

Decision-Making for Capital Budgeting with Using Electre and Copras Methods of Multi-Criteria

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Abstract

The study aims to develop a decision model for capital budgeting decisions with an application of the ELECTRE coined with the COPRAS methods of the MCDM in order to choose the best investment alternative. It presents a financial model for the evaluation and comparison of long-term investment decision making. The selection of one or more investment projects from the set of possible alternatives is an important and difficult task for decision makers. A hypothetical case study is presented for the selection of a machine with three alternatives available. The data was analyzed with the help of five capital budgeting techniques namely the Accounting Rate of Return (ARR), payback period (PB), Net Present Value (NAV), Profitability Index (PI) and Internal Rate of Return (IRR) with the application of the ELECTRE and the COPRAS methods of the Multi Criteria Decision Making (MCDM). After analysis and testing, it is revealed that both the ELECTRE and the COPRAS methods of the MCDM, have given identical rankings for selecting the various investment alternatives, thereby offering a more credible and reliable approach to decision-making. The findings of the study imply that the decision makers should adopt capital budgeting techniques along with the MCDM methods to improve investment decisions. The study is significant for the use of capital budgeting techniques coined with the MCDM methods to simplify as well as improve the investment decision-making from Indian perspective. It provides valuable insights to multiple stakeholders in this regard.

Keywords: Capital Budgeting, Investment Decisions, ARR, PB, NPV, PI, IRR, ELECTRE and COPRAS methods.

1. Introduction

The success and growth of any business enterprise depend upon the efficient utilisation of available resources. An efficient allocation of funds is an extremely important function of finance in the modern times especially in case of acquisition of long term assets of a firm, generally referred to as the capital budgeting or capital expenditure decisions. The introduction of technological improvements and expansion of plant operations represents a major factor in economic growth and increased productivity for a business enterprise. Some of the capital budgeting decisions generally include expansion, acquisition, modernization and

replacement of long term assets. The basic characteristic of capital budgeting is that it typically involves a current outlays or series of outlays of cash resources in acquiring long term assets, also called fixed assets, in anticipation of a stream of future benefits expected to arise over a period beyond one year. These decisions are not easily reversible. An element of risk is involved as benefits are expected to arise in future and future is uncertain. All these features make capital budgeting very vital for the firms involved in such decisions (Yücel & Görener, 2016).

2. Background of Study

The capital budgeting process starts with the estimation and determination of costs and benefits associated with different proposals. Generally many profitable and financially viable proposals are available but all of them cannot be under taken because of capital rationing. Thus, the different proposals are evaluated in order to select the best proposal for the firm within available funds.

3. Rationale of Study:

Capital budgeting is the making of long-term investment decisions. It is a four-step process consisting of the following: 1) identifying possible projects based on opportunities and/or needs, 2) collecting detailed information about each project, 3) choosing (and implementing) one or more of the projects based on their relative merits, and 4) evaluating the performance of the implemented project(s). This study was limited to steps one through three. A number of investment criteria or capital budgeting techniques are used in practice. These techniques can be divided into two broad categories: discounting and non discounting techniques.

The discounting techniques are based on cash flows concept and take into account the extremely important concept of time value of money. Whereas non discounting techniques ignore time value of money and are usually based on accounting profit which is inferior to cash flows concept as profit has innumerable meanings like gross profit, net profit, profit before tax, profit after tax, return on investments, return on equity, return on capital employed and many more and is surrounded by accounting ambiguities. Still managers use these non-discounting techniques for its simple computations and easy understanding. Some managers may prefer a particular technique because of simplicity and understandability whereas others may not prefer it because of its simplicity and other drawbacks. Major concerns with the capital budgeting techniques are that different techniques may give different rankings for project proposals under consideration.

