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Understanding Investment decision Patterns in coal mining sector: A combined AHP-DEMATEL Case Study of MCL

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Abstract
Segregating the resources among the competitive investment opportunities is one of the most crucial decisions that organization has to make as the decision reflects the firm's strategy and has a far-reaching effect where a considerable effort should be given to identify the criteria, driving investment structure and interrelationship between them. Extensive growth of production sector has emerged the need for more designated investment decisions based upon constrains, regulating the investment pattern. So, the paper suggests ancomprehensive AHP-DEMATEL approach to investigate the Prioritization of factors dominating the investment pattern of coal mining sector, interrelationship between them and the impact of attributes, contributing towards capital allocation decision, over each other by taking a case study of Mahanadi Coal Field Ltd.,one of the largest contributing subsidiaries of Coal India Ltd.In this proposed approach first the criteria contributing to the investment decision making process has been identified and ranked as per their prioritization and then the casual relationship between these factors has been analyzed using DEMATEL in order to fulfill the objective of proposing a significant approach to investment decision making.

Keywords- Investment pattern, Prioritization, interrelations, AHP, DEMATEL

JEL Classification- C44, D21, G31

1 Introduction

The coal industry stands as a cornerstone of the energy sector, pivotal in meeting the nation's energy demands. Coal India Limited, a distinguished Maharatna PSU, shoulders the responsibility of contributing approximately 80% of India's total coal production. Its operations span across eight subsidiaries dedicated to coal extraction and mining. Given its significance, the Ministry of Coal relentlessly endeavors to enhance the sector's productivity and performance through strategic policies.Strategic decisions within each coal-producing unit play a crucial role in augmenting productivity and quality. However, these decisions, often informed by evidence, experience, and expertise, may overlook non-financial factors influencing investment choices. Additionally, the complex interrelationships between these factors remain largely unexplored.

Conventional investment decision-making methods primarily fall into two categories: the traditional approach and the strategic approach. While the traditional methods lack consideration for future cash flows and the time value of money, strategic approaches like IRR and NPV provide a more comprehensive evaluation. Yet, these methods may falter in scenarios with limited information and project volatility. (Trigeorgis, 1993; Brennan and Schwartz, 1992; Dixit and Pindyck, 1994)

Recognizing the need to address volatility in investment decisions, identifying influential attributes, and assessing their causal relationships becomes imperative. Multi-Criteria Decision Making (MCDM) emerges as a suitable methodology for navigating decisions amidst conflicting data, particularly in environments with a restrictive number of alternatives and a plethora of decision criteria.

The Analytical Hierarchy Process (AHP) and Decision-Making Trial and Evaluation Laboratory (DEMATEL) models offer robust support for MCDM by evaluating criteria prioritization and cause-effect relationships. While AHP facilitates criterion ranking (Fountzoula, 2021), DEMATEL delves into causal dependency between criteria.Leveraging AHP-DEMATEL, this study aims to analyze investment decision-making attributes in the coal mining sector.

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Expert opinions from professionals managing investment decisions at the organizational level, coupled with a comprehensive review of existing literature, form the basis of this study. By employing AHP-DEMATEL to prioritize criteria and to unravel casual relationships, this research endeavors to offer novel insights into investment decision-making within the coal mining industry. So, this paper adopts a case study approach, focusing on Mahanadi Coal Field Ltd., a subsidiary of Coal India Ltd., operating in Odisha by integrating AHP&DEMATELto study the investment decision making particularly pertinent in scenarios characterized by interdependency among decision factors within the coal mining sector.

2 literature review

Segregating the resources among the competitive investment opportunities is one of the most crucial decisions that organization has to make as the decision reflects the firm's strategy and has a far-reaching effect where a considerable effort should be given to identify the criteria, driving investment structure and interrelationship between them. Filipishyna et al., 2020) Mining industry largely depends on an efficient Project planning and financial management system that results in qualitative production process and sustainable economy. So for the better production there must be attractive investment activity that will bring up more private investments. (Mukherjee & Bera, 1995) In their study to develop strategy for project selection in coal mining sector of India using goal programming has identify some of the factors effecting the project selection decision framework they are Eco and Techo Eco Goal, Efficiency goal, non-economic and social Goal involving number of sub factors under these goals. These factors are evaluated based on the expert's opinion and rating given suggesting the relative importance of the same and alternative decision option has also been evaluated to suggest most efficient capital investment opportunity. (Setiyawan&Ciptomulyono, 2020), has also suggested the application of goal programming-AHP method for selecting the optimum project investment option in coal power plant. They identified some factors contributing towards the investment decision making framework which are categorized into availability, reliability, efficiency and safety and based on the weights derived during the study they suggested the most efficient investment plan among the available alternatives.

