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Operations Research in Financial Services

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***Abstract*— This research paper provides an overview of the state of the art in research on operations in financial services.**

India is today one of the most vibrant global economies, on the back of robust financial services sector. The efficiency of conducting operations in this industry vastly depends upon the scientific methodologies used. This research paper seeks to enumerate different models and quantitative solutions used to co-ordinate operations in the area of financial services. In the final section we state the findings and conclude with a discussion on research directions that may become of interest in the future.

***Index Terms*— Financial Services, Operations Research, Quantitative Methods, Operations Management, Finance.**

I. Introduction

Indian Financial Services Industry is expected to have the highest job growth rate - 2.9% CAGR over the next ten years which lends it the potential of becoming the world's future investment hub.(Money Control, 2019)

This estimation gets its validity from recent data by the Association of Mutual Funds in India (AMFI). Mutual Funds' asset under management (AUM) has been rising steadily. From April 2017 to April 2019, the consolidated AUM of mutual funds has risen by 33 percent, from Rs 19.26 lakh crore to Rs 25.27 lakh crore. The AMFI is targeting nearly fivefold growth in AUM and a more than three times growth in investor accounts to 130 million by 2025.

The public deposit of NBFCs registered a Compound Annual Growth Rate (CAGR) of 36.86 per cent indicating that NBFCs are rapidly gaining prominence as intermediaries in the retail finance space. (IBEF, 2019)

Under the Union Budget 2019-20, the government has allocated Rs 2,455.90 crore (US$ 340.39 million) towards the support to financial institutions and Rs 4,690.19 crore (US$ 650.06 million) is allocated to Department of Financial Services. These measures have been taken because financial services are the backbone of economic growth and development of a nation. Finance industry enables creation of new business and expansion of existing ones. Ultimately this facilitates more employment and job creation with the growth of other mainstream industries. (Singh, 2018)

Financial services industry is an important part of the service sector in an economy that has been growing rapidly over the past few decades but has been volatile too. These firms primarily deal with originating or facilitating financial transactions. The transactions include creation, liquidation, transfer of ownership, and servicing or management of financial assets; they could involve raising funds by taking deposits or issuing securities, making loans, keeping assets in custody or trust, or managing them to generate return, pooling of risk by underwriting insurance and annuities, or providing specialized services to facilitate these transactions.

Even within financial services, there is a wide variety of firms which are characterized by unique production processes, specialized skills and best practices.

Management science generally refers to the application of mathematical or quantitative methods for improving business efficiency and management decision-making. These techniques are used on a wide variety of problems from a vast array of applications in the business world to determine the best practices.

Operations Research methods have been used to improve the operations in areas of Performance measurement and analysis, Pricing, Waiting line management, Personnel scheduling, Forecasting, Inventory and cash management and System design in relation to financial services to increase the overall efficiency in the sector.

II. Overview

The financial services industry is characterized by intense competition at both service and product levels, as well as a high degree of technological adoption.

India has a diversified financial services sector undergoing rapid expansion, both in terms of strong growth of existing financial services firms and new entities entering the market. The banking regulator has allowed new entities such as payments banks to be created recently thereby adding to the types of entities operating in the sector. However, the financial sector in India is predominantly a banking sector with commercial banks accounting for more than 64 per cent of the total assets held by the financial system.

Volatility in the financial sector has resulted in financial institutions struggling to maintain their growth and profitability. Alongside, the global economic slowdown has taken a toll on the Indian economy, pressurising margins as well as the very sustainability of financial service companies. These dynamics call for the need to establish robust business models and ensure quality management. In recent years, technological advancements have ushered in new-age FinTech players, who are continuously challenging and disrupting traditional models. India continues its journey towards a financially inclusive regime through innovative policies involving a multi-pronged approach. The Indian authorities while reforming the financial sector have to

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constantly keep the issues of equity and efficiency in mind.

III. Research Objectives

- To understand
- To find
- To elaborate
- To outline
- To describe

IV. Research Methodology

This paper selects, analyses and consolidates information from various other research papers, which had findings related to the application of operations research in the financial services. An extremely vast set of secondary data was filtered with respect to the parameters of the research objectives and compiled to meet the conclusion. Through secondary analysis, areas of interest could be explored without having to go through the process of collecting data in the field. A theoretical analysis (selection and discussion of theoretical material and descriptive material) and a detailed comparison of theories in terms of their applicability were conducted.

V. Literature Review

Financial Services Performance Measurement and Analysis

Service quality is generally difficult to manage and measure because of the variability in customer expectations and their involvement in the delivery of the service.

