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An Application of Analytical Hierarchy Process to Financial Asset Selection

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Abstract*— Asset selection involves picking up a particular asset within each asset class in such a manner that it would outperform the rest of the assets to maximize the investor's goal of increasing value while mitigating risk. This paper aims to implement a widely used "multi-criteria decision making (MCDM)" technique known as Analytical Hierarchy Process (AHP) for best asset selection. In AHP, the qualitative problems are described and transformed quantitatively, and then the quantitative analysis is used to find the relationship among various decision criteria. In this study, ethical and suitability criteria are used along with the financial criteria to rank the assets based on individual investors' preferences. To demonstrate the efficacy of the problem, a hypothetical data set is used for ethical and suitability criteria, and data set of 10 assets of Nifty 50 companies under the National Stock Exchange (NSE) is collected for financial criteria.

Index Terms*— asset selection, multi-criteria decision making (MCDM), Analytical Hierarchy Process (AHP).

I. INTRODUCTION

In the real world, every investor has an immense desire to beat the market, and from this comes the role of active asset selection. Generally, an investor or investment expert considers the double-barreled goal of maximizing return while minimizing risk over time — the two most important factors for asset selection. The aim is to determine which asset to select or avoid to realize the customer's financial objectives within the range of their risk tolerance. Active asset selection involves the selection of assets within each asset class such that it would outperform the respective asset class. Markowitz mean-variance model [1] used for asset portfolio selection primarily focused on financial criteria to determine the asset quality, but, in real-world problems, not all relevant information can be gathered by mere consideration of the financial criteria. Many other criteria are of equal importance, if not higher, from an investor's perspective. Considering these criteria an investor can obtain results better than the one obtained using financial criteria. Thus, many researchers use multiple-criteria asset portfolio selection models in their research [2], [3], [4], etc.

In this study, in addition to the financial criteria, ethical and suitability criteria are also taken into account. The criteria have been finalized using an extensive search of scientific publications [5], [6], [7], [8], [9] and a literature survey through open search engines. Due to an increase in market failures and corporate fraud instances, investors are forced not only to rely on financial factors for evaluating investment options but also on ethical investing. Researchers have faced many difficulties when it comes to ethical investment. Developing metrics for ethical evaluation and including ethical factors in optimization models for investment decision making are the two main challenges. Therefore, if we model asset choice in a way that considers the "trade-off between ethical and conventional investment," we may generate assets that are in line with the investor's financial as well as ethical preferences. Some of the studies which have considered ethical criteria in the past are [5], [6], and [7].

A behavioral notion known as "suitability" relates to how well an investor's preferences and portfolio characteristics match up. Financial professionals and investment firms profile investors in a variety of ways before recommending an appropriate asset selection. Incorporating an investor's suitability is of great importance because aggrieved investors can make allegations against investment professionals about the mishandling of their account. Many researchers have considered the suitability factor for portfolio selection [8], [9], etc.

Over the past years, MCDM models have been widely used in many financial sectors. MCDM comprises a collection of analytical methods for evaluating the strengths and weaknesses of competing alternatives based on multiple conflicting criteria to come up with an optimal decision according to the preference given by decision experts. The ability of these models to analyze complex real-world problems — considering both qualitative and quantitative data by incorporating subjective opinions as well as decision experts' opinions — makes them widely popular. In real-world financial problems, various extrinsic and intrinsic criteria like economic, political, social, and technological aspects, etc. are taken into consideration to make decisions. MCDM techniques have been cherished widely by researchers in the financial sector. Jeng et al. [10] proposed a decision model using the MCDM technique to provide a solution to the market's need to maximize the overall benefit by evaluating a project portfolio at the early initiation stage. Motameni, and Sharifi Salim [11] used TOPSIS and GAHP

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to develop a model for portfolio selection regarding effective indices on investors' decision making.

