COMBINING AHP, TOPSIS AND CONJOINT ANALYSIS TO RANK SHOPPING CENTERS IN THE LOCALITY OF MBANZA-NGUNGU, DR CONGO

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ABSTRACT

This paper deals with ranking stores in the locality of Mbanza-Ngungu (DR Congo) while considering consumers' preferences. The Conjoint Analysis method is used to determine weights for criteria to evaluate the considered alternatives. Next, we ran AHP and TOPSIS methods to rank these alternatives from the best to the worst. Both used methods agree with the same ranking for the six considered shopping centers. Additional computations had been performed to study the consistency of AHP matrices. The inconsistency rates of all AHP pairwise comparison matrices are lower than 0.1 showing that the AHP is verified.

Keywords: AHP; multicriteria analysis; ranking; shopping center

1. Introduction

Decision-makers often face situations where multiple points of view have to be considered (Mousseau et al., 2000). Such problems are called Multiple Criteria Decision-Making (MCDM) problems. Decision-making is the study of identifying and choosing alternatives to find the best solution based on different factors while considering the expectations of decision makers (San Cristobal Mateo, 2012).

When confronted with several shopping centers installed in a region, a rational consumer is subject to the problem of selecting the center that simultaneously achieves a wide variety of his objectives, the one that respects and satisfies the selection criteria and the constraints as well. Unfortunately, the objectives or criteria on the basis of which decisions are made turn out to be the most conflicting and are as numerous as they are diverse (Jabeur & Martel, 2005; Meyer, 2013).

The choice of the best store for a consumer would not only depend, to be more realistic, on the optimization of the management of the flows of needs. This choice should also take into account the social and economic aspects inherent in satisfying consumer needs.

In this sense, it is often impossible to choose a store that ranks first on all the criteria taken into account. The consumer is subject to an exercise where he must choose, for the purchase of a product, the store that best meets his essential requirements (price, distance, waiting time before being served, etc.).

Since the choice of a store can be influenced by several factors, we postulate that these factors are not all of the same importance in the eyes of the consumer. We will not take the risk of assuming the supremacy of any one factor over the others. Green (1984) proposes a methodology to determine the most influential combination of attributes on consumers' decision-making. Thus, a controlled set of potential alternatives is shown to survey consumers and an analysis is performed to understand how they make choices among these alternatives. Finally, the implicit valuation of the individual elements making up the alternative is determined. This methodology is called Conjoint Analysis (CA).

Several methods are used to solve MCDM problems in order to rank alternatives from the best to the worst. In this direction, Marcarelli and Mancini (2022) use AHP and PROMETHEE to rank high schools in Italy. Moradi (2022) evaluates the performance of University faculties in Instanbul, Turkey by combining BSC, AHP and TOPSIS methods. A literature review of common MCDM methods is provided by Figueira et al. (2005), Ishizaka and Nemery (2013), and Velasquez and Hester (2013). Mancini and Marcarelli (2019) propose a methodology for the choice of a high school considering parents' preferences.

In this paper, we analyze the shopping centers performances in Mbanza-Ngungu, Democratic Republic of the Congo (DRC) from consumers' point of views. To do this, we combine AC, AHP and TOPSIS to rank all the considered alternatives. Such an approach has been suggested by Velasquez and Hester (2013).

The remainder of this article is structured as follows: Section 2 deals with methodology presenting the study environment and a brief literature review of MCDM methods that are used in this paper (AC, AHP and TOPSIS). Section 3 highlights main results using specific characteristics of computing materials and software. It specifies the survey conditions (respondents, period of investigation, selected alternatives and criteria, etc.) and presents an original approach to solve the investigated problem. Section 4 discusses about obtained results before concluding the paper in Section 5.

2. Methodology

2.1 Study environment

Mbanza-Ngungu is a locality in the province of Kongo-Central in the western DRC, located along the Matadi-Kinshasa railway line of which it is the main stage. With nearly 115,580 inhabitants[1], it is the third largest city in the province of Kongo-Central.

The city is located in a region of hills and valleys; a belvedere culminates there at 785 meters above sea level. Formerly a tourist resort, caves known for blind fish without pigment are nearby. Due to its high altitude, Mbanza-Ngungu has a cool and humid tropical climate. It is located 154 km from Kinshasa, 234 km from Matadi and 34 km from Kisantu. Its geographic coordinates are 5° 16′ south, 14° 51′ east.

In June 2013, the locality was granted city status, made up of two municipalities: Ngungu and Noki. This status was not maintained during the administrative reform implemented in 2015.