Asset management is an area within the financial services sector that has received an increasing amount of research attention with regard to best practices from various operations management perspectives. (Pinedo, 2010)&(Alptuna, 2010) present a best practices framework for the operational infrastructure and controls in asset management and argue that it is possible to effectively implement such a framework in organizations that enjoy a strong, principle-based governance. They examine conditions under which the cost-effective strategy of outsourcing asset management operations can be successful for asset managers and their clients.

Data Envelopment Analysis (DEA) which is a technique for evaluating productivity measures that can be applied to service industries, compares productivity measures of different entities (e.g., bank branches) within the same service organization (e.g., a large retail bank) to one another.(Sherman H. D., 1985), (Sherman H. D., 1995), and (Seiford, 1999) performed such studies for US banks while (Berger, 1997) for various international financial services firms. These papers discuss operational efficiency, profitability, quality, stock market performance, and the development of better cost estimates for banking products via DEA. They compare mutual and stock property liability companies and find that in using managerial discretion and cost efficiency stock companies perform better, and in lines of insurance with long payouts mutual companies perform better.

Pricing of Financial Services

Financial services organizations expend serious efforts and resources on pricing and revenue management. Applications include the setting of: Interest rates (APR) on deposits and credit products, trading commissions, custody fees, investment advisory fees, fund fees, and insurance policy premia.

Study on Price and Profit Optimization for Financial Services (Catalina Bolancé, 2018) indicates that a substantial boost in profits for financial services can be expected when applying the Individual Profit Model to optimize the profit generated.

They address the problem that banks and insurance companies face as they seek to fix a price that is high enough to cover potential risk yet low enough to attract customers by presenting and comparing two optimization strategies: the first involves identifying the optimal personalized price discount on a closed-form expression, which permits a straightforward implementation; the second is based on a numerical optimization procedure.

(Wuebker, 2008) also wrote a book on pricing in financial services.

Pricing in Asset Management, Securities Trading and Brokerage, and Credit Cards industry consists primarily of fees charged on a client's assets under management (AUM) in investment vehicles such as mutual funds or separately managed accounts (SMAs) which typically charge asset-based fees on a calendar basis. In contrast, hedge fund pricing constitutes a more representative application of the principal–agent model because it must use more complete incentive mechanisms to minimize informational issues between fund manager (agent) and investor (principal). A typical pricing structure for hedge funds may consist of a base fee and an incentive fee. The manager earns an incentive fee if value is created for the investor according to an agreed-on metric usually based on either monetary units or rates of return (Bailey, 1990). Typically, incentive fee arrangements have asymmetric payoffs, i.e., they reward gains and do not penalize losses. However, they often require that an investment's value be at or above a historical maximum, called a high water mark (HWM), before an incentive fee becomes payable to the manager. (Lynch, 1997) examined how incentive fees compare with asset-based fees, especially in extracting value-creating effort by the manager. The non-linear optionality in incentive fees was found by (Li, 2009) to be optimal even for mutual funds.

A pricing application for brokerage commissions and investment advisory fees was studied by (Altschuler, 2002) They developed models to determine appropriate commission rates for a new discount brokerage channel, and asset-based fees for advice and unlimited trading in full-service accounts introduced by Merrill Lynch. Among the issues to contend with were adverse selection and moral hazard.

Credit card pricing and line management were studied together by (Trench, 2003). They built a Markovian model to

select the optimal APR and credit line for each individual cardholder based on historical behaviour with the goal to maximize Bank One's profitability. Offering an attractive APR and a large credit line to entice a cardholder to transfer a balance presented the moral hazard issue which the model successfully addressed.

Pricing for security transactions has been experiencing a downward trend driven by the dramatic cost reductions brought by technological innovations such as electronic trading (Bortoli, 2004).

Waiting Line Management in Retail Banks and in Call Centres

In financial services, in particular in retail banking, retail brokerage, and retail asset management (pension funds, etc.), queuing is a common phenomenon that has been analysed thoroughly. Queueing occurs in the branches of retail banks with the tellers being the servers, at banks of ATM machines with the machines being the servers, and in call centres, where the operators and/or the automated voice response units are the servers. These diverse queueing environments turn out to be fairly different from one another, in particular with regard to the following characteristics: (i) the information that is available to the customer and the information that is available to the service system (Hatzakis, 2010), (ii) the flexibility of the service system with regard to adjustments in the number of servers dependent on the demand, (iii) the order of magnitude of the number of servers. Even though in the academic literature the arrival processes in queueing systems are usually assumed to be stationary (time-homogeneous) Poisson processes, arrival processes in practice are more appropriately modelled as non-homogeneous Poisson processes.

