International Journal of Science and Research (IJSR)
ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2018): 7.426

Operations Research in Financial Markets

Aashray Juneja[1], Aditya Gogia[2], Ananya Sehgal[3], Ansh Gupta[4], Anuja Mandvekar[5]

Abstract: ***This research paper reviews the application of Operations Research to Financial Markets. A financial market is a market where financial securities are traded and dealt with at low financial cost. Operations Research is the use of scientific and mathematical techniques for making decisions and solving problems. This paper documents the main problems in Financial Markets like determining risk of the stock, deviations of cash flows and how Operations Research can be used to solve them.***

Keywoords: Operations Research, Financial Markets, Finance, Risk Quantification, Risk Indentification, Portfolio Management, Quantitative Modelling.

1. Introduction

Over the recent weeks, the Indian Financial Market has shaken out due to recession anxiety. The growth rate of India has slowed down to 6 per cent but it's expected to gradually recover to 6.9 per cent in the fiscal year 2021 and to 7.2 per cent in the following year. (economic times, 2019) However, the secondary market, the market for Initial Public Offers (IPOs) witnessed rapid expansion. The total amount of Initial Public Offerings (IPO) increased to US$ 1.2 billion raised from 37 between April – June 2018. Investments by Foreign Portfolio Investors (FPIs) in Indian capital markets reached Rs 6,310 crore (US$ 899.12 million) up to November 22, 2018. (India Brand Equity Foundation, 2019).

OR means to use scientific and mathematical techniques for making decisions and solving problems. It is concerned with co-ordinating and controlling the operations or activities within an organization. (Vinay) Over the past 25 years there have been many advances in refining OR techniques and tools by expanding, generalising and making them more applicable for certain problem areas, or for addressing problems that the technique could not be used for in the past. Specialisation around a technique or tool has become the norm that has led to in-depth knowledge and know-how of such techniques and tools. (Ittman, 2009) The emphasis has been on advances in application areas and in identifying areas where OR has not been applied in the past. Hand-in-hand with these developments there has been an explosion in the sophistication and technical complexity of computer technology with the increase of computing power. This has allowed solving problems faster, tackling larger problems that are data-rich, and also problems previously considered impossible to even contemplate attempting to address, let alone solve. Where OR originated in the defence environment, it can now be stated that OR is applied in virtually all walks of life. (Ittman, 2009) Operations research (OR) has been extensively applied to problems in finance during the last half century.

According to Morse & Kimbell, "Operations Research is a scientific method of providing executive departments with a quantitative basis for decisions regarding the operations under their control." (Akrani, 2011) In recent years of organized development, OR has entered successfully in many different areas of research like production management, agriculture, finance, industry, marketing, etc. It takes tools from subjects like mathematics, statistics, engineering, economics, psychology, etc. and uses them to know the implications of possible alternative actions. Operations Research (OR) techniques play a very important role in analysing the finance problems such as equity, debt, foreign exchange markets, design securities, market regulations, risk evaluation and control, regulation of capital reserves, devise pricing equations and analysing market data. In the professional world, OR has influenced financial markets to adopt new finance theories. It is used to manage a portfolio of stocks, bonds, options, etc. The High-Frequency Trading (HFT) is probably the prime example of OR being put into use. These problems have complicated interactions between components or involve a large set of components or alternatives. OR techniques are equipped to formulate such problems as mathematical problems and provide with a feasible solution to such problems. Programming Techniques of the types like Quadratic, Non-Linear, Linear, Integer, Goal, and Dynamic Programming are mostly used. Among these techniques, Monte Carlo Simulation is most widely used. Some other OR techniques like Network models, Markov Chains and Game Theory are also proposed but less commonly used for the purpose. (Reshampal Kaur, 2014)

The following paper considers the application of OR techniques to financial markets. It uses OR models like LPP, Hillier and Hertz's Model, Expected Monetary Value to help investors/fund managers in managing their portfolio. It covers decisions concerning trading by decision makers in financial markets (e.g. the debt, equity and foreign exchange markets and the corresponding derivatives markets) and represents a more recent and still growing area for the application of OR techniques to finance.

2. Objectives

1) **To understand** operations research methods like LPP, Hillier & Hertz and EMV used in financial markets.
2) **To find** an optimal way to manage a portfolio of stocks, debentures, options, etc.
3) **To elaborate** on the effective methods used in portfolio management.
4) **To outline** the applications of operations research in FM.
5) **To describe** the recent changes in operations research.

3. Research Methodology

Operations Research is a science which deals with problem, formulation, solutions and appropriate decision making. It not only deals with everyday problems but also business-related problems like inventory management, portfolio management, sales analysis, risk analysis, supply chain management etc. As Finance students this topic will enhance our knowledge about various tools of Financial Markets. The

objective is to be able to relate to the research articles in the field and for our careers in the Financial Sector. We have gone through approximately 10-15 research papers and few articles. This paper thereby studies and analyses various research papers which have information related to the findings of operations research in financial markets. It considers the utilization of OR techniques to financial markets.

