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ABSTRACT

The research paper specifically concentrates on the actual mathematical use of Operations Research in Financial markets. To understand the use of operation research within the financial market it is important to move with a specified structure covering all aspect of the application of these techniques.

The research paper first begins with discussing the attractiveness of the financial market and the use of operation research within it. The research paper further provides the frequency and percentage of use of different operations techniques in the financial markets, this analysis the proportion of use of certain operation concepts within the financial market. Further, the research paper highlights various financial problems and how Operation Research has applied in these issues: funding decisions, Economic Understanding, strategic problems, regulatory and legal problems and imperfections in financial markets.

This paper also analysis major operations concept such as portfolio theory and its application. The research paper also divulges into the details of valuation of assets such as valuation of MBS and CMO's, bonds and bonds stripping. Operation research is not only applied to decision making or valuations, it has immense use in Enterprise-wide Risk Management, which talks about how the application of Operation Research in the financial world by managing risks helps to reap rewards.

Keywords: Operation Research, Financial Sector, Funding Decisions, Economic Understanding, Strategic Problems, Regulatory And Legal Problems, Imperfections In Financial Markets, Portfolio Theory, Valuation Of MBS And CMO'S, Valuation Of Bonds And Bonds Stripping, Enterprise-Wide Risk Management.

OBJECTIVE

To understand and identify the applications of various operation research concepts and theories to the financial markets and analyses its effects and benefits to the growth and development in creating new methods of calculation, structuring, classifying and solving various problems existing within the financial sector.

ATTRACTIVENESS OF FINANCIAL PROBLEMS

Financial problems are generally separable and well defined. With the objective of maximizing profits or minimising risk, and relevant variables amenable to quantification, these problems are almost always expressed in monetary terms. There exists a certain sense of concern in financial problems, this concern is the identification of the correct question. The way in which an increase in the proportion of a portfolio invested in an asset affects the mean and variance of the portfolio is clear. The resultant OR model is always a good presentation of the actual reality, especially as the non- quantitative factors are often small. Another advantage to financial problems is that any solution produced can be implemented in reality, as opposed other fields where there are higher amounts of uncertainty and inapplicability.

Another advantageous factor is the availability of real-time data, the solutions can often be implemented quickly. Also, as trading in the financial market often involves large sums of money, even a very small improvement in the solution can help save a lot of money. Furthermore, these problems tend to recur every now and then, so just one solution can help save a lot of transactions. This scale and repetition make the development of an OR model more attractive than for small or one-off decisions. Hence, because financial applications, especially financial markets, are predominantly comprising of numerical sums with specific boundaries, and objectives, with clear relationships between variables, OR helps change the quality of the smallest decisions which benefit in the long run.

CONTRIBUTION OF DIFFERENT CONCEPTS OF OPERATION RESEARCH IN FINANCIAL SECTOR

The table gives the frequency of use and percentage of use of every operation technique related to the financial sector to classify and analyse the level of importance of all these techniques.

THE TABLE SHOWS THE APPLICATION OF OR TECHNIQUES IN THE FINANCIAL MARKETS

Technique	Frequency of Use	Percentage
Linear Programming	97	20.17
Goal Programming	4	0.83
Integer Programming	0	0.00
Dynamic Programming	14	2.91
Stochastic Programming	45	9.36
Forecasting	15	3.12
Simulation	25	5.20
Queuing	3	0.62
Heuristics	4	0.83
Statistical Analysis	85	17.67
MIS/EDP	18	3.74

Other Techniques	171	35.55

The study found that the preferred techniques that were used 20 years ago namely Statistical Analysis and Linear Programming are still one of the majorly used methods today. Linear Programming has enjoyed an increase in popularity due to technological advances such as data envelopment analysis (DEA).

The most frequently used techniques (as shown in Table) are linear programming, statistical analysis, other methods, stochastic programming, simulation, and MIS/EDP.

User familiarity with certain techniques play a key role in the choice of the concepts or techniques. Linear Programming is one of the most key techniques used as it helps in finding optimization even with the existence of multiple factors and variables.

