OPERATIONS RESEARCH IN FINANCIAL MARKETS

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ABSTRACT

This paper aims to find the application of Operations Research in the field of Financial Markets. Various OR techniques like Linear Programming, Hillier and Hertz's Model have all been utilised to address a wide range of Stock market challenges. The LPP Model aids in optimising an investor's return with the least amount of risk at any particular time. Our objective is to find the best feasible solutions to avoid risk and increase profit in Finance Market using Operations research techniques and to provide an overview of the applications of operations research in the field of Finance Market. This helps the investor in comparing the returns on the many alternative ideas before deciding on one which is more risk free.

Keywords: Operation Research, Finance Market, Stock Market, Portfolio Selection.

I.   INTRODUCTION

Individual investors in the stock market expanded by 142 lakhs in FY21, according to data from the National Stock Exchange (NSE). This included a 19.7 lakh increase in NSDL, and a 122.5 lakh increase in CSDL accounts. Also, there has been an increase of 6% in the share of individual investors in total turnover on stock exchanges, bringing it to a 45% share.

Optimization techniques have been used in this document to obtain an optimal investment in a selected portfolio that provides maximum efficiency with minimum items based on primary data provided by a market situation. The challenge of determining the available funds and the assignment of each portfolio component to maximize yields and minimize entries by portfolios and management holders that are the main decision makers in the assignment of their resources cannot be quantified. This optimization technique is used to create the best possible investment portfolio that takes into account a company's financial risks.

LPP as a technique of operations research is used here. Using linear programming requires defining variables, finding constraints and objective function (which either needs to be maximized or minimised). It necessitates the formation of inequalities and then graphing those to solve problems. The various areas of application of LPP include production scheduling, inventory policies, investment portfolios, advertising budget allocation, warehouse building and many more. Financial institutions use linear programming to select the most appropriate financing mix while maintaining specific constraints on types of borrowing, choose among a variety of available projects while optimising risk and return whilst also respecting constraints such as maximum break-even period or hurdle rates, and schedule payments.

The research objectives of our research paper are as follows:

- To optimize stock portfolio using Operations Research techniques.
- To find various techniques of operations research like LPP, Hillier and Hertz etc, that can be used to optimise stock market investment.
- To find relation between different terminologies we came across while reading the research papers.
- To find the best feasible solutions to avoid risk and increase profit in Finance Market using Operations research techniques.
- To provide an overview of the applications of operations research in the field of Finance Market (Stock Market).

II.   OVERVIEW

The survey of operations, often abbreviated to the initials OR, is a discipline that deals with the development and application of advanced analytical methods to improve the decision-making process. Sometimes a subfield of mathematical science is considered. When it comes to Financial Market, OR plays a vital role in allocation of investment and portfolio selection so that it yields maximum profit considering all the risk which can affect the data.

III.   LITERATURE REVIEW

Capital Markets play an important role in the development of a country. Market is where all pertinent information is available to all participants at the same time, and where prices respond immediately to available information (Patel, Dave, & Shah, 2016). Stock trading is one of the most essential activities in the financial sector. The act of attempting to anticipate the future value of a stock or other financial instrument traded on a financial exchange is known as stock market prediction. (Reddy, 2018). Non-portfolio problems in financial markets, such as the equities, debt, and foreign exchange markets, as well as the equivalent derivatives markets, are addressed using OR approaches. The main goal of using OR in financial markets is to either obtain workable solutions to highly restrictive problems with multiple factors, or to estimate feasible quantities. Another use of OR would be evaluating the various risks of the market (Board, Sutcliffe, & Ziemba, 2002). We also understand that financial problems like design securities, market regulations, risk evaluation and control, equity, etc are analysed and solved using techniques such as linear programming, forecasting, statistical analysis and simulation. Additionally, financial market research has provided many insights as to when an investment should be made and when it should be sold so that we may earn or reap the most benefits from it. The financial market is quite vulnerable to any change. OR helps the investors in funding decisions in such a way that they achieve a significant positive return on investment in spite of the market's vulnerability (Goyal, Jain, Dhariwal, Dhanak, & Prabhu, 2019).

