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Predictive Analytics and Portfolio Optimization: A Study on Mutual Fund Asset Allocation and Risk Mitigation

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ABSTRACT- This research involves creating an efficient portfolio construction that aims to guide the retail investors about the significance of the data-driven decision-making using the analytical tool Python, especially for financial securities investments with a focus on mutual funds. A dataset comprising necessary information on nearly 625 mutual fund schemes from the dataset obtained from Kaggle has been utilized for analysis and study. The study focuses on applying the modern portfolio theory for portfolio construction proposed by Markowitz, which is a very popular financial theory, in real-world investment strategy in the case of constructing a mutual fund portfolio with an adjusted risk-return tradeoff. The methodology relies on the construction of a portfolio with modern portfolio theory concepts and predicting the possible outcomes of the portfolio with the Monte Carlo simulation technique by running the codes in Python and constructing two distinct portfolios: one with diversified and lower risk, comprising 15 mutual fund schemes for conservative investors, and another with minimum compromised risk, comprising 5 mutual fund schemes, which achieves a higher return than the previous one. The parameters taken for the choice of selecting the schemes from the data set are based on the renowned ones such as the Sharpe Ratio and Sortino Ratio. The findings reveal that the 15 schemes portfolio returns are in the range of 10% and 12% with risk levels between 1.5% and 2.5%, and the 5 schemes portfolio returns are in the range of 15% and 17% with risk levels between 4% and 4.5%. The optimum weights to be invested in each scheme to achieve maximum return at the lowest possible risk are also mentioned in proportion for both the portfolios. The findings can be interpreted in a way that the construction of a portfolio with rational decisions backed by data is more appropriate in the modern world with the availability of analytical tools such as Python for forecasting and predicting the potential return and constructing the portfolio based on that by minimizing risks with the traditional theories, which can be efficiently and easily used with technology.

KEYWORDS- Predictive Analytics, Modern Portfolio Theory, Monte Carlo Simulation, Portfolio Optimization, Risk Mitigation.

I. INTRODUCTION

In a developing nation with the largest population, such as India, where people place a great priority on saving and investing, the majority of people do not know how to properly channel their money for the long term or how to select the best investment route depending on their investment objectives. However, despite the fact that there are some of the best financial theories and concepts that have been produced by different financial counselors and experts, the majority of them are either misunderstood or not applied in practice when investing by individuals or retail investors. Thus, the purpose of this study is to outline, clearly explain, and help people understand the value and applications of financial theories like Modern Portfolio Theory. Although this concept is straightforward, the implementation has proven more challenging for the retail investor who lacks the time, resources, and skills to engage in active portfolio management. The gap that this research fills is in using predictive analytics and sophisticated computational tools such as Monte Carlo simulations to design optimal mutual fund portfolios that align with the various investor preferences. The objective of this paper is to design implementable portfolio strategies using python programming language aimed at protecting conservative investors' wealth growth aspirations while fulfilling the risk growth aspirations of growth-oriented investors seeking higher returns. This research study analyses performance based on a dataset of 625 mutual fund schemes in India using Sharpe and Sortino ratios for gauging returns over risk so that the performance analysis takes into consideration solid risk-adjusted returns. The construction of a diversified 15-scheme portfolio and a concentrated 5-scheme portfolio is used to illustrate how data-driven methodologies can help address diverse investment needs, thus making theoretical frameworks like Modern Portfolio Theory more accessible and relevant to retail investors. This research is important because it not only highlights the practical utility of Modern Portfolio Theory in real-world scenarios but also provides a way for integrating advanced analytics into portfolio optimization. No specific mutual fund schemes are recommended by this study; it merely utilizes them as examples for research purposes. More importantly, the results have implications at a higher level, providing financial advisors and institutional investors with a tool to improve investment decisions and meet changing investor expectations.