Many researches in recent years have suggested the combined approach of AHP and DEMATEL to be great tool for decision making problems and models. It has been used mostly for the complicated scenario of service quality and supply chain management over the years. (There are few literatures suggesting use of AHP for decision making in coal industry has been discovered but the combined approach of AHP and DEMATEL though being efficient tool for complex decision-making framework still it not being used for investment decision making in coal industry.

(Tang et al., 2021) in their study for selection method for logistic service providers used the AHP and DEMATEL approach. They have suggested a combined technique of AHP and DEMATEL concentrating on the construction of a standard selection procedure for the selection of logistic service providers. (Sachin et al., 2019) tried control the climate change affecting the cement manufacturing industry in India by introducing a new strategy and for that they identified the factors mitigating climate change. On the basis of these factors they tried to reach upon the best strategy by prioritizing these factors and analyzing them using an integrated AHP-DEMATEL approach which shows the preferential importance of the factors as well as casual relationship between them and provide a framework for expert decision. Moreover (Sarra et al., 2019) in their study to select an optimized Learning Management system used the combined AHP-DEMATEL approach. In order to have an efficient learning environment in educational institution they selected the optimum LSM by MCDM method. (Amit et al., 2018) with a motive to generate an decision making model for capital procurement to select among the supplier used the AHP-DEMATEL based model considering supplier selection as most important strategy in automobile industry. And the hybrid method helped to identify the optimized supplier by prioritizing and establishing causal relationship between the factors. (Pandey et al., 2019) for mobile app development has evaluated many issues relating to it using the DEMATEL approach. They have defined the problem faced by project managers and app developer and these issues were divided on the basis of cause-and-effect group using DEMATEL and found compatibility issues to be most effecting variable as a cause. This study reduced the risk of developing a mobile app.

3. Research Gap:

The literature review highlights a gap in the current research landscape regarding investment decision approach prevailing in coal mining sector. While traditional techniques have been employed to coal mining sector for investment decision making, there is limited exploration of newer methodologies. Despite the multifactorial nature of investment decisions, there is a lack of studies utilizing advanced decision-making tools in this specific industry context. Furthermore, there is a gap in research focusing on the interrelationship between factors influencing investment patterns in coal mining and the impact of these factors on capital allocation decisions.

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4. Research Objectives

Extensive growth of production sector has emerged the need for more designated investment decisions based upon constrains, regulating the investment pattern. So, the paper suggests ancombined technique of AHP and DEMATEL to investigate the Prioritization of factors dominating the pattern of investmentin coal mining sector, and to evaluate interrelationship between them and the impact of attributes, contributing towards capital allocation decision, over each other by taking a case study of Mahanadi Coal Field Ltd.,one of the major contributing subsidiaries of Coal India Ltd.

5. **Research Methodologies**

5.1 Problem Identification

As suggested by (Mukherjee et al., 1995; De Souza et al, 2018 &Setiyawan et al., 2020)) the capital investment decisions are effected by factors like financial, technological, efficiency, non-economic and social involving number of sub factors under these attributes. Moreover, to identify the preferential factors for investment decisions we have asked for the opinion of the decision makers of MCL. Based on their experience and literature survey we have identified the criteria and sub criteria contributing towards investment decision. They are:

i. Economic Criteria (C1)
   An economic criterion includes sub criteria like capital requirement, Operating Profit and Operating cost that reflect the economic health of the organization.
ii. Technical Criteria (C2)
   Technical factors are those that define the technical ability of the organization for the operating activities which includes; Productivity, Infrastructure and manpower requirements.
iii. Efficiency Criteria (C3)
   Factors like IRR, Profitability, Demand/ Offtake has an impact on the overall efficiency of the organization so they constitute the efficiency criteria here.
iv. Social Criteria (C4)
   In order to survive and grow in the society an organization must bring back to the society that contributes to its existence and so we have considered social factors like Employment, Environmental Expenditure and CSR expenditure.

These criteria are analyzed further in order to suggest a strategic approach for selecting among investment alternatives.

5.2 Data Collection

The data is collected by having discussion and noting the opinions of experts of both finance and project& planning department of MCL who are engaged in investment decision making. We have approached a number of overall 10 officials and we heard only from 8 and the study is based upon their expertise and experiences as they shared using Saaty Scale of measure (Saaty, 1980).

