Application of operations research in financial markets and marketing

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ABSTRACT

This paper reviews the Applications of Operations Research in Financial Markets and Marketing. It shows how OR has become an interface for such dynamic fields. Finance can be described as the science of money management. It is quantitative in nature. Marketing is the study and management of exchange relationships (Bagozzi, Richard, 1975). It is more behavioural and innovative in nature. However, in this paper, we see how similar OR techniques can be applied to two contrasting fields.

Keywords— Finance, Financial markets, Marketing, Operations, Operations research, Applications, Optimisation models

1. INTRODUCTION

Problems in Finance are being solved using OR techniques for at least the last half-century. Financial decisions aim for profit maximisation and reduction of risk. There is a two route connection between techniques of OR and finance. One OR methods have been connected to financial problems and has helped to come up with new finance theories. Two, the finance theories have led to the advancement and change of OR solution techniques. In this paper, the reasons for the attractiveness of general finance problems OR researchers have been considered. The main types of problems arising in the financial markets have been identified and the problems solved using OR are documented. The various applications of OR in Finance are: valuation of Financial Instruments, funding decisions, Strategic Problems, Regulatory and Legal Problems, Portfolio Theory.

Mathematical programming is the most widely used and accepted method in Finance. Programming Techniques of the sorts like Linear, Quadratic, Non-Linear, Integer, Goal, and Dynamic Programming are for the most part utilized. Among these techniques, Monte Carlo Simulation is most generally utilized. OR techniques like Queuing Theory and PERT-CPM have not been connected to financial market up until this point. OR plays an important role in the working and operation of financial markets. This importance is likely to increase over time and this will enable Operations Researchers to play a greater role in this field. The following table shows the frequency of use of OR Techniques in Financial Markets:

<table>
<thead>
<tr>
<th>Technique</th>
<th>Frequency of use</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear programming</td>
<td>97</td>
<td>20.17%</td>
</tr>
<tr>
<td>Goal programming</td>
<td>4</td>
<td>0.83%</td>
</tr>
<tr>
<td>Integer programming</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Dynamic programming</td>
<td>14</td>
<td>2.91%</td>
</tr>
<tr>
<td>Stochastic programming</td>
<td>45</td>
<td>9.36%</td>
</tr>
<tr>
<td>Forecasting</td>
<td>15</td>
<td>3.12%</td>
</tr>
<tr>
<td>Simulation</td>
<td>25</td>
<td>5.20%</td>
</tr>
<tr>
<td>Queuing</td>
<td>3</td>
<td>0.62%</td>
</tr>
<tr>
<td>Heuristics</td>
<td>4</td>
<td>0.83%</td>
</tr>
<tr>
<td>Statistical analysis</td>
<td>85</td>
<td>17.67%</td>
</tr>
<tr>
<td>MIS/EDP</td>
<td>18</td>
<td>3.74%</td>
</tr>
<tr>
<td>Other techniques</td>
<td>171</td>
<td>35.55%</td>
</tr>
</tbody>
</table>

Source: Operations Research Applied to Financial Market
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2. SUITABILITY OF OR TO FINANCIAL PROBLEMS

The following are the general features of financial markets:
- The aim is to maximise profit and minimise risk. These variables can be quantified easily.
- Variables like mean, variance affecting the portfolio are usually well defined.
- Human Behaviour and Preferences are not a restriction on the implementation of some solutions as it is more quantitative in nature. Thus the OR model represents reality.
- Real-time data of prices (traded and quoted) of financial markets is available which can be readily used in OR models. Historical data and recorded market transactions can also be used to implement the solutions quickly.
- Financial problems are recurring in nature, thus they spread the costs of developing OR solutions to a large number of transactions. There can be large benefits with very small improvements in the quality of decision making.
- Thus, Financial Applications are well suited to OR Analysis

2.1 Applications

1) Economic Understanding: The traditional role of OR in Financial Markets is to improve the quality of Decision making. OR can also help to understand the economic forces
shaping the finance sector. Financial Innovation occurs when there is a change in the constraints or the costs of meeting the existing constraints. To solve this problem, Linear Programming Model of a Bank can be applied. This model studies data and computes movements in the prices of various constraints. (Ben Horim and Silber, W.L. (1977)

2) Funding Decisions: Companies need to decide the most appropriate method to raise capital from Financial Markets to finance their activities. OR techniques can help firms to decide the most appropriate method to do so. Brick, Mellon, Surkis, and Mohl (1983) made a chance-constrained linear programming model to calculate the Debt-Equity ratio for various periods to maximise the value of the firm. Ness (1972) made use of Linear Programming to find the least cost financing decision for an investment project by a multinational company.

