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The Application and Impacts of Operation Research Methodologies on Financial Markets

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Abstract:- In today's day and age market participant face a costly and complex labyrinth of challenges that have become the new normal. The arrival of increased computer speed and increased access to better data allowed a lot of these problems to be solved. Many financial firms still face the burden of using outdated analytical methodologies and databases. In order for these firms to remain competitive they need to overcome data issues and use OR techniques to decipher the data and figure out the appropriate level of risk with which to maximize profit and minimize loss. If a firm is able to utilize data in the best manner possible, they can easily be set apart from their competition giving them a strong competitive advantage. The next big challenge is to be able to frame contextual data to the complete story at the time of trade. This will help them to serve their trading customers better and maximize the firm's potential for brokerage revenues. Additionally, the increasing number of new financial regulation also gives opportunities to financial service firms. Also, the traditional system can't handle complex equations employing several variables, hence those need to be modified as well as per current market standards.

Keywords:- *Data, Financial Firms, Analytical Methodologies, Databases, OR Techniques, Financial Regulations, Computer-Intensive Systems*

I. INTRODUCTION

Numerous problems exist when it comes to dealing with the many intricacies in the financial sector. These problems can be solved with the help of OR techniques as these problems have always been expressed as numbers, with targets that are well-defined, with increasing availability of clear, accurate and stable data which makes it suitable. OR techniques help in the case of maximizing profit with minimum risk or cost. Since financial problems employ large quantum of money, thus even a small development in nature of improvement can help in generating a much larger sum of money and cause drastic reductions in cost.

There has always been a relationship between finance and OR, that is operation research techniques have been applied to solve financial problem which has caused financial institutions to adopt new financial theories and regulations. This adoption has in-turn become the boost in improvement and implementation of new OR techniques. Complications pertaining to financial markets tends to recur multiple times a day, hence developing an OR solution fives a framework which can be used over and over which makes it a good investment and more attractive. With the presence of higher processing speeds, and better standards of exchange of data, the use of techniques of OR are anticipated to increase by a multitude.

II. EXISTING PROBLEMS IN THE FINANCIAL MARKETS

The techniques of operations research have been applied in the financial markets from quite some time now. The INFORMS data base of academic papers in journals of OR since 1982 sets out approximately 3% of all entries as being concerned with finance. Since practises of Finance have a lot of numerical difficulties with clear boundaries, objectives, it makes it attractive for application of operations research.

After considering some of the reasons for the attractiveness of finance problems for the application of OR techniques it is important to first discover the areas where application of such techniques are required. Following are a few problems in the financial markets, few OR techniques are also suggested wherever possible basis the problem.

A. Attractiveness of Financial Problems

As specified earlier financial problems are well defined with boundaries, which makes it one of the most important features of these problems. Since financial problems are more numeric in nature thus, they have the advantage of being implemented directly by analysis as they are not governed by any human behaviour or any other subjective factor. Therefore finance practitioners are well acquainted with the quantitative analysis of the problems.

B. Portfolio Theory

Participants usually wish to have diversified portfolios in the financial markets because they have a substantial advantage of reducing risk, while keeping the expected returns same. The objective function is usually given as minimising the risk or maximising the returns or vice versa. Risk is calculated using the variance which therefore makes the objective function to comprise both quadratic variance and covariance terms. Thus variance to calculate risk has been extensively used in finance and thus in applications of OR.

C. Valuation of the Asset in Financial Markets

Another important decision when trading in financial markets is doing the valuation of the asset being traded. To tackle this Monte Carlo simulation proposed by Boyle, 1977 is used as an alternative to binomial model of pricing options.

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D. Imperfections in Financial Markets

Everyone currently is in search of huge profits. Traders are also one such category who are in search of such profits thus, they are keen to find out the imperfections in the financial markets so that they can exploit them and gain these huge profits. One such option is the search of weak form inefficiency. It can be specified as a maximal flow network where the aim is to maximise the funds flow out of the network or as a shortest path of the network. While few problems can be formulated and solved using linear programming, interpretation of the problem as a network calls for computationally faster algorithms.

E. Funding Decision

Another problem that a company may face is the funding decision to carry out its activities. There are various options available to fund the ongoing business however the company's objective will always be to get the most out of the least cost to improve their profits. OR techniques have also produced a solution to this problem Brick, Mellon, Surkis and Mohl (1983) put forward a chance constrained linear programming model to compute the values of the debt-equity ratio each period that maximize the value of the firm.