5.3 Method

As the discussion and previous literature shows a combined approach of both AHP and DAMATEL will do justice to investment decisions. Here with the help of the combined approach we will discover the criteria that are prioritized as per expert opinion and will have a comparison whether it is being reflecting in actual investment decisions of the company.

5.3.1 AHP

AHP segregates the problem into levels starting with the main goal and successive levels represents attributes and their sub attributes that contributes towards the goal. Then the alternatives to be evaluated on the basis of these criteria form the lowest level. In our problem to study the investment pattern the main goal is to select upon the various available mining investment option. Table 1 shows the attributes and their sub attributes considered for investment decision forming the second level of our problem under study. The method suggested by Saaty for Analytical Hierarchy Process can be explained with the below steps;

Step 1: Interrelated weight estimation

The elements are compared pair wise with each other by assigning relative weight to them on the basis of their importance in the decision-making process. Staay has prescribed the weights based on the type of relative importance between the elements. The intensity of importance (aij) is represented by 1-9 scale, where 1 represent equal importance, 3 moderate, 5 strong, 7 very strong, 9 extreme and 2,4,6,8 for in-between importance of the above values. The relative importance between the investment decision criteria has been asked to be scaled by the decision makers. On the basis of the scale we can construct a matrix

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denoted by A where there is a set of elements (A1, A2,A3,……Am) and the quantified decision aij is drawn from the alternatives Ai, Aj by pair wise comparison though the matrix based on above scale.
The elements of levels in hierarchy are C1,..Cn and the elements of the matrix are the product of pairwise comparisons between the elements (C1,…,Cn). If "aij " is the element of row "i" and column "j" of the matrix, then "1/aij" is the element of row "j" and column "i" of the matrix. ie "aji=1/aij". If the element "aij " indicate the strength of "C1" when compared with "Cj". This matrix is denoted by matrix "A". When "aji=1/aij", matrix "A" becomes reciprocal.

Table01; Pairwise compairision matrix

Criteria	C1	C2	C3	C4
C1	1	1.98905	2.701277	0.467138
C2	0.50275257	1	1.15948	0.415533
C3	0.37019528	0.86245558	1	0.366276
C4	2.14069504	2.40654774	2.73018161	1

where aij> 0 (i, j = 1, 2,..,m), aii = 1 (i = 1, 2,…,m), and aij = 1/aji (1; 2;…,m). A is a positive reciprocal matrix. Being a consistency matrix representing the different combinations of decision A, the weights of these combinations can be shown as fig02;

Step: 2 Priority vector
After comparing the elements pairwise, the priority weight vector is computed and the comprehensive solution Aw = λ maxw which is the largest inherent value of matrix A.

Step: 3 Consistency index
The consistency index ensures the consistency of comparison matrix A by computing the consistency of the weights using the expression CI = (λmax−n)/ n−1. If CI is less than 0.10, as here it is 0.021 judgments satisfaction can be computed.

5.3.2 DEMATEL
United States Bastille laboratory in 1971 has proposed the system of Decision Making Trial and Evaluation Laboratory (DEMATEL), a matrix and graph theory to discover the interrelationship between factors and to evaluate the impacting and effected factors. It simplifies the complex experience and advice of the experts and establishes the interrelationship between the elements by plotting it in graph. In our problem under study we are discovering the cause variables among the specified criteria and sub criteria in table 01 for the better decision making framework. DAMATEL can be applied through following steps;

Step 1: Generate the direct relation matrix
In order to define the model for the relations among the n criteria, a matrix is constructed having n × n elements. The impact of row element is evaluated on the elements of each column. If there are more than one expert are involved than the each expert's denoted in matrix form and arithmetic mean of these opinion matrixes presented in direct relation matrix X.

$$X = \begin{bmatrix} 0 & \cdots & x_{n1} \\ \vdots & \ddots & \vdots \\ x_{1n} & \cdots & 0 \end{bmatrix} \quad (1)$$

Table02; X matrix

Criteria	Economic	Technical	Efficiency	Social
Economic	0	2.25	2.25	1.875
Technical	2.125	0	3	2.25
Efficiency	1.5	2	0	1.5
Social	2.5	2.875	2.25	0

Step 2: Normalization of X matrix

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For normalization the rows and columns are sum up and the largest sum value is denoted by K and lastly each elements of matrix X is divided by K to design the normalized direct relation matrix.