OR is critical in assessing specific financial concerns such as the foreign exchange market, securities development, market laws, debt, and so on. The research done on the financial market has provided various inputs as to when an investment should be made and when the investment should be sold off so as to earn or reap the maximum benefits out of it (Goyal, Jain, Dhariwal, Dhanak, & Prabhu, 2019). *Operations Research in Financial Markets* covers the analysis of financial markets Linear Programming Problems (LPP), Hiller and Hertz Model and Expected Money Value (EMV). LPP helps to understand each type of restriction and the best variable it contributes, with this help we can make the decision to invest or not in a portfolio. However, the Hiller and Hertz model helps to identify the risks involved when calculating the mean and variance of the cash flows. The Expected Monetary Value (EMV) is also used to measure risk in order to gain a sense of the overall risk associated with investing in a particular asset (Juneja, Gogia, Sehgal, Gupta, & Mandvekar, 2019).

The Indian stock market has recorded some major anomalies under the categories of index dropping in a single day, bull rallies, earnings announcement anomaly, presence of behavioural biases and seasonal anomalies. (Peswani & Jesudasan, 2018). Market crash is a phenomenon which occurs in stock markets occasionally and leads to loss Therefore, attempts for prediction of this phenomenon is important for the investors, financial institutions and government (Alizadeh, Raei, & Mohammadi, 2015). Hence, accurate forecasting is a vital feature of investing in stock markets. Forecasting, along with the use of Artificial Neural Network (ANN), has given better prediction results in the past few decades than the use of a single method. The forecasting accuracy is verified with reference to an Indian stock market index such as Bombay Stock Exchange. This method is used in fields like finance, mathematics, physics, machine learning, etc (Kumar & Murugan, 2013).

There are two distinct stages of optimizing a stock market portfolio- first is to select the stocks, and second, the distribution of investment in the selected stocks. Artificial Intelligence, Machine Learning and Soft Computing techniques are widely used and considered for studying the markets and evaluating various stocks, which help investors identify stocks with the highest returns and the lowest risks (Pareek & Thakkar, 2015). Portfolio selection and trading techniques require accurate forecasting and measurement of equity return volatility. Implied volatility is widely utilised by practitioners and investors to forecast future volatility when it is available. The results of the ANN technique are the most accurate in tracking the implied volatility of equities returns (D'Ecclesia & Clementi, 2021). A better version of the Markowitz portfolio optimization model, also known as the Mean-Variance model, is explained in Portfolio selection and optimization with higher moments: Evidence from the Indian stock market. The new model eliminates shortcomings of the previous model and optimizes better returns for the investors at any given level of risk. By including four higher moments in this multi-objective programming model, it overcomes the lacking feature of the Markowitz model, which is that it assumes the stock market returns to have a normal distribution, which generates sub-optimal portfolios for the investors (Saranya & Prasanna, 2014).

Emerging stock market volatility and economic fundamentals: the importance of US uncertainty spill overs, financial and health crises looks at economic variables in the United States and around the world that enhance emerging stock market volatility and can be viewed as systemic risk factors that exacerbate financial stability vulnerabilities. It uses the bivariate heavy system of daily and intra-day volatility equations, which is enhanced with powers, leverage, and macro-effects to considerably improve forecasting accuracy (Karanasos, Yfanti, & Hunter, 2021). The majority of stockbrokers employ both technical and fundamental analysis, and time series analysis, when making stock predictions (Reddy, 2018). Time series predictions are also formed using Independent Component Analysis (ICA) and Support Vector Machine (SVM) techniques. The combined technique outperforms the SVM technique when used alone (Grigoryan, 2016). Hybrid machine learning systems based on Genetic Algorithm and time series are also used in financial markets along with a technical trading rule that assists as to when to buy and sell stocks (Kumar, Pandey, Srivastava, & and Darbari, 2011). Application of operations research in the domain of finance includes using techniques of deep learning to estimate mortgage risk (Sadhwani, 2018) .

Moving to other stock exchanges abroad, Empirical analysis on price-volume relation in the stock market of China worked on to study and analyse the price-volume relation of the Shanghai Stock Exchange and the Shenzhen Stock Exchange. Along with this the spill over effect in the periods during consolidation and when the stock markets enter the bull market was also evaluated (Shih-Yung, Li-Wei, Yan, & Lu-Jie, 2019). Relying on the predicting power of volume, Investigating Contemporaneity and Dynamism in the Relationship Between Stock Returns and Trading Volume at Nepalese Stock Market uses daily-pooled panel data of 16 listed non-finance and non-insurance companies from four specified NEPSE sectors, and investigates the contemporaneous and dynamic link between stock returns and trading volume. The rate of information flow and its diffusion to the market determine the returns-volume connection. Trading volume is seen as a crucial piece of data that indicates where returns will go next (Shreshta, 2019).