II. REVIEW OF LITERATURE

Gabler [1] adds the below concept by proposing new long-term equity investments over 20, 30, or even 40-year time horizons. It continues to pose an important problem for portfolio optimization and asset allocation regarding the portfolio return and risk tradeoff. As though the Markowitz Modern Portfolio Theory (1952) established an ideal framework of how efficient portfolios may be designed, it suffers in practical implementation owing to dependence on strong assumptions and estimation sensitivity. His theory highlights the compatibility between the supposed conflicting nature between expected returns and volatility within diversified portfolios. Using already proven portfolio-theoretic premises as well as latest advances of predictive and optimising capabilities, an optimum strategy was conceived. Gabler critically analyses the dominance of the Sharpe ratio and mean-variance optimization, which contradict basic tenets of finance such as diversification. Using a combination of empirical testing along with analytical techniques, his method is shown to be robust across a 44-year out-of-sample period. Innovative rebalancing techniques along with sensitivity studies are used in order to trace portfolio instabilities over sub-periods, and the R software has been used in portfolio optimization and performance evaluation. Therefore, it validates his theories and fills many holes in traditional portfolio theory by presenting a workable long-term investment strategy.

An empirical study comparing the features and performance of mutual funds supported by the public and private sectors in India from May 2002 to May 2005 was carried out by Panwar and Madhumathi (2005). The study measured how changes in portfolio characteristics and degrees of diversification influenced the investment's performance. While there was no significant difference in the mean returns of mutual funds from the public and private sectors, there were substantial differences in the average standard deviation, variance, and coefficient of variation (COV), suggesting that the two groups had different risk profiles. Results in this study based on residual variance use as the parameter for diversification showed considerable divergence in sponsorship classes across portfolio diversifications. For the performance metric measures, Sharpe ratios were negatively impacted by portfolio diversities among mutual funds being statistically different for both public and private sectors. Considering that the impacts of residual variance on performance differ across the various sponsorship categories, diversification among the management of mutual funds needs emphasis. Residual variance has a direct influence on excess standard deviation-adjusted returns [2].

To understand how Indian business professionals invest in mutual funds, Gaurav, Ray, and Pradhan [3] conducted an extremely extensive investigation. Mutual funds have become very much popular for investors because of diversified portfolio management and reasonably low fees. For this study, Exploratory Factor Analysis was performed on primary data from 175 respondents using a convenience sampling and a structured questionnaire to identify underlying determinants of investment behavior in mutual funds. And they have identified the seven factors which are affecting the corporate professionals to invest in mutual funds.

Tursunkhodjayeva [4] explores the progressive development of financial risk management models in terms of investment portfolio formation. The Modern Portfolio Theory by Markowitz was carefully reviewed, which emphasizes diversification and the risk adjusted return. The study also discusses the contributions of W. Sharpe, who extended the original model by introducing the Sharpe Ratio to better quantify risk-adjusted returns. S. Ross introduced the Arbitrage Pricing Theory and evaluated it through its distinctive ability to explain returns on assets as generated by several risk factors unlike the single factor of the CAPM. There was also an "Uncertain Set Model" introduced by Nedosekin and Zaychenko, bringing uncertainty into the optimization of the portfolio and the new view toward investment risk. The comparative analysis of the research has pointed out the subtle differences between these models, thereby helping researchers and practitioners to select appropriate models for formulating financial risk management and investment strategy.

Ledoit and Wolf [5] analyze how transaction costs are included into the Markowitz portfolio selection framework, highlighting significant flaws in the traditional approach. They offer a useful method that explains transaction costs at the portfolio selection stage, ensuring that real trade frictions are taken into account during the optimization process. This change results in a more practical and successful approach that greatly improves the performance of the net portfolio, particularly for high-turnover strategies. It suggests that inefficient portfolios could result from neglecting the transaction costs during the optimization stage. The paper's practical improvement over Markowitz's conventional method is the incorporation of transaction costs into the decision-making process, which furthers the body of literature by bridging theory and practice through portfolio optimization.

To analyze the effect of ESG arguments on mutual fund performance in the later stages of the COVID-19 epidemic, Petridis, Kiosses, Tampakoudis, and Abdelaziz [6] used data envelopment analysis to determine the efficiency of various mutual funds worldwide. The portfolio efficiency index of the data envelopment analysis efficiency rankings suggested that mutual funds with fewer ESG controversies outperformed those with more. Findings Further, the sustainability of the mutual fund companies rest on investing in socially responsible and green activities. The purpose of this study is to help socially aware investors navigate through any uncertain period with a rigorous analysis by investigating whether ESG-based discussions affected the performance during the COVID-19 epidemic.