Debt Problem- In this situation, the firm knows the Debt Equity Ratio it needs. However, they wish to find the cheapest source of financing. Thus, Debt is treated as an input for a Production process and Inventory Models are used to determine the optimal reorder times and quantities. (Bierman, 1966; Litzenberger and Rutenberg, 1972)

3) Portfolio theory: (Harry Markowitz, 1952) Diversified portfolios have the substantial advantage of reducing risk while leaving expected returns unchanged.

The objective function of the portfolio theory is to minimize risk for a given level of expected return or maximize expected return for a given level of risk. Returns produce a linear objective function, whereas the risk is modelled using the variance, which leads to an objective function with quadratic variance and covariance terms. The model used in the portfolio theory is the Markowitz model. It includes non-negativity constraints on the decision variables to rule out short selling of the asset concerned. Markowitz specified the portfolio problem within a mean-variance framework. Along with that, he also developed solution algorithms for more general quadratic programming problems.

4) Valuation of Financial Instruments: (Boyle, 1977) in financial markets, having a good model for valuing the asset being traded is extremely important.

The model we use for the valuation of financial instruments is the Monte Carlo Simulation. Monte Carlo simulation has an added advantage over the traditional binomial system- its convergence rate is independent of the number of state variables. Quasi-Monte Carlo methods have been applied to finance problems to increase the speed of the simulation.

5) Strategic Problems: Recently, decisions facing traders and market makers in Financial Markets have been analysed using Game theory. These models have one or more market makers/traders who may be informed, uninformed, discretionary or non-discretionary. Traders wish to trade at the most attractive prices. Thus, large trades are broken up into a series of smaller trades to reduce the price impact. This becomes a strategic problem where the aim is to devise a strategy to trade a block of shares. The initial trades have an effect on the subsequent trades. Therefore, executing a large trade at a lower cost is a problem.

Game Theory Application: A company has two major shareholders and a large number of small shareholders. Here, the two large shareholders behave strategically while the smaller shareholders don't. This approach determines the highest price a major shareholder will have to pay in the market for corporate control.

3. APPLICATIONS OF OPERATIONS RESEARCH IN MARKETING
3.1 Introduction
With Increase in competition in markets, every market needs to select their product line, product pricing and other factors that influence sale wisely. The market does not stand still. Decisions have to be changed constantly considering the marketing environment and the demand and supply forces. Therefore managers use operations research techniques to overcome these problems.

Marketing has transformed through the years (from the 1960s), from focusing on the distribution process to a functional area of management, creating a lot of opportunities for the usage of operations Research.

Originally there existed a direct application of OR techniques to the problems of marketing, the application being prominent. Later, marketing models developed as an independent field but the interface with OR continued. The interface between OR and Marketing is not only interesting but also important.

The most influential and important areas of application of OR are discussed here:
- Optimisation
- Stochastic process
- Decision support system

3.2 The need of OR in marketing
In the 1900's Marketing was limited to all that happened in the distribution process. Thus there was no need for the optimization process.
In the 1960's, the Marketing Mix and Marketing concept was invented. With the marketing mix, a marketer can increase the demand for his product by improving the quality, lowering the price, by advertising and sales promotions or by simply making the product easily available to his consumers. These marketing actions and efforts incur costs. The question is to find the optimal marketing mix given the different demand and cost effects. The aim is to find the values of Marketing Mix variables which can help us to obtain the highest profit. Thus, OR is needed to solve the Optimization problem in marketing.

Moreover, in recent times, there has been a renewed need for OR-centric methods in marketing due to the customer-centric approach, especially in areas of customer relationship management (CRM), online and viral marketing.