The link between Bitcoin and the stock market was also examined and studied. The Sliding Window approach is used to improve the impulse response signal. First, the S&P 500 has a moderate impact on Bitcoin, whereas the S&P 500 has a minor impact. Furthermore, after using the Sliding Window technique, the impacts of the S&P 500 standard deviation and the Dow Jones mean on the mean of Bitcoin are amazingly substantial, and the S&P 500 standard deviation has a fairly considerable effect on the standard deviation of Bitcoin as well. The S&P 500 and Dow Jones indexes, in general, have a positive impact on Bitcoin. This model and conclusion can be used to make a financial investment (Wang, Chen, & Zhao, 2020).

IV.   METHODOLOGY

To find reference papers for our topic, we used the software engine Publish or Perish. Here we first found over 900 papers related to our subject. Then we filtered out the non-English papers, and were left with nearly 400 papers. Lastly, we had 91 papers relevant to our topic.

To find the relation between the various segments under these papers, we used the software VOSviewer and found out the applicable relations between the topics, and analysed further.
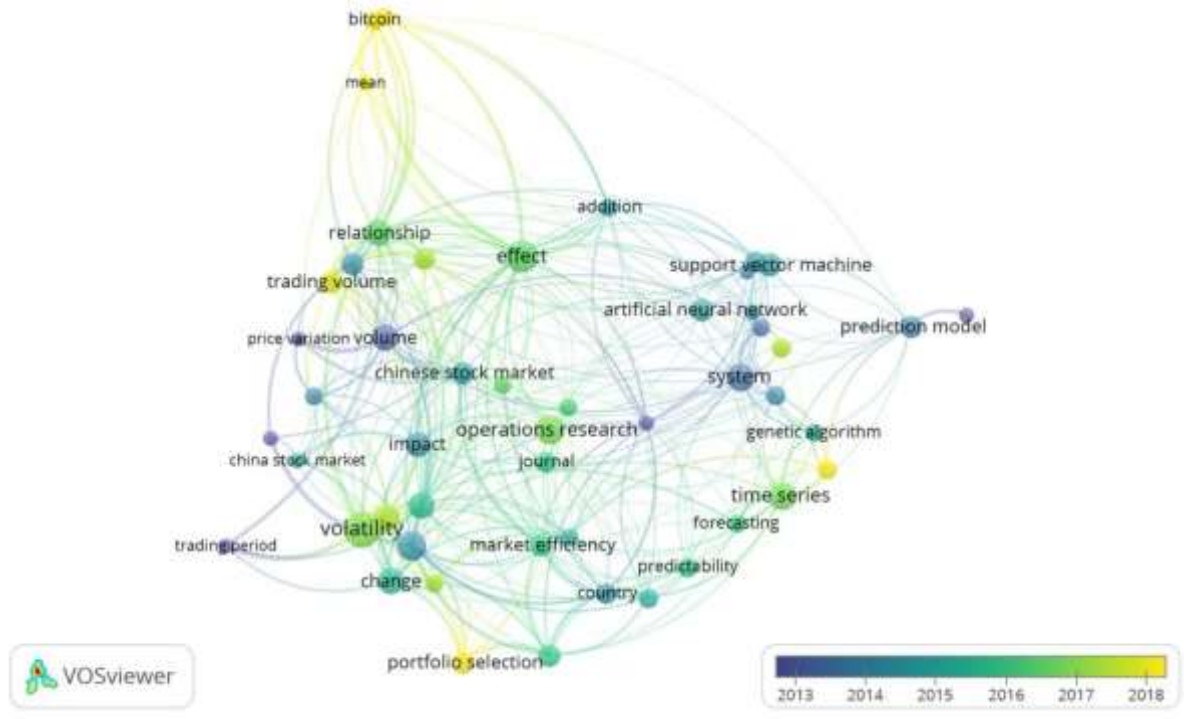
Analysis and Findings-