AHP, developed by Saaty [12], [13], is one of the most flexible and powerful mathematical tools for solving complex decision making problems. It converts the decision making problem into a hierarchy by dividing it into several smaller components called criteria and sub-criteria. Though several studies have been done on the application of AHP, here we are confined to only those which are related to our area of discussion. Tiryaki and Ahlatcioglu [14] combined fuzzy AHP with a portfolio selection problem to determine which stocks are to be chosen for the investment, and in what proportion. There are many applications of AHP in the financial sector [15] such as portfolio management [16], [17], credit evaluation [18], bank acquisition strategy evaluation [19], capital budgeting [20], etc.

In this study, the assets are ranked according to each investor's preferences using a combination of financial, ethical, and suitability criteria using AHP. For illustration, a dataset of 10 assets of Nifty 50 companies under the NSE is used. The remaining paper is organized as follows. In the next section, the problem is defined along with the methodology used, after which in the subsequent section numerical illustrations are provided, and finally in the last section conclusions are given.

II. ASSET SELECTION PROBLEM AND METHODOLOGY

In this section, first, we describe the various factors/criteria which are used for the asset selection problem and then the AHP technique for ranking assets. In this research, the sub-criteria used are similar to the sub-criteria used by Gupta et al. [5, 8] in their work. Interested readers can refer to these papers for further details.

A. ASSET SELECTION CRITERIA

Ethical Criteria[5]

For ethical evaluation of the assets, three main attributes, namely, "environmental sustainability (ES), corporate social responsibility (CSR), and corporate governance and business ethics (CGBE)" are used in this study. ES of a company can be improved by reducing its wasteful practices or carbon footprint. The practices which benefit the company's employees, consumers, and the wider community come under CSR. CGBE refers to maintaining honest, transparent accounting practices and regulatory compliance.

Suitability Criteria[8]

Two main attributes of suitability, namely, "income and savings (IS) and investment experience (IE)" are used in this study. The income and savings criterion seeks to capture the personal characteristics of the investor as well as the capacity to assume risks. The value of the investor's income will define suitability for investments in assets. Investment experience analyzes the investor's expectation with the selection of assets. Experienced investors, in contrast to new entrants, have more expectations from their investments.

Financial Criteria[4]

Four attributes of financial criteria, namely, "short term return (STR), long term return (LTR), liquidity, and risk are used in this study. For any asset, the STR is considered as the average performance of the assets across 12 months and the LTR as the average performance of the assets across 36 months. The liquidity of an asset is measured with the help of the turnover rate, defined as the ratio between the average stock traded at the market and the tradable stock (shares held by the public) of that asset. Risk is measured using standard deviation." Risk helps to determine the spread of asset prices from their average price. A high standard deviation signifies risky investment and a low standard deviation means risk is low. So, an investor selects a less risky asset for investment.

B. ANALYTICAL HIERARCHY PROCESS

AHP is a mathematical tool for solving MCDM problems. In this approach, firstly, the problem is structured in the form of a hierarchy of sub-problems that can be easily realized and evaluated. Secondly, at each level of the hierarchy, the priorities of the elements are determined, and finally, overall priorities of the decision alternatives are established by synthesizing the priorities evaluated in the second step.

Figure 1 shows the four-level decision hierarchy used for asset selection. Here, Level 1 represents the overall goal of asset selection, Level 2 represents the three main criteria used for the asset selection, namely, ethical, suitability, and financial criteria. Level 3 represents the sub-criteria related to the main criteria, and finally, Level 4 represents the alternative assets.

