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Applications of operations research tools in financial engineering

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ABSTRACT

This research paper aims at establishing a dependence of the new era financial services on operations research tools and how operations research tools have become the essence of financial management fields. This paper also introduces Financial Engineering a revolutionary idea that has made finance instability more predictable and manageable.

Keywords— *Simulation models, Portfolio management, Risk management*

1. WHAT IS THE CURRENT MARKET SCENARIO?

Innovation in finance during the past few years has increasingly brought about revolutionary changes in financial instruments & processes. An IPO or FPO is launched every other day. A variety of various other causes such as increased volatility rates of interest etc. have made the market and the young added. Computational algorithms are also devised by financial engineers to implement the tools and calibrate them to financial market data.

The responsibility of a financial engineer is to have full knowledge of financial markets, its volatility, instability, and knowledge of financial literacy. This know-how is used by engineers to develop simulations and predict the behaviour of the market. Of course, the predictions are not accurate, any unexpected issue can happen in the financial market but the risk and uncertainty reduced. Since a financial engineer has a full idea and knowledge about new market trends and previous market performances, the algorithms are used to make future investment predictions. (FinanceWalk)

2. WHAT IS OPERATIONS RESEARCH?

An Operation Research (OR) is an analytical method of problem-solving and decision-making that is useful in organizations management. In operations research, problems are narrowed down into basic components and then solved in steps through quantitative analysis. Analytical methods used in Operations Research comprise of mathematical logic, simulation, network analysis, queuing theory, and game theory.
(Tech Target)

2.1 Define: Financial engineering

The Norman and Adele Barron Professor of Management at Boston University, Zvi Bodie, defined Financial Engineering as:
"The application of science-based mathematical models to decisions about saving, investing, borrowing, lending, and managing risk." (Reuters)

2.2 In simpler terms

Financial engineering uses mathematical techniques for solving financial problems. It uses tools and knowledge from a variety of fields such as computer science, economics, statistics, and applied mathematics which addresses the current financial issues and also, to devise products that are new and innovative.

Financial engineering is also known as quantitative analysis. Insurance agencies, commercial banks, investment banks, and hedge funds use financial engineering for predicting the performance of various stocks and other financial tools in the market.

These quantitative risk models that are run by financial engineers help to predict the performance of an investment tool and if any kind of new offering in the financial sector will be profitable in the long run. They also help to identify the risks presented in each product offering considering the volatility of the market.

Various types of financial securities are covered in financial engineering. Under financial engineering, we follow various operations research modules to come up with assignment under portfolio management, trend analysis, and performance. Various departments where financial engineering is applicable are as follows:
- Risk management
- Portfolio management

- Derivative
- Corporate finance
- Structured products
- Mergers and Acquisitions

3. DOMAIN OF FINANCIAL ENGINEERING

3.1 Risk Management

Market risk refers to adverse changes in prices and rates of various commodities. It also includes changes in stock prices, forex rates, and energy prices. Another major risk is credit risk. Credit risk is a risk of default on financial obligations such as loans. Various aspects of financial risk management include:
(a) Transaction risk
(b) Portfolio risk
(c) Enterprise risk
(d) Systematic risk

Models which contain extreme financial events and also have the capacity of computing the risk of large portfolios in a timely manner.

Operations research theory used- simulation techniques (Monte Carlo Simulation Algorithms)

3.2 Portfolio Management: Major problem of portfolio optimization is to find an investment strategy that is suitable for the decision maker's needs and preferences. Mutual funds, universities and foundation endowments, pension funds, insurance companies, and individual investors, they all face the same problem of allocating their capital among different investment so that they're able to generate good and sufficient returns to meet their future goals. Portfolio Management is a computationally challenging because they are so many securities to invest in and a lot of times the portfolio can be updated. Taxes and investment may introduce features such as nonlinearity and integer constraints.

Operations research theory used: linear programming

With the companies' portfolio defined, and the indicators of liquidity, profitability, Risk and return collected, the optimization model was implemented.

Example: John has \$20,000 to invest in three Securities A, B, and C. Security A is offering a return of 2% and has a low risk. Security B offers a return of 4% and has a medium risk. Security C offers a return of 5% but has a high risk. To be on the safe side, John invests no more than \$3000 in C and at least twice as much as in A than in B. Assuming that the rates hold till the end of the year, what amounts should he invest in each Security in order to maximize the year-end return?