The performance and risk assessment of Indian mutual funds across the Small Cap, Mid Cap, and Large Cap funds market capitalization groups was compared by Sharma and Tripathi [7]. They had used various risk measures for performance evaluation at multiple investment horizons, including Standard Deviation, Beta, Sharpe Ratio, Jensen's Alpha, and Treynor's Ratio. Results found that the different categories had drastically different growth potentials and risk features, with small-cap funds presenting higher growth potentials but higher risks, while large-cap funds revealed relatively stable growth with lower risk. The analysis points out how investment decisions ought to be more consistent with the degree of risk involved and the goal of the investors.

Tripathi and Japee [8] studied the performance evaluation of selected equity mutual funds in India with respect to the risk-return relationship of large-cap, mid-cap, and small-cap funds. The study revealed that large-cap funds are more stable while small-cap and mid-cap funds offer higher returns but at increased risk levels by using statistical parameters such as Jenson's Alpha, Beta, Standard Deviation, and the Sharpe Ratio. This research will add to the understanding of the risk-return profiles of mutual fund categories in India and facilitate informed decision-making for investors.

A comparative study on the portfolio optimization techniques for Indian mutual funds was done by Bajpai et al. [9] reviewing methods such as Mean-Variance Optimization (MVO), Risk Parity, and Hierarchical Risk Parity (HRP). Each technique was able to indicate strengths and weaknesses, including the characteristics of the techniques in risk adjusted return. The authors showed that the portfolio robustness was significantly improved by introducing a novel hybrid approach combining HRP and MVO, achieving the highest Sharpe ratio and expected returns compared to other methods. The advanced optimization models highlighted by this study create an effective portfolio with good investment potential in this highly changing and rapidly developing environment of the Indian mutual fund industry. To maximize precision during the portfolio-construction process, advanced computational methods were applied- specifically the Ledoit-Wolf shrinkage method along with CAPM. To leverage this idea into Python programming libraries like PyPortfolioOpt and NumPy, an HRP/MVO-based hybrid strategy managed to have effectively diversified risks as well as get greater Sharpe ratios. These findings underpin the whole notion of computational finance and its signification in optimizing portfolios based on investor profiles in the Indian mutual fund market.

III. RESEARCH METHODOLOGY

The optimization of mutual fund portfolios by mitigating risk and the prediction of potential return is done using a holistic approach that bridges the theory with advanced analytical tools to provide actionable insights for retail investors. The research used a dataset that comprised 625 mutual fund schemes, gathered from a recognized database, Kaggle. It included rigorous data cleaning and preprocessing using Python, which ensured that the final dataset included key financial metrics necessary for portfolio evaluation, which are mutual fund scheme name, category, expected return, Sharpe ratio, and Sortino ratio. As per the research objectives, two separate portfolios were built. The first was a diversified 15-scheme, which would have the least risk and maximum stability for that the filtering of 15 schemes among 625 is done by selecting the top three schemes that have a high Sharpe ratio and that belong to each of the five categories that are equity, debt, hybrid, solution-oriented, and others. The second was concentrated 5-scheme portfolios for higher return in contrast to high levels of risk, and these 5 schemes are selected from the 15 schemes that are already filtered using the Sortino ratio as the basis. This metric will give it a balanced view of risk and return. The Sharpe ratio is the measure of excess returns over total risk, and the Sortino ratio is the measure of downside risk specifically. In this research, the Monte Carlo simulations were used effectively to build and analyze the portfolios using the loop function in python. These simulations produced thousands of possible portfolio configurations by randomly assigning weights to the chosen schemes. Simulations were run to model different possible outcomes, and based on this, portfolios lying on the efficient frontier were identified with the best possible risk-return trade-off. The correlation matrix was also part of the analysis to see the interdependencies between funds, thus creating an opportunity for understanding diversification and more about controlling risk management in portfolios. Moreover, the paper assumed that Monte Carlo simulations would allow the dynamic and flexible framework of portfolio optimization to surpass traditional mean-variance approaches. All these analyses are done solely by using Python libraries such as Numpy, Pandas, Matplotlib.pyplot, Seaborn, Sklearn, and Statsmodels.api.

IV. RESULTS

Table 1 is the representation of the selected 15-scheme portfolio, selected based on their Sharpe ratio under each category of mutual fund scheme and its recommended optimal weights based on the adjusted return with mitigated risk characteristics, and Figure 1 illustrates the efficient frontier, showing the portfolio's placement relative to other configurations with color differences.

