therefore use a DSS approach consisting of a combination of information systems (IS) + relational database (RDB) + decision support database + HMI:

- The IS must organise information in such a way that it is useful when retrieved, facilitate access to and management of information, easily adapt to updates in data and analytical programmes and be easily understood by users from an operational perspective.
- The relational database management system (RDBMS) used for the development of their work is 4D and a 4D Server. It includes a 4th generation programming language, which allows full integration of data manipulation with the models through graphical interfaces.
- The decision support database consists of decision support methods such as Simple Additive Weighting (SAW); TOPSIS and the ELECTRE family of methods, ELECTRE I and ELECTRE TRI, which the user can select according to his or her preference to assist in the decision-making process.
- The GUI allows the user not only to apply one of the available decision support methods, but also to modify or view the data stored in the database.

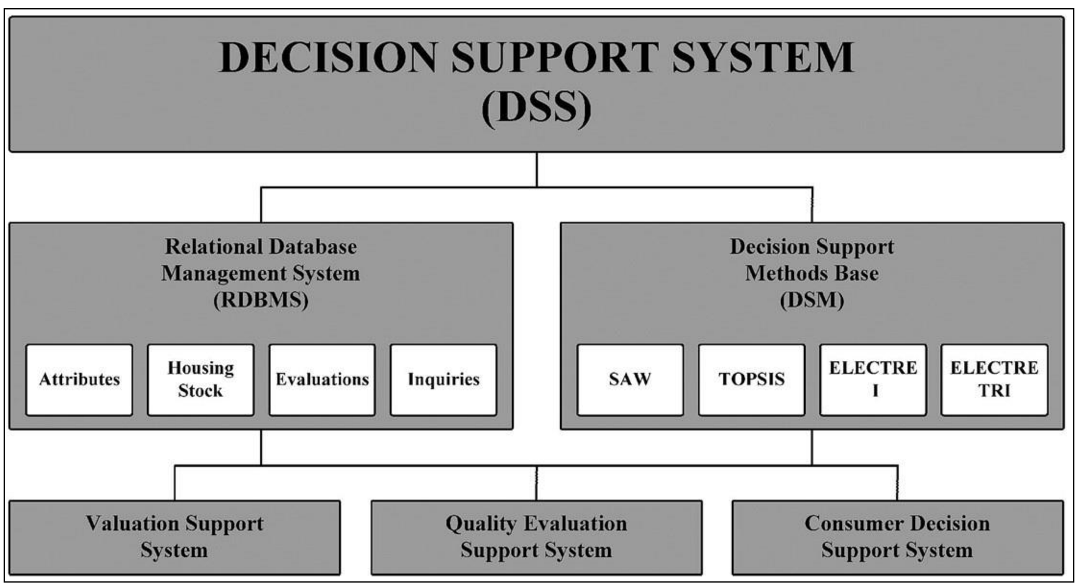

Fig. 1: DSS Architecture

As the assignment of houses to predefined classes is a sorting issue, they implement the SAW and TOPSI methods which are full aggregation methods, that is, they calculate an aggregated performance for each alternative (here the houses) but the limitation is that a good performance in one criterion cannot compensate for a low score in another criterion. The ELECTRE I and ELECTRE TRI methods used are based on the outranking relationship. This has the advantage that poor performance on one criterion cannot be compensated for by good scores on other criteria.

The tests carried out by this approach using the dataset in Fig. 2 yielded Fig. 3, showing the outranking relationships generated by the ELECTRE I method on a set of alternatives (houses 28 and 34 would be the best choices).