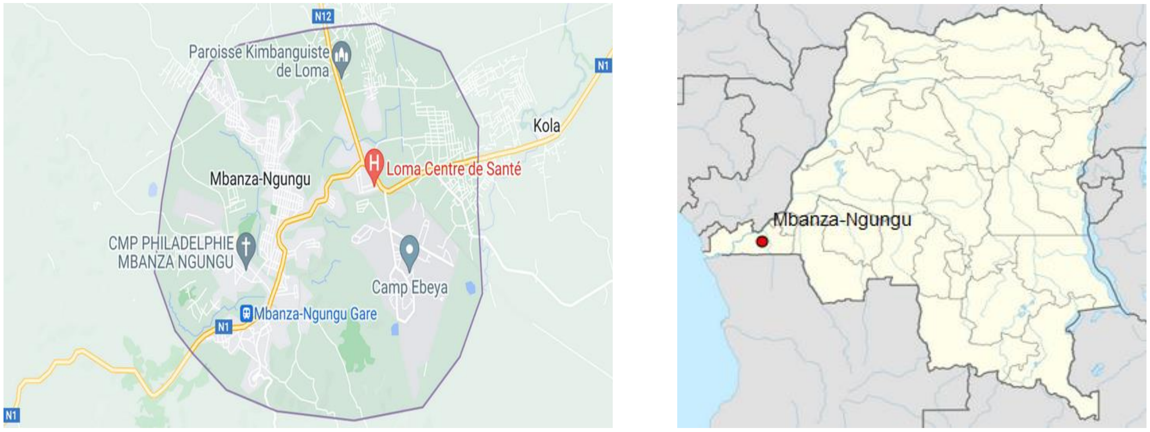

Figure 1 The locality of Mbanza-Ngungu, Democratic Republic of the Congo

2.2 Conjoint Analysis (CA)

Green's work in the 1970s marked the beginning of the consideration of conjoint analysis in marketing research. The so-called "joint measures analysis" method, which has been increasingly developing since the 1980s, aims to better understand the behavior of individuals and, in particular, of the consumer.

The CA is based on the decomposition of preference into partial utilities. To determine the total utility of a product, it is assumed that the individual adds up the attributes partial utilities of the product. This is called an additive model. In the end, the individual chooses among the products the one that gives him the highest total utility. The estimation thus makes it possible to obtain, for each factor and its levels, partial utilities as well as the importance of each attribute. What counts is therefore the individual as he reacts in a given situation (Carricano & Poujol, 2008).

[1] The DRC does not provide exact demographic data since there is no official census for many decades. This estimation is from 2016.

CA belongs to decomposition models where the importance of characteristics is estimated from the consumer's stated preferences and his ratings of the different products on several characteristics. It allows to analyze the importance of product characteristics in the preferences formation.

Table 1
Conjoint Analysis applications[2]

For everyday consumer goods	
New products	72.0%
Price	61.0%
Segmentation	48.0%
Advertising	39.0%
Distribution	7.00%

2.3 Analytic Hierarchy Process (AHP)

AHP is a multi-criteria decision support method whose oldest reference that we found is (Saaty, 1972). Then, an article published in the Journal of Mathematical Psychology (cf. Saaty, 1977) had precisely described the method. A large number of applications still use AHP as described in this first publication and are unaware of the developments that have resulted from it.

Table 2
Recent articles on AHP approach

N°	Authors	Application Areas	Specific Objective	Used tools
1.	RazaviToosi and Samani (2016)	Government	Water management strategies	AHP, TOPSIS, Max-Min
2.	Wang Chen et al. (2016)	Manufacturing	Green Supplier Selection	AHP, TOPSIS
3.	Efe (2016)	Industry	ERP system selection	AHP, TOPSIS
4.	Lee and Chou (2016)	Industry	Sustainable development	AHP, TOPSIS, Delphi
5.	Leong, Raymond, Kathleen, and Chew (2016)	Industry	Industrial plants	AHP
6.	Prakash and Barua (2016)	Manufacturing	Reverse logistic partner	AHP, TOPSIS
7.	Azadeh and Zadeh (2016)	Manufacturing	Maintenance policy selection	AHP, FTOPSIS
8.	Shafiee (2015)	Social	Risks in offshore wind farms	AHP, ANP
9.	Budak and Ustundag (2015)	Social	Real-time location systems	AHP
10.	Ugurlu (2015)	Others	Oceangoing watch keeping officers	AHP
11.	Kumar, Shankar, and Debnath (2015)	Industry	Telecom sector	AHP, DEA
12.	Uygun et al. (2015)	Industry	Outsourcing provider selection	AHP, ANP, DEMATEL
13.	Beskese et al. (2015)	Government	Landfill site selection	AHP, TOPSIS
14.	Parameshwaran et al. (2015b)	Industry	Robot selection	AHP, Delphi, VIKOR
15.	Nguyen et al. (2014)	Manufacturing	Machine tools	AHP, ANP, GRA
16.	Satir (2014)	Social	Ballast water treatment	AHP
17.	Yu et al. (2014)	Industry	Vendor/Supplier selection model	AHP
18.	Bilis¸ ik et al. (2014)	Government	Garage locations	AHP
19.	Demirtas¸ et al. (2014)	Engineering	Technology selection	AHP, ANP
20.	Kahraman et al. (2014)	Political	Health research investment	AHP
21.	Kumru and Humru (2014)	Manufacturing	3D machine selection	AHP, ANP
22.	Ghoseiri and Lessan (2014)	Social	Waste disposal site selection	AHP, ELECTRE
23.	Lima Junior et al. (2014)	Manufacturing	Supplier selection	AHP, TOPSIS
24.	Kabir and Sumi (2014)	Social	Power substation locations	AHP, PROMETHEE
25.	Kilic et al. (2014)	Industry	ERP systems	AHP, TOPSIS
26.	Ballı and Korukoglu (2014)	Others	Basketball candidates	AHP, TOPSIS
27.	Pang and Bai (2013)	Manufacturing	Supplier selection	AHP, ANP

[2] These data are provided by (Carricano & Poujol, 2008). The interested reader is referred to the authors for more details.