Links between OR & Financial Market 1
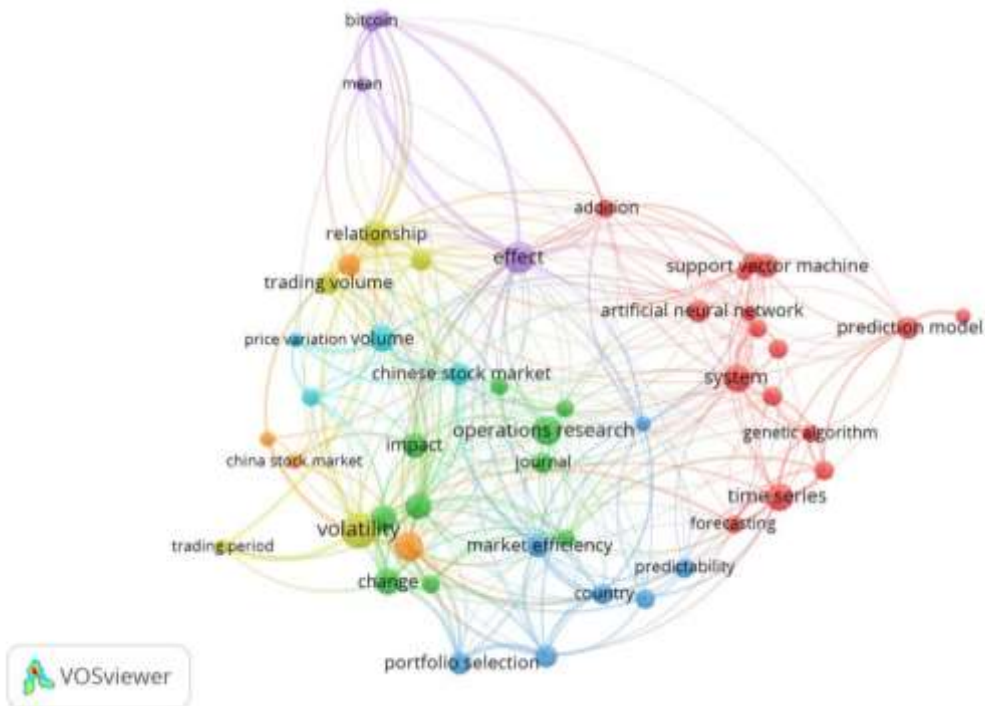
Source: VOS Viewer

Link b/w OR & Financial Mkt wrt Timeline 1

Source: VOS Viewer

The two diagrams above are a result of the connection between our research papers.

In the first diagram, we are able to observe the clusters and groups formed among the various linked topics of the research papers we have gone through. The largest cluster formed, as seen in Diagram 1, contained the components- Addition, Support vector machine, artificial neural network, prediction model, system, genetic algorithm, time series and forecasting. They were, thus, the most commonly used terms and topics across the papers. Support vector machine is a technique that learns by the method of assigning labels to objects and