Table 1: Optimal Portfolio with 15 Schemes

S. No.	Scheme Name	Category	Sharpe Ratio	Optimal Weights
1	Quant Liquid Plan – Direct Growth	Debt	3.52	0.119232
2	ICICI Pru Ultra Short-Term Fund	Debt	2.40	0.090958
3	ICICI Pru Credit Risk Fund	Debt	2.15	0.041167
4	Quant Infrastructure Fund	Equity	2.30	0.018182
5	Templeton India Equity Income Fund	Equity	2.26	0.025090
6	SBI Contra Fund	Equity	2.13	0.026754
7	SBI Conservative Hybrid Fund	Hybrid	2.23	0.100989
8	Nippon India Hybrid Bond Fund	Hybrid	2.17	0.100443
9	Quant Absolute Fund	Hybrid	2.12	0.039171
10	ICICI Pru Income Optimizer Fund	Other	2.37	0.099865
11	ICICI Pru Asset Allocator Fund	Other	1.99	0.101092
12	Kotak Multi Asset Allocator FoF–Dynamic–Di…	Other	1.91	0.024326
13	HDFC Retirement Savings Fund	Solution Oriented	1.92	0.025193
14	HDFC Retirement Savings Fund	Solution Oriented	1.88	0.114601
15	UTI-Retirement Benefit Pension Plan–Direct	Solution Oriented	1.88	0.072939

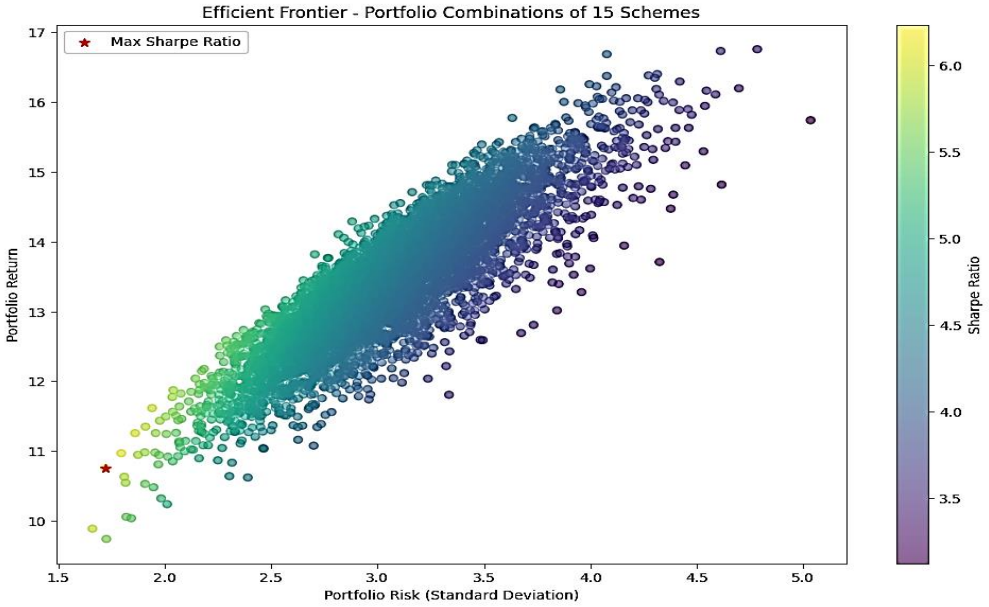

Figure 1: Efficient Frontier of selected 15 Schemes

From Figure 1, we can interpret that the maximum possible return is 17% and risk is 1.5%. And the optimal portfolio, or the efficient frontier, lies between 1.5% and 2.5% risk levels with risk-adjusted returns from 10% to 12%. We can also see the possible returns calculated using Monte Carlo simulation showing a linear graph. On the other hand, Table 2 is the representation of the selected 5-scheme portfolio, selected based on their Sortino ratio among the filtered schemes in each category and its recommended optimal weights based on the adjusted return with mitigated risk characteristics, and Figure 2 illustrates the efficient frontier, showing the portfolio's placement relative to other configurations with color differences.