N°	Authors	Application Areas	Specific Objective	Used tools
28.	Mirhedayatian et al. (2013)	Engineering	Tunnel ventilation system	AHP, DEA
29.	Kengpol et al. (2013)	Government	Power plant locations	AHP, TOPSIS
30.	Isalou et al. (2013)	Government	Landfill site selection	AHP, ANP
31.	Alcan, Balin, and Bas¸ lıgil (2013)	Social	Energy management systems	AHP, TOPSIS
32.	Roshandel, Miri-Nargesi, and Hatami-Shirkouhi (2013)	Manufacturing	Supplier selection in detergent industry	AHP, FTOPSIS
33.	Ishizaka and Nguyen (2013)	Others	Bank account selection	AHP
34.	Demirel et al. (2012)	Political	Agricultural strategies	AHP, ANP
35.	Taha and Rostam (2012)	Manufacturing	Machine tool selection	AHP, PROMETHEE
36.	Nazari et al. (2012)	Social	Landfill sites	AHP
37.	Nguyen and Gordon-Brown (2012)	Education	Constrained analysis	AHP, FA/FR
38.	Kubat and Yuce (2012)	Industry	Supplier selection model	AHP, GA
39.	Mentes and Helvacioglu (2012)	Others	Mooring systems	AHP, TOPSIS
40.	Shaw et al. (2012)	Manufacturing	Low carbon suppliers	AHP, LP
41.	Fouladgar et al. (2012)	Manufacturing	Maintenance management	AHP, COPRAS
42.	Choudhary and Shankar (2012)	Government	Power plant locations	AHP, TOPSIS
43.	Yazdani-Chamzini and Yakhchali (2012)	Engineering	Machine selection	AHP, TOPSIS
44.	Sarfaraz et al. (2012)	Industry	ERP implementation	AHP
45.	Yücenur, Vayvay, and Demirel (2011)	Industry	Supplier selection model	AHP, ANP
46.	Liao (2011)	Industry	Market strategy selection	AHP, MSGP
47.	Mohammady and Amid (2011)	Manufacturing	Modular virtual enterprise	AHP, VIKOR
48.	Taha and Rostam (2011)	Manufacturing	Machine tool selection	AHP, NN
49.	Zeydan et al. (2011)	Manufacturing	Supplier selection	AHP, TOPSIS, DEA
50.	Durán (2011)	Manufacturing	CMMS management	AHP
51.	Kilincci and Onal (2011)	Manufacturing	Supplier selection	AHP
52.	Golestanifar et al. (2011)	Engineering	Tunnel excavation method	AHP, TOPSIS
53.	Önüt et al. (2010)	Engineering	Shopping center sites	AHP, TOPSIS
54.	Chen and Hung (2010)	Personal	Outsourcing manufacturing partners	AHP, TOPSIS
55.	Celik et al. (2009)	Personal	Shipping registry alternatives	AHP
56.	Cebeci (2009)	Industry	ERP systems BSC	AHP, SWOT
57.	Vahidnia et al. (2009)	Social	Hospital sites	AHP
58.	Önüt et al. (2009)	Manufacturing	Telecommunication suppliers	AHP, ANP, TOPSIS
59.	Önüt, Kara, and Efendigil (2008)	Manufacturing	Machine tool selection	AHP, TOPSIS
60.	Durán and Aguilo (2008)	Manufacturing	Machine tools	AHP
61.	Chan, Kumar, Tiwari, Lau, and Choy (2008)	Industry	Global supplier selection	AHP
62.	Wang et al. (2007)	Manufacturing	Maintenance management strategies	AHP
63.	Tolga, Demircan, and Kahraman (2005)	Others	Operating system selection	AHP
64.	Enea and Piazza (2004)	Others	Project selection	AHP
65.	Marcarelli and Mancini (2022)	Education	Ranking of school and academic performance	AHP, PROMETHEE
66.	Kubler, Robert, Derigent, Voisin and Le Traon (2016)	Others	State-of-the-art	FAHP
67.	Ertuğrul and Karakaşoğlu (2008)	Manufacturing	Facility location selection	AHP, TOPSIS
68.	Lee, Chen and Chang (2008)	Manufacturing	Evaluating performance of IT department in the manufacturing industry in Taiwan	BSC, AHP
69.	Seçme, Bayrakdaroğlu and Kahraman (2009)	Banking	Performance evaluation in Turkish banking sector	AHP, TOPSIS
70.	Ertuğrul and Karakaşoğlu (2009)	Industry	Performance evaluation of Turkish cement firms	AHP, TOPSIS
71.	Gumus (2009)	Transportation	Evaluation of hazardous waste transportation firms	AHP, TOPSIS
72.	Bentes, Carneiro, da Silva and Kimura (2012)	Industry	Multidimensional assessment of organizational performance	BSC, AHP
73.	Bhutia and Phipon (2012)	Transportation	Supplier selection problem	AHP, TOPSIS
74.	Önder, Taş and Hepsen (2013)	Bank	Performance evaluation of Turkish banks	AHP, TOPSIS
75.	Sundharam, Sharma and Stephan Thangaiah (2013)	Manufacturing	Sustainable growth of manufacturing industries	BSC, AHP
76.	Fallah Shams Lialestanei, Raji and Khajeh Poor (2013)	Industry	Evaluate the performance of organization branches in Tehran	BSC, AHP, TOPSIS
77.	Vinodh, Prasanna and Prakash (2014)	Industry	Selecting the best plastic recycling method	AHP, TOPSIS
78.	Aly, Attia, and Mohammed (2014)	Education	Prioritizing faculty of engineering education Performance	BSC, AHP, TOPSIS
79.	Graham, Freeman and Chen (2015)	Environment	Green supplier selection	AHP, TOPSIS
80.	Sehhat, Taheri and Sadeh (2015)	Social	Ranking of insurance companies in Iran	AHP, TOPSIS
81.	Yudatama and Sarno (2016)	Education	Priority determination for higher education strategic planning	BSC, AHP, TOPSIS
82.	Pramanik, Haldar, Mondal, Naskar and Ray (2017)	Industry	Resilient supplier selection	AHP, TOPSIS
83.	Moradi, Malekmohammad and Jamalzadeh (2018)	Industry	Performance evaluation of digital game industry	BSC, AHP
84.	Chou, Yen, Dang and Sun (2019)	Personal	Assessing the human resource in science and technology for Asian countries	AHP, TOPSIS