hence assimilating through illustrations. This technique is used to forecast stock prices, and is achieved through studying a large sample of stock prices and the different trends during different periods of time. Time series, similar to prediction model, is data collected over time, while one of the variables is time. The role of genetic algorithm, which is a search-based algorithm, in machine learning is to solve optimization problems. Artificial Neural Network is a system that is patterned or based after the functioning of the human brain and it has been regularly used commercially to recognise patterns which further enhances the use of operation research and forecasting in terms of financial markets and investing in them. Furthermore, these cluster of elements, i.e., relationship, trading volume, trading period and volatility are connected. There is a huge relationship between the volume of a traded stock and its volatility. When a stock is bought in huge quantities, the price or value rises abruptly; but, when the stock is sold in large quantities a few minutes later, the price or value falls sharply. A trading period, on the other hand, is a predetermined amount of time, usually a few weeks, months, quarters, or years, during which sales are tracked and compared to preceding periods. The price of the stock fluctuates during the trading period from its market value until the end of the transaction, reflecting the relationship between return and market value. The bottom most group in the diagram, consists of Portfolio selection, market efficiency, country and predictability. The stock market is very volatile in nature and therefore it is an absolute necessity for investors to keep in mind while selecting their portfolio with respective to the nature and quantity of stocks they want to purchase. Additionally, this should be accompanied by accurate forecasting of data to understand when to sell and buy the stocks in the future. Lastly, the most recent collection we identified, which studied the latest relations and trends, was based around Bitcoin. Initially, Bitcoin is distinguished by its crypto currency. The data and information gathered are then used with two operations research techniques: Markov Chains and Queue Theory. Finally, using an information management method, the newly discovered data is turned into beneficial knowledge. Quantitative and qualitative analysis techniques associated with operations research and information management can be combined to characterise an object or process, capture data and information associated with it, predict its behaviour, and transform that information into knowledge that generates added value, allowing the right decision making in a specific context. In the second diagram, the element of time is added to the different topics identified from the research papers gathered, and common groups made, were distinguished based on the topics period of relevance. The earliest and the relatively older models and topics include basic terms such as price variation, trading period, etc. Following this, we have the collection of Support vector machine models, Artificial Neural Networks, and the Chinese Stock markets prevailing in the years 2014-15. Lastly, in the more recent years, the terminologies and techniques of Bitcoin, portfolio selection, mean values, etc. have the most prevalent relations with the financial market. One of the relevant techniques that we found out for our topic after analysing the papers, was Linear programming problems. Then we researched online for data regarding the current market returns and risks associated with investment in the stock markets, and formulated a problem with two stock market investments as its variables, with its returns and risk components being in accordance with the current market averages.

V. PROBLEM

An investor is creating their stock portfolio. They have 2 options of investments - investment 'A' and investment 'B'. The returns and risk associated with each of the investments are different. The details are given below:

- Total money available for investment is Rs. 10,00,000
- Investment A gives a return of 10% and has a risk factor of 4(10 being the highest).
- Investment B gives a return of 17% and has a risk factor of 8.
- A minimum of 13% total returns is required on the investments.
- The total maximum risk factor is 6.5 on the total investment made.
- Maximum investment in a single security cannot exceed 80% of the total investment.

The investor wants to optimize their stock portfolio so as to get the maximum returns on their investment, while complying to the set guidelines.

VI.   SOLUTION AND ANALYSIS

From the above problem, we can see that there are 2 Variables X1 and X2. These variables depict the total investment made in the market. The market situation (Hypothetical) is such that when X1 amount is invested there's a 10% of return with risk factor being 4 unit and when X2 is invested in the market there's 17% of return with 8 unit of risk. As the return increases the risk also increases showing a direct relation.

To find the best optimal solution we had to maximize the investment variables to its best so that we get the most returns out of it.

Thus Z=0.1X1 + 0.17X2 being the maximizing equation.

There were 5 constraints:

1) X1 + X2 <= 10,00,000   (total Investment)

2) 0.1X1 + 0.17X2 >= 1,30,000   (being the minimum returns required)

3) 4X1+8X2 <= 6.5x10,00,000 = 65,00,000   (being the maximum risk)

  =>   X1 + 2X2 <= 16,25,000

4) X1, X2 <= 8,00,000   (maximum investment allowed in a single security)

5) X1, X2 >= 0   (non-negativity constraint)