A project proposal cannot be evaluated on the basis of one technique rather these have to be

assessed from various perspectives (different techniques/ criteria) which may be conflicting in nature. For some particular (maximising) criteria like NPV, PI, IRR and ARR, the largest value is the best while for other (minimising) criteria like payback period the smallest value is the best. The units of criteria measurement are also different. It makes the results quite tricky to interpret. The use of single evaluation measure may lead to unreliable conclusion about the best performing algorithm. So it is necessary to find single integrated criterion to compare and evaluate each alternative to find out the best among them. To tackle this problem, two analytical methods of the MCDM, namely, the ELECTRE and the COPRAS were employed for evaluating the alternatives comparatively. The study finds that the two methods have given identical results among the various investment alternatives. This paper attempts to develop a model to combine all five capital budgeting techniques along with the application of MCDM methods.

4. Review of Literature

A brief review of the relevant studies has made in order to identify the usage of Major MCDM Methods. The considered methods have been studied for review as used in various fields. Many authors propose the use of MCDM methods for selection of the most suitable project. ELECTRE is a multi-criteria decision making model that is proved to be effective in ranking several decision making problems. Fuzzy ELECTRE I (Elimination Et Choix Traduisant la Realite) is one of the fuzzy multi criteria decision making methods for resolving the ambiguity of concepts that are associated with decision makers' judgments. Wu and Chen (2009) developed a methodology for solving multi-attribute decision-making problems with intuitionist fuzzy sets using the ELECTRE method which uses the concept of outranking relationship. Pang, Zhang and Chen (2011) presented a study on selection of reliability design scheme for computer numerical control (CNC) machine. In practice, reliability design scheme decision for CNC machine usually consists of multi-objective optimization model. Thus, various effective factors of optimized model need to be considered in the decision process. They proposed a novel AHP based ELECTRE I

method. The AHP method was applied to determine the weights of reliability design factors through the decision model. ELECTRE I method was then designed to rank reliability design scheme in order of decision maker's preference. An illustrative example of CNC machine was used to evaluate the performance of the developed algorithm. The computational results showed that the proposed approach was reliable and performed well. Aytaç et al. (2011), conducted a study in which fuzzy ELECTRE I method was applied to catering firm selection problem of a textile company to select the best among the various alternatives. Uysal and Yavuz (2014) established a study to determine the appropriate facility location in western Black sea, Turkey. After determining eleven logistics factors that affect the facility location, they ranked and concluded the optimal facility location among six alternative region using ELECTRE method. Sahaaya and Suganya (2016) proposed a model which took inputs from multiple stakeholders using 100-point method. An optimised ranking was obtained using ELECTRE method. The developed system was validated using a pilot project and was found to be efficient in terms of saving cost of implementation and man-hours needed for implementation. Yücel and Görener (2016) evaluated an investment group's local acquisition opportunities by ELECTRE method. They listed six important criteria that influence the selection of local acquisition alternatives in Turkey. The criteria are financial performance, accreditations and authorisations, Administrative and accounting, technical infrastructure, staff expertise & experience and customer portfolio. AHP was used to evaluate the criteria and then ELECTRE method was used for ranking the alternatives. An empirical case study was used to exemplify the methodology.

COPRAS (COmplex Proportional Assessment) is another MCDM method which is extensively used by decision makers in various fields. Madhuri, Chandulal and Madugula (2010) developed a model based on multi-attribute evaluation of web sites. The evaluation embraces the identified attributes influencing the process of selection of web sites. The evaluation methods are used for the effectiveness of web site is a critical issue in both practice and research. The evaluation process involves human subjectivity and it is a