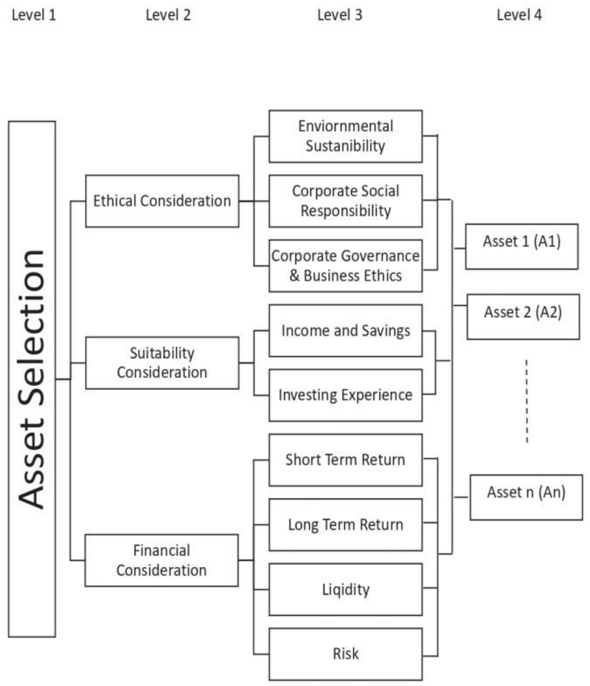

Figure 1 Decision hierarchy for asset selection

In AHP [21], a nine-point scale [22] (see Table 1) is used to rate elements of each level of the decision hierarchy using pair-wise comparison. A paired comparison matrix is formed after all the elements have been compared pair by pair. The number of elements at each level defines the order of the matrix. At each level, the number of such matrices depends on the number of elements at the immediate upper level to which they link. Once all the paired comparison matrices are formed for each matrix, the eigenvector or the relative weights representing the degree of relative importance amongst the elements and the maximum eigenvalue (λ_{max}) are calculated. In AHP, the λ_{max} value is an important validating parameter that is used as a reference index to screen information by calculating the consistency ratio of the estimated vector (eigenvector) to validate whether the paired comparison matrix provides a completely consistent evaluation. The following steps are used to calculate the consistency ratio.

Step 1. "Calculate the eigenvector or the relative weights and λ_{max} for each matrix of order n"

Step 2. "Compute the consistency index (CI) for each matrix of order n as"

$$CI = (\lambda_{max} - n)/(n - 1)$$

Step 3. "The consistency ratio (CR) is then calculated using the formula"

$$CR = CI/RI$$

"where RI is a known random consistency index that has been obtained from a large number of simulation runs and varies according to the order of the matrix. For a matrix, at each level of the hierarchy, the acceptable value of CR is less than or equal to 0.1 [22]. The degree of consistency is satisfactory if $CR \leq 0.1$. However, serious inconsistencies may exist if $CR > 0.1$ and hence meaningful results may not be yielded by AHP. The evaluation process should, therefore, be reviewed and improved. To calculate the global weights, the eigenvectors are used if there is an acceptable degree of consistency for the selection criteria."

Table 1 Illustration of scale for pairwise comparison

Scale	Definition
1	Compared criteria are equally important
3	Compared criterion is moderately more important than the other
5	Compared criterion is strongly more important than the other
7	Compared criterion is very strongly more important than the other
9	Compared criterion is extremely more important than the other
2,4,6,8	Intermediate values
Reciprocals	Inverse comparison

III. NUMERICAL ILLUSTRATIONS

In this section, we used the real-world data set coming from the NSE site (www.nseindia.com). The NSE is the 10^{th} largest stock exchange in India, located in Mumbai. We have selected the Nifty 50 index, which is a benchmark Indian capital market index that represents the weighted average of the 50 largest Indian companies listed on the NSE. Financial assets of 10 major companies, namely, Reliance Industries Limited (A1), ITC Limited (A2), Tata Steel Limited (A3), Tata Consultancy Services Limited (A4), NTPC Limited (A5), Larsen & Toubro Limited (A6), Adani Ports and Special Economic Zone Limited (A7), HDFC Bank Limited (A8), Maruti Suzuki India Limited (A9), and HCL Technologies Limited (A10) are randomly selected to illustrate the proposed AHP technique and highlight its main features.

In this study, three categories of investors are chosen, namely, young investors below age 30, middle-aged investors between 30–55, and retired persons above age 55. To get data for pair-wise comparison matrices in respect of the overall goal and also for various criteria/sub-criteria related to ethical and suitability criteria, a list of questions is prepared and shared with the investors. The verbal scale provided in Table 1 is used to obtain the response to the questions shared. For example, the response obtained from an imaginary investor is shown in Figure 2. From the figure, it is clear that for an investor in respect of suitability criteria, income and savings sub-criteria is three times more important than the sub-criteria, investment experience. Also, the historical data of 10 assets were downloaded from NSE site for the three financial years and their daily closing prices are used for the calculation of STR, LTR, liquidity, and risk. Depending upon the investors' type and their response towards each level of the hierarchy, the ranking of the assets may vary. Thus, to show the variations in asset selection, diversity in investors' responses is introduced at the first two levels of the hierarchy.