After plotting the constraints on the LPP graph we get the following diagram.
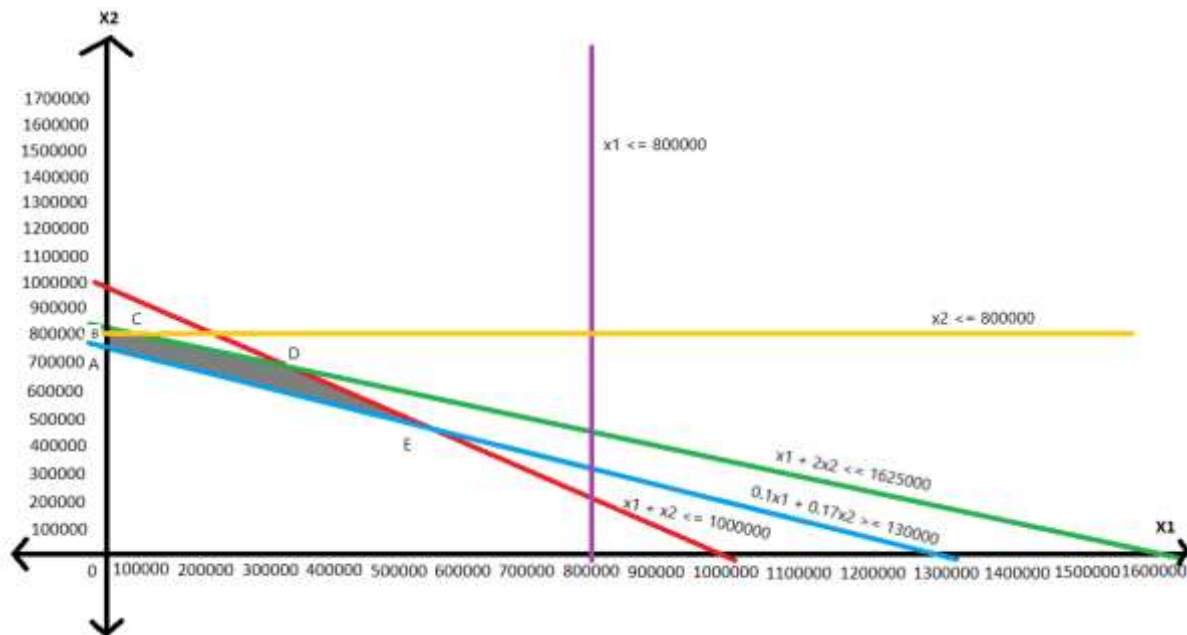
Graph 1

In the graph, the feasible region is denoted by the shaded region ABCDE. Here, we get 5 points of the feasible region.

After substituting all 5 points in the maximizing equation, we get point D (3,75,000 , 6,25,000) as the optimal point.

This says that the optimal returns which could be earned in this situation would involve an investment of Rs. 3,75,000 in investment 'A' and of Rs. 6,25,000 in investment 'B'. Here the returns would be of Rs. 1,43,75, on the investment of Rs 10,00,00.

VII.   CONCLUSION

To conclude, we have attempted to provide an outline of operations research's applicability in the Stock Market in this paper. We've found a number of special traits that distinguish Stock Market from other industries in terms of Investment Strategy and Portfolio Management. Linear Programming, Hillier and Hertz's Model have all been utilised to address a wide range of Stock market challenges. The LPP Model aids in optimising an investor's return with the least amount of risk at any particular time. As we all know, a project must provide a

sufficient return on investment. The whole point of promoting a project or investment proposition is to get good returns on your money. The investor should be able to compare the returns on the many alternative ideas before deciding on one which is more risk free. From the contents of this article, it is obvious that many processes in the Stock Market have received little study attention from an operational standpoint, and that there are various areas that merit further research efforts. As a result, we may conclude that OR methods play a crucial role in financial decision-making, and that this role will grow with the present emotional improvements in continual access to information. As a result, OR will have more opportunities in financial markets and decision-making.

VIII.   LIMITATIONS AND RECOMMENDATIONS

There should be an objective which should be clearly identifiable and measurable in quantitative terms which may not be available in real life. There are also some intangible factors s i.e., non-measurable human factors which OR techniques can't take into consideration. Portfolios often include options which have extremely asymmetric payoffs, which makes quantifying risk exposure difficult. Analytical solutions for determining the probability in the lower tail of the pay-out distribution are unreliable for such securities. Traders in stock markets strive to trade at the best prices, therefore large trades are sometimes split up into a series of smaller trades to reduce the price impact. The price of subsequent deals is influenced by the earlier trades, therefore executing the enormous trade at the lowest cost is a dynamic challenge.

These components are immense, and quantifying them and creating links between them necessitates extensive calculations that computers can manage. Simplex is a complex method but can accommodate 3 factors whereas LPP can only take 2 factors into consideration and is comparatively simple. This also creates a miscommunication between managers and analysts. This is why most people invest in stock markets without actually analysing using OR techniques which may lead to poor decision making.

We would personally recommend investors :-

- Firstly, Stock Market is unpredictable so investors should take the Market Situation into consideration. Sometimes certain stocks are controlled by market influencers so at such times investors should not go with OR techniques.
- Investors should not go and invest in rumours. They should actually apply analysis behind the stocks and with those results should move further if they want to invest or not. OR takes all the risks into consideration so one should not rely on rumours.
- These are few indicators of stocks which the investors should consider before investing in Stock Market: P/E ratio and Moving average. These factors will help OR analysis become more efficient for the investors.