N°	Authors	Application Areas	Specific Objective	Used tools
85.	Chatterjee and Stević (2019)	Manufacturing	Supplier evaluation in manufacturing environment	AHP, TOPSIS
86.	Guru and Mahalik (2019)	Banking	Performance measurement of Indian public sector banks	AHP, TOPSIS
87.	Ban, Ban, Bogdan, Popa and Tuse (2020)	Manufacturing	Performance evaluation model of Romanian manufacturing listed companies	AHP, TOPSIS
88.	Yildiz, Ayyildiz, Taskin Gumus and Ozkan (2020)	Engineering	ATM site selection problem	BSC, AHP, TOPSIS
89.	Yucesan and Gul (2020)	Health	Hospital service quality evaluation	AHP, TOPSIS
90.	Moradi and Moradi (2021)	Social	Performance evaluation of a project-based growth and entrepreneurship organization in Iran	BSC, AHP, TOPSIS
91.	Moradi (2022)	Education	Performance evaluation of faculties at the University	BSC, AHP, TOPSIS

This method proposes to divide a complex decision problem (therefore multi-criteria) into a hierarchy. This hierarchy takes place according to several levels starting with the object of the problem, followed by the criteria, sub-criteria and finally the different possible alternatives (Saaty, 1980).

The AHP method consists of representing a decision problem by a hierarchical structure reflecting the interactions between the various elements of the problem, then proceeding to pairwise comparisons of the elements of the hierarchy, and finally determining the priorities of the actions.

The steps of this method are as follows:

1. Define the problem.
2. Construct a hierarchical analysis of the problem. That is to say, breaking down the problem from the general (the objectives to be achieved, and therefore the criteria to be taken into account) to the specific (the different possible alternatives).
3. Build a judgment matrix for all the elements of the first level (criteria level). This matrix is constructed from pairwise comparisons based on judgment scales.
4. Determine the eigenvector of this judgment matrix (the first eigenvector corresponds to the weight vector relating to the criteria).
5. Check the relevance of this weight vector with the different actors.
6. Next, the pairwise comparison is performed at the lower hierarchical level. One then obtains new matrices for which one determines the eigenvectors.
7. Procedure 6 is repeated for each hierarchical level.
8. At the last level (level of actions), the various vectors obtained previously are compiled to obtain a final vector which makes it possible to rank the actions.

In general, only 2 (or even 3 at most, if there are sub-criteria) hierarchical levels are considered for a problem. A first level for the criteria, and a second for the different alternatives.