$$k = max\left\{max \sum_{j=1}^{n} x_{ij}, \sum_{i=1}^{n} x_{ij}\right\} \quad (2)$$

Where, $N = \frac{1}{k} * X$

Step 3: Derive total relation matrix

Followed by the normalization matrix a fuzzy total relation matrix is generated.

$$T = \lim_{k \to +\infty} (N^1 + N^2 + \cdots + N^k) \quad (3)$$

OR $$\mathrm{T} = \mathrm{N} \times (I - N)^{-1} \quad (4)$$

Step 4: Final output and create a causal diagram

The final step involves summation of each rows and column of matrix T. the total of the row elements are represented by (D) and columns by (R)

$$D = \sum_{j=1}^{n} T_{ij} \quad (5)$$

$$R = \sum_{i=1}^{n} T_{ij} \quad (6)$$

Finally the D+R shows the importance of I criteria and D-R shows the effect of I in the entire system.

Table 03; synthesized matrix for normalization and prioritization of criteria

Criteria	C1	C2	C3	C4	PriorityVector
C1	0.24915	0.317838	0.355855	0.207714	0.28264
C2	0.125261	0.159794	0.152745	0.184768	0.155642
C3	0.092234	0.137815	0.131736	0.162866	0.131163
C4	0.533355	0.384552	0.359663	0.444653	0.430556

λ max = 4.057485,CI=0.01916183 RI=0.89, CR=0.02153014 < 0:1 OK.

The CI here is 0.021 which is less than 0.1 so we can derive a satisfactory judgment from the given expert opinions. As per the priority weight of these factors we can conclude the social factor as the most prioritized for investment decision followed by economic, technical and efficiency attributes sequentially**.**

6 Result and discussion

Table 04; Pair wise comparison matrix for all the sub criteria under each criterion;

Criterion	**Criteria/ Sub Criteria**	**Priority Vector**	**Prioritization**
Economic Criteria	Capital Req	0.389478	2
	Operating Profit	0.412572	1
	Operating cost	0.19795	3
Technical Criteria	Productivity	0.418864	1
	Manpower	0.235588	3
	Infrastructure	0.345507	2

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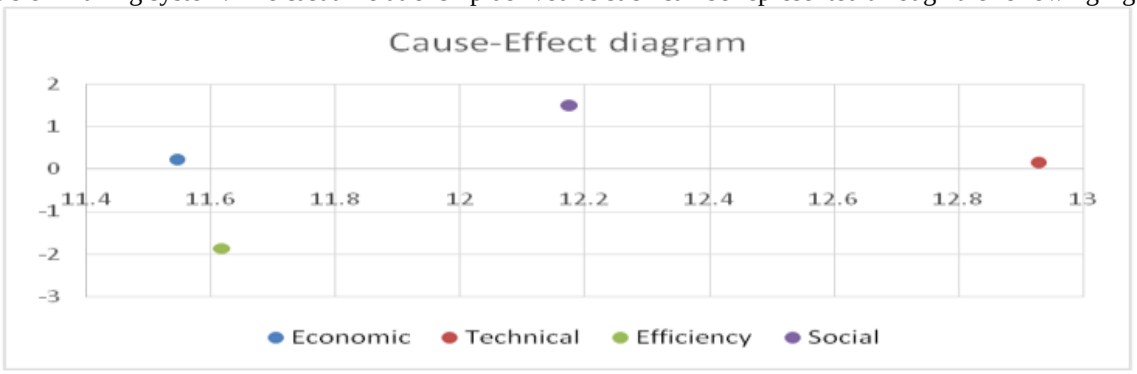
Efficiency Criteria	IRR	0.338082	2
	Profitability	0.206062	3
	Offtake	0.455856	1
Social criteria	Employment	0.405648	1
	Envt. Exp	0.276127	3
	CSR Exp.	0.318225	2

The above table as derived by evaluating the sub criteria under different factors and their contribution towards the main goal. The priority vector shows the percentage of importance they carry in the whole system of capital investment decision. From the above table we derive that the Operating cost in economic factor, production capacity under technical, IRR under efficiency and employment under social factor as most prioritized attributes for investment decision in the coal mining company. In any commercial undertaking profit is the main motive. Here also MCL focuses on increasing operating profit from the mining activity by managing the capital requirements and operating cost under the economic criterion. The decision makers are more concern for technical criterion of productivity and the infrastructure and manpower is channelized for the same as more productivity will result in better performance of the company. Also MCL focus on the coal demand or offtake for the production and mining activities and based on which the profitability and Internal Rate of Return (IRR) is determined. Moreover to fulfil the coal demand and achieving higher productivity manpower management plays an important role so it manages the existing manpower and provides employment opportunities. Apart from these the coal mining company spent a considerable amount on CSR and environment protection activities.