MCDM problem in the presence of many quantitative and qualitative attributes. They considered the application of Grey Relations Methodology for defining the Utility of alternatives, and COPRAS method with Grey relations (COPRAS-G) was used. The study investigated three web sites with the proposed method. The results obtained showed that this method may be used as an effective decision aid in multi-attribute selection. Ebrahimi, Fathi, and Irani (2015) proposed a study on Customer relationship management (CRM) based on the integration of two novel MCDM methods namely Fuzzy Shannon's entropy and COPRAS. CRM is a multiple perspective business paradigm which helps companies gain competitive advantage through relationships with their customers. Five main criteria of the CRM performance measurement were identified through expert opinion and questionnaire. Fuzzy Shannon's entropy was applied for calculating the relative importance and for demonstrating the applicability of the model. Three subsidiary branches which were applying CRM systems, were ranked by fuzzy COPRAS based on their CRM performance. Dey and Ghosh (2015) conducted a study on education sector with regard to non teaching staff. They designed a new mathematical model based on the existing information system using multi-criteria decision making to analyze the performance of a non-teaching staff with the help of eight methodologies containing AHP, COPRAS, SAW, TOPSIS, Fuzzy TOPSIS, PROMETHEE-2, Compromise Programming and Weighted Average. They compared the results and determined the rank using group decision making method.

5. Research Gap

The review of literature has revealed that several studies have been conducted to assess the capital budgeting decisions using capital budgeting techniques but very few using the MCDM methods. The ELECTRE and the COPRAS methods have been extensively used in various fields of science and commerce. This study is unique as it employs the ELECTRE and the COPRAS methods of MCDM for the first time in relation to capital budgeting decisions. Hence, this study tries to bridge the lacuna in this research arena to some extent. The study integrates capital budgeting

techniques with application of the ELECTRE and the COPRAS methods to choose the best investment alternative. An attempt has been made to analyse a case study aimed at assisting the investment decision with regard to acquisition of long-term assets. Expert opinion was obtained to determine the weights of the various criteria and sub-criteria.

6. Objectives of the Study

1. To develop an understanding of how to compare different Investment proposals.
2. To compare and evaluate to rank the investment alternatives through the application of the ELECTRE and the COPRAS methods.

7. Research Methodology

- Sample Design and Data Collection

A hypothetical case study is presented in order to illustrate the applicability and efficiency of the proposed model.

- Case Study

Suppose the decision makers of a firm have to decide to acquire a machine to augment the firm's installed capacity to meet the growing demand for its product. They want to choose that machine which will maximize the returns and ensure quick recovery of initial investment. There are three machines (alternatives) under consideration of the management which are to be chosen on the basis of the five capital budgeting techniques (indicators/ criteria) as shown in

Table 1: Criteria and symbols

S. No.	Criteria (C)	Symbol
1	ARR	C1
2	PB	C2
3	NPV	C3
4	PI	C4
5	IRR	C5

Weights

To estimate weights, W_j of the criteria, the method of expert evaluation was applied with respect to condition:

$$\sum_{j=1}^5 W_j = 1$$

Cost and Revenue details

The relevant details including estimated sales, yearly expenditure and other Input characteristics of available projects are presented in Table 2.

Table 2: (all figures in Rs. Lakhs)

Machines (Alternatives=A) →	Machine 1 (A1)	Machine 2 (A2)	Machine 3 (A3)
Initial Investment required	500	1,000	1,400
Estimated annual Sales	400	600	700
Cost of Production (estimated)			
Direct Material	50	40	25
Direct Labour	50	35	25
Factory overheads	60	40	30
Administrative overheads	20	15	10
Selling & Distribution overheads	10	10	10
Total cost	190	140	100
Economic life	5 years	5 years	5 years
Scrap value at the end of life	50	100	200

Assumptions: (a) All sales and expenses are in cash (b) Corporate tax rate is 30 %. (c) Cost of capital is 12 %. (d) Straight line method of depreciation is used. (e) Capital gain/ loss tax rate is 20 %.

Performance evaluation measures

In this study, performance evaluation measures are five capital budgeting techniques. All these measures are crucial for evaluating the various alternatives. These measures are explained briefly:

Accounting Rate of return (ARR)

The accounting rate of return is the ratio of the project's average after tax income in relation to its average book value.

$$\text{ARR} = \frac{\text{Average annual profit after taxes}}{\text{Average Investments in the project}} \times 100$$

Where average investments = $\frac{1}{2}$ (Initial cost – Scrap value) + working capital + scrap value.