Solution: Let x be the amount invested in A, y the amount invested in B and z the amount invested in A.

$$x + y + z = 20{,}000$$
$$z = 20{,}000 - (x + y)$$

Objective: Total return R of all three Securities is given by

$$R = 2\%\ x + 4\%\ y + 5\%\ z = 0.02\ x + 0.04\ y + 0.05\ (20{,}000 - (x + y))$$
$$R(x,y) = 1000 - 0.03\ x - 0.01\ y$$

Subject to constraint:

$$x \geq 0$$
$$y \geq 0$$
$$z \geq 0$$

$x \geq 0$		
$y \geq 0$		
$(x+y) \geq 17{,}000$	(0,17000)	(17000,0)
$(x+y) \leq 20{,}000$	(0,20000)	(20000,0)
$x \geq 2y$	(0,0)	(10000,5000)

Substitute z by 20,000 - (x + y) in the above inequality to obtain

$$20{,}000 - (x + y) \geq 0$$

Which may be written as

$$x + y \leq 20{,}000$$
$$z \geq 0 \Rightarrow x + y \leq 20{,}000$$

John invests no more than \$3000 in C, hence

$$z \leq 3000$$

Substitute z by 20,000 - (x + y) in the above inequality to obtain

$$20{,}000 - (x + y) \leq 3000$$

Which may be written as

$$x + y \geq 17{,}000$$

Standard form of LPP

$$x \geq 0$$
$$y \geq 0$$
$$(x+y) \geq 17{,}000$$
$$(x+y) \leq 20{,}000$$
$$x \geq 2y$$

Line Co-Ordinates

Feasible region inequalities: Equations provide FR

Graph: See Annexure 1

Extreme points co-ordinates:

(20000, 0): R (20000, 0) = 1000 - 0.03 (20000) - 0.01 (0) = 400
(17000, 0): R (17000, 0) = 1000 - 0.03 (17000) - 0.01 (0) = 490
(11333, 5667): R (11333, 5667) = 1000 - 0.03 (11333) - 0.01 (5667) = 603
(13333, 6667): R (13333, 6667) = 1000 - 0.03 (13333) - 0.01 (6667) = 533

For maximum return, John has to invest \$11333 in Security A, \$5667 in Security B and \$3000 in Security C.

3.3 Derivative

Derivative securities, such as stock options and commodities, have payoffs which are related to the value of an underlying asset, such as stock or commodity. Derivative securities mainly transfer the financial risk from hedgers to investors when there is a possibility of gain for the investors.

For instance, a company could be facing a risk of increasing commodity and energy prices that will make production in the future more expensive. In such a condition, the company can hedge those risks by entering into financial contracts or agreements. Such financial contracts act as insurance which protects it against adverse market events. Interest rates derivatives, equity derivatives, commodity and energy derivatives, credit derivatives, and currency derivatives are the most important segments of global derivative markets.

The classic problem of financial engineering is finding the relationship between the derivative security's place and that of an underlying asset. The development of realistic stochastic models for the underlying asset and market variables, leading to more accurate prices for derivative securities, and the development of efficient algorithms for computing derivative prices easily and quickly.

Operations research theory used: graphical representation

Example: Mr. John wants to invest in two shares of derivative markets. John wants to buy the shares of BHEL and Reliance Ltd. as he expects them to rise in the future.

Company	Strike price	Expected price	Profit
BHEL	300	400	100
Reliance Ltd.	80	130	50

But due to risk factors, he buys up to 11000 shares. Also in BHEL, he will invest in only up to 6000 shares while in Reliance Ltd. it will be up to 8000 shares. Find out a number of shares he should buy in order to maximize profit.

Solution:

Objective: 100X + 50Y

Subject to Constraint:

$$X + Y \leq 11000$$
$$X \leq 6000$$
$$Y \leq 8000$$

Standard form of LPP:

$$X + Y \leq 11000 \text{ – Equation 1}$$
$$X \leq 6000 \text{ – Equation 2}$$
$$Y \leq 8000 \text{ – Equation 3}$$

Line Co-ordinates:

X=0, Y=11000; Y=0, X=11000 (0,11000) (11000,0)
X=6000; Y=0 (6000, 0)
X=0; Y=8000 (0, 8000)

Feasible Region Inequalities: Equation 1, 2 and 3 FR region towards the origin.