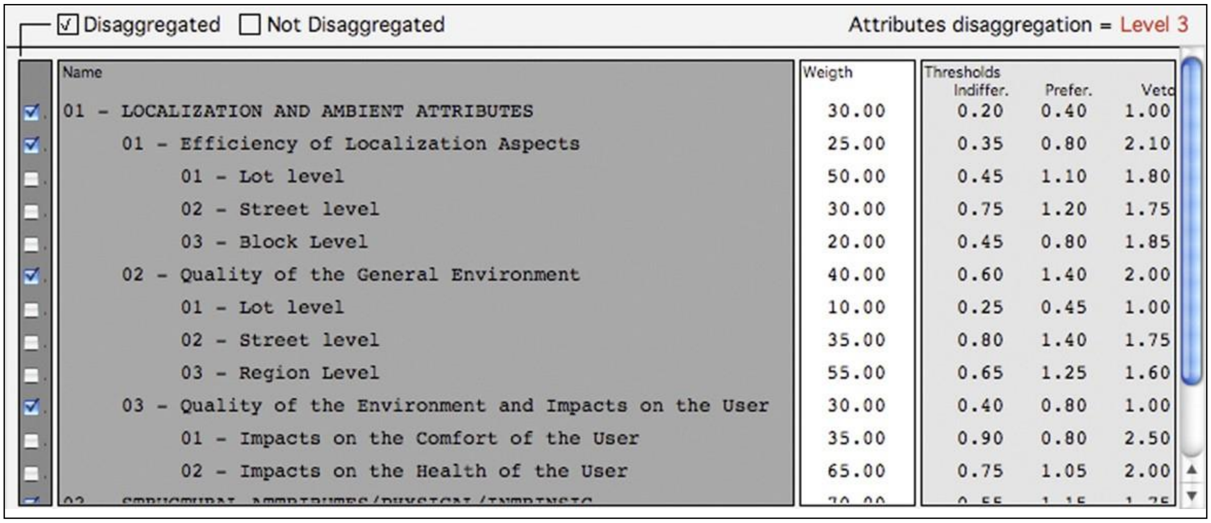

Fig. 2: Defining the Weight (Importance) and Thresholds of Each Criterion

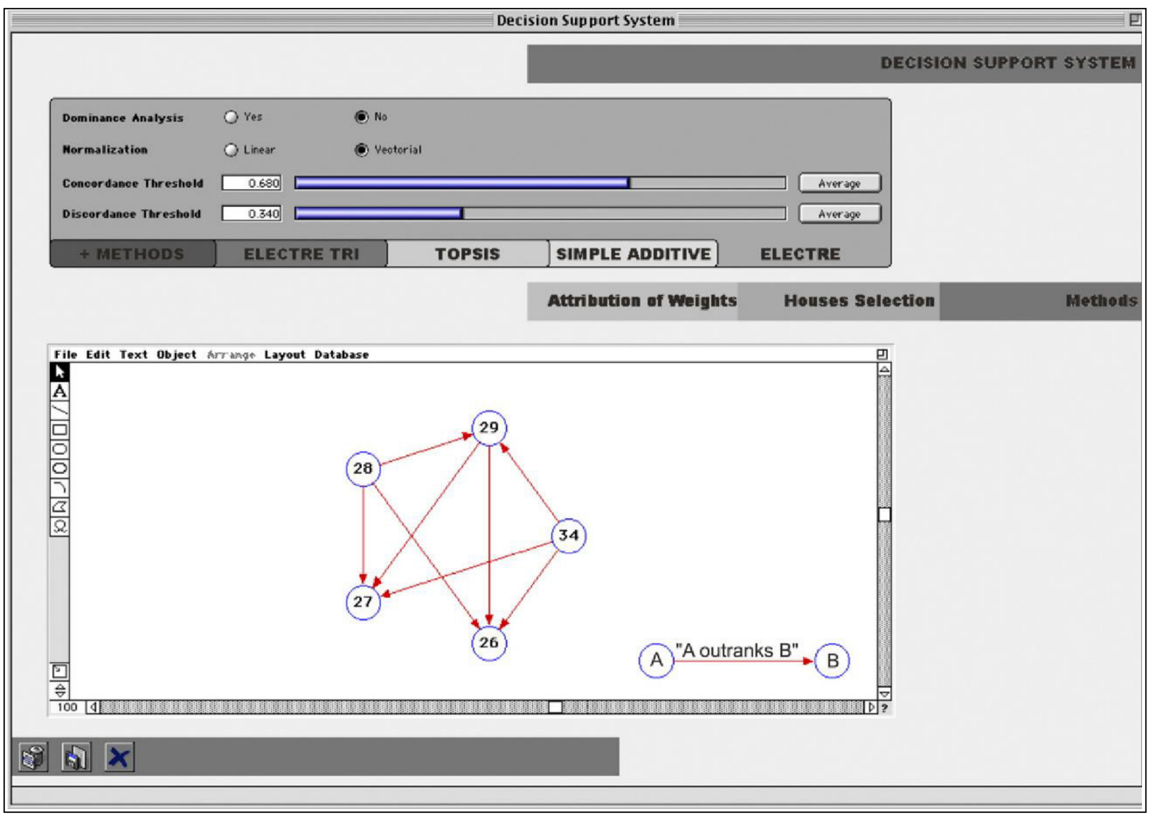

Fig. 3: ELECTRE I Results - Representation of the Out-Ranking Relationship

In ELECTRE TRI, the DSS ranks the selected alternatives according to the type of assignment, pessimistic or optimistic and depending on the user's degree of requirement. The main advantage of this method is that the required technical parameters, such as weights or thresholds for indifference, preference and veto in ELECTRE (see Fig. 2) are freely defined by the user; thus giving him/her full control over the decision process.

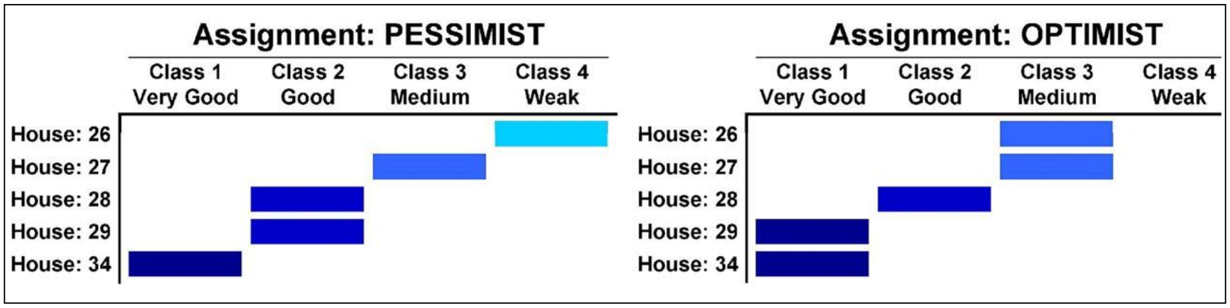

Fig. 4: ELECTRE TRI - Assignment

The main advantage of this approach is that the user can interact with the DSS in several phases of the decision process: he can filter and select, among the properties available in the system, those which, according to certain characteristics, correspond to his preferences. The main limitation of this approach is that it does not allow multiple users to make their choices throughout the decision process.