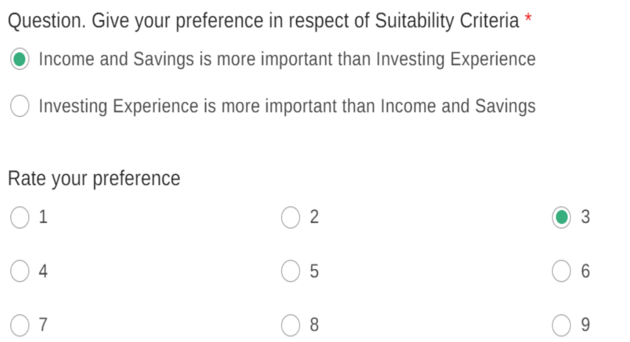

Figure 2 Investor's response

A. Example 1

In this example, we consider the first category of investors i.e., young investors, who are of age below 30, with no dependents. They have a strong desire for a high return and a high tolerance for risk. These investors have little savings and no investment experience. They like to invest in a company that is more focused on social values. Based on the questionnaire, all the information thus obtained is analyzed using the paired comparison matrices, see Table 2–Table 5. Using the historical data of the assets downloaded from NSE site, STR, LTR, liquidity, and risk of the assets are calculated and then normalized, see Table 6. A pairwise comparison matrix is constructed using the verbal scale provided in Table 1 and based on the experience of financial experts, see Table 7. Next, the computations of the AHP procedure are described to calculate the final AHP rating of the assets. In the first step, the local weights of the three criteria with respect to the overall goal of asset selection are determined (see Table 2). In the second step, local weights of the various sub-criteria with respect to their parent criterion are determined (see Table 3). At last, the local weights of all 10 assets with respect to each of the nine sub-criteria for asset selection are determined (see Table 4, Table 5, and Table 7).

Table 2 Pairwise comparison of the main criteria with respect to the overall goal

Criteria	Ethical	Suitability	Financial	Local weight
Ethical	1	3	1/5	0.19319
Suitability	1/3	1	1/7	0.08331
Financial	5	7	1	0.72351

Table 3 Pairwise comparison of the sub-criteria with respect to the main criteria

Ethical	ES	CSR	CGBE		Local weight
ES	1	1/5	1/3		0.10614
CSR	5	1	3		0.63341
CGBE	3	1/3	1		0.26045
Suitability	IS	IE			
IS	1	3			0.75000
IE	1/3	1			0.25000
Financial	STR	LTR	Liquidity	Risk	
STR	1	1/7	5	1/2	0.12471
LTR	7	1	9	5	0.63396
Liquidity	1/5	1/9	1	1/7	0.04075
Risk	2	1/5	7	1	0.20059

Table 4 Pairwise comparison of the alternatives with respect to the sub-criteria ES, CSR, and CGBE

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Local weight
ES											
A1	1	1/6	1/5	1/9	1/3	1/6	1/7	1/8	1/5	1/9	0.01407
A2	6	1	5	1/5	5	1/3	1/3	1/5	2	1/5	0.06238
A3	5	1/5	1	1/7	3	1/5	1/5	1/7	1/3	1/7	0.03168
A4	9	5	7	1	8	5	4	3	6	1	0.24252
A5	3	1/5	1/3	1/8	1	1/5	1/7	1/7	1/3	1/8	0.02099
A6	6	3	5	1/5	5	1	1/3	1/3	3	1/4	0.08135
A7	7	3	5	1/4	7	3	1	1/3	5	1/4	0.11221
A8	8	5	7	1/3	7	3	3	1	5	1/3	0.15505
A9	5	1/2	3	1/6	3	1/3	1/5	1/5	1	1/6	0.04302
A10	9	5	7	1	8	4	4	3	6	1	0.23672

