Managing criteria direction in Multi-Criteria Decision-Making Models for Facility Location Selection: a case study in African Developing Countries

Marino Lauria S.*, Bait S.*, Schiraldi M.M.*

* *Department of Enterprise Engineering, University of Rome "Tor Vergata", Via del Politecnico 1- Rome – Italy (serena.marino.lauria@uniroma2.it ; stefania.bait@uniroma2.it ; schiraldi@uniroma2.it)*

Abstract: Multi-criteria decision-making (MCDM) models are widely used to evaluate criteria involved in assessing different alternatives. The methodology requires the definition of criteria weights. Among all the techniques applied to solve MCDM problems, the Analytic Hierarchy Process (AHP) is the most used. Specifically, it aims at determining weights through pairwise comparisons of criteria, asking the respondent whether one criterion is more important than another. Once the relative criteria importance is defined, the weights are inserted in the objective function to identify the best solution. However, typical AHP questionnaires implicitly assume that compared criteria have the same positive/negative impact on the objective function for all respondents; on the contrary, although two experts may agree that a criterion is highly important, one may intend that the objective function should maximize that criterion, the other may imply that it should minimize it. While in AHP theory this problem is addressed by incorporating negative values or clustering criteria that are opposite in direction into costs and benefits, there is no evidence that it has been faced in facility location selection problems, where multi-criteria approaches are crucial; indeed, it is worth noticing that, in industrial plant location choice, criteria direction strongly depends on sector typology and company strategy. As a result, it is not appropriate to assume the positivity or negativity of a criterion in advance. This paper aims at showing how the different direction of the criteria can significantly alter the results within a case-study for industrial plant location selection in developing countries. Specifically, on the one hand, it is demonstrated that assuming the same criteria direction can lead to incorrect evaluations and, on the other hand, practical suggestions for the development of facility location multi-criteria surveys are provided.

Keywords: Multi-criteria decision making; AHP; Industrial Settlements; Criteria direction; Facility Location Selection; Developing Countries Industrialization.

1. Introduction

The facility location problem is a process that involves several manufacturing companies that seek to start or expand their business in foreign countries. It is well known that a non-optimized selection can adversely affect plants performance (Yang & Lee, 1997). Among all the models, manufacturing companies can rely on multi-criteria decision-making models (MCDM) to select plant location, usually based on Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methodologies.

The analytic hierarchy process (AHP) is a technique through which it is possible to determine the preferences of a subject or group within a decision-making process from criteria pairwise comparisons (Saaty, 2001; Saaty, 2000). Once the criteria involved in evaluating several alternatives have been identified, pairwise comparisons are made between all the criteria to define their weights. The identified weights are then entered into the objective function aiming at determining the best alternative.

Typical AHP questionnaires cluster criteria as costs or benefits according to general assumptions, without analyzing specific respondent evaluations. Questionnaires compare paired criteria with the imposed restriction that have both the same – positive or negative – impact on the objective function. Actually, in decision-making, there are often criteria that are opposite in direction to other criteria and sometimes need to be distinguished by using negative numbers (Ozdemir & Sahin, 2018). Nevertheless, AHP applications to industries location choices seem not to adequately consider the opposite criteria direction. Location selection is strictly related to the company strategy, which also depends on the sector typology, and it is not possible to beforehand determine the positivity or negativity of a criterion. Hence, whereas for one company a criterion is strategically assessed with positive impact - thus to be maximized - for another one it can be negatively ranked - thus to be minimized.

This paper aims at consolidating the methodology to be used for a production plant location selection, mainly showing the impact of criteria direction on the AHP results. Particularly, it aims to analyse the effect of the criteria direction within a case study on the selection of facility location in developing African countries. Indeed, developing countries, particularly African ones, are becoming an attractive destination for manufacturing companies, and to fully exploit their opportunities there is the need to minimize the risks through a multi-criteria-model that matches the industries requirements to the countries characteristics.