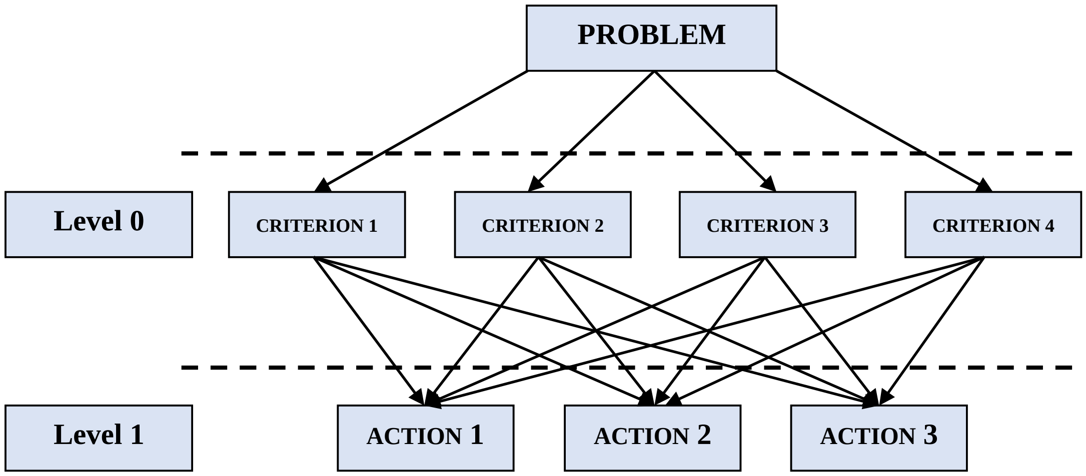

Figure 2 Hierarchy of a problem for the AHP method

First, we seek to prioritize the different criteria that have been considered. For this, the decision maker defines the preferences he has with respect to each pair of criteria. Next, these preferences, which are expressed in verbal forms, are translated into numerical forms according to the table 3 below.

Table 3
Equivalences of pairwise comparisons

Verbal scale	Numerical scale
Both elements are equal	1
The element moderately dominates the other (slightly more important)	3
The element strongly dominates the other (more important)	5
The element very strongly dominates the other (much more important)	7
The element is absolutely dominant (absolutely more important)	9

Intermediate values (2, 4, 6, 8) between two judgments can be used to refine the judgment. So, if, for example, a decision maker considers that the price is absolutely more important than the design of the car, the price criterion will then have a score of 9 compared to the design one. In contrast, the design will have a score in relation to the price which will be the inverse of the score for the price according to him, i.e. 1/9.

To verify the judgments expressed by the decision makers, several measures of consistency have been proposed in the literature. Saaty suggested the Consistency Index (CI):

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

(where n is the number of elements and λ_{max} the eigenvalue associated with judgment matrix) and

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

where RI (Random index) is the average of CI values associated with several pairwise comparison matrices (of size n) randomly generated (Saaty & Vargas, 1982). If CR is less than 0.1, then the matrix may be considered to have acceptable consistency; otherwise, the judgments must to be revised.

Table 4
Random indices

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

2.4 TOPSIS

The TOPSIS method (Technique for Order Preference by Similarity to Ideal Solution) is an aggregation function in Multicriteria Analysis dedicated to the ranking problem. It is one of the classic methods for solving certain MCDM problems. It was introduced by Hwang and Yoon (1981). Recently, an extension of TOPSIS has been proposed to integrate fuzzy data (performance, criteria and weight of criteria).

The explained steps of the TOPSIS procedure are listed below.

Step 1: Calculation of normalized preferences

All the scores of the matrix of levels attributed to the criteria are normalized. To do this, the formula given below is applied to obtain the new entries r_{ij} of the matrix:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}}$$

Step 2: Calculation of normalized preferences with weights associated with the criteria

In this step, we calculate the product of the normalized performances by the coefficients of relative importance of attributes.

Step 3: Identification of ideal and anti-ideal solutions

For each criterion (Attribute), the most favorable associated value A+ is computed according to the nature of the criterion (favorable or unfavorable). If the criterion is favorable, the highest value of each column is chosen. If the criterion is unfavorable, the smallest value of each column is selected.

Step 4: Distances between alternatives and ideal and anti-ideal solutions

This step includes two sub-steps:

(4.1) In this step, we compute for each alternative its deviation from the most favorable value already evaluated in step 3. All the deviations are expressed by the vector E+. Each deviation is expressed as a Euclidean distance between the value of each associated criterion and the associated value of A+;
(4.2) This step is analogous to the previous step where it suffices to use the components of the vector A– instead of A+. We thus compute the set of deviations from the anti-ideal E–
.
Step 5: Calculation of the similarity index to the ideal solution

In this step, we calculate the coefficient associated with each alternative which determines its rank in the choice. Each coefficient is computed from the components associated with the vectors E– and E+ according to the quotient:

$$S(a_i) = \frac{E^-}{E^- + E^+}$$

Step 6: Order of preference
Choose the action with the highest similarity index (for a choice problem) or rank actions in descending order of similarity indices (for a ranking problem).

The main contribution of the TOPSIS method is the introduction of ideal and anti-ideal notions. It is easy to apply. However, it has some drawbacks: the first is that attributes must be cardinal and preferences are a priori fixed. The second one is that if all the actions are bad, the method proposes the best action among the bad ones.