CSR											
A1	1	5	6	1/3	5	3	1/5	7	1	1/3	0.09972
A2	1/5	1	3	1/6	1	1/3	1/7	5	1/5	1/5	0.03590
A3	1/6	1/3	1	1/7	1/3	1/5	1/8	3	1/6	1/7	0.02132
A4	3	6	7	1	6	5	1/3	8	3	1	0.17223
A5	1/5	1	3	1/6	1	1/3	1/7	5	1/5	1/5	0.03590
A6	1/3	3	5	1/5	3	1	1/6	6	1/3	1/3	0.06212
A7	5	7	8	3	7	6	1	9	5	3	0.30022
A8	1/7	1/5	1/3	1/8	1/5	1/6	1/9	1	1/7	1/9	0.01401
A9	1	5	6	1/3	5	3	1/5	7	1	1/3	0.09972
A10	3	5	7	1	5	3	1/3	9	3	1	0.15886
CGBE											
A1	1	4	3	2	6	8	1/3	7	5	1	0.16471
A2	1/4	1	1/2	1/3	3	5	1/5	4	2	1/4	0.05886
A3	1/3	2	1	1/2	3	7	1/4	5	3	1/3	0.08205
A4	1/2	3	2	1	5	8	1/4	7	4	1/2	0.11908
A5	1/6	1/3	1/3	1/5	1	5	1/7	3	1/2	1/6	0.03521
A6	1/8	1/5	1/7	1/8	1/5	1	1/9	1/5	1/5	1/8	0.01411
A7	3	5	4	4	7	9	1	8	7	3	0.29205
A8	1/7	1/4	1/5	1/7	1/3	5	1/8	1	1/4	1/7	0.02480
A9	1/5	1/2	1/3	1/4	2	5	1/7	4	1	1/5	0.04443
A10	1	4	3	2	6	8	1/3	7	5	1	0.16471

Table 5 Pairwise comparison of the alternatives with respect to the sub-criteria IS and IE

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Local weight
IS											
A1	1	1/2	1/6	5	1/3	4	3	5	9	1/3	0.08907
A2	2	1	1/5	7	1/2	5	4	5	7	1/2	0.11386
A3	6	5	1	8	3	7	6	7	9	5	0.31723
A4	1/5	1/7	1/8	1	1/7	1/5	1/5	1/3	3	1/8	0.01997
A5	3	2	1/3	7	1	5	5	6	9	2	0.16749
A6	1/4	1/5	1/7	5	1/5	1	1/2	3	6	1/5	0.04693
A7	1/3	1/4	1/6	5	1/5	2	1	3	7	1/4	0.05630
A8	1/5	1/5	1/7	3	1/6	1/3	1/3	1	5	1/7	0.03164
A9	1/9	1/7	1/9	1/3	1/9	1/6	1/7	1/5	1	1/9	0.01309
A10	3	2	1/5	8	1/2	5	4	7	9	1	0.14442
IE											
A1	1	2	1/2	5	7	4	3	9	7	5	0.20261
A2	1/2	1	1/3	5	7	3	3	8	7	4	0.16146
A3	2	3	1	7	8	5	3	9	7	5	0.26808

A4	1/5	1/5	1/7	1	5	1/3	1/4	7	2	1/2	0.04881
A5	1/7	1/7	1/8	1/5	1	1/5	1/5	4	1/3	1/5	0.02286
A6	1/4	1/3	1/5	3	5	1	1/2	6	5	3	0.08471
A7	1/3	1/3	1/3	4	5	2	1	7	5	3	0.10637
A8	1/9	1/8	1/9	1/7	1/4	1/6	1/7	1	1/5	1/7	0.01362
A9	1/7	1/7	1/7	1/2	3	1/5	1/5	5	1	1/2	0.03360
A10	1/5	1/4	1/5	2	5	1/3	1/3	7	2	1	0.05787

Table 6 Normalized NSE data of 10 assets for four sub-criteria of Financial criteria

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
STR	0.02261	0.01214	0.04212	0.01283	0.01907	0.01897	0.00367	-0.00097	0.00923	0.01450
LTR	0.01890	-0.00545	0.03093	0.01694	-0.00046	0.00820	0.02164	0.00669	0.00434	0.02305
Liquidity	0.00112	0.00189	0.00658	0.00063	0.00210	0.00155	0.00327	0.00204	0.00231	0.00121
Risk	0.09304	0.07288	0.14001	0.06882	0.08944	0.09283	0.10131	0.08181	0.09892	0.09875