In order to achieve our above mentioned objectives we have further used OR techniques like LPP, Hiller & Hertz and Expected Monetary Value. Wherein, LPP helped in understanding the optimal variables for each type of constraint and its contribution and with the help of this, we can arrive at a decision of whether to invest in a portfolio or not. If yes, then how much should be allocated in each type of bond, stocks, etc. The data and equations used in these techniques have been formulated to fit our study and may vary for different perspectives. The Hiller and Hertz model helped in identifying the risk involved by calculating the mean and variance of the cash flows. Furthermore, we used the Expected Monetary Value (EMV) to quantify the risk in order to get an idea about the total risk involved in investing in an asset. Thus with the help of the above techniques and research papers we were able to understand the main components involved in financial markets and how these components influence the investor decision making. However, the data is purely experimental and qualitative in nature.

4. Literature Review

4.1 Portfolio Management

This paper covers the use of Linear Programming Problem for portfolio selection and formulation faced by a mutual fund manager. It takes a very simple model in place of a complex method like Markowitz Approach to highlight the problems and obstacles faced and how to accurately device a portfolio that minimizes risk and maximises returns. This paper suggests that with approximate modification, the use of linear approximation can not only help fund managers decide which fund to invest in, to form a diversified portfolio but also suggests its use for a varied range of objectives. (University of Washington, Seattle)

4.2 Risk Analysis

There are various OR methods that can be used in risk analysis of a company, and the methods we have covered in this paper are Hiller and Hertz model (Pradeep Prabhakar Pai,2012) which is used to compare risks of various projects. In this book Pai explains the method and gives us a case of the way the method is used. The book also states the different places the method can be used for example Valuation of startups, Analysis of projects, Investment planning, etc. The another method that was used for risk analysis was the Expected Monetary Value (EMV). (Roopdarshan Walke, 2010) This technique is an integral part of risk management and is usually used in medium, large, and complex projects. It is a simple but effective approach for quantification of risks and thus helps to achieve the objectives of the RMC. The proposed approach has three stages as mentioned below -

- Risk identification, categorization and classification.
- Risk prioritization
- Risk quantification

Risk quantification approach proposed in this paper, using EMV is a simple and effective tool to quantify risks in terms of cost. It helped the owners of the RMC decide upon the risk response strategies by identifying the high risk areas which need to be controlled and monitored for the achievement of objectives. Thus the above approach can be made suitable for incorporating and implementing with a computer aided decision support system, provided precise data is made available.

5. Findings

5.1 Profit Maximisation: Linear Programming Problem

Case - Maximising returns with a pre-determined budget given to finance a portfolio with a variety of financial instruments.

Defining the problem- In this particular case, we aim to evaluate the possibility of acquiring an optimal portfolio where the constraints are considered to be the most important requirements of an average investor, in terms of the returns expected and the potential risk associated with each of the instruments. We further detail this process of financial planning by considering the portfolio manager to have a budget of 1,00,00,000 to finance these investments. The portfolio takes into account 4 different instruments, given with the respective rate of return and a rank for the associated risk on a scale of 1 – 10. (1 being the most favourable while 10 bearing the most risk). The instruments include private equity, government bonds, illiquid assets and commercial loans.

Instrument/Invest	Return (%)	Risk
Equity	17%	8
Government Bonds	8%	1
Illiquid Assets	9%	4
Commercial Loans	14%	6

Once the portfolio is created, the excess funds available from the budget are invested into a savings account with a return of 4% without any identified risk.

The following are the considered criteria which are to be addressed while allocating the funds:-

1) The average rate of return should not be below 10%.
2) The associated risk factor should not be above 5.
3) To have at least 20% of the funds invested in Illiquid assets.
4) The summation of the amount invested in private equity and commercial loans, should be lesser than or equal to the amount invested in government bonds.
5) The surplus funds are invested in the savings account at the rate of 4% with no risk associated, postthe portfolio formation.

Model - The number of investments made are numbered from 1 to 4. Let ‘xi’ be the investment made in ‘i’ and ‘xs’ be the surplus funds to be put in the savings account.

