

## An Integrated Three Tier Architecture of AHP-GP for Stock Portfolio Management

H. S. Hota<sup>1</sup>, Vineet Kumar Awasthi<sup>2</sup>, Sanjay Kumar Singhai<sup>3</sup>

<sup>1</sup>Department of CSA, Bilaspur University, Bilaspur, C.G., India,  
e-mail: profhota@gmail.com

<sup>2</sup>Department of I.T., Dr. C.V. Raman University, Bilaspur, C.G., India,  
e-mail: vineet99kumar@gmail.com

<sup>3</sup>Dept of EE, Govt Engineering College, Bilaspur, C.G., India,  
e-mail: ersanjaysinghai@gmail.com

### Abstract

Stock portfolio management is a tedious task due to high volatile nature of stock market. On the other hand creating a good stock portfolio for the purpose of investment by any individual or organization is beneficial in terms of high gain and low risk. This research work focuses on design of stock portfolio with three tier architecture starting from raking of available top Indian stock indices and then ranking of stocks within highest ranked stock index respectively in tier 1 and tier 2 with the help of Analytical Hierarchy Process (AHP) and finally stocks of best Index are divided into four different groups for the diversification of available fund with the help of Goal Programming (GP). Empirical results shows that integrated approach of AHP-GP produces high annual return of 35.15% against expected 40% annual return with lowest risk value. The results of proposed integrated approach was also compared with earlier work of the same authors where portfolio annual return was obtained without AHP and found to be better. **Key Words:** Goal Programming (GP), Analytical Hierarchy Process (AHP), Portfolio Management.

## 1 Introduction

Portfolio management is always been a key research interest area of researchers. Markowitz [1] has introduced a mean variance model for portfolio optimization, based on two important factors: risk and return as these are most common factors to all the investors apart from these some other factors are also available that affects the investment with a great deal. Some other factors like assets allocation; minimum and maximum investment can be added into the selection of stock portfolio. Goal Programming (GP) is widely used for portfolio management and was first introduced by Charnes et al. [2] and Charnes et al. [3] and then later extended by Ijiri [4], Lee [5] and Ignizio [6]. Author [7] [8] have used goal programming method for the inventory control and supplier selection problem. Other authors [9][10] have also used GP for the portfolio management. A Decision Support System (DSS) is presented by author [12] for the investor to take optimal investment decisions using GP, based on constraints and a different weight structure is used in GP [13] to check and improve the performance of mutual fund portfolio. This paper is an extension of the Hota et al. [14] with

respect to goals, constraints and rank obtained using various MCDM methods with the latest data of financial year 2016-17. In this research work an integrated approach of Analytical Hierarchy Process (AHP) and GP was proposed, where AHP [15] is used to find out rank of stock indices and stocks within selected best index and further GP was used to diversify available fund within stock based on its strength obtained through AHP in terms of AHP weight. The goals, constraints etc. were taken from the paper of Sharma et al. [12]. Integrated three tier approach of AHP-GP produces high annual return of 35.15% against expected 40% annual return. The outcome of the research work is compared with earlier work of Hota et al. [14] and other similar works of other authors and found to be satisfactory.

## 2 Integrated AHP-GP Based Stock Portfolio Selection

The proposed integrated approach of three tier architecture of AHP-GP is depicted in Figure 1. The purpose of each tier is explained as listed below:

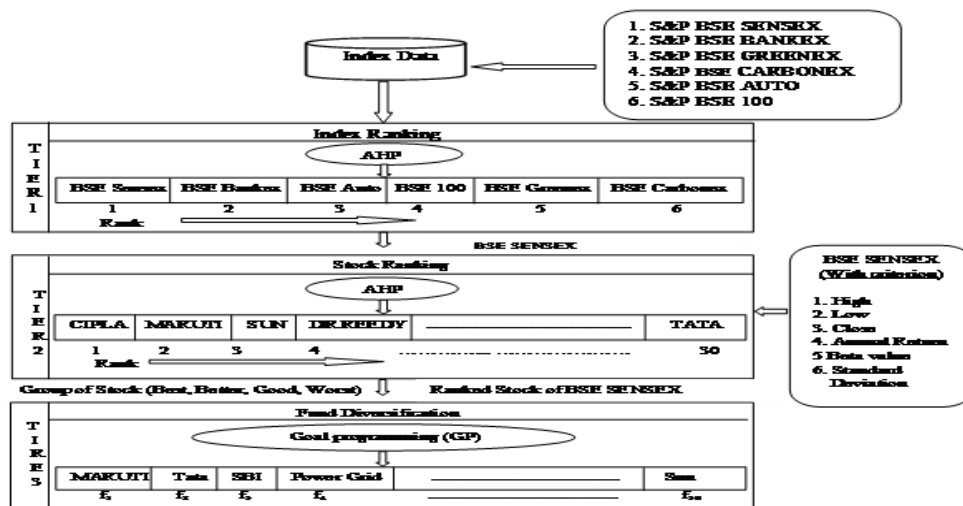


Figure 1: Three Tier Architecture of AHP-GP for Stock Portfolio Management

Tier 1: Initially six stock indices: BSE SENSEX, BSE BANKEX , BSE GREENEX ,BSE CARBONEX, BSE AUTO and BSE 100 are considered, these stock indices are downloaded from [16] and consisting High (C1), Low (C2), Close (C3), P/E ratio (C4), P/B ratio (C5) and Dividend (C6) six criterion. A 6X6 matrix[7] is given as input to the AHP, after a step by step calculation of various factors, AHP weights were obtained and as per the highest weight BSE 30 index has gained the highest rank. This tier is exclusively used to find out best stock index among available six stock indices using ranking based optimization method.

Tier 2: Input to this tier is highest ranked stock index i.e. BSE30, this tier find out rank of all

30 stocks within BSE30 using AHP method, once again using six criterion [17]. The stocks were grouped in four different groups based on AHP weights obtained. Tier 3: This tier uses GP for fund diversification among four different groups of stocks obtained from tier 2. Fund was diversified into different stocks based on different constraints to achieve high annual return and low risk. GP is basically used to solve multi objective problems with conflicting criteria. Main goal of this technique is to find best possible solution for achieving the goals with given constraints of the problem. Among various types of GP, Lexicographic Goal Programming (LGP) is quite useful to solve the problems in financial planning because financial criteria can be easily expressed in terms of goals. A general format of LGP [12] model is as follows:

$$\begin{aligned} & \text{Minimize } [P_1(\bar{d}), \dots, P_k(\bar{d}), \dots, P_K(\bar{d})], \\ & \text{Subject to, } f_i(X) + d_i^- - d_i^+ = b_i, \quad i = 1, 2, 3, \dots, J \\ & d_i^-, d_i^+, x \geq 0 \text{ and } d_i^- \cdot d_i^+ = 0 \end{aligned}$$

Where  $P_k(\bar{d}) = P_k (w_{ik}^- d_{ik}^- + w_{ik}^+ d_{ik}^+)$  and  $P_k$  is the  $k^{th}$  priority structure,  $w_{ik}^-$  and  $w_{ik}^+$  are the numerical weights associated with the deviational variables  $d_{ik}^-$  and  $d_{ik}^+$  respectively at the priority level  $P_k(\bar{d})$  is the vector of decision variables,  $X$  is stock,  $f_i(X)$  is the  $i^{th}$  goal constraint,  $d_{ik}^-$  and  $d_{ik}^+$  represents negative and positive deviation variables respectively.