### 3.3 Applications

1) **Optimisation Model**:

   The model building approach for decision making in Marketing is provided by Kotler(1971).

   In this model, the marketing decision is formulated as a Mathematical Programming Problem. The aim is to maximise certain Goal variables within a set of given constraints where:
   - Marketing decision variables: Marketing mix instruments.
   - Goal variables: Profit, Sales, Market Share etc.
   - Constraints: Budget limitations, Price limitations, Capacity etc.

   OR techniques used: Linear programming problem, integer programming, dynamic programming, non-linear programming problem. Marketing Problems sometimes have to be mutilated to fit them to existing OR techniques (Montgomery and Weinberg, 1973)

2) **Stochastic process**:

   Stochastic Processes have always been a prominent area of Operations Research. (Hillier and Lieberman, 2010)

   Stochastic Brand Choice Models (Massy, Montgomery and Morrison 1970; Wierenga 1974): using these models we can determine the brands that a consumer chooses when he makes consecutive purchases in a product class. *Markov Models and Bernoulli models* are used to studying this concept called Brand Loyalty.

   Under Markov Model (first order), Transition probabilities are studied by marketers. The transition probability can be depicted by pij which is the probability of the consumer to shift from brand i to j. Higher order Markov Chains are used for longer brand choice processes. Markov Chains are also used to study Customer Relationship Management (Pfeifer and Carraway, 2000)

3) **Media Planning for Marketing**:

   Today even media plays a very important role in the promotion of a product and many managers use operation research techniques for media selection. One such technique used is Linear Programming. Linear programming technique can help marketing managers to allocate a fixed budget to maximize reach, frequency and thus profit but at the same time to minimize cost.

   Taking an example of company A which sells products “PA” has to select at what time to show its advertisements on TV. The money to be spent on TV advertisements for one week in November is Rs.400,000. The estimated audience:

<table>
<thead>
<tr>
<th>Time</th>
<th>Audience Reached</th>
<th>Cost per ad (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morning</td>
<td>2000</td>
<td>60,000</td>
</tr>
<tr>
<td>Evening</td>
<td>4000</td>
<td>75,000</td>
</tr>
<tr>
<td>Night</td>
<td>8000</td>
<td>90,000</td>
</tr>
</tbody>
</table>

### Additional Conditions:

   The Advertisement has to be displayed a minimum 5 times a day there are 10-day time spots and 6 evening news spots available.

   Using this information the manager can know his objective that is to maximize audience Z=2000p+4000q+8000r

   Even the constraints would be known by the manager.

   **Price constraint**
   
   60,000p+75,000q+90,000r<= 400,000

   **Spot constraint**
   
   p<=10, q<=6

   **Advertisement constraints**
   
   p>=1, q>=1, r>=1
  
   p+q+r>=5

   Using all this information a manager can decide which are the slots that he should select so that his advertisement reaches maximum people keeping the budget in mind.

4) **Product distribution**:

   Manufacturers and distributors can use LP simulation to find the most cost-effective way for distribution. But LP models are not always effective therefore using other techniques like transportation and assignment models can also help managers.

   Consider a t-shirt company having 4 factories with different capacities and 5 outlets with different demands therefore in 20 (4*5) ways the t-shirts can be distributed. Given the transportation costs per a load of each of 20 routes between the factories and the shops, the manager can easily select the routes in such a way that transportation cost is minimum and maximum efficiency is obtained.

### New opportunities for intensifying the marketing- OR interface:

1) Customer-Centric Marketing
2) Customer Relationship Management
3) Online Marketing
4) Viral Marketing

### 4. CONCLUSION

Operations Research is suited to two contrasting fields: Finance and Marketing. Mathematical Programming techniques have been used to solve a range of problems across these fields. Other techniques like Simulation are used in financial markets whereas Stochastic Process is used in Marketing. The relationship between OR and these fields is bi-directional. Not only is OR applied to problems in these fields but finance and marketing theories have created a need to develop and improve OR solution techniques. The role of OR will increase in Financial Markets whereas in marketing there are important opportunities (if not necessities) for intensifying the Marketing- OR interface.

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