In contrast to a teller environment, the number of ATMs at a branch is fixed and cannot be adjusted as a function of customer demand. However, the teller environment and the ATM environment do have some similarities. In both environments, a customer can observe the length of the queue and can, therefore, estimate the amount of time (s)he has to wait. In neither the teller environment, nor the ATM environment, can the bank adopt a priority system that would ensure that more valuable customers have a shorter wait. (Kolesar, 1984) did an early analysis of a branch with two ATM machines and collected service time data as well as arrival time data. However, it became clear very quickly that a bank of ATMs is capable of collecting some very specific data automatically (e.g., customer service times and machine idle times), but cannot keep track of certain other data (e.g., queue lengths, customer waiting times). (Larson, 1990), therefore, developed the so-called queue inference engine, which basically provides a procedure for estimating the expected waiting times of customers, given the service times recorded at the ATMs as well as the machine idle times. Since the late 1980s, banks have started to invest heavily in call center technologies. All major retail banks now operate large call centers on a 24/7 basis.

Personnel Scheduling in Retail Banks

In contrast to manufacturing industries, workforce scheduling in the service industries has to adapt itself to a fluctuating customer demand, which in practice is often based on non-homogeneous Poisson customer arrival processes. Adapting the number of tellers or operators to the demand process can be done through an internal pool of flexible workers, or through a partnership with a labour supply agency (Larson R. C., 2000). As the assignment of tellers and the hiring of operators depend so strongly on anticipated customer demand, a significant amount of research has focused on probabilistic modelling of arrival processes- (Stolletz, 2003), on statistical analyses of arrival processes (Brown, 2005) and (Robbins, 2006), and on customer demand forecasting in order to accomplish a proper staffing see (Weinberg, 2007). From a research perspective, the personnel scheduling problem has been tackled via a number of different approaches, namely, simulation, stochastic modeling, optimization modeling, and artificial intelligence. The application areas considered included the scheduling of bank tellers as well as the scheduling of the operators in call centers. (Slepicka, 1981) and (Hammond, 1995) used simulation to schedule bank tellers and call center operators. (Thompson, 1993) studied the impact of having multiple periods with different demands on determining the employee requirements in each segment of the schedule; see also (Chen, 2001). (Green, 2007), (Hatzakis, 2010) and (Feldman, 2008) have addressed the problem from a stochastic point of view and have developed staffing rules based on queueing theory.

Forecasting

Forecasting is very important in many areas of the financial services industry. In its most familiar form in which it presents itself to customers and the general public, it consists of economic and market forecasts developed by research and strategy groups.

Banks that offer these credit facilities must set aside adequate, but not excessive, funds to satisfy the demand for cash by facility borrowers. (Duffy, 2005) describe a Monte Carlo simulation model that Merrill Lynch Bank used to forecast these demands for cash by borrowers of their revolver portfolio. The model uses industry data for revolver usage by borrower credit rating, and assumes Markovian credit rating migrations, correlated within and across industries. The model was used by Merrill Lynch Bank to help manage liquidity risk in its multi-billion portfolio of revolving credit lines.

In the last few decades, the securities brokerage industry has seen dramatic change. Traditional wire- houses charging fixed commissions evolved or were replaced by diverse organizations offering full service, discount, and online trading channels, as well as research and investment advisory services. Firms are interested in forecasting channel choice decisions by clients, because they greatly impact capacity planning, revenue, and profitability. (Altschuler, 2002) discuss simulation models developed for Merrill Lynch's retail brokerage to forecast client choice decisions on introduction of lower-cost offerings to complement the firm's traditional full-service channel.

(Labe, 1994) describes an application of forecasting the likelihood of affluent prospects becoming Merrill Lynch's

priority brokerage and investment advisory clients (defined as clients with more than US$250,000 in assets). Merrill Lynch used discriminant analysis, a method akin to classification scoring, to select high quality households to target in its prospecting efforts.

Forecasting the number and value of trades during a clearing and settlement cycle can help the organization meet the above objectives; it can achieve this by modeling the clearing and settlement operation using stochastic simulation. A different approach is used by (Lascurain, 2011) they develop a linear programming method to model the clearing and settlement operation of the Central Securities Depository of Mexico and evaluate the system's performance through deterministic simulation. The model's formulation in (Lascurain, 2011) is a relaxation of a mixed integer programming (MIP) formulation proposed by (Guntzer, 1998), who show that the bank clearing problem is NP-complete.

Inventory and Cash Management

Organizations, households, and individuals need cash to meet their liquidity needs. In the era of checks and electronic transactions, an amount of cash does not have to be in physical currency, but may correspond only to a value in an account that has been set up for this purpose.