The goals and constraints are set by the decision-maker to determine the feasible solution. The main idea is to minimize a weighted sum of deviations from target goal. The goals and constraints of the LGP as decided by Hota et al. [14][12] are considered for stock portfolio management to diversify fund. The following notifications are used to design the LGP model [14][12]:

Goals:

- (i) Utilize total available funds for investment within specified constraints.
- (ii) Maximize the portfolios expected annual return set by the investor.
- (iii) Minimize the portfolios risk (Beta and Standard Deviation) as much as possible.

The Constraint:

- (i) Investments: Decision maker wants to invest maximum amount of fund into all the stocks.
- (ii) Annual return: The main objective of portfolio management is to maximize the total annual return from all the stock from the new stock portfolio.
- (iii) Portfolios risk: Beta value and Standard deviation is considered as the risk associated with the stock. Beta value presents the systematic risk and standard deviation refers the deviation of the stock value from the mean value. The investor always wants to minimum risk for the investment.
- (iv) Fund Diversification: To reduce the portfolio risk and enhance the portfolio annual return is done through intelligent allocation of some amount of fund into all the stocks. The diversification of fund prefers the investment of minimum amount into multiple stocks and a big amount into some specific set of stock of portfolio that perform as Best. Along with this, it is also important that not more than a certain percentage of total funds are invested in a single stock and some of the minimum fund must be invested into all the stocks.

### 3 Experimental study

Experiment of the proposed research work is done with the help of self developed software for calculating weights of AHP and other MCDM methods and LINGO. The detail of outcome of each tier is explained below:

Tier 1: AHP and integrated MCDM methods were applied for stock index ranking of six BSE related stock indices of year 2016-17 in the work of Hota H.S. and et al. [14]. It is also found that consistency ratio (CR) is less than 0.1 and is in acceptable range. Weights of corresponding criteria were calculated and then all six stock indices values were applied into criterion weight to calculate final AHP weights. Further another two popular MCDM methods Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Simple Additive Weighting (SAW) methods were also applied along with AHP to calculate the ranks of alternatives [17] (Stock Index). At the end the BSE SENSEX is identified as 1st ranked stock index as an experimental result.

Tier 2: BSE SENSEX is the top ranked index identified in Tier1 which consist 30 stocks with four variables High, Low, Close and Open etc. These values were used to derive new useful variables like Beta value, Standard deviation and annual return. These variables (Beta, Standard Deviation and Annual return) along with High, Low and Close were considered as criteria for applying AHP method. Step by step mathematical calculation were done which gives consistency ratio (CR) value as 0.07627 which is less than 0.1, that proves that the weights are consistence. Then a matrix with six criterion and 30 alternatives was given as input. Finally AHP weights were calculated to find the rank of all 30 stocks. The final rank obtained through AHP is shown in Table 1 along with its rank. On the basis of range of weights, stocks were divided into following four groups:

Group 1: Best- AHP weight  $\geq 12$ , Group 2: Better- AHP weight  $< 12$  and  $\geq 7$

Group 3: Good- AHP weight  $< 7$  and  $\geq 5$ , Group 4: Worst- AHP weight  $< 5$  .

The above groups consists 10,6,7 and 7 stocks respectively

Table 1: Performance of all 30 stocks of BSE SENSEX .