After reviewing the literature about the AHP technique and its application to location selection problems in section 2, the approach is proposed in section 3. Subsequently, the AHP survey is developed and integrated with the criteria direction questions. As reported in section 4.1, four companies belonging to various sectors filled the questionnaire confirming that different sectors can have different criteria directions. Particularly, in section 4.2, gathered weights and directions are applied to a model that ranks the most suitable African countries based on the selected company requirements. Specifically, the model uses AHP methodology to weight criteria and TOPSIS one to rank countries. The application shows how dissimilar directions can strongly affect location selection. Finally, in section 5, conclusions and future development are outlined.

2. Literature and methodology review

The literature review is divided into three parts. The first is related to AHP methodology, mainly investigating how negative criteria are managed when combined with positive ones. The second investigation area concerns the specific AHP usage for location decision models, mainly for manufacturing industries production facilities. Finally, a brief insight on African industrialisation opportunities is provided to show the strong interest in analysing a model that guide facility location in African developing countries.

The Analytical Hierarchy Process (AHP) is a technique introduced in the 1970s, and it is used for managing complex decisions (Saaty, 2001; Saaty, 2000; Aragonés-Beltrán, et al., 2014). Among all the MCDM tools, AHP is one of the widely used due to its ability to compare performance among numerous alternatives (Mark Velasquez, 2013). It aims at structuring complex problems in a hierarchical structure by evaluating all relevant criteria in decision making (White, 1987; Talinli, et al., 2011). AHP is used for several investigations due to its interesting features, such as follows (Aragonés-Beltrán, et al., 2014; Choudhary & Shankar, 2012; Uyan, 2013): (i) it allows to manage complex, not structured, and multi-attribute problems (ii) it helps in analysing significant problems dividing them in more straightforward and affordable sub-systems (iii) it uses a hierarchical structure to deal with complicated decision issues (iv) it can be applied on quantitative and qualitative data (v) it gives the possibility to measure the consistency of the evaluation procedures (vi) its solution can be calculated by using simple tools. Notably, literature reviews show that AHP is widely used to calculate the weight of criteria, while other techniques such as TOPSIS are used to evaluate alternatives. (Rosaria de Russo, 2015). To better understand the AHP procedure, a summary of the primary procedure steps (Uyan, 2013) is provided in Appendix A. As anticipated, AHP measurement is based on comparing criteria in pairs with the imposed restriction that both are positive, however, in decision-making, there are often criteria that have opposite directions, and sometimes need to be distinguished by using negative numbers (Saaty & Ozdemir, 2003; Ozdemir & Sahin, 2018). The positive and negative criteria impact in AHP is an addressed problem in the literature (Millet & Schoner, 2005; Saaty & Ozdemir, 2003; Tchangani, 2012; Pedro Godinho, 2011). However, among all the proposed solution, no one suggests the criteria evaluation for each specific respondent.

AHP is used in different fields due to its potential and adaptability. Some researchers provide a comprehensive list of AHP applications in operations management. Based on their review, they suggest extending the use of AHP to other sectors, including manufacturing industries (Subramanian & Ramanathan, 2012). The plant location selection, commonly known as "facility location problem", is a manufacturing companies' key choice and it can affect both cost and performance (Yong, 2006). It is a fundamental application of the AHP, which can assist managers in analysing various location factors, evaluating location site alternatives, and making final location selections (Yang & Lee, 1997). In this section, some of the most recent applications of AHP for facility location problems are analysed. The analysis highlights that the directions of the criteria are not addressed in facility location MCDM models. In the first analysed study, the AHP model has been formulated and applied to a real case to select the plant location for a manufacturing industry (Gothwal & Saha, 2015). Here, all factors affecting the plant location have been identified but the direction of the criteria has not been considered. Among the highlighted criteria there are market size and proximity to consumers, suppliers, and industrial sites; for instance, these specific criteria are among those that may be controversially interpretated by respondents, as it is shown later in this paper. Indeed, although a generic preference for these criteria might be assumed, this cannot be necessarily given for granted. For example, there are cases where a company may prefer to be away from other industrial sites so that their employees do not increase the turnover rate by being able to choose between several companies to be employed by. Similarly, among the criteria highlighted by Gothwal there is also the climate: but a company might prefer a warm climate rather than a cold climate depending on its production process. Thus, knowing that the climate is an important factor – but not knowing if a warm or a cold environment is preferable – it may be impossible to translate the AHP results into an immediate selection of the ideal territory for the facility location. Another study from Rikalovic et al. listed the most important factors for facility location from the investors perspective (Rikalovic, et al., 2014): however, in this application the respondent is asked if one criterion is more important than another but is not asked whether a high value of that criterion rather than a low one is preferred. Another study (Ramya & Devadas, 2019) identified suitable locations for agro-based industrial use in India: here, AHP and TOPSIS techniques have been applied to provide pairwise comparison between criteria for priority ranking industrial location. Settlements, labour availability, location of barren lands, climate and proximity of major functional centres are some of the parameters considered in this study. However, criteria direction has not been fully investigated to correctly evaluate experts' opinions in determining the parameters weights and subsequently, the industrial location suitability map. Thus, according to the literature findings, there is no evidence of per-respondent criteria direction evaluation in facility location problems using AHP.

