



A MULTI-CRITERIA DECISION ANALYSIS USING THE CRITIC AND TOPSIS METHODS

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Abstract: Decision-making is an important part of daily life for both individual and organizations. Although the multi-criteria decision-making methods provide decision makers with the necessary tools, they have difference in terms of the assumptions and fundamental theory. Hence, selecting the right decision-making method is at least as important as making the decision. CRITIC and TOPSIS method are powerful multi-criteria decision-making tool used to make decision. The CRITIC-TOPSIS is an outranking multi-criteria decision-making approach that helps to select the best candidate in consideration of a set of predefined criteria. This method simultaneously measures the distance of each alternative to the best ideal solution and anti-ideal solution. It provides a closeness coefficient denoting the suitability of a particular option so that experts can easily identify the best. This study proposed CRITIC and TOPSIS methods used to select the best school among the seven government schools in Oyo town. The school assessment was proposed with two subjects, that is English Language and Mathematics which was used in evaluating the performance of schools. The weight of each alternatives was determined by CRITIC. In order to get the ideal and anti-ideal solution, seven alternatives were considered, School of Science, Community Secondary School Oke Olola, Community High School Orayan, Isale Oyo Community Grammar School, Community Secondary School Durbar, Community Secondary School Idi Ope, and Olivet Baptist High School. The result of performance evaluation show that among the seven school, the best school is Olivet Baptist High School which have closeness coefficient value of 0.9999. Olivet Baptist High School is the overall best and should be emulated by order schools in Oyo town to improve the educational system in the state.

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INTRODUCTION

In recent years, multi-criteria decision making (MCDM) have become increasingly popular for qualitative evaluation of complex economic or social processes. Criteria are one of the most important aspects of multi-criteria problems. Given that criteria weights can have a substantial impact on the outcome of a decision-making process, it is evident that extra attention must be made to criteria weighing objectivity, which is regrettably not always present when solving real situations. The manner in which the weights are determined must agree with the multi-criteria model to be employed. Procedures for establishing the weights of criteria have been the topic of years of study and discussion. One of the most difficult aspects of a multi-criteria analysis model is determining criteria weight. Subjective and objective techniques to defining weight criteria are the most common. The subjective approach is based on assessing the weight of criteria based on information provided by decision makers or experts involved in the decision-making process. The subjective method represents decision makers' subjective opinions and intuitions, implying that decision makers have control

over the decision-making process. Objective approaches, in contrast to subjective approaches, are based on determining criteria weight using data from the initial decision matrix. The opinions of decision-makers are ignored in objective approaches. In the subjective method, the decision maker or expert expresses their view on the importance of criteria for a certain procedure based on their personal preferences. There are several subjective approaches to determining criteria weight, and they differ in the number of people involved in the process, the methodologies used, and the manner final criteria weights are formed.

In addition to subjective and objective approaches, Wang et al. (2009) offer combination weighting methods as a third weighting method in their rank-order weighting methods classification category. In general, decision makers' opinions are considered while estimating criteria weights. As a result, the weights obtained this way are considered subjective inputs in such studies. Subjective weighting approaches (e.g., Simple Multi-Attribute Rating Technique (SMART), SIMOS, Revised SIMOS,

SWING, Analytic Hierarchy Process (AHP), pairwise comparison method, Delphi method, etc.) are used in these types of analyses to derive weights based only on decision makers' preferences. Due to the decision maker's level of expertise and experience in the relevant field, analytical conclusions or rankings of alternatives based on the weights can be influenced by the decision maker (Ahn 2011). Objective weighting methods, on the other hand, determine weights by solving mathematical models without considering the decision-preferences maker's (e.g., Entropy, Criteria Importance Through Intercriteria Correlation (CRITIC), Mean Weight (MW), Standard Deviation (SD), Statistical Variance procedure, and so on).

AIM AND OBJECTIVES

The aim of this research work is to use the proposed Criteria Importance Through Intercriteria Correlation (CRITIC) method to determine the weight of criteria and also use TOPSIS to rank the alternatives in multi-dimensional data.

The specific objectives of this research are:

1. to obtain the relevant decision matrix for the M alternatives in term of N criteria.
2. to determine the weight for each criterion by CRITIC method.
3. to determine the ideal solution and anti-ideal solution.
4. to select the best alternative by numerical ranking using TOPSIS

LITERATURE REVIEW

Sitorus et. al. (2019) provides a comprehensive overview of the applications and trends of MCDM methods for the choice problem (i.e., determining the best option from a set) in mining and mineral processing. 90 articles published between 1999 and 2017 were selected following a searching methodology and eligibility criteria detailed in this manuscript. In addition, for the purpose of the survey, different types of selection problems were identified. The results show that there are two phases of growth in the application of MCDM techniques to the choice problem in mining and mineral processing. The first phase, from 1999 to 2007, shows a very low number of publications with only a moderate increase by the end, whereas the second phase, from 2007 to 2017, shows a significant growth in the number of published articles. The review also shows that the most addressed problem has been the selection of mining methods, while the Analytical Hierarchy Process (AHP) has been the most used MCDM method. The rise in the application of hybrid MCDM methods is also discussed. This review paper provides insight into the current state of applications of MCDM in mining and mineral processing and discusses pathways for

future research directions in the development of MCDM methods that would benefit these fields.