Rank Id	Company	AHP Weight	Performance level	Rank Id	Company	AHP Weight	Performance level
X <sub>1</sub>	Maruti Suzuki In.	28.32	BEST	X <sub>16</sub>	Cipla Ltd.	7.13	BETTER
X <sub>2</sub>	Tata Steel Ltd.	23.67	BEST	X <sub>17</sub>	Hero Motocorp	4.69	GOOD
X <sub>3</sub>	SBI	22.54	BEST	X <sub>18</sub>	Gail (India) Ltd.	4.41	GOOD
X <sub>4</sub>	Power Grid	19.12	BEST	X <sub>19</sub>	M & M	3.98	GOOD
X <sub>5</sub>	Adani Ports	18.53	BEST	X <sub>20</sub>	Hindustan Uni	2.66	GOOD
X <sub>6</sub>	HDFC	16.28	BEST	X <sub>21</sub>	Bharti Airtel	2.60	GOOD
X <sub>7</sub>	HDFC Bank Ltd	15.53	BEST	X <sub>22</sub>	Coal India Ltd.	1.28	GOOD
X <sub>8</sub>	Larsen & Toubro	12.69	BEST	X <sub>23</sub>	Lupin	0.02	GOOD
X <sub>9</sub>	NTPC Ltd.	12.68	BEST	X <sub>24</sub>	TCS	-0.26	WORST
X <sub>10</sub>	Reliance Ind.	12.41	BEST	X <sub>25</sub>	Wipro Ltd.	-3.13	WORST
X <sub>11</sub>	Tata Motors Ltd.	11.03	BETTER	X <sub>26</sub>	ONGC.	-4.09	WORST
X <sub>12</sub>	Asian Paints	10.75	BETTER	X <sub>27</sub>	Dr.Reddy's Lab.	-4.57	WORST
X <sub>13</sub>	ICICI Bank Ltd.	8.09	BETTER	X <sub>28</sub>	ITC Ltd.	-6.00	WORST
X <sub>14</sub>	Axis Bank Ltd.	7.87	BETTER	X <sub>29</sub>	Infosys Ltd.	-6.14	WORST
X <sub>15</sub>	Bajaj Auto Ltd.	7.66	BETTER	X <sub>30</sub>	Sun Pharma.	-6.25	WORST

Tier 3: As explained this tier uses LGP for fund diversification in all the 30 stocks to get best possible solution for specified goals with constraints. In this level LPG is used for the diversification. The LGP model [14] for stock portfolio problem is formulated as follows:

Constraints: (1)The goal constraint for total investment (100%) in various stocks is:

$$\sum_{i=1}^{30} X_i + d_1^- - d_1^+ = 1$$

(2)The goal constraint for annual return from investment is:  $\sum_{i=1}^{30} X_i + d_2^- - d_2^+ = 1$

(3)The goal constraint for the portfolio's beta is given as:  $\sum_{i=1}^{30} B_i X_i + d_3^- - d_3^+ = 0.8882$

(4)The goal constraint for standard deviation is given:  $\sum_{i=1}^{30} B_i X_i + d_3^- - d_3^+ = 0.0214$

(5)The upper limit for investment in each stock can be:  
 $X_i + d_{i+4}^- - d_{i+4}^+ = 0.1 \quad (i=1, \dots, 10), \quad X_i + d_{i+14}^- - d_{i+14}^+ = 0.05 \quad (i=1, \dots, 6),$   
 $X_i + d_{i+20}^- - d_{i+20}^+ = 0.03 \quad (i=1, \dots, 7), \quad X_i + d_{i+27}^- - d_{i+27}^+ = 0.01 \quad (i=1, \dots, 7),$

(6)The lower limit for investment in each stock can be:  
 $X_i + d_{i+34}^- - d_{i+34}^+ = 0.05 \quad (i=1, \dots, 10), \quad X_i + d_{i+44}^- - d_{i+44}^+ = 0.02 \quad (i=1, \dots, 6),$   
 $X_i + d_{i+50}^- - d_{i+50}^+ = 0.015 \quad (i=1, \dots, 7), \quad X_i + d_{i+57}^- - d_{i+57}^+ = 0.01 \quad (i=1, \dots, 7),$

(7)Stocks of BEST performed group must be at least 40% of total investment:  $\sum_{i=1}^{30} X_i + d_{65}^- - d_{65}^+ = 0.4$

The priority structure:

The priority of a goal is basically a weight assigned to the goal. The priority structure of LGP is shown in Table 2. The importance of a goal is presented by assigning some priority to that goal. The equal priority has been assigned to all goals with objective to provide equal importance to each goal. This research work assigns same weight to all goals to check the performance of the model.

Table 2: Priority of goals.