For acceptance or rejection of a project, ARR is compared with a pre-determined minimum rate of return. If ARR is greater than the required rate of return, the project is acceptable, otherwise it is not.

The major drawback of ARR technique is that it does not consider time value of money. Another drawback is that it is based on the concept of accounting profit which is inferior to cash flows concept.

Payback (PB) Period

It refers to the length of time in years required to recover the initial cost of the project. Payback period is computed as follows when the projected annual cash flows are uniform:

$$\text{PB} = \frac{\text{CFO}}{\text{CFA}}$$

Where CFO refers to the initial cash outflows and CFA refers to the project's average cash inflows.

The shortest payback period among the various investment proposals is most acceptable. The payback period is more a method of capital recovery rather than a measure of profitability of a project.

Net Present Value (NPV)

NPV is perhaps the most important and widely used technique of capital budgeting. NPV is the difference between the present value of cash inflows and the present value of cash outflows. NPV is calculated using the following formula:

$$\text{NPV} = \sum_{t=1}^n \frac{\text{CF}_t}{(1+k)^t} - \text{CFO}$$

Where CF_t is the net cash inflows in time period t , k is the cost of capital and t is life of the project in years.

The decision rule associated with NPV is accept the project if NPV is positive and reject if NPV is negative. If NPV is zero then it is a matter of indifference between acceptance and rejection of the proposal.

Profitability Index (PI)

PI, also known as Benefit cost ratio, refers to the ratio of the present value of cash inflows to the present value of cash outflows.

$$\text{PI} = \frac{\sum_{t=1}^n \frac{\text{CF}_t}{(1+k)^t}}{\text{CFO}}$$

The decision rule associated with PI is accept the project if PI is greater than one and reject if PI is less than one. If PI is one then there is no difference in accepting or rejecting the proposal.

Internal Rate of Return (IRR)

IRR of a proposal is the discount rate at which its NPV is zero. In other words, IRR is the discount rate at which the present value of cash inflows is equal to the present value of cash outflows. It can be calculated using the formula:

$$\sum_{t=1}^n \frac{\text{CF}_t}{(1+k)^t} + \frac{\text{SV} + \text{WC}}{(1+k)^n} - \text{CFO} = 0$$

The exact IRR can be found by interpolating between two discount rates. For acceptance or rejection of a project, IRR is compared with a pre-determined minimum rate of return. The decision rule associated with IRR is accept the project when IRR is greater than the required rate of return. An investment in projects with higher IRR is more acceptable.

• Multi Criteria Decision Making (MCDM) Methods

MCDM is a very well known branch of decision-making. It is a branch of a general class of Operations Research models which deals with decision making problems under the presence of a number of decision criteria. MCDM is the process of finding the best alternative where all the alternatives can be evaluated according to a number of criteria or attributes which are usually conflicting in nature. Many methods of MCDM are generally used. Of the many methods, two methods have been used, namely the ELECTRE and the COPRAS. These methods have been selected for various reasons like simple calculation algorithm, because of their simplicity and popularity, non complicated procedure and ability to produce easily understandable outputs

which can be performed without requiring any special software.

A. ELECTRE method

The ELECTRE method is an outranking relation method to rank a set of alternatives to analyse the data for decision making. This method was devised by Roy (1968). This method depends on comparison of pairs of set of alternatives. The concordance and discordance indexes can be viewed as a measurement of satisfaction that a decision maker uses in choosing one alternative over the other. The process of ELECTRE consists of these steps:

$$A = (a_1, a_2, a_3, \dots, a_n)$$

(1)

Let $A = (a_1, a_2, a_3, \dots, a_n)$ be a set of alternatives.

$$C = (C_1, C_2, C_3, \dots, C_n)$$

(2)

Let $C = (C_1, C_2, C_3, \dots, C_n)$ be a set of criteria.