3. Results

3.1 Computing material and software

The result was carried out using a computer with the following characteristics: DELL Precision5530, Intel(R) core i7, with 12 x 2.6 Ghz CPU and 16484MB RAM. Statistics are obtained using IBM SPSS Statistics 23 © software.

3.2 Respondents

The surveyed respondents are consumers who use to buy items in the considered shopping centers. The number of respondents is 128 and the survey period runs from January 2021 to March 2021.

3.3 Alternatives

We have considered six shopping centers as alternatives. Their names are kept in confidential due to the request of marketing expert. We will consider selected shopping centers as A, B, C, D, E and F.

3.4 Criteria

Four criteria are considered to formalize this problem:

- Price: The average cost of items that the shopping center sells;
- Quality: The quality of sold items[3]
- Distance: This criterion refers to the distance between the consumer and the shopping center.
- Welcome: This criterion refers to the quality of the welcome to customers by the store.

3.5 Results of CA

3.5.1 Importance of criteria

The CA has been used, in this study, to produce the importance (weight) of the factors (criteria) considered to evaluate the stores of the locality of Mbanza-Ngungu. The results it produces are obtained from respondents' ratings on fictitious stores.

Table 5
Importance of criteria

Criteria	Weight (importance)
Price	27.095
Quality	32.371
Distance	15.644
Welcome	24.890

It is clear from Table 5 that quality is the most important criterion or attribute in the process of choosing a store for the surveyed consumers. Some consumers consider price as an index of quality. However, the evaluation made of the quality-price ratio is not always fair (Duhaime et al., 1996). In the same vein, since the price is considered an index of quality, a lower price can be unfavorable to the sale of the product. The price of products is ranked second in terms of importance in the eyes of the consumer. Welcome and Distance are ranked third and fourth respectively.

3.5.2 Partial utilities of modalities

This is the measurement, at the individual level, of consumer well-being (Igersheim, 2004). For this, the more an action brings happiness to an individual, the greater will be its usefulness in the eyes of this individual. Thus, Table 6 shows the utilities calculated by the AC method for each modality.

[3] In general, the products made in China which are sold in Mbanza-Ngungu are of poor quality but at a good price.

Table 6
Utility for each modality

Criteria	Modalities	Utilities	Std. Error
Price	Cheaper	-0.100	0.138
	Affordable price	-0.201	0.276
	Expensive	-0.301	0.414
Quality	Bad quality	0.676	0.138
	Good quality	1.352	0.276
	Best quality	2.028	0.414
Distance	Close	-0.682	0.239
	Distant	-1.364	0.478
Welcome	Unwelcoming	0.286	0.138
	Less welcoming	0.572	0.276
	Welcoming	0.858	0.414
Constant		4.883	0.586

3.5.3 Correlations

Before analyzing the results of a CA, first arises the question of whether reject or not individuals who have too low correlation rates, which reflects an inconsistency in the answers of the interviewee. According to Auty (1995), this choice depends on the researcher and the number of respondents. If the latter is too low, we can accept individuals who alter the reliability of the study. Otherwise, these data must be eliminated from the analysis. The rejection limit is traditionally 0.7 for Pearson's rho and 0.5 for Kendall's tau (Liquet, 2001).

Table 7
Correlations between estimated and observed preferences

	Value	Signification
r de Pearson	0.950	0.000
Tau de Kendall	0.889	0.000

Both correlation tests (Pearson and Kendall) indicate a correlation between estimated preferences and observed preferences. SPSS did not provide us with Kendall's tau for the items excluded in our analysis. This means that there is no correlation between estimated and observed preferences for the excluded items.

3.5.4 Inversions

By specifying LINEAR models for all factors, we choose an expected direction (LESS or MORE) for the linear relationship between the value of the variable and the preference for that value. The conjoint procedure keeps track of the number of subjects whose preferences indicated the opposite of the expected relationship – for example, a higher preference for high prices or a lower preference for ‘Better quality’. These observations are called reversals or inversions.

Table 8
Summary table of inversions

Number of inversions	Number of respondents
1	19
Factors	**Number of respondents**
Distance	7
Welcome	5
Price	6
Quality	1

The results in Table 8 show that, despite the high number of objects to rank, only very few respondents (19 out of 128 or 14.84%) made inversions. For our case, for example, an inversion would consist for a respondent ranking a more expensive store ahead of a cheaper one if both of them have the same values on the other factors.

Inversions were more frequent for distance (7) and less frequent for quality (1). This reflects the fact that respondents make very few compromises on quality given its importance (32.371% against 27.095% for price, 24.89% for welcome and 15.644% for distance).