Analytic Hierarchy Process (AHP)

Some works use the AHP approach as a decision support process in the housing sector. The idea of the solution is to integrate a Geographic Information System (GIS) into the DSS that will provide the different locations with the parameters entered in the DB (Krupesh Chauhan, 2008). AHP is a decision support algorithm based on mathematics and human psychology. It involves decomposing the decision problem into a hierarchy of more comprehensible sub-problems (each of which can be analysed independently), representing and quantifying their elements, relating their elements to the overall objectives and evaluating alternative solutions (Bouyssou et al. (2006).

The hierarchical structure is composed of a variable number of levels, each subordinate to the level before it: 1) general objective - decision problem; 2) criteria (or factors) and sub-criteria (the number of sub-levels depends on the needs); and 3) possible alternatives for each criterion and/or sub-criterion. In the study conducted by Krupesh (Krupesh Chauhan, 2008):

- The overall objective of the residents' housing selection is to connect planning at the level of unit, neighbourhood, scope, guideline, finances and building materials.
- The first level of the hierarchy consists of the following criteria: infrastructure, road network, climatic conditions, availability of building materials and amenity.
- The sub-levels are made up of sub-criteria derived from the criteria of the higher level.
- The last level of the hierarchy consists of the alternatives generated by the GIS.

Once the hierarchy has been constructed, decision-makers systematically evaluate the elements that make up the hierarchy by comparing them in pairs and assigning them a "priority" weighting in relation to their impact on an element above them in the hierarchy. To make comparisons, decision-makers can use hard data or their own judgements about the significance and relative importance of elements. Stakeholders' opinions can be treated equally, or they can be weighted according to their competence, experience, connection to the issue, interest, legitimacy, etc. This technique involves an adapted questionnaire, in which stakeholders have to make redundant pairwise comparisons. In the work of Krupesh (Krupesh Chauhan, 2008), the weights were made using a matrix as shown in Table 1a, based on the authors' judgements (questionnaire) using the relative importance scale for pairwise comparison (Table 1b) (Aleksandar Rikalovic et al., 2013).

Table 1a: The Pair-Wise Combination Scale

Table 1: The pair wise combination scale	
Intensity definition explanation	
1	Equal importance two activities contribute equally to the object
3	Moderate importance slightly favor one over another
5	Essential or strong importance strongly favors one over another
7	Demonstrated importances Dominance of the demonstrated in practice
9	Extreme importances Evidence favoring one over another of highest
Possible order of affirmation	
2, 4, 6, 8 Intermediate values when compromise is needed	

Table 1b: Camparison Matrix at Level II

Table 2: Comparison Matrix at Level II

Residents' selection	Unit level	neighbor-hood	Financial	Building material	Vastu	Weight
Unit level	1	5	1	4	5	2.152
Neighborhood	1/5	1	1/4	3	4	0.903
Financial	1	4	1	2	7	2.237
BuildingMaterial	1/4	1/3	1/2	1	1	0.530
Vastu	1/5	1/4	1/7	1	1	0.372

The relative weights are calculated for each alternative (dwelling) according to a mathematical basis established by Saat. The process consists of following a path from the top of the hierarchy to each alternative at the lowest level and multiplying the weights along each segment of the path. The result of this aggregation is a normalised vector of the overall weights of the options. At the end of this process, a normalised matrix of weights for each dwelling is obtained, with the lowest weight indicating that they are the least chosen or moderately more important. This technique, although relatively simple, has several limitations:

- The explosion in the number of pairwise comparisons when dealing with a large number of items.
- The number of comparisons becomes very high when the number of criteria increases, which makes it unsuitable for problems with a large number of criteria.
- The reversal of the rank of alternatives due to the deletion/addition of one or more alternatives.

Multi-Criteria Method Based on Geographic Information Systems (GIS)

GIS is a set of procedures that enable data capture, storage and retrieval, mapping and spatial analysis for spatial and attribute data to support organisational decision-making activities. GIS are used in conjunction with other systems and methods such as DSS and multi-criteria decision making (MCDM). This approach was used in the work of Aleksandar (Aleksandar Rikalovic et al., 2013) for multi-criteria selection of an industrial site; the idea of the solution being to combine GIS with MCDM to ensure efficiency and quality of spatial analysis. The site selection process is based on a set of user-defined criteria as shown in Fig. 3. The criteria considered include: availability of skilled labour, labour costs, geographical position of municipalities and road infrastructure; each of the criteria having been weighted. In the industrial site selection phase, the role of the GIS is to geo-reference and analyse the possible alternatives which will then be taken into account in the evaluation phase. In the evaluation phase, the role of GIS is to produce criteria, constraints and suitability maps based on the results of the multi-criteria decision analysis and the value judgements of the decision makers.

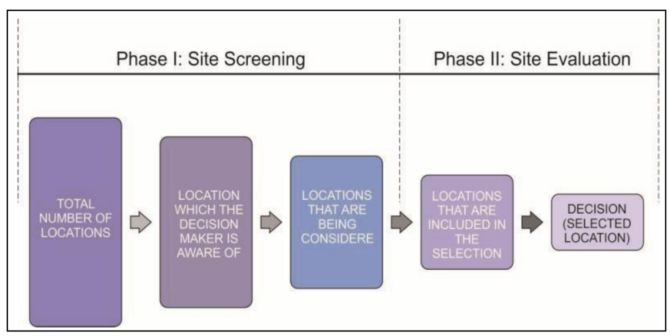

Fig. 5: Basic Steps in the Site Selection Process

Following this phase, Aleksandar (Aleksandar Rikalovic et al., 2013) proposes a GIS-based MCDM architecture with two main phases: site selection and site evaluation.