F. Strategic problem in trading

Financial traders are always in the view of gaining most profits through their trading activity, thus they trade the most at cheap price. Which is why large stocks are broken up into smaller stocks to minimise the price impact. This can be viewed as strategic problem and a strategy must be devised for trading the block of shares which is why Bertsimas and Lo (1998) use stochastic dynamic programming to define "best execution" and to compute an optimal trading strategy.

G. Regulatory and Legal Problems

Financial regulators have become increasingly concerned about financial markets with their very large and rapid international financial flows. An increasingly popular approach to this problem is to quantify the value at risk (VAR). However, there are other techniques as well such as Data envelopment analysis (DEA) which is used to predict bank efficiency and to predict the bank failures, majorly it comes into picture during a bank regulation, which is discussed in this paper.

H. Economic Understanding

Since financial markets are all about the companies and their performance in the markets, a factor that determines the companies' performance is the prevailing economic condition. Due to these economic conditions the financial markets also become extremely volatile to these conditions. 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 deposit's constraint led to the financial innovation of negotiable CDs. This study can be used to tackle the problems existing in the financial markets.

III. LINEAR PROGRAMMING

Linear Programming is used with the help of the fundamental premise of modern portfolio theory in order to allocate funds between different portfolios in such a way that it will maximize return and minimize risk. For this we will need to take the ratios of each company's dividend, risk and liquidity to the total for each of the parameters.

In the illustration done below shows how it is applied:

	Zenith Bank (P)	Fidelity Bank (Q)	Diamond Bank (X)	Dangote Cement (Y)	7up Bottling (Z)
Dividend (per ₦)	29.00	4.06	4.34	6.00	2.20
Risk Factor (%)	4.20	1.19	1.67	20.83	6.03
Liquidity (₦ trillions)	1.85	1.23	1.12	2.00	1.39

Table 1
Source: Annual report of the above establishment

In order to obtain the values of the coefficients for the maximization equation, we multiplied the return of investment for each company by its liquidity and then divided by the risk on investment for that company, respectively. From this we are able to derive the linear programming problem:

Maximize Z= 12.77P +4.20 Q +2.91X + 0.58Y + 0.51 Z

Subject to the constraints:

$0.64P + 0.09Q + 0.10X + 0.13Y + 0.05Z < 45.60$
$0.12P + 0.04Q + 0.05X + 0.61Y + 0.18 Z < 33.92$
$0.24P + 0.16Q + 0.15X + 0.26Y + 0.18 Z < 7.59$

$P,Q,X,Y,Z,S1,S2, S3 \geq 0$

Which we can then formulate in a tabular format which can be solved through simplex like this:

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	Cj		4.20	2.91	0.58	0.51	0	0	0	
Rows		Soln	Q	X	Y	Z	S_1	S_2	S_3	P
1	0	S_1	0	0.02	-0.06	-0.16	1	0	-1.19	9.77
2	0	S_2	0	0.02	0.63	0.15	0	1	-0.19	28.63
3	4.20	Q	1	0.95	1.67	0.14	0	0	4.76	27.33
		Zj	4.20	3.99	7.01	4.79	0	0	19.99	114.79
		Cj-Zj	0	-1.08	-6.43	-4.28	0	0	-19.99	

Table 2

From this we obtain the first best stock to invest in. In order to obtain the 2nd best stock to invest in we rewrite the original table:

	Fidelity Bank (Q)	Diamond Bank (X)	Dangote Cement (Y)	7up Bottling (Z)
Dividend (per ₦)	4.06	4.34	6.00	2.20
Risk Factor (%)	1.19	1.67	20.83	6.03
Liquidity (₦ trillions)	1.23	1.12	2.00	1.39

Table 3

From the above, we retake the values of the ratios which allows us to create a new maximization problem:

Maximize Z =4.20Q + 2.91X + 0.58Y + 0.51 Z

Subject to the constraints:
0.25Q + 0.26X + 0.36Y + 0.13Z <16.6
0.04Q + 0.06X+ 0.70Y + 0.20Z <29.72
0.21Q + 0.20X + 0.35Y + 0.24Z <5.74 Q, X, Y, Z, S1, S2, S3 ≥ 0

Solving using Simplex:

	Cj		0.288	18.57	36.83	2.01	3.67	0	0	0	
Row		Soln	P	Q	X	Y	Z	S_1	S_2	S_3	P0
1	0	S_1	0	-0.34	-0.30	-0.56	-0.43	1	0	-2.67	25.34
2	0	S_2	0	-0.04	-0.03	0.48	0.09	0	1	-0.50	30.12
3	12.77	P	1	0.67	0.63	1.08	0.75	0	0	4.17	31.65
		Zj	12.77	8.56	8.05	13.79	9.58	0	0	53.25	404.17
		Cj-Zj	0	-4.36	-5.14	-13.21	-9.07	0	0	-53.25	

Table 4

From this we obtain the 2nd best stock to invest in. Repeat the same in order to obtain 3rd choice.