Table 2: Optimal Portfolio with 5 Schemes

S. No.	Scheme Name	Sortino Ratio	Optimal Weights
1	Quant Liquid Plan– Direct Growth	8.60	0.044582
2	ICICI Pru Asset Allocator Fund	5.89	0.273099
3	ICICI Pru Income Optimizer Fund	5.43	0.173328
4	ICICI Pru Ultra Short-Term Fund	4.76	0.097874
5	SBI Contra Fund	4.43	0.411117

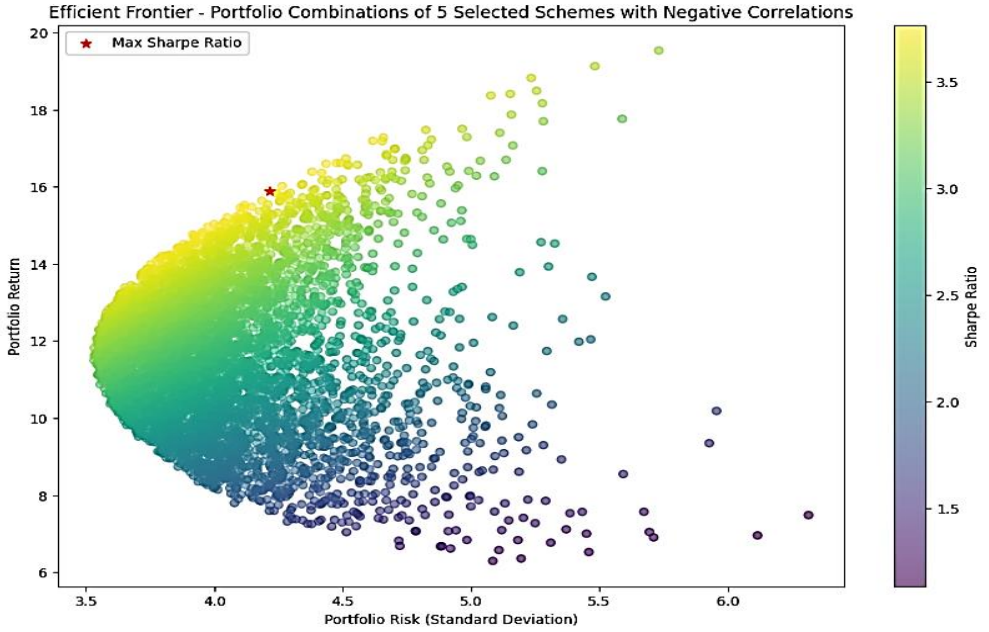

Figure 2: Efficient Frontier of selected 15 Schemes

From Figure 2, we can interpret that the maximum possible return is 20% and risk is 3.5%. And the optimal portfolio, or the efficient frontier, lies between 4% and 4.5% risk levels with risk-adjusted returns from 15% to 17%. We can also see the possible returns calculated using Monte Carlo simulation showing a curve shaped graph.