Several studies had highlighted that Africa offers many opportunities for manufacturing industries (Marino Lauria, et al., 2020; Opoku & Yan, 2019; Signé, 2018; Bank-Group, 2017; Fessehaie & Rustomjee, 2018; UNDP, 2013). However, industrialization is constrained by a set of limitations, among the ability of companies to deliver goods, the infrastructures quality, human capital education, and political stability (Davies, 2012; Zeparu, 2014). Validating a facility location problem in Africa is a necessary study to give investors comfort around mission protection and social value creation (UNDP, 2013). For these reasons, the proposed case study is applied to the establishment of a manufacturing company in African developing countries.

3. Proposed approach: AHP questionnaire with criteria direction integration

The literature review revealed the need to integrate AHPs related to facility location problems with criteria direction evaluation. The followed approach consists of two phases. First, the criteria were collected, then the AHP questionnaire was constructed and integrated with questions related to criteria direction.

As anticipated, first the criteria involved in a new manufacturing settlement strategic location choice in a foreign country have been defined. Specifically, those criteria have been firstly gathered from literature (Marino Lauria, et al., 2020), secondly discussed and validated with a panel of experts within the Operations Excellence Think Tank (TTOPEX) of "Tor Vergata" University of Rome. The TTOPEX was founded in 2019 to share information, exchange ideas, create knowledge, and disseminate Operations Excellence best practices in industries. It is currently composed of 12 experts with managerial or executive positions in various multinational companies operating in different industries: production of robotics and automation technologies, consumer goods, food, beverage, pharmaceutical, and textile manufacturing. Specifically, the validation method followed was the Delphi one. In fact, the TTOPEX panel of experts has been asked to express opinions through questionnaires and open emails to validate the criteria through mutual comparison and progressive sharing. A total of 7 macro-criteria and 34 sub-criteria were identified. The criteria structure is collected in Figure 1.

Secondly, the AHP questionnaire was designed specifying to the respondents that its goal is to rank and select the most suitable country for their specific process requirements. The questionnaire has the following features:

1) Respondents are asked to pairwise compare the 7 macro-criteria with a total of 21 questions.
2) For each macro-criterion, users are asked to select only the sub-criteria they consider relevant for their production facility location choice.