The usage of the ordinary simplex method allows us to choose the three best stock to invest in to optimize profit. The choice of the 2nd and 3rd choice was independent from the 1st choice as the equation was reformulated in order to choose the next stock to invest in. The first choice states that investing 31.64 in stock P gives us maximum yield of 404.17. However, if we go for the 2nd choice, investing 27.33 of the total fund in stock Q will give a maximum yield of 114.79. The 3rd choice tells us that if a sum of 18.04 is invested in stock X, we can expect a return of 52.50. This gives us a good idea of what we can expect from the investment should the stated amount be actually invested.

➢ *DEA and Bank-Efficiency*

To compute the efficiency of numerous decision-making units when multiple outputs and inputs are presented by the production process, we use linear programming methodology of Data Envelopment Analysis. The best-practice production frontier for a sample of banks is constructed through a piecewise linear combination of actual input-output correspondence set that envelops the input-output correspondence of all banks in the sample (Thanassoulis, 2001). Every bank is given an efficiency score between 0 and 1. The scores are only relative to the banks in the sample, with higher scores indicating a more efficient bank. One of the well-known advantages of DEA is that it works relatively well with small samples. Other advantages of DEA are that it does not require any assumptions to be made about the distribution of inefficiency and it does not need a particular functional form on the data in determining the most efficient banks.

However, DEA is also subject to few limitations. Two of the best known limitations are that DEA assumes data to be free of measurement error, and that it is sensitive to outliers. Coelliet al. (2005) also point out that: (1) having couple of perceptions and numerous sources of info and additionally yields will bring about numerous organizations showing up on the DEA wilderness, (2) treating inputs/yields as homogenous products when they are heterogeneous may inclination the outcomes, (3) not representing contrasts in the earth may give deceiving results, (4) standard DEA doesn't control for multi-period improvement or hazard administrative basic leadership.

IV. METHODOLOGICAL ISSUES

A. Efficiency Measures.

A large portion of the investigation's centres around the specialized proficiency of banks. This productivity measure shows whether a bank utilizes the base amount of contributions to deliver a given amount of yields or boosts the yield amount given a specific number of sources of info. Regardless, when worth data for the wellsprings of information or conceivably yields are available one can in like manner check cost just as advantage profitability measures. Viable expense is the aftereffect of particular capability and allocative profitability. The last indicates the limit of a bank to use the perfect blend of wellsprings of information given their specific expenses.

B. Constant vs Variable Returns to Scale.

DEA can be implemented by taking the following assumptions constant returns to scale (CRS) or variable returns to scale (VRS)., Charnes et al., in a seminar study, proposed a model that had an input orientation and assumed CRS. This model gives a score that specifies the overall technical efficiency (OTE) of every bank. Banker et al. (1984) suggested the use of variable returns to scale (VRS) that decomposes OTE into product of two components, pure technical efficiency (PTE) and scale efficiency (SE). The former relates to the ability of managers to utilize firms' given resources, while the latter refers to exploiting scale economies by operating at a point where the production frontier exhibits CRS.

C. Output-Input Orientation.

Technical Efficiency can be estimated under two approaches, an input-oriented or output- oriented approach. As Coelli et al. (2005) point out, the input-oriented technical efficiency measures address the question: "By how much can input quantities be proportionally reduced without changing the output quantities produced?" In contrast, the output-oriented measures of technical efficiency address the question: "By how much can output quantities be proportionally expanded without altering the input quantities used?" By far, studies in banking obtain efficiency estimates under the input-oriented approach. This is most likely due to the assumption that bank managers have higher control over inputs (e.g. personnel, expenses) rather than outputs (e.g. income, personal loans, etc). Nevertheless, there are some studies that adopt the output-oriented approach (e.g. Ataullah et al., 2004; Ataullah and Le, 2006) or report the results from both (e.g. Casu and Molyneux, 2003; Beccalli et al., 2006). It should be mentioned that the input-oriented and output-oriented measures always provide the same value under CRS but they are not equal when assumption is that of VRS.