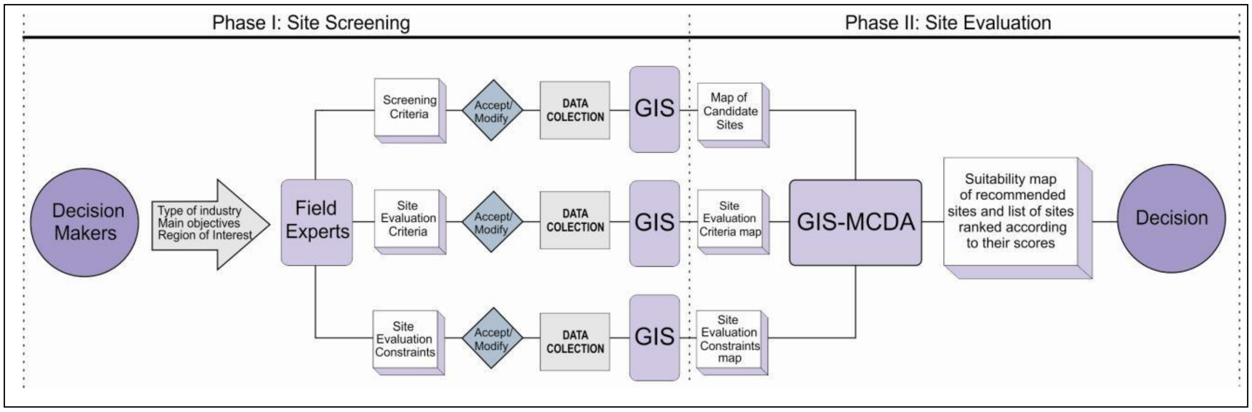

Fig. 6: Architecture of the GIS Based MCDA Approach for Industrial Site Selection

The geographical data provided in the model can be analysed according to two approaches: the map layer approach where the data are organised by theme and the object approach where the objects represent real world elements. The universal model is presented in the form of a GIS-based multi criteria analysis for the selection of an optimal industrial site in 10 steps. The developed model allows for a 10-step decision making process, with the generation of alternatives and the evaluation of alternatives using GIS and MCDM methods for industrial site selection. It has the advantage of reducing the decision making time and increasing the decision making efficiency.

Comparative Study of Existing Method Families

The Table 2 presents a comparative study of existing solutions:

Table 2: Summary of the Specificity of the Issues

	MCDM	
	MADM	*MODM*
Alternatives	Limited	Limited
Solution(s)	One or more	One or more
Criteria	Qualitative and/or quantitative	Qualitative

In this comparison, we can see that the families of multi-attribute methods, although taking into account a limited number of parameters are able to handle both quantitative and qualitative criteria, unlike the families of the second group. The Table 3 presents the classification of existing multi-attribute decision support methods dealing with the problem of housing selection.

Table 3: Comparative Table of Existing Models

Method	*Type of Procedure*	*Approach*	*Criterion Weighting*
ELECTRE TRI	Affectation	Upgrade	Yes
ELECTRE I (Is, Iv)	Choice	Upgrade	Yes
AHP	Hierarchical	Peer comparison	Yes

MODMs have several limitations: they are unable to include quantitative criteria in the decision process; they lead to the identification of a set of solutions that are quantitative criteria in the decision-making process; they lead to the identification of a set of solutions from which none can be favoured; most of the methods developed are based on a single decision-maker Most of the methods developed are based on a single decision-maker and therefore only on his/her preferences. However, the existing solutions However, the existing solutions have a common limit as regards the taking into account of the preferences of the actors involved in the decision the decision-making process. This means that the selection of a best alternative in the face of several criteria integrating various opinions remains a problem. Thanks to its capacity to take into consideration pseudo-criteria and the use of a concordance index applied to threshold criteria, which makes it perfectly adapted to this context, we use the adapted to this context, we use the ELECTRE Is method in order to propose a decision model capable of overcoming the above-mentioned limitation and further satisfying the requirements of the problem.

Multi-Attribute and Multi-Actor Model Based on ELECTRE Is

The multi-criteria model we propose is based on the ELECTRE Is method. Its role is to solve the selection problem in an environment where the parameters are fixed. The originality of this method, compared to the classical version of the ELECTRE Is method, is its ability to share the decision making among several decision makers.

The figure below present the proposed model:

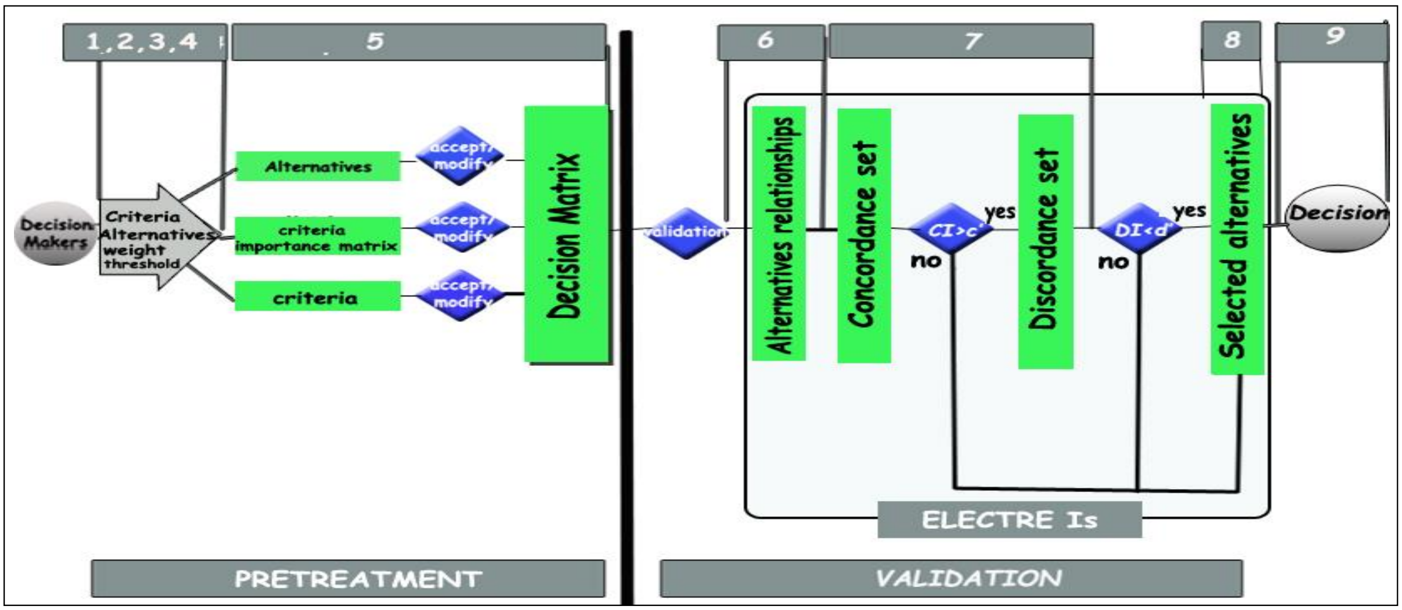

Fig. 7: Multi-Attribute and Multi-Actor Model Based on ELECTRE Is

The model has nine steps:

Step 1: Determining the Alternatives: The alternatives are the possible choices that meet the expectations of the decision-maker according to his criteria.

Step 2: Determination of the Criteria: The criteria (Cj where j =1,...,n) to be identified are the characteristics to which the decision-maker refers in order to choose an alternative during the decision support process and may vary from one decision-maker to another. These criteria can be qualitative or quantitative in nature. In our case, the criteria used are: comfort, cost, number of rooms, surface area, accessibility and safety of the neighbourhood.

Step 3: Assigning Weights to the Criteria: This step consists, firstly, in assigning the importance of n criteria by K researchers and, secondly, in calculating the weight (wj) of each criterion (Cj where j = 1... n), based on equation III.1. This makes it possible to establish the importance matrix of the criteria (W) expressed as follows:

$$W = [w_1\ w_2\ \dots\ w_n]$$

$$w_j = \frac{1}{k}[w_j^1 + w_j^2 + w_j^3 + \cdots. + w_j^k] \qquad \text{III.1.}$$

Step 4: Determination of Thresholds (Preference, Indifference and Veto): Preference thresholds designate the set of minimum values that are not significant in the choice of an alternative; indifference thresholds are the values that are clearly significant for a decision-maker; veto thresholds are the values that are clearly penalising for the choice of an alternative. All these thresholds are defined by the researcher.

Step 5: Evaluation of the Alternatives: This step makes it possible to evaluate the score (g_i (a_j)) of each housing unit (A_i, i = 1...m) based on the weight of each criterion. This work is carried out by specialists depending on the context and environment. The resulting performance table or decision matrix is as follows:

Criteria	C_1	C_2	...	C_j	...	C_n
Alternatives						
a_1	$g_1(a_1)$	$g_2(a_1)$	...	$g_j(a_1)$	...	$g_n(a_1)$
a_2	$g_1(a_2)$	$g_2(a_2)$	...	$g_j(a_2)$	...	$g_n(a_2)$
...	...	...		...		...
a_i	$g_1(a_i)$	$g_2(a_i)$	...	$g_j(a_i)$	...	$g_n(a_i)$
...	...	...		...		...
a_m	$g_1(a_m)$	$g_2(a_m)$	...	$g_j(a_m)$	...	$g_n(a_m)$
Weight	k_1	k_2	...	k_j	...	k_n
Thresholds	p_1 q_1	p_2 q_2	... ...	p_j q_j	... ...	p_n q_n
	v_1	v_2	...	v_j	...	v_n

Fig. 8: Decision Matrix

Where ($g_i(a_j)$), ∀ i,j is the score A_i (i=1,2,...,m) while satisfying the C_j criterion.

Step 6: Determining the Relationships between the Alternatives: At this stage, the relationships (aPb, aIb and aQb) between the alternatives are determined with respect to each criterion (Cj where j = 1,..., n). The pairwise comparison of the alternatives (a and b where k in [i,., m] and k 6= i) is established on the basis of equations III.2, III.3 and III.4:

$$aPb \text{ si } p_j < g_j(a) - g_j(b) \qquad \text{III.2}$$

The set of criteria for which alternative a is preferred to alternative b.

$$aIb \text{ si } g_j(a) - g_j(b) \le q_j \qquad \text{III.3}$$

The set of criteria for which alternative a does not differ from alternative b.

$$aQb \text{ si } p_j < g_j(a) - g_j(b) \le q_j \qquad \text{III.4}$$

The set of criteria for which alternative a is weakly preferred to alternative b.