Objective function: To maximize,

$Z = 17x_1 + 8x_2 + 9x_3 + 14x_4 + 4x_5$

Subject to:

$x_1 + x_2 + x_3 + x_4 + x_5 \leq 1{,}00{,}00{,}000$ (1)

Formulation:

$\frac{8x_1 + 1x_2 + 4x_3 + 6x_4}{x_1 + x_2 + x_3 + x_4} \leq 5$ (2)

$\Rightarrow \quad 3x_1 - 4x_2 - x_3 + x_4 \leq 0$

$x_3 \geq 20\% \ (x_1 + x_2 + x_3 + x_4)$ (3)

$\Rightarrow \quad 0.2x_1 + 0.2x_2 - 0.7x_3 + 0.2x_4 = 0$

$x_1 + x_4 \leq x_2$ (4)

$\Rightarrow \quad x_1 + x_4 - x_2 \leq 0$

$\frac{17x_1 + 8x_2 + 9x_3 + 14x_4}{x_1 + x_2 + x_3 + x_4} \geq 10$ (5)

$\Rightarrow \quad 7x_1 - 2x_2 - x_3 + 4x_4 \geq 0$

(Solved using solver on excel)

Analysis

As seen in the above case, linear programming helps arrive at the most suitable combination of allocations, while being restricted by a defined budget.We can use the above finding to maximize the rate of return which the investor can achieve which also respecting the minimum level of risk they are comfortable bearing. We also succeed in quantifying the problem with the help of mathematical rules and equations which helps us justify our eventual findings. Since we cannot further add any nonlinear objective to the above case without changing the methodology, we find the extent to which the technique of linear programming is applicable in the field of financial management.

5.2 RiskIdentification: Hillier and Hertz's Model (Pai)

Case - Helion Venture Partners(VC firm) got an investment proposal of 2 start-ups and it doesn't have sufficient money to fund both the start-ups. The returns from both the investments are similar but not the probability of the cash flows. The firm has to decide to invest in one of the company. Both the investments are mutually exclusive.The investment proposals have the discrete probability distribution of expected inflows as given in the table below.

Column1	Start-up A	Start-up B
Cost	₹20,000.00	₹20,000.00
Time till stability	2 years	2 years
Cash Flow(per year)	₹12,000.00	₹12,000.00
Salvage Value	₹ 0.00	₹ 0.00

Upon further analysis, the probability of the cash inflows for each project per year was found to be as –

Startup A		Startup B	
Cash-Inflow(₹)	Probability	CashInflow(₹)	Probability
10000	0.2	11000	0.2
12000	0.6	12000	0.6
14000	0.2	13000	0.2

The risk can be calculated using the mean of NPV-

$$M = \sum_{i=0}^{n} (1+r)^{-i} M_i$$

And the variance of NPV

$$\sigma^2 = \sum_{i=0}^{n} (1+r)^{-2i} \times \sigma_i^2$$

Analysis

After solving the problem we get the variance of the cash flows which helps us in understanding the risk. This risk can be used by the portfolio managers and VC firms to plan their risk using different ratios such as Sharpe ratio and Jensen's alpha. However, this method doesn't consider qualitative aspects.

5.3 Risk Quantification: Expected Monetary Value (Roopdarshan Walke, 2010) , (Pai)

Case - ICICI prudential fund manager has projected the probability of getting certain cash flows in the future of the fund .what is the EMV calculated by the fund manager random variables as a cash flow and their probability estimates. Also find the present value of the future cash flows using a 12% discount rate.

Yearly cash flow data and probability of cash flows:

Cash Flow	Year1	Year2	Year3
5000	0.2	0.4	0.4
10000	0.3	0.3	0.2
13000	0.3	0.1	0.3
15000	0.1	0.1	0.4

(It is solved using the expected values and Standard deviation)

Analysis

After calculating the combined standard deviation the fund manager can estimate how much will the deviation of the cash flows. Fund manager can compare this with the industry deviation and according to his risk intake he can decide whether to invest in it or not.

6. Conclusion

In this research paper, we have attempted to present an overview of operations management in the financial market industry and tried to make the case that this industry has several unique characteristics. We have used Linear Programming, Hillier and Hertz's Model and Expected Monetary Value Model to take care of an extensive scope of issues in financial markets. The LPP Model helps in maximizing the investor's return with minimum risk at a given point of time. Whereas the Hillier & Hertz Model asserts that the computation of standard deviations of several ranges of cash flows to enable a firm to determine the uncertainty involved in future projects.

As we know that a project should contain sufficient return on investment. Likewise, any proposal involving some cash outflow should be worthwhile only when the cash inflows generated by such an investment are sufficient. The very idea of promoting a project or investment proposal is to earn attractive returns on investments. If there are alternative investment options or proposals, prima facie which appear similar or appear to be more or less equal in profit-earning capacity, the investor should be able to make a comparative study of the returns on the different alternative proposals before choosing one. Thus, investment analysis is the key to

the success of any project proposal or for evaluating investment options. Different methods discussed in this paper helps an entrepreneur, investor make the correct decision. It is possible that some practical limitations restrict the utility of some of the methods enumerated in various sections. Operations Research techniques can, therefore, be utilized by various financial institutions and regulators in managing their investors/clients portfolio by maximizing the return and minimizing risk. Thus we can conclude by saying that OR techniques play a critical part in financial decision making and, with the current emotional upgrades in the constant accessibility of information this part will increment. Thereby creating a greater scope for OR in financial markets & financial decision-making.