Jankowski (1995) presents a framework for integrating geographical information systems (GIS) and MCDM methods. In this framework the MCDM methods are classified and matched with choice heuristics used by the decision-makers in the presence of competing alternatives and multiple evaluation criteria. Two strategies for integrating GIS with MCDM are proposed. The first strategy suggests linking GIS and MCDM techniques using a file exchange mechanism. The second strategy suggests integrating GIS and MCDM functions using a common database. The paper presents the implementation of the first strategy using PC-ARC/INFO, a file exchange module, and four different MCDM computer programs.

Wang et. al. (2009) proposed a new fuzzy TOPSIS for evaluating alternatives by integrating using subjective and objective weights. Most MCDM approaches consider only decision maker's subjective weights. However, the end-user attitude can be a key factor. Also, a novel approach that involves end-user into the whole decision-making process was proposed. In this proposed approach, the subjective weights assigned by decision makers (DM) are normalized into a comparable scale. In addition, they also adopt end-user ratings as an objective weight based on Shannon's entropy theory. A closeness coefficient is defined to determine the ranking order of alternatives by calculating the distances to both ideal and negative-ideal solutions. A case study is performed showing how the propose method can be used for a software outsourcing problem. With our method, we provide decision makers more information to make subtler decisions.

Deng et. al. (2000) formulates the inter-company comparison process as a multi-criteria analysis model, and presents an elective approach by modifying TOPSIS for solving the problem. The modified TOPSIS approach can identify the relevance of the financial ratios to the evaluation result, and indicate the performance difference between companies on each financial ratio. To ensure that the evaluation result is not affected by the inter-dependence of the financial ratios, objective weights are used. As a result, the comparison process is conducted on a commonly accepted basis and is independent of subjective preferences of various stakeholders. An empirical study of a real case in China is conducted to illustrate how the approach is used for the inter-company comparison problem. The result shows that the approach can reflect the decision information emitted by the financial ratios used. The comparison of

objective weighting methods suggests that, with the modified TOPSIS approach, the entropy measure compares favorably with

Odu (2019) provides an overview of different weighting methods applicable to multi-criteria optimization techniques. There are a lot of concept been reported from the literature that are very useful in solving multicriteria problems. The present work emphasized on the use of these weighting methods in determining the criteria preference of each criterion to bring about desirable properties and in order to establish and satisfy a multiple measure of performance across all the criteria selected by identifying the best options possible. And from the results, it shows that subjective weighting methods are easy and straight forward in terms of their

computations than the objective weighting methods which derived their information from each criterion by adopting a mathematical function to determine the weights without the decision-maker's input. This can be seen from the pairwise comparison which gives an internal storage and random-access memory of a smart phone a weight value of 0.33 and 0.22 respectively as they have the highest criteria weights.

Kazan and Ozdemir (2014) analyzed financial statements of the fourteen large-scale conglomerates which were traded on Istanbul Stock Exchange. Firstly, nineteen financial ratios of these holdings and their financial ratio weights were calculated by CRITIC method and then financial performance scores were found by TOPSIS method.

METHODOLOGY

The proposed method CRITIC Method

1. Normalization of decision matrix

In order to normalize maximum and minimum attributes of the decision matrix, the following is used respectively.

$$\bar{X}_{jkl} = \frac{x_{ijkl} - x_{ikl}^{worst}}{x_{ikl}^{best} - x_{ikl}^{worst}} \tag{1}$$

Where \bar{X}_{jkl} represents a normalized value of the decision matrix for i th observation in j th alternative, k th criterion and l th years.

x_{ijkl} indicates the element of the decision matrix for i th observation, j th alternative, k th criteria and l th years.