This step allows us to have the local concordance tables Cj (a, b) associated to each criterion, where Cj (a, b) expresses to what extent, taking into account the thresholds, the performances of the alternatives on the jth criterion agree with the statement "a at least as good as b". It is obtained by the formula (III.2).

Step 7: Concordance and Non-Discordance Test: This step is carried out after the calculation of the concordance index (C) and discordance index (DI). Concordance index (CI): This index expresses how much the hypothesis (a outperforms b) is consistent with the reality represented by the evaluation of the alternatives (ai where i =1,...,m). We note that 0≤ C (a, b) ≤1

- Concordance Discordance Index C

$$C\ (a, b) = \frac{\sum_{1 \le j \le n} kj\ cj(a,b)}{\sum_{1 \le j \le n} kj}$$

- Discordance Index DI

$$DI_j\ (a, b) = \begin{cases} 1 & si\ gj(b) - gj(a) \le p \\ 0 & si\ gj(a) - gj(b) \le v \\ P_j - \dfrac{\left(g_j(b) - g_j(a)\right)}{p - v} & if\ not \end{cases}$$

We note that 0≤ DI(a,b) ≤ 1

Step 8: Filtering of Alternatives: This step extracts, from the potential alternatives ai (where i = 1, m), the set of alternatives that respect equation III.5. From this set, one alternative will be finally selected. This is the alternative that outranks the most alternatives. We note that S is the outranking relation (aSb means that a is at least as good as b).

$$\boldsymbol{aSb \Leftrightarrow \begin{cases} C(a,b) \ge c' \\ et \\ D(a,b) \le d' \end{cases}} \qquad \text{III.5}$$

Where:

-c' is the concordance threshold above which the aSb hypothesis will be considered valid,

-d' is the discordance threshold below which the aSb hypothesis will no longer be valid.

Step 9: Decision: This step consists of presenting the list of alternatives that meet the criteria specified by the researcher in the form of a graph, thus allowing the researcher to make the choice as easily as possible.

Case Study: Finding Accommodation in Yaoundé

In this section, we describe the case study from the point of view of alternatives, criteria and decision-makers involved in the best alternative decision process. Then, we detail the application of our model and the results obtained. Finally, we carry out a sensitivity analysis to verify the stability of the results obtained with respect to the variation in the weight of the evaluation criteria.

Development Environment

- *Operating System:* Windows 10.
- *Data Collection and Manipulation Software:* MS Excel 2016.
- *Modelling Software:* J-Electre-v3.0 which is free and open source software developed in java whose source. code we have modified to adapt it to our model.
- *Development Environment:* NetBeans IDE 8.0.2.

Presentation of the Case Study

In this case study, we apply our model to two examples with qualitative and quantitative criteria. The criteria concern the selection of a studio among six potential alternatives (C_1, C_2, C_3, C_4, C_5 and C_6) meeting the criteria as specified in Table 4 as well as the selection of a flat, among six potential alternatives (A_1, A_2, A_3, A_4, A_5 and A_6) as specified by Table 5. The decision is made by two decision-makers (D_1 and D_2) who make their choice on the basis of the following six evaluation criteria: (C_1) comfort; (C_2) cost; (C_3) number of rooms; (C_4) surface area; (C_5) accessibility and (C_6) safety of the neighbourhood.

The definitions of the evaluation criteria are given in Table 4. This table shows all the criteria, their meaning and their nature.

Table 4: Definition of Criteria

Criteria	*Definitions*	*Units*
(C_1) Comfort	Finishing and aesthetics of the accommodation (modern (M), good standard (BS), high standard (HS), very high standard (THS))	Qualitative
(C_2) Coastt	Cost of housing	Quantitative
(C_3) Number of rooms	Number of rooms in the dwelling (bedroom, living room, kitchen, shower, garage)	Quantitative
(C_4) Area	Space in square metres over which the dwelling extends	Quantitative
(C_5) Accessibility	It refers to the means of access to the dwelling (location, proximity to the paved road)	Qualitative
(C_6) Neighbourhood safety	Reputation and image of the neighbourhood	Qualitative

Table 5: Apartments Selected for the Study

	A_1	A_2	A_3	A_4	A_5	A_6
Comfort (c_1)	THS	HS	M	HS	HS	BS
Coast(c_2) in Fcfa/month	185.000	110.000	90.000	120.000	120.000	130.000
Nober of pieces (c_3)	6	5	5	5	7	6
Area (c_4) in m^2	120	120	90	92	80	136
Accessibility (c_5)	Roadside	Accessible	Roadside	Accessible	Roadside	Accessible
Security (c_6)	High	High	High	High	High	High

Application of the Method to the Case Study

To help the decision-makers (D_1, D_2) to find the best flat among the six alternatives (A_1, A_2, A_3, A_4, A_5 and A_6) facing the six criteria (C_1, C_2, C_3, C_4, C_5 and C_6) in an environment with fixed parameters, we apply our MAADM method. This application is detailed below:

Determination of Pseudo Criteria (Preference and Indifference Thresholds and Veto Thresholds)

- *Cost Criteria (C_2):* decision-makers consider a rent difference of q1=12000 to be insignificant. On the other hand, any difference of 15000 or more is clearly considered significant by the decision-maker p1=15,000. The decision-makers consider that a difference in rent of around 18000 is penalising v_1=18000
- *Number of Rooms Criteria (C_3):* q_2= 2 ; p_2=2 ; v_2=3
- *Area Criteria (C_4):* q_3= 1 ; p_3=2 ; v_3=0

The different thresholds are then normalised to conform to the values in the performance table based on the average of the costs, the number of rooms and the area.