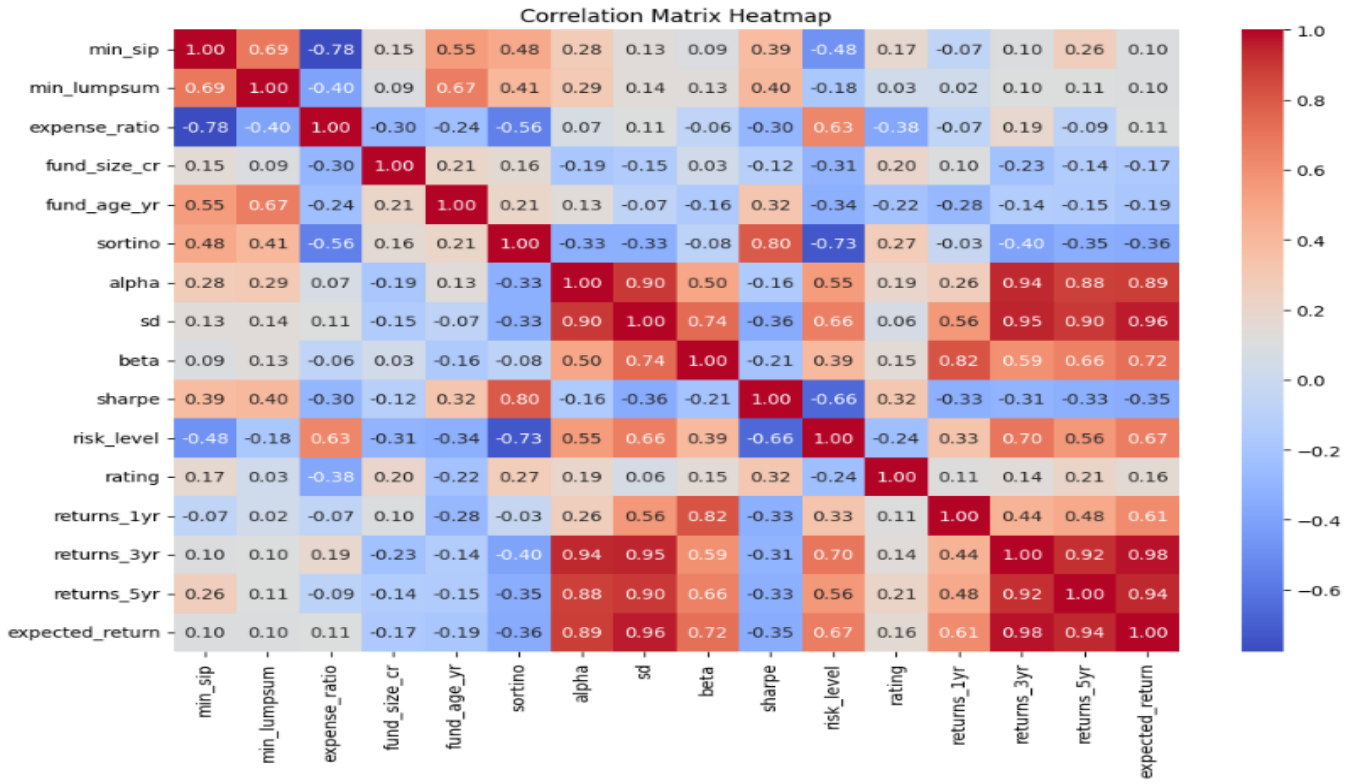

Figure 3: Correlation Matrix

The dataset's correlation matrix, shown in Figure 3, shows a substantial negative correlation between the Sortino ratio and risk level, indicating that the chosen portfolios are extremely low risk exposure.

V. DISCUSSION

The results of this study provide good evidence for the practical application of Markowitz's Modern Portfolio Theory in constructing mutual fund portfolios that cater to varying risk-return preferences of investors. The diversified 15-scheme portfolio is showing a linear graph because there is not much diversification; it merely replicates the top schemes among available mutual fund schemes in the dataset. Thus, it completely relies on and replicates the overall market performance; it can also be taken for the evaluation of the market performance. In contrast, the concentrated 5-scheme portfolio achieved higher returns of up to 17% but with slightly elevated risk levels of 4% to 4.5%. That's to say that with a little risk appetite, we can attain even higher returns than the proportion of risk we have taken. It also shows a curve-shaped graph, which is because the chosen schemes in securities are not positively correlated as compared to previous portfolio construction. Thus, it is understood that the optimal portfolio need not be constructed with a high number of securities; rather, limiting it with an efficient and effective one will be a better option. The previous works which are taken for literature review explores the areas such as risk mitigation techniques, Portfolio optimization techniques and significance of diversification. But this research tries to use the Monte Carlo simulation technique for predicting the possible or expected returns of portfolios that are constructed, thus having an overview of their investment makes an investor take informed and rational decisions. Correlation matrix analysis further reiterated the role of diversification in lowering unsystematic risk, similar to earlier studies, which found low or negative correlation between assets was good. In this study, some limitations arise: Using only historical data limits it from producing accuracy in projecting the future condition of the market, given unanticipated economic or political shocks. However, there may also be cases when MPT's underlying assumptions—that static correlations apply and that the normal distribution holds for returns—fail in real-world markets. As a result, it can sometimes break down at the extremities of a condition. There are no factors to include the effect of macroeconomic variables and the investor behavioral pattern. Further studies can further minimize these limitations by including real-time data along with machine learning techniques to adapt more flexibly to market conditions that keep changing over time. This research doesn't focus on the macroeconomic factors, behavioral factors, and biases made by people during investment and decisions that are affected by irrational factors and market sentiments and various other qualitative factors. Future research has scope in dealing with such areas.

VI. CONCLUSION

The main finding of this study is that the advanced analytical tools, such as Python, can be used by the retail investors to construct and predict the portfolio and its outcomes. And it paves a way to apply the financial theory in real-world decision-making driven by analysis of data. This study outlines that portfolio management is not that tough with the

presence of modern tools that can process large amounts of information and provide actual solutions.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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