EXPLAINING FINANCIAL PROBLEMS AND CONTRIBUTION OF OPERATION RESEARCH TO THESE FIELDS

The following points explain the contribution of operation research to these financial problems, it showcases the use of different techniques incorporated into the solution to these problems:

1. **Funds Raising decisions**
   OR techniques are frequently used to assist firms in determining the most appropriate method by which they can raise capital from financial markets to finance the various activities that are conducted by the firm. Mathematicians like Brick, Melon, Surkis, and Mohl in 1983 made a chance-constrained linear programming model to compute the values of the debt-equity ratio that helps firms maximise their value. Other studies have specified the choice between various types of funding as a linear goal programming problem that is used to find the least cost financing decisions for various investment projects by multinational companies. Another financing decision model was created by Kornbluth and Vinso, which catered to 2 goals- to minimize the overall cost of capital and achieving target debt-equity ratios in each country. In this case, debt can be treated like any other input to the productive process, and inventory models used to determine the optimal "reorder" times and quantities.

2. **Strategic problems**
   When on the stock market traders have the main goal of making profits so, therefore, all the traders seek to work at attractive prices and large trades are often broken up into a sequence of smaller trades. These financial decisions have been analysed using the game theory. This OR technique helps to solve a strategic problem in the stock market by breaking large trades into smaller trades.

3. **Regulatory and legal problems**
   Operation research techniques have helped to keep a check on the very large and very rapid financial flows in and out of the financial markets. It has helped to regulate the capital reserves in the bank. By designing appropriate strategies, it has helped to ensure compliance with various legal requirements. To know the amount of capital required by the firm it is necessary to quantify the value at risk. VAR involves quantification of the lower tail of the probability distribution of outcomes from the firm's portfolio. Since traders were required to put margin when they trade options. Rudd and Schroeder have developed a linear programming model in which the problem was modeled as a transportation problem for determining the minimum required margin.

4. **Economic understanding**

   Apart from improving quality of decision making when considering financial markets, OR also helps try understanding the economic force that shapes the finance sector. When there is an exogenous change in the constraints or costs of meeting existing constraints, financial innovation in terms of OR occurs.

   Example: Using a linear programming model of a bank, Ben-Horim and Silber (1977) employed annual data to compute movements in the shadow prices of the various constraints. They suggested that a rise in the shadow price of the deposits constraint led to the financial innovation of negotiable CDs.

4. **Imperfections in Financial Markets**

   Trader seeks the need to make easy money by finding imperfections in the financial market which can be exploited to make profits. One aspect of this is the search for weak form inefficiency (i.e. that an asset's past prices can be used as the basis of a profitable trading rule). A very important feature of financial markets is the existence of no-arbitrage relationship between prices, and these small discrepancies can be exploited by arbitrage trades to give huge amounts of underserved, reckless profits. OR network models have been often used to find opportunities between sets of currencies. This problem can be specified as a maximal flow network, where the aim is to maximise the flow of funds out of the network, or as the shortest path network. While some network formulations are linear and could be formulated and solved as linear programming models, interpretation of the problem as a network enables the use of computationally faster algorithms.

OPERATION RESEARCH TECHNIQUES APPLIED IN FINANCIAL MARKETS

Portfolio Theory and its applications

Portfolio theory:

Portfolio theory was developed by Henry Markowitz, it is a quadratic programming problem used especially to solve financial problems. People getting involved in financial markets usually wish to have diversified portfolios as that has risk-reducing advantages, without changing the expected rates of return. While returns produce a linear objective function, the risk is modeled using the variance, leading to an objective function with quadratic variance and covariance terms. The Markowitz model also includes non-negativity constraints on the decision variables to rule out short selling of the asset concerned. Markowitz also developed solution algorithms for more generic quadratic programming problems. This helps provide an example of involvement with finance and OR, with the latter being tailored to meet the needs.

APPLICATIONS OF QUADRATIC PROGRAMMING IN FINANCIAL MARKETS

Quadratic programming is used in financial markets in the following manner:

- While the application of portfolio theory is most frequently used in equity portfolios, there exists a wide range of applications of this theory.