$x_{ikl}^{best} = \max(x_1, x_2, \dots, x_m)$ and $x_{ikl}^{worst} = \min(x_1, x_2, \dots, x_m)$

2. Correlation Coefficient

$$\rho_{jkl} = \frac{\sum_{i=1}^m (\bar{x}_{ijkl} - \bar{\bar{x}}_{jkl})(\bar{x}_{ijql} - \bar{\bar{x}}_{jql})}{\sqrt{\sum_{i=1}^m (\bar{x}_{ijkl} - \bar{\bar{x}}_{jkl})^2 \sum_{i=1}^m (\bar{x}_{ijql} - \bar{\bar{x}}_{jql})^2}} \tag{2}$$

Where $\bar{\bar{X}} = \frac{1}{m} \sum_{i=1}^m \bar{x}_{ijkl}$

3. The quantity of the information in relation to each criterion.

$$S_{jk} = \sqrt{\frac{1}{n-1} \sum_{j=1}^n (x_{ij} - \bar{x}_i)^2}; \quad i = 1, 2, \dots, m \tag{3}$$

$$C_{jk} = S_{jk} \sum_k^p (1 - \rho_{jkl})$$

4. The objective weight of attribute

$$w_j = \frac{\sum_l^q C_{kl}}{\sum_k^p \sum_l^q C_{kl}} \tag{4}$$

The proposed CRITIC-TOPSIS method.

1. Normalized decision matrix

$$\bar{X}_{jkl} = \frac{\sum_l^q x_{ijkl}}{\sqrt{\sum_k^p (\sum_l^q x_{ijkl})^2}} \tag{5}$$

2. The weight of attribute w_j is gotten from CRITIC

3. The weighted normalized decision matrix

$$v_{jkl} = w_j \cdot \bar{X}_{jkl} \quad j = 1,2,3, \dots, n, \quad k = 1,2,3, \dots, p. \tag{6}$$

4. The ideal A_k^+ and anti-ideal A_k^- solution

$$A_k^+ = \text{The best value} = (V_1^+, V_2^+, \dots, V_n^+)$$

$$A_k^- = \text{The worst value} = (V_1^-, V_2^-, \dots, V_n^-)$$

5. The Euclidean distance of each alternative with positive ideal solution and negative ideal solution.

$$S_j^+ = \sqrt{\sum_{k=1}^p (v_{jkl} - v_k^+)^2} \tag{7}$$

$$S_j^- = \sqrt{\sum_{k=1}^p (v_{jkl} - v_k^-)^2} \tag{8}$$

6. The closeness for every alternative A_j to the ideal solution

$$C_j = \frac{S_j^-}{S_j^+ + S_j^-}, \quad j = 1,2, \dots, n \tag{9}$$

7. Determine the rank in descending order.

DATA STRUCTURE

Table 3.1: Multi-dimensional data structure

Alternatives	Years	Criteria				P
		English (1)	Mathematics (2)			
1	1	X_{i111}	X_{i121}	...	X_{i1p1}	$i = 1,2, \dots, m_{11}$
	2	X_{i112}	X_{i122}	...	X_{i1p2}	$i = 1,2, \dots, m_{12}$
	
	q	X_{i11q}	X_{i12q}	...	X_{i1pq}	$i = 1,2, \dots, m_{1q}$
2	1	X_{i211}	X_{i221}	...	X_{i2p1}	$i = 1,2, \dots, m_{21}$
	2	X_{i212}	X_{i222}	...	X_{i2p2}	$i = 1,2, \dots, m_{22}$
	
	q	X_{i21q}	X_{i22q}	...	X_{i2pq}	$i = 1,2, \dots, m_{2q}$
...	
N	1	X_{in11}	X_{in21}	...	X_{inpq}	$i = 1,2, \dots, m_{n1}$
	2	X_{in12}	X_{in22}	...	X_{inpq}	$i = 1,2, \dots, m_{n2}$
	
	q	X_{in1q}	X_{in2q}	...	X_{inpq}	$i = 1,2, \dots, m_{nq}$

$i = 1,2, \dots, m, \rightarrow$ Observation

$j = 1,2, \dots, n \rightarrow$ Alternative

$k = 1,2, \dots, p \rightarrow$ Criteria

$l = 1,2, \dots, q \rightarrow$ Years

RESULT AND DISCUSSION

Table 1: The objective weight of alternatives.

Schools	Weight
School of Science	0.0771
Community Secondary School Oke Olola	0.0012
Community High School Orayan	0.2273
Isale Oyo Community Grammar School	0.3146
Community Secondary School Durbar	0.0331
Community Secondary School Idi Ope	0.1339
Olivet Baptist High School	0.2128

To compute the CRITIC weight, the first step is normalization of the data set using equation (3.2). After data normalization by using the CRITIC weight method derived from equation (3.14), the evaluation indicator weight of School of Science, Community Secondary School Oke Olola, Community High School Orayan, Isale Oyo Community Grammar School, Community Secondary School Durbar, Community Secondary School Idi Ope and Olivet Baptist High School were computed. The results are shown in Table 4.1. The results show that, In Isale Oyo Community Grammar School had the largest weight value of 0.3146 while Community Secondary School Oke Olola had the smallest weight of 0.001.