Priority	Description	Deviations
P1	Utilize available funds and satisfy restrictions on Investment	$[w_1^+ d_1^+ + w_1^- d_1^- + w_{i+4}^+ d_{i+4}^+ + w_{i+34}^- d_{i+34}^- + w_{65}^- d_{65}^-],$ $i=1, \dots, 30$
P2	Maximize the portfolio's expected annual return	$w_2^- d_2^-$
P3	Minimize the portfolio's risk (Beta and Standard Deviation)	$w_3^+ d_3^+ + w_4^+ d_4^+$

### 4 Result Analysis and Comparative Study

Outcome from the proposed three tier architecture of integrated AHP-GP were studied using three different cases as per expected annual return value of investor, as listed below with minimum beta value = 0.8882 and minimum Standard Deviation = 0.021445.

Case I: If expected annual return = 20% of investment from the investor's choice then the fund diversification by LGP in all available stocks ( $X_1, X_2, \dots, X_{30}$ ) is obtained through LINGO are as follows:

X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>	X <sub>8</sub>	X <sub>9</sub>	X <sub>10</sub>	X <sub>11</sub>	X <sub>12</sub>	X <sub>13</sub>	X <sub>14</sub>	X <sub>15</sub>
0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.02	0.02	0.05	0.02	0.03
X <sub>16</sub>	X <sub>17</sub>	X <sub>18</sub>	X <sub>19</sub>	X <sub>20</sub>	X <sub>21</sub>	X <sub>22</sub>	X <sub>23</sub>	X <sub>24</sub>	X <sub>25</sub>	X <sub>26</sub>	X <sub>27</sub>	X <sub>28</sub>	X <sub>29</sub>	X <sub>30</sub>
0.05	0.03	0.015	0.03	0.03	0.03	0.03	0.03	0.01	0.02	0.02	0.02	0.015	0.01	0.02

Each cell of above table represents diversified fund value in percentage out of 1 (100%). LGP has achieved objective function value as zero with total of 100% fund diversification along with 23.2% annual return and risk value: Beta = 0.8778, standard deviation = 0.0157(1.5%).

Similarly for other two cases fund diversification was done by LGP as follows:

Case II: If expected annual return = 30% of investment from the investor’s choice then the value of objective function has achieved to zero with 100% investment. Calculated annual return in this case is 30%, calculated Beta value=0.888 and calculated Standard Deviation= 0.016(1.6%).

Case III: If expected annual return = 40% of investment from the investor’s choice then the objective function value has achieved zero value with 100%, investment with calculated annual return 35.15%, calculated Beta value=0.888, calculated Standard Deviation= 0.0152(1.52%).

It can be observed that calculated annual return in case I and II is always higher than expected annual return however in case III model is producing 35.15% annual return against 40% expected annual return, risk values (Beta and standard deviation) are consistent (0.8 and 1.6 respectively) in all three cases. The obtained annual return values in all three cases along with beta value and standard deviation is shown in Figure 2.

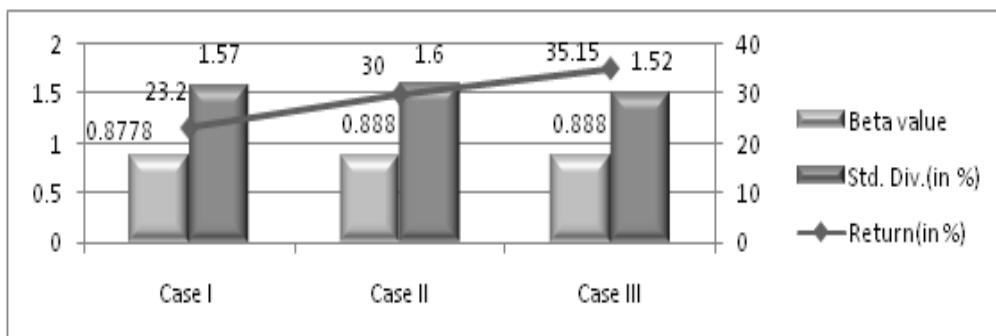


Figure 2: Comparative performance of ranked stock portfolio of all three cases.