3.6 Results of AHP

All level 0 and 1 matrices are consistent since they satisfy the Saaty test (See Tables 9 and 10). The AHP analysis ends with the determination of a vector called Value For Money vector (VFM). This vector is obtained by multiplying the matrix of the scores of the alternatives (also called Option Preference Matrix (OPM)) by the eigenvector of the level 0 matrix (also called Relative Value Vector (RVV)). This operation consists in considering the components of the vector RVV (eigenvector of the criteria) as the weights of the criteria and then computing the weighted sum of each row of the matrix OPM. So we have:

$$VFM = OPM \times RVV$$

Table 9
Level 0 Matrix (pairwise comparisons on criteria)

	Price	Quality	Distance	Welcome	Geom. mean	Eigenvector	λ_{max}	4.05107528
Prix	1	1/2	4	2	1,41421356	0,2854252	CR	0.01891677*
Quality	2	1	5	3	2,34034732	0,4723431	CI	0.01702509
Distance	1/5	1/5	1	1/3	0,35930411	0,0725169	RI	0.90
Welcome	1/2	1/3	3	1	0,84089642	0,1697148		
		Total			4,95476141	1		

* The judgment is consistent since CR<0.10

Final scores (Cf. Table 11) indicate that Shopping center C ranks ahead of all other ones with 31.61%. A is the worst of all with 3.24%. AHP final ranking is given in Table 12.

Table 10
Level 1 Matrices (performances of alternatives on criteria)

				Price						
	A	B	C	D	E	F	Geom. mean	Eigenvector	λ_{max}	6,13493814
A	1	1/4	1/7	1/6	1/4	1/5	0,25839065	0,032840687	CR	0,02176422*
B	4	1	1/4	1/3	1	1/2	0,74183638	0,094285209	CI	0,02698763
C	7	4	1	2	4	3	2,95956725	0,376152244	RI	1,24
D	6	3	1/2	1	3	2	1,9441613	0,247097151		
E	4	1	1/4	1/3	1	1/2	0,74183638	0,094285209		
F	5	2	1/3	1/2	2	1	1,22221176	0,1553395		
			Total				7,8680037	1,000000000		
				Quality						
	A	B	C	D	E	F	Geom. mean	Eigenvector	λ_{max}	6,16778124
A	1	1/5	1/7	1/7	1/3	1/4	0,26420566	0,03257913	CR	0,02706149*
B	5	1	1/3	1/3	3	2	1,22221176	0,150710609	CI	0,03355625
C	7	3	1	1	5	4	2,73658042	0,337447008	RI	1,24
D	7	3	1	1	4	3	2,51323688	0,309906574		
E	3	1/3	1/5	1/4	1	1/2	0,54074187	0,066678737		
F	4	1/2	1/4	1/3	2	1	0,83268318	0,102677942		
			Total				8,10965976	1,000000000		
				Distance						
	A	B	C	D	E	F	Geom. mean	Eigenvector	λ_{max}	6,13435549
A	1	1/5	1/7	1/7	1/4	1/5	0,24264275	0,030580695	CR	0,02167024*
B	5	1	1/3	1/3	2	1	1,01771517	0,128264443	CI	0,0268711
C	7	3	1	1	4	3	2,51323688	0,316747689	RI	1,24
D	7	3	1	1	4	3	2,51323688	0,316747689		
E	4	1/2	1/4	1/4	1	1/2	0,62996052	0,079395039		
F	5	1	1/3	1/3	2	1	1,01771517	0,128264443		
			Total				8,10965976	1,000000000		
				Welcome						
	A	B	C	D	E	F	Geom. mean	Eigenvector	λ_{max}	6,16023845
A	1	1/5	1/7	1/7	1/3	1/4	0,26420566	0,032071061	CR	0,02584491*
B	5	1	1/3	1/3	3	1	1,08886689	0,13217399	CI	0,03204769
C	7	3	1	1	5	4	2,73658042	0,332184546	RI	1,24
D	7	3	1	1	5	4	2,73658042	0,332184546		
E	3	1/3	1/5	1/5	1	1/2	0,52100073	0,063242575		
F	4	1	1/4	1/4	2	1	0,89089872	0,108143282		
			Total				8,10965976	1,000000000		

* The judgment is consistent since CR<0.10

Table 11
Overall AHP scores for alternatives

		Price	Quality	Distance	Welcome	
	RVV	0.2854252	0.4723431	0.0725169	0.1697148	VFM
Alternatives	A	0.032840687	0;03257913	0.030580695	0.032071061	0.032422638
	B	0.094285209	0.150710609	0.128264443	0.13217399	0.129831713
	C	0.376152244	0.337447008	0.316747689	0;332184546	0.346100289
	D	0.247097151	0;309906574	0.316747689	0.332184546	0.29625618
	E	0.094285209	0;066678737	0.079395039	0.063242575	0.074897299
	F	0.1553395	0;102677942	0.128264443	0.108143282	0.120491881
	Total	1.000000000	1.000000000	1.000000000	1.000000000	1.000000000

Table 12
Final AHP ranking for alternatives

Shopping center	AHP score	Rank
A	3.24%	6
B	12.98%	3
C	34.61%	1
D	29.63%	2
E	7.49%	5
F	12.05%	4

3.7 Results of TOPSIS

The start-up of the TOPSIS method requires preliminary work which is common to all the multi-criteria methods. This work consists first of all in successively defining all the potential actions, here stores in the locality of Mbanza-Ngungu, then the criteria, scales and corresponding weights. These two steps allow us to establish a matrix of judgments from which TOPSIS can work.