Table 7 Pairwise comparison of the alternatives with respect to the sub-criteria STR, LTR, Liquidity, and Risk

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Local weight
STR											
A1	1	6	1/2	5	2	3	8	9	7	4	0.21149
A2	1/6	1	1/6	1/2	1/5	1/4	3	4	2	1/3	0.04132
A3	2	6	1	6	3	4	8	9	7	5	0.28104
A4	1/5	2	1/6	1	1/4	1/3	4	5	3	1/2	0.05709
A5	1/2	5	1/3	4	1	2	7	8	6	3	0.15297
A6	1/3	4	1/4	3	1/2	1	6	7	5	2	0.11062
A7	1/8	1/3	1/8	1/4	1/7	1/6	1	2	1/2	1/5	0.02092
A8	1/9	1/4	1/9	1/5	1/8	1/7	1/2	1	1/3	1/6	0.01557
A9	1/7	1/2	1/7	1/3	1/6	1/5	2	3	1	1/4	0.02925
A10	1/4	3	1/5	2	1/3	1/2	5	6	4	1	0.07973
LTR											
A1	1	8	1/3	2	7	3	1/2	4	5	6	0.14778
A2	1/8	1	1/9	1/9	1/5	1/6	1/9	1/8	1/9	1/7	0.01279
A3	3	9	1	4	8	5	2	6	7	7	0.27882
A4	1/2	9	1/4	1	7	2	1/3	3	4	4	0.10778
A5	1/7	5	1/8	1/7	1	1/5	1/8	1/6	1/7	1/5	0.02186
A6	1/3	6	1/5	1/2	5	1	1/4	2	3	4	0.07587
A7	2	9	1/2	3	8	4	1	5	6	7	0.20566
A8	1/4	8	1/6	1/3	6	1/2	1/5	1	2	2	0.05889
A9	1/5	9	1/7	1/4	6	1/3	1/6	1/2	1	2	0.05071
A10	1/6	7	1/7	1/4	5	1/4	1/7	1/2	1/2	1	0.03984
Liquidity											

A1	1	1/5	1/8	1/5	1/6	1/5	1/8	1/6	1/6	1/2	0.01657
A2	5	1	1/5	6	1/4	3	1/5	1/3	1/3	2	0.05973
A3	8	5	1	9	4	7	2	4	3	7	0.27183
A4	5	1/6	1/9	1	1/7	1/6	1/9	1/7	1/7	1/3	0.02360
A5	6	4	1/4	7	1	5	1/3	2	1/2	6	0.11972
A6	5	1/3	1/7	6	1/5	1	1/5	1/4	1/4	4	0.05114
A7	8	5	1/2	9	3	5	1	3	2	7	0.19969
A8	6	3	1/4	7	1/2	4	1/3	1	1/2	5	0.09725
A9	6	3	1/3	7	2	4	1/2	2	1	6	0.13290
A10	2	1/2	1/7	3	1/6	1/4	1/7	1/5	1/6	1	0.02757
Risk											
A1	1	1/4	6	1/4	1/4	1/3	5	1/3	4	4	0.07274
A2	4	1	9	1/2	3	4	7	2	6	6	0.20214
A3	1/6	1/9	1	1/8	1/9	1/7	1/4	1/7	1/6	1/5	0.01391
A4	4	2	8	1	3	4	7	3	5	5	0.24186
A5	4	1/3	9	1/3	1	4	7	1/2	5	5	0.13857
A6	3	1/4	7	1/4	1/4	1	6	1/3	4	4	0.09047
A7	1/5	1/7	4	1/7	1/7	1/6	1	1/6	1/3	1/4	0.02317
A8	3	1/2	7	1/3	2	3	6	1	4	4	0.13531
A9	1/4	1/6	6	1/5	1/5	1/4	3	1/4	1	1/2	0.03821
A10	1/4	1/6	5	1/5	1/5	1/4	4	1/4	2	1	0.04361

Each of the pairwise comparison tables is tested for consistency and each of them has a $CR < 0.1$, which according to Saaty [22] passed the test for being a consistent pairwise comparison matrix.