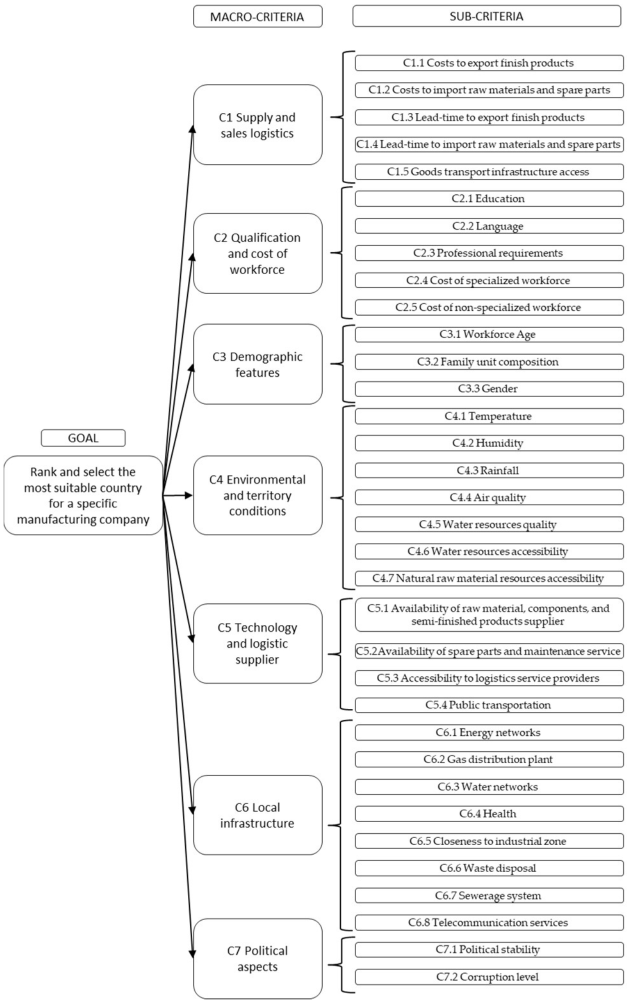

Figure 1: criteria involved in choosing a location in a foreign developing country

3) Only for those sub-criteria judged relevant, the paired comparison is required. This feature reduces the number of questions that a respondent is asked to give.
4) Confirmation about the direction is finally required for each sub-criterion (see Table 1 inside paragraph 4.1 for the case study details). Specifically, it is asked whether that criterion is preferable to have a high or low value. In fact, one criterion may be more important than another, but while one respondent may intend to maximise it the other to minimise it.

The used scale to pairwise compare the criteria is a discrete one from 1 to 9 where 1 represents the equal importance of two factors and 9 is the highest possible importance of one factor over another (Saaty, 1994). To build the questions, the following process was followed:

1) An a priori analysis was carried out to hypothesise the most likely direction of the criteria. This direction would have been the one used if respondents had not been asked for their criteria direction assessment. More clearly, the predictable direction would be, for example, costs and time to be minimised and accessibility to be maximised. 2) Questions to gather indications on the direction of the criteria were formulated, asking if it is better that each parameter increases (↑) or decreases (↓).

Then, the responses about the criteria direction can be analysed. Finally, the identified criteria weights and direction can be inserted into a TOPSIS and AHP model for the selection of the African country in which to locate a manufacturing plant (methodology in Appendix C).

4. Case study results

The questionnaire was filled by four respondents, each representing a different company, respectively operating in electrotechnics, beverage, chemical-pharmaceutical-cosmetic (CPC), and fashion retail (FR) sectors. The Appendix B shows the complete results of the application, i.e. the weights and directions of the four companies. The next paragraphs first show how different companies have different direction evaluations based on their own production process and strategy. Secondly, the criteria weights and directions are used within a model aimed at identifying the best industrial location in Africa.

4.1 Criteria direction comparison among sectors

As mentioned above, the first type of carried out analysis is about the criteria direction. The *a priori* supposed directions and the criteria directions preferred by the majority are reported in Table 1. The (↑↓) symbol indicates where the vote ended in tie.