Table05; **Total relationship matrix for investment decision making factors**

Criteria	R	D	D+R	D-R
Economic	5.661	5.885	11.546	0.224
Technical	6.388	6.541	12.929	0.154
Efficiency	6.743	4.874	11.617	-1.87
Social	5.341	6.834	12.175	1.493

The total relationship matrix is showing the degree of importance of factors (D+R) and their casual relation (D-R) in the whole decision making system. The casual relationship derived as such can be represented through the following figure.



Cause-effect relation

The above relational matrix and cause-effect diagram indicates that if the Economic, technical and social factors are managed strategically than the overall efficiency constrain of the organization can be alleviated. Moreover for the capital investment decision Technical attributes should be given a higher degree of importance.

The next tables demonstrate the casual relation between each subordinate factors of the four primary criteria sequentially and take into account the DEMETAL technique mentioned above in order to determine the internal relationship between them.;

Table06; Casual Relationship matrix for sub criterion:

Economic Criteria	**R**	**D**	**D+R**	**D-R**	**Cause/ Effect**
Capital Req	3.621	4.681	8.302	1.059	Cause
Operating Profit	3.956	4.37	8.326	0.414	Cause

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Operating cost	4.43	2.957	7.387	-1.473	Effect
Technical Criteria	**R**	**D**	**D+R**	**D-R**	**Cause/ Effect**
Productivity	5.052	6.749	11.801	1.697	Cause
Manpower	7.083	5.333	12.416	-1.75	Effect
Infrastructure	6.25	6.303	12.553	0.053	Cause
Efficiency Criteria	**R**	**D**	**D+R**	**D-R**	**Cause/ Effect**
IRR	6.306	6.565	12.87	0.259	Cause
Profitability	7.253	5.697	12.949	-1.556	Effect
Offtake	5.834	7.131	12.965	1.297	Cause
Social criteria	**R**	**D**	**D+R**	**D-R**	**Cause/ Effect**
Employment	24.393	22.342	46.735	-2.051	Effect
Envt. Exp	20.786	22.068	42.855	1.282	Cause
CSR Exp.	19.803	20.573	40.376	0.769	Cause

The DEMATEL approach has identified the casual relationship and degree of importance of each sub criteria constructing the basic attributes. The result demonstrates how operational cost restraint under economic criteria is dependent on operating profit and capital demanded. Similarly technical criteria like productivity and infrastructure has a causal impact on manpower. Additionally, the IRR of the investment option and the demand for coal have an impact on profitability. Moreover Social concerns like CSR and environmental costs have an indirect impact on employment.

As a result of the integrated AHP-DEMATEL framework, we have determined that the social criteria are the most important factor. This is because, as a public enterprise, the government places a high priority on CSR and green initiatives in order to partially offset the environmental risks that the mining industry poses, such as a polluted workplace for workers and the eviction of residents for land acquisition

7 Implications of the study

The study undertaken here has suggested a scientific approach for the capital investment decision of the coal mining company by integrating the MCDM models of AHP and DEMATEL. We have found out from the study undertaken regarding the criterion that by managing the economic, technical, and social factors, the efficiency in terms of growing profitability of the coal mining company can be strengthened. To be more precise, the overall effectiveness of MCL can be increased by focusing more on capital requirements, operational costs as economic elements, productivity and infrastructure as technical factors. Lastly environmental expenses and CSR expenses as social aspects should also be emphasized so that it will result in increasing the goodwill and motivating the employee to improve overall effectiveness of the organization.

8 Conclusions

One of the strategic decision scenarios is investment decision making problem that includes various contributing attributes and different opinions based on expertise and experiences of the experts demanding for a multi objective decision making system. This paper attempts towards studying the complex capital investment decision making framework by scientific method based on integrated model of AHP and DEMATEL. The coal mining company has an significant importance for capital investment decision as it define the efficiency of the total production and mining system of the industry. The case study undertaken here has indicated the importance of economic, technical and social criterion for investment decisions to increase the overall profitable efficiency. MCL should prioritize these factors accordingly in order to improve the effectiveness in coming days.

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