- While Konno and Kobashi proposed using portfolio theory to form portfolios of both equities and bonds, others have used quadratic programming to maximise expected value, for interest rate risk management, and have also applied this theory to select a portfolio of fixed interest securities (Mortgage Backed Securities), that maximise expected utility of terminal wealth and several other such fields.

- Quadratic programming is also applied in pension funds that hold both asset and liability portfolios. These problems of selecting an investment policy for a pension fund can be analysed using asset and liability management models that allow for the non-zero correlations between values of assets and liabilities.

- Portfolios of currencies

- Generalised hedging to minimize variance between a given portfolio of a given set of assets and liabilities- which was then extended to selecting a portfolio for domestic equities, foreign equities, and foreign exchange forward contracts.

- Constructing index tracking portfolios, to achieve minimum risk when combined with making short position in the index to be tracked.

- Finally, quadratic programming is also used in fields not very involved in financial markets, developed in recent times- for example- Farming.

Portfolio Management:

- xj – decision variables, j= 1,2…n

- Rj – rate of return. rjt , t= 1,2…T; E(Rj) = rj = Σ trjt /T

- Expected return: E(Σ j Rj xj)= Σ j rj xj

- Risk of Return: Var(Σ j Rj xj

Sharpe's Improvement of s Improvement of the model

- Modify the objective function to Z=(1-λ)Return- λRisk

- Adding more constraints with industry consideration

Valuation of Assets

Operations research has been used to value financial assets as an equation can be derived by inputting variables associated with an asset which differs from asset to asset and would then be factored in to arrive at a conclusion which would be a feasible as well as an optimal solution.

These equations may also help us to select an asset which would have the least amount of risk and highest amount of gains an asset which has a High P/E ratio and also an Asset which has long-term Gains. To figure this we would also be required to factor in variables such as the price, Maturity period, Risk associated, Yield ratio, Market Variability index, Etc. Such fields can be added to ensure that quality in an asset.

Valuation of MBS and CMO's

Mortgage-Backed securities are shares presenting loans given out the people and allowing private investors to invest in them these securities often suffer from the risk associated by defaulting the payment. It may also be the case that the loaned prepays the amount. These securities also played important role in the 2008 economic crisis. These loans work in such a way that the loans are given out by banks and then such loans are clubbed by the bank in bundles and then these bundles are sold to private investors, these bundles may also be graded by private agencies to make them look more lucrative.

The associated with these also sink in and risk associated with the rate of interest payable on flexible-rate mortgages, making the whole game a Very variable and hence increasing the % of risk involved. Over here Monte- Carlo method can be used to plan out the yield returns for the future and also use these to plan out the cash flows from them and also included these in the value of MSB we can come to the actual value of the MSB. These MSB then can be actually judged on how much are they actually worth and how high should a person go while investing in them.

CMO's or collateralized mortgage obligations CMO's represent a mortgage Pool Structured into a series of bonds and each of them having a different maturity and risks.

Here computing the actual value of bonds takes a toll because there are different types of bonds there are hybrid securities convertible securities callable and puttable securities which provides a similar kind of problem like valuing MSB's and requires similarly intensive solution methods.

Valuation of Bonds and Bonds Stripping

After we have computed the yield curve which shows us the output of each of the interest rates on different maturities, which can be used by a trader to value the bond price and then he can select the most optimal one. One must not include the coupon value of the bond valuing the bond because most m bonds have coupons when using them to compute yield curve. It was proposed to solve these equations using LLP and simplex method which guarantees a set of bond prices which is arbitrage free.

This basically means that if two bonds have a similar maturity period the one with a higher risk would be given the higher preference. This ensures the risk to be low, profits are high and hence gives us the higher benefit.

ENTERPRISE-WIDE RISK MANAGEMENT

The relevance of OR in the changing financial world is explained in this segment of the research paper. OR provides some indispensable tools to support financial decision making. Several dynamics added by OR shows a new paradigm of integrative enterprise-wide risk management that adds significant value to financial decision making.