Table 1: questions related to criteria direction

Supposed directions	ID	Supposed directions	Majority directions
Costs for export procedures for finished products.	C.1.1	↓	↓
Costs for import procedures of raw materials, components, semi-finished products, and parts.	C.1.2	↓	↓
Time for exporting finished products to target markets.	C.1.3	↓	↓
Supply times for raw materials, components, semi-finished products, and parts.	C.1.4	↓	↓
Accessibility to freight infrastructures (airports, ports, railways, and motorways).	C.1.5	↑	↑
Average level of education of the workforce.	C.2.1	↑	↑
Level of knowledge of the interchange language.	C.2.2	↑	↑
Average level of existing professionalism.	C.2.3	↑	↑
Average cost of specialised labour.	C.2.4	↓	↓
Average cost of unskilled labour.	C.2.5	↓	↓
Average age of the workforce.	C.3.1	↓	↑
Household size.	C.3.2	↓	↑
Gender balance of the workforce.	C.3.3	↑	↑
Average annual temperature.	C.4.1	↑	↓
Average humidity level.	C.4.2	↓	↑↓
Average precipitation level.	C.4.3	↓	↑↓
Air quality level.	C.4.4	↑	↑
Quality level of the natural water source.	C.4.5	↑	↑↓
Accessibility to natural water sources (groundwater and surface water).	C.4.6	↑	↑
Accessibility to natural sources of raw materials (deposits, rare earths, cotton, etc.).	C.4.7	↑	↑↓
Accessibility to suppliers of raw materials, components, semi-finished goods, and parts.	C.5.1	↑	↑
Accessibility to suppliers of maintenance services and spare parts.	C.5.2	↑	↑
Accessibility to freight logistics service providers.	C.5.3	↑	↑
Accessibility to public transport systems for employees.	C.5.4	↑	↑
Accessibility to electrical infrastructure.	C.6.1	↑	↑
Accessibility to water infrastructure.	C.6.2	↑	↑
Accessibility to gas infrastructure.	C.6.3	↑	↑↓
Accessibility to public or private health services.	C.6.4	↑	↑
Distance from other industrial areas.	C.6.5	↓	↑↓
Accessibility to infrastructures for the treatment of industrial sewerage and effluents.	C.6.6	↑	↑
Accessibility to waste management and treatment service: the higher the better.	C.6.7	↑	↑
Accessibility to telecommunication networks.	C.6.8	↑	↑
Political stability.	C.7.1	↑	↑
Level of corruption.	C.7.2	↓	↓

Complete results on the criteria direction of the four companies can be found in Appendix B. The results demonstrated that not all the assumed directions coincided with the respondents' evaluation, which can change from sector to sector, from company to company. Figure 2 shows those criteria for which the respondents rated criteria direction differently. On the x-axis the criteria are reported, on the y-axis it is specified whether that criterion is to be minimised or maximised for the related company, as per legend. Despite the experts agreed on the importance of including these criteria in the AHP, most of them had conflicting opinions on maximising or minimising them.

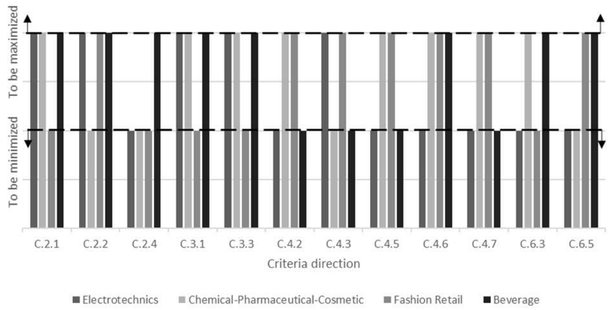

Figure 2: different criteria directions among respondents

Specifically, the following 12 sub-criteria out of a total of 34 recorded different evaluations between the four respondents:

1. Average level of education of the workforce.
2. Level of knowledge of the interchange language.
3. Average cost of specialised labour.
4. Average age of the workforce.
5. Gender balance of the workforce.
6. Average humidity level.
7. Average precipitation level.
8. Quality level of the natural water source.
9. Accessibility to natural water sources.
10. Accessibility to natural sources of raw materials.
11. Accessibility to gas infrastructure.
12. Distance from other industrial areas.

For example, the level of temperature and humidity may depend on the requirements of the production process. The distance from other industrial areas may be preferred high so that employees cannot easily find a new job with competitive salaries. However, for another respondent it might be preferred to be low to benefit the commodities of an industrialised area. Analysing the workforce age and level of education, it is interesting to note that some companies prefer young people not highly educated workforce, while others look preferably for highly educated adults.