D. Selection of Inputs and Outputs.

There is an on-going talk in the money related composition regarding what the most ideal significance of wellsprings of data and yields is. In the statements of Bergendahl (1998): There have been almost a similar number of doubts of data sources and yields as there have been usages of DEA". Berger and Humphrey (1997) perceive two essential procedures for the assurance of wellsprings of data and yields, "creation approach" and the "intermediation approach". The first acknowledge that banks produce advances and stores record organizations, using work and capital as data sources, and that the number and kind of trades or reports took care of measure yields. The resulting procedure considers banks to be budgetary go between among savers and monetary experts. Berger and Humphrey (1997) battle that neither of these two approaches is faultless in light of the way that they can't totally get the twofold activity of cash related associations as providers of trades/report taking care of organizations and besides being budgetary go-betweens. They point out that the creation approach may be somewhat better for surveying the efficiencies of bank workplaces and the intermediation approach may be progressively appropriate for evaluating cash related establishments as a rule. Also, there are difficulties in social event the quick and dirty trade stream information required in the age approach. Thus, the intermediation approach is the one supported in the writing.

E. Adjusting for the Environment.

Coelli et al. (2005) talk about four methodologies that can be utilized to consolidate ecological factors in DEA applications.14 The principal strategy, by Banker and Morey (1986), requires the natural factors to be requested from the least to the most destructive ones for effectiveness. The productivity of the firm is contrasted and the organizations in the example those have an estimation of the ecological variable which is not exactly or equivalent to the given firm. This ensures banks are not contrasted and companions working in a great domain. The second method, by Charnes et al. (1981), requires the investigator to: (i) isolate the example into sub-tests and tackle DEA issues for each sub-test, (ii) venture every single watched datum focuses into their planned boondocks, and z(iii) understand a solitary DEA utilizing the anticipated focuses and evaluate any distinction in the mean proficiency of the two sub-tests. As indicated by Coelli et al. (2005) the accompanying two issues are basic in the two strategies: (I) by separating the example they lessen the correlation set, and (ii) just a single natural variable can be considered for each situation in this manner constraining the extent of the examination.]

- *How Artificial Intelligence is Managing Operations in Financial Markets?*

"Predicting the future isn't magic, its artificial intelligence"- Dave Waters.

Artificial intelligence or AI can be defined as simulating human cognitive processes by computer systems. These processes often involve self learning, analysing and correcting; hence improving its decision making on its own, over-time.

Artificial intelligence code works by:-

1. Identifying a pattern in a dataset. It conducts calculations and analyses unique characteristics of that dataset
2. Based on these characteristics it further identifies future pattern in the dataset through forecasting
3. It communicates the result with the user, who further uses it for decision making
4. Any inaccuracies and errors, mistakes input by the users helps AI to further make corrections in identified characteristics

AI today is used in financial systems all around the world in different formats. For having a successful financial services business, these changes are necessary to be adopted. The technology provides scope to act on huge chunks of data and provide directions accordingly. Example: the technology can be fed with data related to 2008 crisis causing determinants, systems can then accurately predict instances of any such cataclysm if the conditions become economically similar to the time of crisis.

Before the advent of AI, the processes used to be carried out via different approaches, in financial houses. The method of the firms to make profits was different. But with approaches integrating newer technologies, there was a complete overhaul in each of the building blocks.

Traditionally scale of assets was given preference, in order to receive economies of scale and earn better margins. But now, technology will make operations efficient enough that asset size, although still important, will no longer be sufficient on its own to build a successful business. As a result, competition to achieve scale of data flow-through will be more important to sustain cost advantages.

Earlier physical locations and standardised financial products drove cost effective growth, now revenue is driven by highly specialised individual-centered interactions that AI makes possible.

Hitherto, it was difficult to switch service providers, so customers stuck with one provider; also processes were function of human labour and know how. Now, customers will stay with an institution, not because it's hard to walk away but because their benefits are better there than anywhere else. Also process efficiency will result from the interplay of human and artificial strengths.

AI applications include algorithmic trading, portfolio composition and optimisation, model validation, back testing, robo- advising, etc. But three specific areas in which AI is currently changing the financial services industry, is;-

(1) : algorithms can analyse millions of data points to detect fraudulent transactions that would tend to go unnoticed by humans. At the same time it helps improve the precision of real-time approvals and reduces the number of false rejections. Credit card fraud detection is one of the most successful applications of machine learning

(2) banking chatbots and robo-advisory services: are algorithm based digital platform that offers automated financial advice or investment management services.

These calibrate a financial portfolio to the user's goals and risk tolerance. Also these technologies have gained traction from millennial customers who are not willing to conduct trade in proximity and foreseeing of human advisor.