IX.   REFERENCES

[1]   Ahmad, M. (2017). Impact and Implications of Operations Research in Stock Market.

[2]   Alizadeh, A. M., Raei, R., & Mohammadi, S. (2015). Prediction of stock market crash using self-organizing maps. Financial Reseach Journal.

[3]   Board, J., Sutcliffe, C., & Ziemba, W. (2002). Applying Operations Research Techniques to Financial Markets.

[4]   D'Ecclesia, R., & Clementi, D. (2021, April). Volatility in the stock market: ANN versus parametric models . Retrieved from Research Gate:

https://www.researchgate.net/publication/337406414_Volatility_in_the_stock_market_ANN_versus_parametric_models

[5]   Goyal, R., Jain, R., Dhariwal, R., Dhanak, S., & Prabhu, S. (2019). Operations Research in financial markets. International Journal of Advance Research and Development, 35-37.

[6]   Grigoryan, H. (2016, August). A stock market prediction method based on support vector machines (svm) and independent component analysis (ica). Retrieved from IDEAS.ORG:

https://ideas.repec.org/a/aes/dbjour/v7y2016i1p12-21.html

[7]   Juneja, A., Gogia, A., Sehgal, A., Gupta, A., & Mandvekar, A. (2019). Operations Research in Financial Markets. International Journal of Science and Research (IJSR), 1651-1656.

[8]   Karanasos, M., Yfanti, S., & Hunter, J. (2021, April). Emerging stock market volatility and economic fundamentals: the importance of US uncertainty spillovers, financial and health crises. Retrieved from link.springler: https://link.springer.com/article/10.1007/s10479-021-04042-y

[9]   Kumar, D., & Murugan, S. (2013, Feb). Performance analysis of Indian stock market index using neural network time series model. Retrieved from IEE: https://ieeexplore.ieee.org/document/6496450

[10]   Kumar, L., Pandey, A., Srivastava, S., & and Darbari, M. (2011). A Hybrid Machine Learning System for Stock Market Forecasting.

[11]   Pareek, M., & Thakkar, P. (2015). Surveying stock market portfolio optimization techniques. Retrieved from IEE EXPLORE.IEE: https://ieeexplore.ieee.org/document/7449613

[12]   Patel, M., Dave, M., & Shah, M. (2016). Stock price and liquidity effect of stock split: Evidence from Indian Stock Market.

[13]   Peswani, S., & Jesudasan, S. (2018, March). Anomalies in the Indian Stock Market. Retrieved from Research Gate:

https://www.researchgate.net/publication/324517189_Review_of_the_Anomalies_in_the_Indian_Equity_Market

[14]   Reddy, V. (2018, October). Stock market prediction using machine learning. Retrieved from Analytics Vidhya:

https://www.analyticsvidhya.com/blog/2018/10/predicting-stock-price-machine-learningnd-deep-learning-techniques-python/

[15]   Sadhwani, A. (2018, March). Applications Of Operations Research In. A Dissertation Submitted To The Department Of Management Science & Engineering And The Committee On Graduate Studies Of Stanford University In Partial Fulfillment Of The Requirements For The Degree Of Doctor Of Philosophy.

[16]   Saranya, K., & Prasanna, P. (2014, May). Portfolio selection and optimization with higher moments: Evidence from the Indian stock market. Retrieved from IDEAS.ORG:

https://ideas.repec.org/a/kap/apfinm/v21y2014i2p133-149.html

[17]   Shih-Yung, W., Li-Wei, L., Yan, S., & Lu-Jie, Z. (2019). Empirical analysis on price-volume relation in the stock market of China. INTERNATIONAL JOURNAL OF ECONOMICS AND FINANCIAL ISSUES.

[18]   Shreshta, B. (2019, Jan). Investigating Contemporaneity and Dynamism in the Relationship Between Stock Returns and Trading Volume at Nepalese Stock Market. Retrieved from SSRN.com:

https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3255534

[19]   Wang, X., Chen, X., & Zhao, P. (2020, April). The relationship between Bitcoin and stock market . Retrieved from IDEAS: https://ideas.repec.org/a/igg/joris0/v11y2020i2p22-35.html