Construction of the Criteria Importance Matrix (W)

First, each decision-maker (D = 1, 2), according to his or her preferences, linguistically estimates the importance of each evaluation criterion (C_j where j = 1, ..., 6). The estimates are then converted into weights (W_{11}, ..., W_{26}), using the measurement scale. Subsequently, the final weight of each evaluation criterion (W_1, ..., W_6) is calculated by equation III.1. From this calculation, the normalised evaluation criteria importance matrix (W) is presented in Table 8.

Table 6: Linguistic Variables of Criteria Importance

Language Term	*Weight*
Very Weak	[1-2]
Weak	[2-2.5]
Medium	[2.5-3]
strong	[3-4]
Very strong	[4-5]

Table 7: Importance of Criteria Assigned by Decision Makers

Criteria	k_1	k_2
C_1	4	4.75
C_2	3.5	3.2
C_3	3	3
C_4	2	2.5
C_5	4.5	4
C_6	5	5

Table 8: Standardised Criteria Importance Matrix

Criteria	*Weight*
C_1	0.875
C_2	0.67
C_3	0.6
C_4	0.45
C_5	0.425
C_6	0.5

Construction of the Performance Table (Decision Matrix)

The linguistic evaluation of the six alternatives against the six criteria (see Table 9) is carried out by professionals using the measurement scale presented in Table 7. The decision matrix (D) results from the calculation of the final score (g_{ij}) of each alternative against a criterion using the equation $g_{ij}=k_j.g_{\_j}$ (a) and is given in Table 8.

Table 9: Scale of Linguistic Evaluations of Alternatives

Linguistic Terms	*Note Interval*	C_1	C_2 *(Fcfa/Month)*	C_3 *(number of Pieces)*	C_4 *(m^2)*	C_5	C_6
Very weak (VW)	[0-4]						
Weak (W)	[5-9]						
Passable (P)	[10-11]						
Too good (TG)	[12-13]	Modern (standard)	≥185.000	5	80	Accessible	Good
Good (G)	[14-16]	Good standing	≥185.000	5 or 6	[80-100]	Accessible	Good
Very good (VG)	[16-17]	High standing	[150.000-180.000]	6	[100-120]	Accessible	Good
Excellent (E)	[18-19]	Very high standing	[100.000-145.000]	6 and more	[130-160]	Roadside	Good
perfect (P)	[19-20]	Luxurious	[80000-100000]	6 and more	≥160	Roadside	Good

Determining the Relationships between the Alternatives

Once the decision matrix (D) has been constructed and using equations III.2, III.3 and III.4, we carry out pairwise comparisons between pairs of alternatives A_i and A_k (where k ∈ [1, 2, 3]) according to their final score (g_{ij}) against a given criterion; this allows us to obtain the local agreement matrices associated with each criterion thanks to equation (III.2). From this matrix, we can then extract the global concordance and discordance matrices associated with each pair (a_i, g_i).

Table 10: Performance Matrix of ELECTRE Is

Actions: 6 Criteria: 6 Matrix Solve Graph Save

Matrix	g1	g2	g3	g4	g5	g6
Q	0	12	2	10	0	0
P	0	15	2	15	0	0
V	0	18	1	20	0	0
W	0.875	0.67	0.6	0.45	0.425	0.5
a1	16,42375	9,3599	11,262	8,3655	8,075	8,75
a2	16,8	12,864	8,328	8,3655	7,48	9,99
a3	17,22	13,1856	8,322	6,948	8,075	8,99
a4	14,84875	12,6831	8,322	7,047	8,01975	9
a5	14,74375	12,6496	12	5,85	8,16	9
a6	16,2225	12,4218	10,2	8,1	8,44475	9,15

Table 11: Global Concordance Matrix

	a1	a2	a3	a4	a5	a6
a1	-	0.6094	0.6094	0.858	0.7372	0.7372
a2	0.7088	-	0.6307	0.8793	0.7088	0.8793
a3	0.8295	0.858	-	0.858	0.5668	0.7372
a4	0.4602	0.6094	0.6307	-	0.7088	0.4886
a5	0.7514	0.6094	0.7514	0.7514	-	0.4886
a6	0.7514	0.6094	0.7514	1.0	1.0	-

Table 12: Global Discordance Matrix

	a1	a2	a3	a4	a5	a6
a1	-	1.0	1.0	1.0	1.0	1.0
a2	1.0	-	1.0	1.0	1.0	1.0
a3	1.0	1.0	-	1.0	1.0	1.0
a4	1.0	1.0	1.0	-	1.0	1.0
a5	1.0	1.0	1.0	1.0	-	1.0
a6	1.0	1.0	1.0	0.0	0.0	-

We note that $0 \leq DI(a, b) \leq 1$

Concordance and Non-Concordance Testing

From the results obtained previously, it becomes possible to determine the best alternative(s). To do this, we perform a concordance test and a non-mismatch test using equation III.5 and the ELECTRE Is outranking algorithm. For the first test, the concordance test, we take the threshold c'=0.7 and for the non-mismatch test, we take the threshold d'=0.3; this allows us to have the Electre IS outranking matrix presented as follows:

Table 13: Upgrade Matrix

	A_1	A_2	A_3	A_4	A_5	A_6
A_1	-	1	1	1	1	1
A_2	1	-	1	1	1	1
A_3	1	1	-	1	1	1
A_4	1	1	1	-	1	1
A_5	1	1	1	1	-	1
A_6	1	1	1	0	0	-

Alternatives Filtering and Decision

Based on these two tests, we can conclude that the relationships CI (A_4, A_6) and CI (A_5, A_6) satisfy the concordance test. DI (A_4, A6) and DI (A_5, A_6) do not satisfy the non-discordance tests. This means that the relationships (A_4, A_6) and (A_5, A_6) are the only valid outranking relationships, as they are sufficiently consistent and also sufficiently inconsistent with the hypothesis "A_4 outranks A_6 and A_5 outranks A_6". Therefore, the best alternatives that are part of the core and are not outclassed by any other action are: N= {A_4, A_5}. We represent these results in the graph shown in Fig. 9. This figure shows the outranking relationship between the pairs of alternatives.

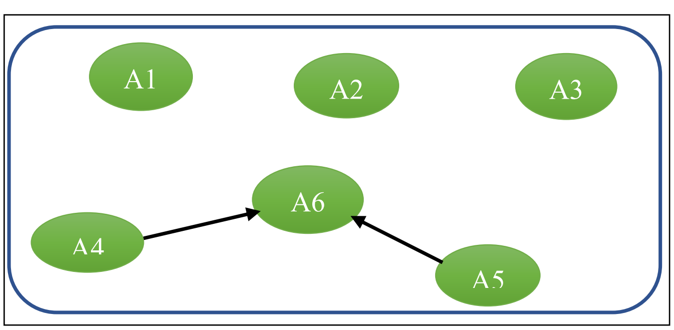

Fig. 9: Upgrade Graph

Sensitivity Analysis

The aim of this section is to carry out a sensitivity analysis (see Table 14), based on several scenarios. The objective is to verify the stability of the results obtained with respect to the variation of the weights of the criteria used to evaluate the different potential alternatives. To do this, we apply our method to five experiments while varying the weights of the evaluation criteria in each experiment. This allows us to study the impact of the change in weight of the evaluation criteria on the selection of the best flat.

Table 13 shows the weights assigned to the evaluation criteria and the location(s) selected in each experiment.

- In the first experiment, all the weights of the alternatives are set to zero. In this case, it can be seen that no alternative is retained; which confirms the fact that the model is strongly dependent on the priorities in the choice of criteria.
- In experiments 2 and 3, all the weights have been equalised; it can be seen that the alternatives considered as the best are A_4 and A_5.
- In experiments 5 and 6, criteria C_1 and C_2 were maximised and all others minimised to the same weight; alternative A_4 is considered the best.
- In experiment 7, criteria C_1 and C_2 were minimised and the others maximised to 1. It can be seen that alternatives A_4 and A_5 are proposed as the best.
- These results prove that our method remains stable for intervals of the weights assigned to the six criteria. They also show that the criteria that most closely condition the chosen alternative in our practical case are the comfort and cost criteria.

Table 14: Sensitivity Analysis

Experiment Number	*Description*	*Selected Alternatives*
1	All criteria weights =0	No alternative selected
2	All criteria weights =0.5	A_4 and A_5
3	All criteria weights =0.8	A_4 and A_5
4	All criteria weights =1	A_4 and A_5
5	C_1= 1, C2=1 and weight of other criteria =0.5	A_4
6	C_1= 1, C2=0.8 and weight of other criteria =0.5	A_4
7	C_1= 0.5, C2=0.5 and weight of other criteria =1	A_4 and A_5

Conclusion

The purpose of this article was to propose an optimised process for finding a house in the major cities of Cameroon. Therefore, a multi-attribute and multi-actor process model has been developed in nine steps. This process model is based on the ELECTRE Is method, whose objective is to select the best alternative among a set of potential alternatives. To achieve this objective, our model evaluates the different alternatives not only according to various criteria but also by taking into account the matching preferences of several decision-makers involved in the decision process. In this process, each decision-maker is invited to express his or her preferences, on the one hand, on the importance of the evaluation criteria and, on the other hand, with regard to all the potential alternatives. In order to illustrate the interest of the model, we conducted a case study to choose a better flat in the city of Yaoundé among six potential alternatives. These alternatives are evaluated by two decision-makers against six criteria. The results obtained show that the model meets the desired objective. On the other hand, in order to verify the reliability of the result provided by this model and its sensitivity to variations in the weights attributed to the evaluation criteria by the decision-makers, we conducted a sensitivity analysis based on seven experiments. The results showed that our model remains stable for intervals of the weights attributed to the six criteria. They also show that the criteria that most closely condition the alternative chosen in our practical case are the comfort and cost criteria. Although our model meets the different objectives set in advance and allows for a more accurate multi-actor choice among a set of multi-criteria alternatives, it remains limited in terms of taking into account threshold values for qualitative criteria, which can have an impact on the alternatives selected and therefore on the final decision. To overcome this limitation, one solution would be to set up a mechanism that allows qualitative thresholds to be taken into account. It would also be relevant to test our model on other real problems in various fields in order to validate its generalisation. As data and needs are extremely variable and evolve over time, it is appropriate to propose an adaptation in the Big Data context.

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