7. Challenges

Important limitations of these techniques are:

1) Operations research techniques involve the use of mathematical models, equations and similar other mathematical expressions. Assumptions are always incorporated in the derivation of an equation and such an equation may be correctly used for the solution of the business problems when the underlying assumptions and variables in the model are present in the concerning problem. If this caution is not given due care then there always remains the possibility of wrong application of the Operations research techniques. Quite often there are many solutions without being able to find problems that fit.
2) Operations research techniques usually prove very expensive. Services of specialised persons are invariably called for while using Operations research techniques. Even in big business organisations, we can expect that Operations research techniques will continue to be of limited use simply because they are not in many cases worth their cost. As opposed to this a typical portfolio manager, exercising intuition and judgement may be able to make a decision very cheaply. Thus, the use of Operations research techniques is a costlier affair and this, in fact, constitutes a big and important limitation of such techniques.
3) Operations research techniques do not take into consideration the intangible factors i.e., non-measurable human factors: Operations research techniques make no allowances for intangible factors such as skill, attitude, vigour of the management people in taking decisions but in many instances success or failure hinges upon the consideration of such non-measurable intangible factors. (Qua)
4) Operations research techniques are just the tools of analysis and not the complete decision-making process. It should always be kept in mind that Operations research techniques, whatsoever it may be, alone cannot make the final decision. They are just tools and simply suggest best solutions but in the final analysis, many business decisions will involve the human element. Thus, Operations research analysis is at best a supplement rather than, a substitute for management; subjective judgement is likely to remain a principal approach to decision making.

8. Acknowledgment

The authors wish to thank Prof. Richa Saxena for her extraordinary cooperation, invaluable guidance and supervision. We would also like to express our gratitude to Prof. NandipVadiya at NMIMS University, for sparing his valuable time to help us achieve our goal.

References

[1] Ahmad Mobin Operations Research Applied to Financial Market [Report]. - [s.l.] : International Journal of Mathematics and Statistics Invention (IJMSI), 2017.
[2] Akhil Jain Akansha Menghrajani, Aditya Nikale, Aayush Gosrani, Aayush Sanghai,"Application of Operations Research in Banking & Finance" [Journal]. - [s.l.] : International Journal of Innovative Science and Research Technology, 2017 .
[3] Akrani Gaurav Operations Research - Definition Meaning Features Limitations [Online] // Kalyan City Life Blog. - September 2011. - https://kalyan-city.blogspot.com/2011/09/operations-research-definition-meaning.html.
[4] Economic times,"Bangladesh, Nepal ahead of India as growth in South Asia slows down: World Bank report" [Online] // ww.economictimes.com. - October 2019. - https://economictimes.indiatimes.com/news/economy/indicators/bangladesh-nepal-ahead-of-india-as-growth-in-south-asia-slows-down-world-bank-report/articleshow/71562925.cms.
[5] Ghaharian Kasra Christopher,"A Mathematical approach for Optimizing the Casino slot floor: ALinear Programming Application" [Report]. - [s.l.] : UNLV, 2010.
[6] "India Brand Equity Foundation Financial Services in India", [Report]. - [s.l.] : India Brand Equity Foundation, 2019.
[7] Ittman Hans,"Recent developments in operations research: A personal perspective" [Report]. - [s.l.] : Orion, 2009.
[8] John Board Charles Sutcliffe, William Ziemba, "Applying Operations Research Techniques to Financial Markets" [Journal]. - [s.l.] : ResearchGate, 2003.
[9] Mapsofindia Growth of Financial Sector in India [Online] // Mapsofindia.com. - https://business.mapsofindia.com/sectors/financial/growth.html.
[10] Pai Pradeep Prabhakar,"Operations Research Principles and Practice" [Book]. - [s.l.] : Oxford Higher Education.
[11] Quantitative Techniques [Book]. - [s.l.] : Vardhaman Mahaveer Open University, Kota.
[12] Reshampal Kaur Ranjit Singh,"Role of OR Techniques in Financial Decision Making" [Journal]. - Mohali, Punjab, India : International Journal of Management & Business Studies, 2014.
[13] Roopdarshan Walke Vinay Topkar, Sajal Kabiraj,"Risk Quantification Using EMV Analysis – A Strategic Case of Ready Mix Concrete Plants" [Journal]. - [s.l.] : IJCSI International Journal of Computer Science Issues, 2010.
[14] Sharpe William,"A Linear Programming Algorithm for Mutual Fund Portfolio Selection" [Report]. - 1967.

[15] Vinay,"Operations Research Origin (History)" [On-line] // www.universalteacherpublications.com. - http://www.universalteacherpublications.com/univ/ebooks/or/Ch1/origin.htm.