4.2 Application to a facility location problem in African countries

This section aims to demonstrate how dissimilar directions evaluations can lead to different results. To achieve this objective, the identified criteria weights and direction have been fed into a TOPSIS and AHP model to select the African country in which to locate a manufacturing plant. More details on the model are briefly reported in Appendix C. The model has been implemented on the CPC company by applying its own criteria weights alternately using:

1) its own criteria direction, namely the criteria directions of the CPC company.
2) the criteria directions that would have been assumed if the criterion direction analysis was not executed, i.e. the supposed directions in Table 1.
3) the criteria directions that prevailed among the four companies, i.e. the most voted directions (Table 1 - majority directions). Where the vote ended in tie, the supposed directions have been used.

Table 2 shows the fifteen most suitable African countries according to the CPC company weights, and the different criteria directions applied. The "CPC directions" column shows the ranking considering the directions provided by the own CPC company. The "Supposed directions" column shows the ranking applying the directions that would have been assumed without the evaluation. The "Majority directions" column shows the ranking by applying the predominant directions among the four companies.

Table 2: results applying different directions of the criteria

Rank	CPC directions	Supposed directions	Majority directions
1	Namibia	Botswana	Namibia
2	Malawi	Zimbabwe	Malawi
3	Central African Republic	Cabo Verde	Central African Republic
4	Senegal	Madagascar	Senegal
5	Mauritania	Mozambique	Nigeria
6	Nigeria	Ghana	Mauritania
7	Comoros	Egypt	Comoros
8	Morocco	Libya	Morocco
9	Sao Tome and Principe	Mauritius	Sao Tome and Principe
10	Benin	Togo	Benin
11	Egypt	Tanzania	Egypt
12	South Africa	Eritrea	South Africa
13	Sierra Leone	Lesotho	Sierra Leone
14	Cote d'Ivoire	Guinea-Bissau	Cote d'Ivoire
15	Somalia	Benin	Cameroon

Applying the model with the CPC company own weights and directions, Namibia ranks first as a suitable country, followed by Malawi and the Central African Republic. If the directions were supposed, as in Table 1, without adding the ad hoc evaluation for each respondent, the ranking would have been different. In fact, in this case, Botswana would have been at the first position. It is interesting to note that in the "CPC directions" classification, Botswana would only have twenty-third place. Similarly, Namibia, which is in first place in the "CPC directions" ranking, would be at the thirty-second place using the supposed directions. Thus, disregarding the precise direction of the criteria would lead to a very inconsistent result. Conversely, it is evident that using the four companies' predominant directions would minimise the error: only Mauritania and Nigeria assume different rankings. However, this error is minimised because the company has similar directions to the majority ones. If the same analysis were executed on the FR company, whose directions evaluations deviate more from the majority, the rankings would be even more sensitive (Table 3).

Table 3: FR results applying its own & majority directions

Rank	FR directions	Majority direction
1	Mauritius	Botswana
2	Botswana	Mauritius
3	Rwanda	Morocco
4	Morocco	Rwanda
5	South Africa	South Africa
6	Kenya	Namibia
7	Namibia	Kenya
8	Lesotho	Djibouti
9	Benin	Lesotho
10	Eswatini	Benin

Hence, including wrong directions in a facility location model leads to inconsistent and wrong results. The same analysis can be replicated for the other three companies, and the results invariably would show different rankings based on different directions.