Enterprise-wide risk management (ERM) is defined as *the strategy that aligns the firm's business with the risk factors of its environment in the pursuit of strategic objectives. It consists of the conceptual framework, organizational approaches, and tools that integrate market, credit, liquidity, operational, and business risks in achieving the organization's objectives.*

There are four key functions which make the pillars of enterprise risk management strategies. These strategies are:

1. **Pricing**
2. **Securitization**
3. **Asset and liability management**
4. **Indexation**

Operations research provides essential tools to support these key functions of enterprise risk management. The pricing of complex path-dependent options — whose prices depend on a history of asset prices and not just the asset value on exercise — requires Monte Carlo simulation methods. For several derivatives, the decision whether to exercise the option or not, follows from the solution of an optimization problem. Theoretical models of the price evolution of the risky assets must be linked with dynamic programming algorithms to arrive at options prices resulting from optimal exercise strategies.

OPERATIONS RESEARCH PROVIDES ESSENTIAL TOOLS TO HELP ENTERPRISE RISK MANAGEMENT IN ALL THESE FOUR PILLARS

FOR PRICING

The pricing of complex path dependent options, whose pricing depends on not just the asset value in view but a history of asset prices, requires Monte Carlo Simulation methods*. For several derivatives, the decision of not exercising the option follows from the solution of the optimization problem. Theoretical models of price evolution of the risky assets must be linked with dynamic programming algorithms to arrive at options prices resulting from optimal strategies.

Arbitrage opportunities are created when pricing options are not optimal; arbitrageurs push the market toward optimal strategies, although they do not do so with the overt use of optimization algorithms. Furthermore, pricing in incomplete markets requires specification of preference assumptions that can only be resolved in an optimization framework. Linear programming and linear complementary problems occur in options pricing. Sometimes the operations research models appear as alternative formulations to other options pricing formulas, enjoying some computational advantages. In other instances, they provide the only formulations.

FOR SECURITIZATION

Securitization is done with the innovation of financial products and the repackaging of financial risks. Which can be made more effective with the use of optimization models. Just like engineers, who use optimal methods to optimize structural designs for safety, stability, cost or fuel efficiency- financial technicians use optimization models for the competing dimensions of risk and rewards.

FOR MANAGEMENT OF ASSETS AND LIABILITIES

The management of assets and liabilities using the principles of diversification relies on quadratic optimization models. Significant developments since Markowitz's pioneering contribution in the 1950s — derivative securities that violate assumptions on the normality of returns, long time horizons of complex liability structures, increasing transaction costs for derivative securities — ushered a new generation of multi-period portfolio optimization models. Dynamic financial analysis was developed to go beyond the single-period decisions of mean-variance analysis to the optimization of dynamic strategies.

FOR INDEXATION

Finally, portfolio indexation and portfolio compression rely on the combination of pricing and simulation models with optimization models. The market's response is replicated by the risk factors of the index which are simulated and optimization models create portfolios that respond to the risk factors. When the risk factors are properly identified and correctly simulated, the optimized portfolio will closely track the index.

The following methods are the process by which operations management helps avoid financial risks and helps take a sound financial decision in all enterprises. Every enterprise is bound to involve in assets for investment, and bear liabilities as a sacrifice for the profits that it aims to make. To carefully manage all financial instruments in order to maximise the enterprise's productivity comes with making sound decisions, which is where Operations Research comes into play.

*Monte Carlo simulation is a computerized mathematical technique that allows people to account for risk in quantitative analysis and decision making

The complete analysis of the frequency and percentage of use of operation techniques within the financial sector and the application of certain concepts and theories for financial problems showcases the importance of operation research to the financial market.

The conclusion that most certainly can be drawn is that the nature of the financial sector being structured and numerical with quantifiable variables results in operation research being an attractive measure for calculation of variables such as valuation, risk, proportions, and ratio important for businesses and people to give a quantifiable and understandable method to analyse financial problems.

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