After all the local weights are found, a bottom-up process of successive multiplication in terms of AHP is used to find the global weights of each asset alternative. For example, the local weight of an asset alternative A1 obtained in respect of risk sub-criteria is multiplied by the risk sub-criteria's local weight which is obtained in relation to the parent criteria, i.e. financial criteria, finally, this product is multiplied by the financial criteria's local weight calculated with respect to the overall goal of asset selection. Thus, nine global weights are obtained for each asset alternative. The final AHP weight of asset selection for each asset is then determined by adding all the global weights of the asset (see Table 8). Finally, the ranking of the assets is done. It is observed that asset alternatives A3, A7, and A1 are ranked first, second, and third, respectively.

B. Example 2

The second category of investors is married couples aged 35–55. The couples have an above-average or an average level of expected return and average or low-risk tolerance. These investors have some savings and little investment experience. They like to invest in a company that is more focused on business ethics. In this example, we have introduced investor diversity at Level 2 and Level 3, so, for this investor type, the local weights of the criteria and the sub-criteria are different but there is no change in the local weights of the alternatives. Here, we have listed only the global weights of the alternatives over the nine sub-criteria, and the final AHP weights and intermediate calculations are skipped for the sake of repetition of calculations.

C. Example 3

The third category of investors is retired persons above age 55. They expect an average level of return with almost no risk tolerance. These investors have much investment experience. They like to invest in a company that is more focused on environmental safety. Again, we have listed only the final AHP weights and not included the intermediate calculations done to find the final AHP weights.

Lastly, the rank of the alternative assets for three investor types is compared to check the consistent performance of the assets for the decision making process, presented in Table 11. From the table, it is clear that alternatives A3 and A7 continuously performed well by holding first and second rank, respectively, for all three categories. However, the rank of other assets is not consistent, for example, alternatives A1 and A4 have the same ranks for the first two categories of investors, but for the remaining assets, the rank is not consistent.

Table 8 Final AHP weights and ranking of the assets (Example 1)

	ES	CSR	CGBE	IS	IE	STR	LTR	Liquidity	Risk	AHP weight	Rank
A1	0.00029	0.01220	0.00829	0.00557	0.00422	0.01908	0.06778	0.00049	0.01056	0.12847	3rd
A2	0.00128	0.00439	0.00296	0.00711	0.00336	0.00373	0.00587	0.00176	0.02934	0.05980	8th
A3	0.00065	0.00261	0.00413	0.01982	0.00558	0.02536	0.12789	0.00801	0.00202	0.19607	1st
A4	0.00497	0.02108	0.00599	0.00125	0.00102	0.00515	0.04944	0.00070	0.03510	0.12469	4th
A5	0.00043	0.00439	0.00177	0.01047	0.00048	0.01380	0.01003	0.00353	0.02011	0.06501	7th
A6	0.00167	0.00760	0.00071	0.00293	0.00176	0.00998	0.03480	0.00151	0.01313	0.07410	6th
A7	0.00230	0.03674	0.01470	0.00352	0.00222	0.00189	0.09433	0.00589	0.00336	0.16494	2nd
A8	0.00318	0.00171	0.00125	0.00198	0.00028	0.00140	0.02701	0.00287	0.01964	0.05932	9th
A9	0.00088	0.01220	0.00224	0.00082	0.00070	0.00264	0.02326	0.00392	0.00555	0.05220	10th
A10	0.00485	0.01944	0.00829	0.00902	0.00121	0.00719	0.01827	0.00081	0.00633	0.07542	5th

Table 9 Final AHP weights and ranking of the assets (Example 2)