The proposed research work is compared with earlier work of Hota H.S. et al. [14] where fund diversification were done through LGP without ranking of BSE SENSEX of the financial year 2016-17. The goals and constraint for investment, annual return, and portfolio risk remains same however restrictions in fund diversification were not considered except constant value for minimum and maximum investment. The experimental results of earlier research work with the three cases is shown in Figure 3 which clearly reflects annual return value of 20%, 29.5% and 29.5% against the expected annual return value of 20%, 30% and 40% for case I, II and III respectively with acceptable range of risk (Beta value and standard deviation).

Based on data presented in Figure 2 and 3, a comparative analysis was done in between non ranked portfolio management using GP and ranked portfolio management using AHP-GP (Proposed) and

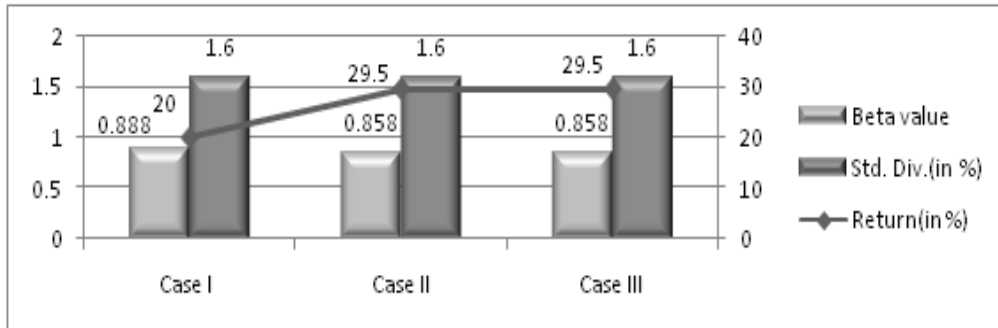


Figure 3: Comparative performance of non ranked stock portfolio of all three cases.

presented in Figure 4. This figure clearly reflects that AHP-GP approach of portfolio management is better than GP approach in all three cases considered in this research work. For example in case III (Where expected annual return is 40%), AHP-GP model is producing 35.15% annual return however it is 29.5% in case of GP. On the other hand risk values are almost similar in case of both the models.

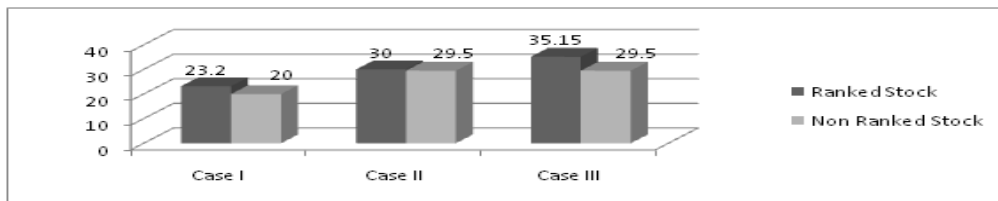


Figure 4: comparative performance of portfolio of ranked (AHP-GP) Vs non ranked stock (GP).

### 5 Conclusion

Portfolio management not only requires experience and high intelligence level of fund manager but also requires intelligent tool for high expected annual return with lower risk value. Creating a good portfolio with intelligent tools and techniques are always been a key research area now a days. This research work proposes a new intelligent model known as AHP-GP for portfolio management, where AHP is used to rank the stocks to divide the available stocks in four different categories according to its strength and then GP is used to diversify fund based on priority and expected annual return values. The experimental work carried out through self developed software for AHP and LINGO for GP shows that integrated three tier approach of AHP-GP is producing remarkable annual return with maximum of 35.15% against expected annual return 40%. This work is also compared with the earlier work done with the help of GP only and found to be better.

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