Step 1: Construct the decision matrix:

$$\begin{array}{ccccccc} d_{11} & d_{12} & - & - & - & d_{1n} \\ d_{21} & d_{22} & - & - & - & d_{2n} \\ d_{ij} = & - & & & & \\ - & & & & & \\ d_{m1} & d_{m2} & - & - & - & d_{mn} \end{array}$$

Where d_{ij} is the performance rating of alternative A_i with respect to criteria C_j and i refers to number of rows and j stands for number of columns.

Step 2: Construct the normalized decision matrix using the following equation in case of benefit criteria.

$$r_{ij} = \frac{d_{ij}}{\sqrt{\sum_{i=1}^m d_{ij}^2}} \quad (3)$$

For non benefit criteria, the following formula will be used.

$$r_{ij} = \frac{1/d_{ij}}{\sqrt{\sum_{i=1}^m (1/d_{ij})^2}} \quad (4)$$

Step 3: Construct weighted normalized decision matrix by multiplying normalized decision matrix and its weights.

$$V_{ij} = r_{ij} \times w_j \quad (5)$$

Step 4: Ascertainment of concordance and discordance sets.

Weighted normalized decision matrix is compared for every pair of alternatives. If a pair of alternative is better than or equal to the other element of pair, then it is considered under concordance set to be denoted by C .

$$C_{(a,b)} = \{j \mid x_{aj} \geq x_{bj}\} \quad (6)$$

If the pair of alternative is worse than the other element of the pair for relevant criteria then it is considered under discordance set which is denoted by D .

$$D_{(a,b)} = \{j \mid x_{aj} \leq x_{bj}\} \quad (7)$$

Step 5: Calculate the concordance matrix

Concordance matrix is generated by summation of the values of weights of concordance set elements. $C(a,b)$ can be obtained using the formula:

$$C(a,b) = \sum_{j \in C_{a,b}} W_j \quad (8)$$

The concordance matrix is drawn up as follows:

$$C = \begin{matrix} & - & C_{(1,2)} & \dots & C_{(1,n)} \\ C_{(2,1)} & - & \dots & \dots & C_{(2,n)} \\ \vdots & \vdots & \ddots & \ddots & \vdots \\ C_{(m,1)} & C_{(m,2)} & \dots & \dots & - \end{matrix} \quad (9)$$

Step 6: Calculate the discordance matrix

Discordance matrix is prepared by dividing discordance set member values to total values of whole set.

$$D_{(a,b)} = \max_{j \in J} |V_{aj} - V_{bj}| \quad (10)$$

$$\max_{j \in J} |V_{mj} - V_{nj}|$$

The discordance matrix is formulated as follows:

$$D = \begin{matrix} & - & D_{(1,2)} & \dots & D_{(1,n)} \\ D_{(2,1)} & - & \dots & \dots & D_{(2,n)} \\ \vdots & \vdots & \ddots & \ddots & \vdots \\ D_{(m,1)} & D_{(m,2)} & \dots & \dots & - \end{matrix} \quad (11)$$

Step 7: Calculate the net superior and inferior value

Let c_a and d_a be the net superior and inferior values respectively for all alternatives. c_a refers to the summation of number of competitive superiority for each alternative. Higher the value, the better it is. The c_a for each alternative is computed as follows:

$$c_a = \sum_{a=1}^n c(a, b) - \sum_{b=1}^m c(b, a) \quad (12)$$

On the contrary, d_a is calculated to find out the inferiority ranking for the alternatives:

$$d_a = \sum_{a=1}^n d(a, b) - \sum_{b=1}^m d(b, a) \quad (13)$$

Lower the value of d_a , the better it is.

After the computation of c_a and d_a find out the ranks of all alternatives from net superior and net inferior values.

B. COPRAS method

The name COPRAS stands for Complex Proportional Assessment. It is a preference ranking method which was introduced by Zavadskas and Kaklauskas (1996). In this

method, the influence of maximizing and minimizing criteria on the evaluation result is considered. The best alternative is selected on the basis of ideal and anti-ideal solutions with respect to different criteria and their associated weights.