	ES	CSR	CGBE	IS	IE	STR	LTR	Liquidity	Risk	AHP weight	Rank
A1	0.00005	0.00192	0.00699	0.01579	0.00449	0.00601	0.06028	0.00159	0.01475	0.11187	3rd
A2	0.00023	0.00069	0.00250	0.02018	0.00358	0.00118	0.00522	0.00574	0.04098	0.08029	6th
A3	0.00012	0.00041	0.00348	0.05623	0.00594	0.00799	0.11373	0.02614	0.00282	0.21686	1st
A4	0.00090	0.00332	0.00505	0.00354	0.00108	0.00162	0.04396	0.00227	0.04903	0.11077	4th
A5	0.00008	0.00069	0.00149	0.02969	0.00051	0.00435	0.00892	0.01151	0.02809	0.08533	5th
A6	0.00030	0.00120	0.00060	0.00832	0.00188	0.00315	0.03095	0.00492	0.01834	0.06964	7th
A7	0.00042	0.00578	0.01239	0.00998	0.00236	0.00059	0.08388	0.01920	0.00470	0.13930	2nd
A8	0.00058	0.00027	0.00105	0.00561	0.00030	0.00044	0.02402	0.00935	0.02743	0.06905	8th
A9	0.00016	0.00192	0.00188	0.00232	0.00074	0.00083	0.02068	0.01278	0.00775	0.04907	10th
A10	0.00088	0.00306	0.00699	0.02560	0.00128	0.00227	0.01625	0.00265	0.00884	0.06782	9th

Table 10 Final AHP weights and ranking of the assets (Example 3)

	ES	CSR	CGBE	IS	IE	STR	LTR	Liquidity	Risk	AHP weight	Rank
A1	0.00075	0.00131	0.02091	0.00093	0.01477	0.03611	0.00595	0.00714	0.00594	0.09380	4th
A2	0.00331	0.00047	0.00747	0.00119	0.01177	0.00705	0.00051	0.02574	0.01650	0.07402	7th
A3	0.00168	0.00028	0.01042	0.00330	0.01954	0.04798	0.01122	0.11713	0.00114	0.21269	1st
A4	0.01286	0.00227	0.01512	0.00021	0.00356	0.00975	0.00434	0.01017	0.01975	0.07802	6th
A5	0.00111	0.00047	0.00447	0.00174	0.00167	0.02612	0.00088	0.05159	0.01131	0.09936	3rd
A6	0.00431	0.00082	0.00179	0.00049	0.00617	0.01888	0.00305	0.02204	0.00739	0.06495	10th
A7	0.00595	0.00396	0.03708	0.00059	0.00775	0.00357	0.00828	0.08605	0.00189	0.15512	2nd
A8	0.00822	0.00018	0.00315	0.00033	0.00099	0.00266	0.00237	0.04191	0.01105	0.07086	9th
A9	0.00228	0.00131	0.00564	0.00014	0.00245	0.00499	0.00204	0.05726	0.00312	0.07924	5th
A10	0.01256	0.00209	0.02091	0.00150	0.00422	0.01361	0.00160	0.01188	0.00356	0.07194	8th

Table 11 Rank comparison of the alternatives based on Investor type

	Young Investor	Middle-Aged Investor	Retired Persons
A1	3rd	3rd	4th
A2	8th	6th	7th
A3	1st	1st	1st
A4	4th	4th	6th
A5	7th	5th	3rd
A6	6th	7th	10th
A7	2nd	2nd	2nd
A8	9th	8th	9th
A9	10th	10th	5th
A10	5th	9th	8th

After going through the AHP process, it was found that alternative A3 holds the first rank for all three investor types, which helps the investors to rely on this asset alternative more, as compared to other asset alternatives used in this study. Also, from Table 11, it is clear that with a change in investors' preferences towards various criteria, the ranking of the assets also changes. So, it may assist investors, depending on their preferences to make wise decisions and choose an asset that can meet their requirements.

IV. CONCLUSION

In this paper, the Analytic Hierarchy Process is used for the best asset selection. Ethical and suitability criteria are used along with the financial criteria to rank the assets based on individual investors' preferences. To demonstrate the effectiveness of the problem, a data set of 10 assets of Nifty 50 companies under the NSE is collected. The responses from three categories of hypothetical investors are collected based on how the ranking of the assets is done. In the future, this study can be extended by doing a survey with the investors and capturing their responses in the form of a questionnaire to validate the method. Also, the model can be extended in a fuzzy environment to incorporate vagueness in the investor's response.

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