(3) algorithmic trading: Algorithmic trading involves use of complex AI systems to make extremely fast trading decisions. Major benefits include the ability to make trade at best possible prices, increased accuracy and simultaneously checking multiple market conditions.

Prodigious companies today depend a lot on AI for making trades. A Barclay's Hedge has concluded that majority of hedge managers responsible for managing investments, are relying on machine learning to develop the strategies.

96 Billion dollar AUM Man group have half of their investments in technology based vehicles that make buy and sell decisions independently.

Citadel, a Chicago based hedge fund, its aspired competitive advantage comes from being able to use technology, machine learning, and human capital to amass all available public data, and make sound decisions by accurate interpretations.

However, machine learning should be used to assist human judgement rather than substitute it. Even though there are a lot of benefits of using such a technology, but over-reliance on it can be harmful. Firstly such a technology requires huge investment on various ends, hence would be accessible only to the bigger and richer organisations, promoting inequality and making the markets less fair. Secondly, it can also lead to crowding (when many people would buy the same stock), this can lead to large amounts of volatility.

There are two Operations Research techniques that can be used in conjunction with each other-Artificial Neural Network and Fuzzy Inference System.

The former one is used in short-term forecasting of share prices, say the next day or two whereas the latter one is used to inspect the dips and rises in predicted share prices in the long-term.

A. Artificial Neural Network

Process: We pre-process the data, here we use Principal Component Analysis which converts real and related vectors to a set of new uncorrelated vectors. Basically, this nullifies the trend between vectors if there was any. These transformed vectors are called principal components. This can also be referred to as feature extraction.

The pre-processed data is put into the Artificial Neural Network (ANN) for predicting future stock prices.

Architecture: Artificial Neural Network is a parallel processor made up of nodes. These nodes can be equated to the neurons in our body. These are specialized in recognizing patterns and trends in very complex and intricate data that cannot be identified by humans or computers. It differs from computers in the way that it doesn't require any pre-decided polynomial equations.

➢ *Network Training*

After the neural system model is developed, preparing of the neural system is the following basic advance of the determining model. Here, we train the network model so that it can perform non-linear optimization of weights and biases of the network. When the network is appropriately trained, it is able to give more accurate output. The network model learns by training where it iteratively frames the connections weights. A set of input is introduced to the input node. The relevant output is then presented at the output node to compare it with the desiredresponse. As a result, an error signal is produced.

➢ *Performance Measurement*

The last step consists of checking the accuration of prediction of the results i.e. the stock prices. In Mobin Ahmad , "Impact and Implications of Operations Research in Stock Market", Jazan University, Saudi Arabia, June 2017, they used normalized mean square error to check the accuracy of the closing prices of stock.

B. Neuro-fuzzy network

In another paper related to forecasting closing prices of Indian companies, the prices predicted by the artificial neural network were fed to a Fuzzy Inference System (FIS) to deduce a pattern. When ANN and FIS are used together, they are referred to as a neuro-fuzzy system. It is a commonly used method in which ANN training algorithm are used to polish the parameters of FIS. These network systems can thus, be used to make buy or sell decisions in uncertain, unknown situations. Here, Fuzzy Inference System (FIS) has been recommended for use to find out the uncertainty modelling capability.

According to neuro fuzzy research paper, the proposed neuro-fuzzy technique produced 100% accurate results. This shows that this technique is reliable and can be used to analyse the stock market.

V. CONCLUSION

There are several technical problems faced by different financial institutions worldwide, above discussed are some operations research methods getting adopted to address those problems. Recent trends seem fair towards adopting different artificial learning and formulated techniques to make the process flawless and manage via huge quantum of derived data. Future speaks for those who know how to manage data and learn development via foreseeing opportunistic trends.

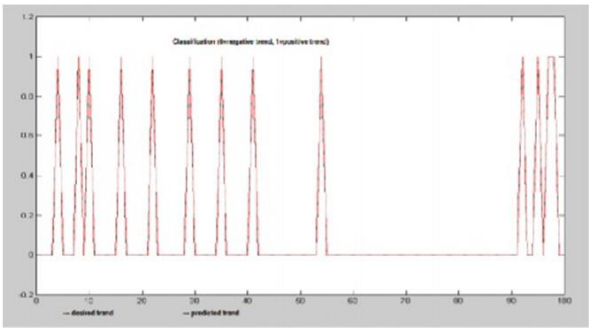

Fig 1:- Test Results for Trend Prediction using EFuNN

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