5. Conclusions and further developments

This paper aimed to show the importance of evaluating the criteria direction in the AHP methodology. In fact, typical AHP questionnaires have the imposed restriction that compared criteria have the same impact to every respondent's objective function. Although two experts may agree that a criterion is fundamental one may intend that the objective function should maximize that criterion, the other may imply that it should minimize it. Particularly, it has been shown how criteria directions can have different orientations among different respondents. Hence, considering the same criteria directions for all respondents is unrealistic. This is particularly true when it concerns strategic business choices, such as production plant location selection. Specifically, there is no evidence of criteria direction integration in literature, especially in the latest uses of AHP in location problems. Integrating questions about the criteria direction into the AHP methodology gives robustness to the method and avoids incorrect results. In this paper, four companies' weights and directions have been collected and fed into a MCDM model aimed at selecting the best African developing country based on company requirements. Alternately changing different directions of the criteria, it is shown how not considering the criteria directions can lead to inconsistent choices. Indeed, the rankings are strongly sensitive to the applied directions (Table 2). Consequently, the criteria direction is a critical assessment to insert in MCDM models to achieve sustainable choice. In this paper the application focused only on one of the four companies, but the same analysis could be further done for the others. Furthermore, it could be interesting to collect data from other companies in the same sector to study common characteristics between sectors and cluster criteria directions according to the production process.

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Appendix A: AHP methodology

Step 1: set the criteria to select the best alternatives. The selected criteria should be measurable, helping the alternative enumeration (Vereecke, et al., 2006). **Step 2:** paired compare criteria and alternatives using each criterion. Create a matrix based on the expert's pairwise comparisons, using the fundamental scale from 1 to 9 explained in Table 4:

Table 4: AHP criteria evaluation scale

Values of scale	Meaning
1	Equal importance
3	Weak importance on one over another
5	Essential or strong importance
7	Demonstrated importance
9	Absolute importance
2,4,6,8	Intermediate values between the two adjacent judgements
Multiplicative inverse	$a_{ji} = \frac{1}{a_{ij}}$

The obtained matrix is a *nxn* one, where n denotes the number of criteria. **Step 3**: compute a normalized pairwise comparison matrix with the following procedure:

a. Compute the sum of every column.
b. Divide every member of the matrix respectively by its related column sum.
c. Average the rows to obtain relative weights.

Step 4: calculate Eigenvector, maximum Eigenvalue, and Consistency Index (CI) that is calculated as follow:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

Where, λ_{max} is Eigenvalue of paired comparison matrix and n is the number of criteria. **Step 5:** calculate Consistency Ratio (C.R.) as follows:

$$CR = \frac{CI}{RI}$$

R.I. is the random index; its values are based on the matrix size and are showed in the Table 5:

Table 5: random consistency index (R.I.)

Matrix Size	Random consistency index (RI)
1	0.00
2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

The acceptable range of C.R. value strictly depends on the matrix order, e.g. C.R. value for a 3×3 matrix is 0.05, for a 4×4 matrix is 0.08, and 0.1 for orders≥5 (Saaty, 2008).

Appendix B: AHP results

In Table 6 the four companies' criteria directions (D) and weights (W) are reported.