The weights of the considered criteria are those provided by the Conjoint Analysis. The scores of the alternatives (stores) are obtained by computing the average of the scores allotted by the surveyed respondents to alternatives on each criterion. After various calculations, the judgment matrix on which the TOPSIS method will be performed is that reported in Table 13 below.

Table 13
Decision matrix for TOPSIS

	Price	Quality	Distance	Welcome
Weight	0.27095	0.32371	0.15644	0.2489
Max	10	10	10	10
A	3.45	3.78	3.27	3.27
B	5.7	6.06	4.88	5.13
C	7.41	7.09	5.6	6.37
D	6.91	6.92	5.72	6.43
E	5.41	5.01	4.47	4.33
F	6.17	5.64	4.93	5.01

After running all steps of TOPSIS method, we obtain the final score as indicated in Table 14.

Table 14
TOPSIS scores and ranking

Alternative	TOPSIS score	Rank
A	0.12981436	6
B	0.45754626	3
C	0.60409756	1
D	0.59719888	2
E	0.32207457	5
F	0.44865734	4

4. Discussions

The performed conjoint analysis shows that quality is the most important criterion in the process of choosing a shopping center for the surveyed consumers. This assertion is supported by the number of respondents-made inversions. Indeed, only 19 out of 128 respondents made inversions. This implies that they understood the questionnaire and made the choice consciously.

This is the reason why the selected criteria importance that the CA produced is used in the AHP method. To achieve the AHP judgment matrices (pairwise comparison matrices), we used the following formulas :

$$f(a_i, a_k) = \begin{cases} Rd\left(\frac{g(a_i)-g(a_k)}{m} + 1\right) \; if \; g(a_i) > \; g(a_k) \\ \frac{1}{Rd\left(\frac{g(a_k)-g(a_i)}{m}+1\right)} \quad else \end{cases} \tag{4.1}$$

Where $Rd(x)$ denotes the nearest integer to the real x and m the mean deviation[4] and $g(a_i)$ is the performance of element a_i.

[4] We admit that $Rd(4.5) = Rd(4.9) = 5$ but $Rd(1.1) = Rd(1.4) = 1$.

$$m = \frac{max - min}{n} \quad (4.2)$$

With :

- ✓ max : the highest score
- ✓ min : the lowest score
- ✓ n: the number of elements

Considering the weights of the criteria as well as the scores obtained by the alternatives on the criteria, we realized the different matrices for the AHP method. Thus, we found that all the obtained matrices were consistent, compared to Saaty's consistency ratio.

Thus, after representing a shopping center selection problem by a hierarchical structure reflecting the interactions between the various elements of the problem, and after pairwise evaluation of the actions, the AHP method allowed to determine the priorities of the actions as follows:

1. Shopping center C
2. Shopping center D
3. Shopping center B
4. Shopping center F
5. Shopping center E
6. Shopping center A

To confirm the results obtained, we proceeded to a new classification of the shopping center through the TOPSIS method. The obtained ranking totally agrees with the AHP-computed one.

5. Conclusion

In this paper, we investigated the performance of shopping centers located at Mbanza-Ngungu (DR Congo) from consumers' perspective. A questionnaire (see Appendix) was submitted to respondents in order to collect their opinions about the considered alternatives performances on selected criteria.

First, we performed CA to determine the utilities (weights) for criteria. Next, we performed AHP and TOPSIS methods on the same collected data. Both methods agree with the same ranking: shopping centers C and A are respectively the best and the worst of all the considered alternatives.

In addition, we performed consistency computations on AHP matrices and found that all of them reflect consistent judgments since Saaty's consistency ratios are less than 0.1. This means that the formulas (4.1) and (4.2) used to obtain pairwise matrices from 0-10 grades are efficient.

For future studies, we suggest to use more MCDM methods and other statistical analyses to investigate this problem. Using fuzzy preferences would be more realistic than classical ones.

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APPENDIX

During the research process the following questionnaire was submitted to respondents.

1. Please allot a 0-10 grade to each store on the following criteria[5]:

	Price	Quality	Distance	Welcome
A				
B				
C				
D				
E				
F				

2. Please allot a 0-10 grade to each fictious store according to your preferences:

Price	Quality	Distance	Welcome	Grade
Expensive	Good quality	Close	unwelcoming	
Expensive	Best quality	Close	Less welcoming	
Affordable price	Bad quality	Close	Less welcoming	
Affordable price	Best quality	Distant	Unwelcoming	
Affordable price	Good quality	Close	Welcoming	
Cheaper	Best quality	Close	Welcoming	
Cheaper	Bad quality	Close	Unwelcoming	
Expensive	Bad quality	Distant	Welcoming	
Cheaper	Good quality	Distant	Less welcoming	

[5] True names of stores were used during the survey.