CRITIC-TOPSIS method

Table 2: Weighted normalized decision matrix

Schools	English	Mathematics
	V	V
School of Science	0.0219	0.0228
Community Secondary School Oke Olola	0.0003	0.0003
Community High School Orayan	0.0485	0.0466
Isale Oyo Community Grammar School	0.0325	0.0337
Community Secondary School Durbar	0.0060	0.0059
Community Secondary School Idi Ope	0.0184	0.0205
Olivet Baptist High School	0.1821	0.1815

According to the results two evaluated criteria were selected for performance evaluation of seven listed government secondary schools in Oyo town. The CRITIC approach was used to determine the weights of alternatives and then the ranking of the schools was determined by the TOPSIS method. In order to investigate the performance of these companies, this study employed the CRITIC and TOPSIS model to evaluate the performance of the listed school, and compare the results of the schools. We substitute the results of the CRITIC weight (shown in table 4.1) into equation (3.19) to obtained the weighted normalized decision matrix as show in table 4.2.

Table 3: The ideal (A_j^+) and anti-ideal (A_j^-) solution.

	Schools	English	Mathematics
Ideal solution A_j^+	Olivet Baptist High School	0.1821	0.1815
Anti-ideal solution A_j^-	Community Secondary School Oke Olola	0.0003	0.0003

Table 4.3 shows that Olivet Baptist High School has the best values in English language (0.1821) and Mathematics (0.1815) while Community Secondary School Oke Olola has the worst values in English language (0.0003) and Mathematics (0.0003).

Table 4: Euclidean distance of each alternative with positive and negative ideal solution.

Schools	S+	S-
School of Science	0.2254322	0.0311655
Community Secondary School Oke Olola	0.2565898	0.0000005
Community High School Orayan	0.1897989	0.0668079
Isale Oyo Community Grammar School	0.2102437	0.0463566
Community Secondary School Durbar	0.2486594	0.0079309
Community Secondary School Idi Ope	0.2295417	0.0271006
Olivet Baptist High School	0.0000007	0.2565896

The ideal solution is the calculated relative proximity to the closeness of the alternatives. The positive ideal solution is formed as a combination of the best points of each criterion and the negative ideal solution is formed as a combination of the worst points of each criterion.

Table 5: The closeness for every alternative to the ideal solution and the rank in descending order.

Schools	C	Rank
School of Science	0.1215	4
Community Secondary School Oke Olola	0.000002	7
Community High School Orayan	0.2604	2
Isale Oyo Community Grammar School	0.1807	3
Community Secondary School Durbar	0.0309	6
Community Secondary School Idi Ope	0.1056	5
Olivet Baptist High School	0.9999	1

Finally, the closeness coefficient (C) was conducted using equation (3.21) and used to rank the performance of the seven listed schools (shown in Table 4.5). the result of performance evaluation show that among the seven listed schools, the top three ranking government schools were Olivet Baptist High School, Community High School Orayan and Isale Oyo Community Grammar School, which have closeness coefficient value of 0.9999, 0.2604 and 0.1807 respectively. That is, Olivet Baptist High School of the seven schools listed had the best performance rate. For this school, the probability of performance distress is very low. Based on the result of Isale Oyo Community Grammar School which has the smallest closeness coefficient of 0.1807 from the top three school. Finally, the three ranked government schools that performed best, which are Baptist High School (0.9999), Community High School Orayan (0.2604) and Isale Oyo Community Grammar School (0.1807) and the worst three performance schools ranked are Community Secondary School Idi Ope (0.1056), Community Secondary School Durbar (0.0309) and Community Secondary School Oke Olola (0.000002), which indicate that Olivet Baptist High School and Community Secondary School Oke Olola is the best and worst performed government schools.

CONCLUSION

In this study, a new CRITIC and TOPSIS method was proposed to handle multi-criteria decision-making problem. The main purpose of this research work is to ascertain the best government school in Oyo town, to select the best evaluation criteria and to construct a performance evaluation process. Firstly, we use the CRITIC method to determine the weight of each schools. Secondly, we applied TOPSIS to evaluate the performance of the seven government schools. CRITIC weighting result show the maximum CRITIC value among the schools. In conclusion, according to the average performance rankings on the schools table 4.5, Olivet Baptist High School ranked first and we therefore choose it as the best performing school in Oyo town and the worst performing school is Community Secondary School Oke Olola.

RECOMMENDATION

One of the most important things to look at when choosing a school is the academic and overall performance of each school. Finding the best school for your children is one of the most important decisions you will make as a parent. It can be difficult to determine which school is best for your family, especially if you are unfamiliar with the area. But the area is just one element that you will be required to

think about, as there are other factors that you must consider before making decision. In this analysis, there performance in English language and Mathematics is consider in finding the best school, which show that Olivet Baptist High School is recommended as the best school.

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