Table 6: directions and weights from the application

ID	Electrotechnics		CPC		FR		Beverage	
C	D	W	D	W	D	W	D	W
1.1	↓	0.0279942	↓	0.02322187	↓	0.10195	↓	0.01208
1.2	↓	0.0358638	↓	0.02464191	↓	0.10195	↓	0.01208
1.3	↓	0.0279942	↓	0.06181687	↓	0.10195	↓	0.00807
1.4	↓	0.03192907	↓	0.02356187	↓	0.10195	↓	0.00807
1.5	↑	0.0202439	↑	0.0359443	↑	0.10195	↑	0.00444
2.1	↑	0.01851713	↑	0.01593883	↓	0.00375	↑	0.01384
2.2	↑	0.00867012	↓	0.0068605	↑	0.00375	↑	0.01384
2.3	↑	0.00867012	↑	0.00809001	↑	0.00375	↑	0.01384
2.4	↓	0.0048007	↓	0.0082490	↓	0.00375	↑	0.01384
2.5	↓	0.00942845	↓	0.00656842	↓	0.00375	↓	0.01384
3.1	↑	0.09779308	↑	0.10073638	↓	0.01098	↑	0.10731
3.2	↑	0.12321155	↑	0.10073638	↑	0.01098	↑	0.10731
3.3	↑	0.15523683	↑	0.10073638	↓	0.01098	↑	0.10731
4.1	↓	0.03009328	↓	0.01859360	↓	0.02372	↓	0.01623
4.2	↓	0.03009328	↑	0.01859360	↑	0.02372	↓	0.01623
4.3	↑	0.03009328	↓	0.03098289	↑	0.02372	↓	0.03274
4.4	↑	0.03009328	↑	0.02900685	↑	0.02372	↑	0.01623
4.5	↓	0.03009328	↑	0.02659848	↑	0.02372	↓	0.01934
4.6	↓	0.03009328	↑	0.01859360	↑	0.02372	↑	0.01914
4.7	↓	0.03009328	↑	0.01032018	↑	0.02372	↓	0.01246
5.1	↑	0.03397636	↑	0.01331145	↑	0.02685	↑	0.01806
5.2	↑	0.03397636	↑	0.05528685	↑	0.02685	↑	0.01806
5.3	↑	0.03397636	↑	0.03259251	↑	0.02685	↑	0.01806
5.4	↑	0.03397636	↑	0.02894839	↑	0.02685	↑	0.09034
6.1	↑	0.00536500	↑	0.00513335	↑	0.00941	↑	0.00169
6.2	↑	0.00737421	↑	0.00877902	↑	0.00941	↑	0.00196
6.3	↓	0.00737421	↑	0.03771000	↓	0.00941	↑	0.00196
6.4	↑	0.00790149	↑	0.01889876	↑	0.00941	↑	0.00278
6.5	↓	0.01535649	↓	0.04054963	↑	0.00941	↑	0.00196
6.6	↑	0.00737421	↑	0.02000989	↑	0.00941	↑	0.00196
6.7	↑	0.00737421	↑	0.03054630	↑	0.00941	↑	0.00196
6.8	↑	0.00590018	↑	0.00692061	↑	0.00941	↑	0.00196
7.1	↑	0.00953405	↑	0.01576056	↑	0.04484	↑	0.13541
7.2	↓	0.00953405	↓	0.01576056	↓	0.04484	↓	0.13541

Appendix C: Countries ranking methodology

The methodology used to evaluate African countries ranking is presented in the Figure 3.

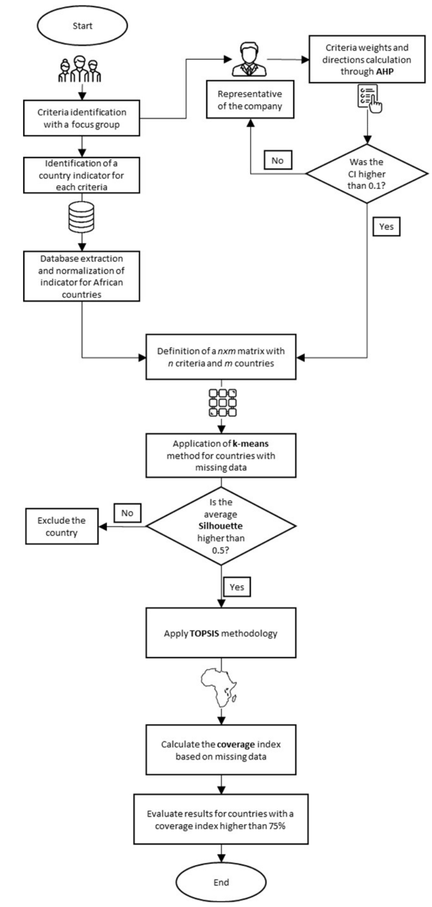

Figure 3: steps of the applied model

The main steps are:

1. For each sub-criterion involved in the location selection choice a key indicator is chosen.
2. For each indicator African countries data are extracted from World Bank databases and standardized.
3. The criteria weights and directions are gathered.
4. A *nxm* matrix is developed (n is the criteria number and m the African countries number).
5. The k-means and Silhouette techniques are used for alternatives with no available data.
6. The TOPSIS methodology is applied to evaluate and rank the alternatives.
7. Alternatives with more than 75% of available data are the only ones considered for the analysis.