Structure of COPRAS is shown below:

Step 1: Identical to Electre method:

Step 2: Construct the normalized decision matrix:

$$r_{ij} = \frac{d_{ij}}{\sum d_{ij}} \quad (14)$$

Where r_{ij} is the normalized performance rating of an element.

Step 3: Construct the weighted normalized decision matrix by multiplying the normalized decision matrix and its weights:

$$V_{ij} = r_{ij} \times w_j \quad (15)$$

Where w_j is weight of the j th criterion.

Step 4: Calculate the S_{+i} (maximizing indexes) and the S_{-i} (minimizing indexes). S_{+i} and S_{-i} are calculated as follows:

$$S_{+i} = \sum_{j=1}^n V_{+ij} \quad (\text{for each benefit criteria}) \quad (16)$$

$$S_{-i} = \sum_{j=1}^n V_{-ij} \quad (\text{for each non-benefit criteria}) \quad (17)$$

Step 5: Calculate Q_i and U_i values for each alternative as follows:

$$Q_i = S_{+i} + \frac{S_{-min} \sum_{i=1}^m S_{-i}}{S_{-i} \sum_{i=1}^m S_{-min}/S_{-i}} \quad (18)$$

$$= S_{+i} + \frac{\sum_{i=1}^m S_{-i}}{S_{-i} \sum_{i=1}^m 1/S_{-i}} \quad (19)$$

Step 6: Calculate the U_i for each alternative as shown below:

$$U_i = \frac{Q_i}{Q_{max}} \times 100 \quad (20)$$

Step 7: Rank the alternatives according to their U_i value in the descending order.

8. Data Analysis and Interpretation

The questionnaire for estimating the weights of the selected criteria were submitted to a number

of academicians. Seven fully filled in forms were received. The experts were asked to assess the weights of the different criteria in two steps: first to estimate the weights of the criteria inside each particular group and then to estimate the weights of two groups namely discounting and non discounting techniques. The ultimate weight W_j of the j th criteria was

calculated by multiplying its weights, WSC (weight of sub-criteria) inside the group by the weight, WC (weight of criteria) of the group in the integrated criteria:

$$W_j = WSC \cdot WC$$

The ultimate weights of the evaluation criteria are presented in Table 3.

Table 3: Weight of criteria on MCDM

Criteria	Description	Weights (Wc)	Weights (Wsc)	Ultimate Weight (Wj)
C1	ARR	0.30 (Non discounting Technique)	0.40	0.12
C2	PB		0.60	0.18
C3	NPV	0.70 (Discounting Technique)	0.50	0.35
C4	PI		0.20	0.14
C5	IRR		0.30	0.21
		TOTAL		1.00

As straight line method of depreciation has been assumed. Annual depreciation is computed for all the investment alternatives as shown in Table 4.

Table 4: Computation of depreciation

Computation of Depreciation			
Machines →	A1	A2	A3

Initial Cost	500	1,000	1,400
Life in years	5 years	5 years	5 years
Scrap realized	50	100	200
Annual Depreciation = (Cost - Scrap)/ life in years	90	180	240

From the information as per case study, five capital budgeting techniques have computed in Table 5.

Table 5: Computation of five criteria namely ARR, PB, NPV, PI and IRR

Computation of ARR, PB, NPV, PI and IRR			
Estimated Sales	400	600	700
Less: Cash expenses	190	140	100
Profit before depreciation & tax	210	460	600
Less: Depreciation (D)	90	180	240
Profit before tax	120	280	360
Less: Tax @ 30 %	36	84	108
Profit after tax (PAT)	84	196	252
cash flow after tax (CFAT=PAT + D)	174	376	492
PV @ 12 % of CFAT (3.605)	627.27	1355.48	1773.66
PV @ 12 % of scrap realised (0.567)	28.35	56.70	113.40
Total PV of cash Inflows	655.62	1412.18	1887.06
Less: Initial cash outlays	500	1,000	1,400
NPV =	155.62	412.18	487.06
PI =PVCIF/PVCOF	1.31	1.41	1.35
Payback Period	2.87 years	2.66 years	2.84 years
IRR =	23.60%	27.17%	24.64%
ARR =	30.54%	35.63%	31.50%