Graph: See Annexure 1 (2)

Extreme Point Co-ordinates

A (8000, 0)
B (8000, 3000)
C (5000, 6000)
D (0, 6000)
E (0, 0)

Extreme Point Method

A (8000, 0) = 100(8000) + 50(0) = 800000
B (8000, 3000) = 100(8000) + 50(3000) = 950000
C (5000, 6000) = 100(5000) + 50(6000) = 800000
D (0, 6000) = 100(0) + 50(6000) = 300000
E(0, 0) = 0

ISO profit line

100X + 50Y = 500000
X=0, Y=10000
Y=0, X=5000
I1=(5000,10000)

For I2 line coordinates of point C (5000,6000).

Product Mix

X=5000 shares
Y=6000 shares
Maximum Profit = Rs.800000

For earning maximum profit John needs to buy 5000 shares of BHEL and 6000 shares of Reliance Ltd.

4. CONCLUSION

As we have observed operations research is the essence of modern-day financial services. Each financial service in some way or another uses operations research tools for its working. Operations research not only helps in optimizing profit but also helps in calculating the risk associated with every investment and thus helps in ascertaining whether the investment is feasible or not. With the passing of time new operations research tools such as Monte Carlo simulation which are developed especially for these financial engineering services and is used to calculate various risks associated with an investment. Linear programming is widely used to make an investment decision when profit maximization is the main concern and various alternatives are available. Even derivative market decisions can be easily made by linear programming through graphical analysis by maximizing the difference between the strike price and sell price. The dependence of financial engineering on operations research can be ascertained by the fact that many universities have started a course Operations research and Financial Management. Thus financial engineering and operations management go hand in hand.

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ANNEXURE

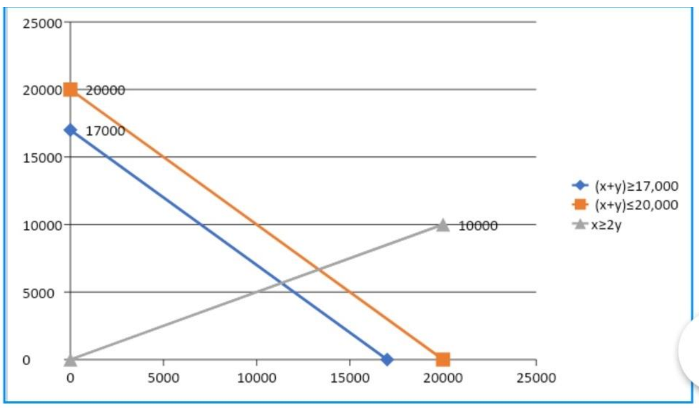

Fig. 1: Annexure 1

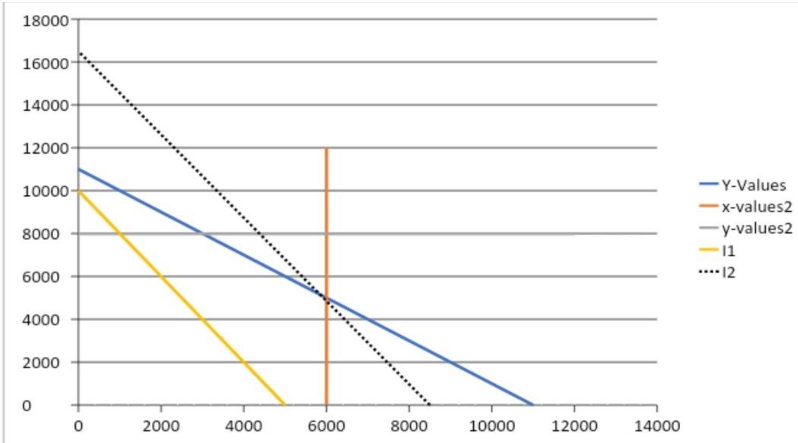

Fig. 2: Annexure 1