The result of five capital budgeting techniques summarized below in Table 6.
in relation to the three investment proposals are

Table 6: Consolidated results of five criteria

Criteria	A1	A2	A3
ARR	30.54%	35.63%	31.50%
PB	2.87 YEARS	2.66 YEARS	2.84 YEARS
NPV	155.62	412.18	487.06
PI	1.31	1.41	1.35
IRR	23.60%	27.17%	24.64%

ELECTRE

The nine steps of this technique are computed below.

Decision matrix is shown in Table 7 in which elements d_{ij} indicates the performance of alternatives A_i when it is evaluated in terms of decision criteria C_j .

Step 1: Construct the decision matrix.

Table 7: Decision matrix as per ELECTRE method

C A	C1	C2	C3	C4	C5
A1	30.54%	2.87 YEARS	155.62	1.31	23.60%
A2	35.63%	2.66 YEARS	412.18	1.41	27.17%
A3	31.50%	2.84 YEARS	487.06	1.35	24.64%

Step 2: Construct the normalized decision matrix

rating for each element using equations (3) and (4).

Normalized decision matrix is shown in Table 8 in which element r_{ij} indicates normalized

Table 8: Normalized decision matrix as per ELECTRE method

C A	C1	C2	C3	C4	C5
A1	0.5403	0.5603	0.2370	0.5572	0.5411
A2	0.6304	0.6045	0.6276	0.5998	0.6229
A3	0.5573	0.5662	0.7416	0.5742	0.5649

Step 3: Construct weighted normalized decision matrix.

weighted normalized decision matrix using equation 5.

Normalized decision matrix is displayed in Table 9 which shows values (V_{ij}) indicating

Table 9: Weighted normalized decision matrix as per ELECTRE method

C A	C1	C2	C3	C4	C5
A1	0.0648	0.1009	0.0829	0.0780	0.1136
A2	0.0756	0.1088	0.2197	0.0840	0.1308
A3	0.0669	0.1019	0.2596	0.0804	0.1186

Step 4: Determine concordance and discordance sets

Concordance and discordance sets are determined using equations (6) and (7) as shown in Table 10.

Table 10: Concordance and Discordance sets

C(1,2)	(2)	D(1,2)	(1,3,4,5)
C(1,3)	(2)	D(1,3)	(1,3,4,5)
C(2,1)	(1,3,4,5)	D(2,1)	(2)
C(2,3)	(1,4,5)	D(2,3)	(2,3)
C(3,1)	(1,3,4,5)	D(3,1)	(2)
C(3,2)	(2,3)	D(3,2)	(1,4,5)

Step 5 and 6: Calculate the concordance and discordance indexes

Concordance matrix is generated using equation (8). For example the concordance index of C(2,1) can be calculated as follows:

$$C(2,1) = \sum_{j \in Z,1} W_j$$

$$= 0.12+0.35+0.14+0.21= 0.82$$

A1	-	0.1800	0.1800
A2	0.8200	-	0.4700
A3	0.8200	0.5300	-

Discordance matrix is generated using equation (9). For example the discordance index of D(1,2) can be calculated as follows:

$$D_{(a,b)} = \max_{j \in J} |V_{aj} - V_{bj}|$$

$$\max_{j \in J} |V_{mj} - V_{nj}|$$

$$D(1,2) = \text{Max} [0.0108, 0.1367, 0.0060, 0.060] = 0.1367$$

A1	-	1	1
A2	0.0570	-	1

Table 12: Ranking of alternatives on the basis of net superior and net inferior values

	Net superior values	Net inferior values	Ranking of the Net superior values	Ranking of the Net inferior values
A1	-1.2800	1.9368	3	3
A2	0.5800	-0.2487	2	2
A3	0.7000	-1.6881	1	1

After sorting it is found that both net superior and net inferior values give identical ranks between various alternatives. From Table 12, it can be seen that A3 (Machine 3) is the best

alternative among the three alternatives which means that this proposal can be characterised by the strongest state of performance and A1 ranks last as per the ELECTRE method.

Table 11: Concordance and Discordance Indexes

C(1,2)	0.1800	D(1,2)	1.00
C(1,3)	0.1800	D(1,3)	1.00
C(2,1)	0.8200	D(2,1)	0.0570
C(2,3)	0.4700	D(2,3)	1.00
C(3,1)	0.8200	D(3,1)	0.0062
C(3,2)	0.5300	D(3,2)	0.3057

Step 6: Calculate the net superior and inferior value

Net superior and net inferior values are computed using equations (13) and (14) as shown in Table 12.

$$C1 = (0.1800+0.1800) - (0.8200+0.8200) = -1.2800$$

$$C2 = (0.8200+0.4700) - (0.1800+0.5300) = 0.5800$$

$$C3 = (0.8200+0.5300) - (0.1800+0.4700) = 0.7000$$

$$D1 = (1+1) - (0.0570+0.0062) = 1.9368$$

$$D2 = (0.0570+1) - (1+0.3057) = -0.2487$$

$$D3 = (0.0062+0.3057) - (1+1) = -1.6881$$

COPRAS

This technique involves seven steps which are computed below.

Step 1: Identical to the Electre method.

Step 2: Construct the normalized decision matrix, using Equation (16), as shown in Table 13.

Table 13: Normalized decision matrix as per the COPRAS method

	C1	C2	C3	C4	C5
A1	0.31269	0.34289	0.14753	0.32187	0.31296
A2	0.3648	0.3178	0.39074	0.34644	0.3603
A3	0.32251	0.33931	0.46173	0.3317	0.32675

Step 3: Construct the weighted normalized decision matrix, using Equation 17 as shown in

Table 14: Weighted normalized decision matrix as per the COPRAS method

	C1	C2	C3	C4	C5
A1	0.03752	0.06172	0.05163	0.04506	0.06572
A2	0.04378	0.0572	0.13676	0.0485	0.07566
A3	0.0387	0.06108	0.16161	0.04644	0.06862

Step 4: Determine S_{+i} and the S_{-i} from Equations 18 and 19.

It is summarised in Table 15.

Table 15: S_{+i} and the S_{-i} by the COPRAS method

A	S_{+i}	S_{-i}
A1	0.1999	0.06172
A2	0.3047	0.0572
A3	0.3154	0.06108

Step 5, 6 and 7: Determine Q_i for each alternative using Equations 21 and compute U_i using Equation 22 for each alternative. Rank the alternatives according to their U_i value in the descending order.

The computed values are shown in Table 16

Table 16: Values of Q_i , U_i and Rankings by the COPRAS method

A	Q_i	U_i	Rank
A1	0.2582	69.00	3
A2	0.3676	98.23	2
A3	0.3742	100.01	1

From Table 16, it can be observed that A3 (Machine 3) is the best alternative among all

the alternatives and A1 (Machine 1) ranks last as per the COPRAS method.

• Comparison

Comparison between various alternatives based on two methods of the MCDM namely the ELECTRE and the COPRAS are shown in Table 17, which shows that the rankings given by both the methods are identical.

Table 17: Ranking by the ELECTRE and the COPRAS methods

Alternatives	ELECTRE Rank	COPRAS Rank
A1	3	3
A2	2	2
A3	1	1

9. Conclusion and Policy Implications

The study has revealed that the two methods of the MCDM have given identical rankings for selection among the various investment alternatives. It becomes easy for the decision-maker to make the selection among various investment alternatives using this model. We propose to use capital budgeting techniques along with the application of the ELECTRE and the COPRAS methods of the MCDM.

10. Future Scope of Study

In future studies, exploring more cases and conducting more empirical studies are recommended to further validate the usefulness of the proposed financial evaluation model. Finally, other analytical methods of MCDM can be employed for evaluating and comparing capital budgeting decisions.

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