Researchers have produced over the last few decades a significant body of work by applying the principles of inventory theory to cash management. (Whistler, 1967)discussed a stochastic inventory model for rented equipment that was formulated as a dynamic program; this work served as a model for the cash management problem. One of the early works produced an elegant result that became known as the Baumol–Tobin economic model of the transactions demand for money, independently developed by (Baumol, 1952) and (Tobin, 1956).The model assumes a deterministic, constant rate of demand for cash. It calculates the optimal ''lot sizes'' of the risky asset to be converted to cash. (Thompson S. a., 1970)proposed models based on mathematical control theory, in which demand for cash is deterministic but does vary with time.

In what became known as the Miller–Orr model for cash management, (Miller-Orr, 1966) extended the Baumol–Tobin model by assuming the demand for cash to be stochastic. The cash balance can fluctuate randomly between a lower and an upper bound according to a Bernoulli process, and transactions take place when it starts moving out of this range; units of the risky asset are converted into cash at the lower bound, and bought with the excess cash at the upper bound. Transaction costs were assumed fixed, i.e., independent of transaction size. In a critique of the Miller–Orr model, (Weitzman, 1968) finds it to be ''robust,'' i.e., general results do not change much when the underlying assumptions are modified.

(Mehrotra, 2010), which is a paper in the special issue of Production and Operations Research, addresses the problem of obtaining efficient cash management operating policies for depository institutions. The mixed-integer programming model developed for this purpose seeks to find ''good'' operating policies, if such exist, to quantify the monetary impact on a depository institution operating according to the new guidelines.

In a simple application of margin lending, the brokerage houses extend a margin loan to a client of up to the value of equity securities held in the client's portfolio. (Rudd-Schroeder, 1982) presented a simple transportation model formulation for calculating the minimum margin, which represented an improvement over the heuristics used in practice.

Financial Services System Design

The nature of customer contact has influenced service design thinking by creating front-office/back-office functions (Sampson, 2006)(Shostack, 1984). Shostack also pioneered the use of service blueprinting for identifying fail points where the firm may face quality problems. She illustrated this methodology for a discount brokerage and correctly identified that many of the operational processes are not seen by the customer; she then focused on the telephone communication step, the only one with client contact. This focus on client contact tasks, whether in the front office or in the back office, is widespread in services research in general and in research on financial services operations in particular.

Retail banking has the most attention among financial services with respect to service design, but here the focus is more on disparate single visits to the branch or Automated Teller Machine (ATM), rather than as part of a life cycle of firm–customer interactions.

Several descriptive studies have focused on retail banking (Menor, 2001), the use of distribution channels (Xue, 2007) and self-service technologies such as ATMs, (Campbell, 2010). These studies talk about the types of customers who use the various different channels and how firms have diversified their delivery of services using these new channels as newer technologies have become available. There are few quantitative metrics to measure a product (e.g., its complexity vis-a-vis customer knowledge), a process (e.g., face to face vs. automated), and proximity (on-site or off-site) to help a manager navigate financial service operations strategies from a design standpoint based on where their firm is now.

VI. FINDINGS

In this paper, we provide an overview of the various operational processes in financial services and highlight the ones that have attracted attention in operations research literature. It becomes immediately clear that many processes in the financial services industries have applied the knowledge of scientific methods and made use of models to reach optimality. These include optimizing each step in the financial product and service life cycle as well as in the customer relationship life cycle.

The paper intends to shed some light on the workings and applications of operations research in the financial world, specifically the services that it provides. This research paper helped in understanding the usage and application of operations research tools, specifically in the financial services sector. It aided in finding and stating optimal ways which can improve the quality of services in the financial industry by focusing on optimization of operations. Operations research

may be key in enabling visionary ideas to revolutionise the financial services industry and increase efficiency manifold.

The operational research done on financial services ensures that they are:

- Easier to understand for the customer (resulting in fewer calls to call centers),
- Easier to use (better online and face-to-face interactions, with less waiting),
- Better cash management to ensure stable liquidity conditions
- Improved service design to reduce time required to provide services
- Easier to forecast and arrange the necessary operational resources for, and
- Able to take advantage of pricing and revenue management opportunities.

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

VII. CONCLUSION

In this paper, we have attempted to present an overview of the application of operations research in the financial services industry. We have identified a number of specific characteristics that make financial services unique as far as product design and service delivery are concerned, requiring an interdisciplinary approach. From the contents of this paper, it becomes immediately clear that many processes in the financial services industries have received scant research attention from the operational point of view and that there are several areas that are worthy of research efforts in the future. These include each step in the financial product and service life cycle as well as in the customer relationship life cycle.

Service designs need to recognize the fact that financial services are relatively sticky, involve enduring relationships with customers, and are at the same time prone to attrition due to poor performance or frustrating service encounters. There is an extensive literature on traditional service operations research topics such as waiting lines, forecasting, and personnel scheduling that are applicable to financial services as well. Inventory models have been successfully applied to cash and currency management.

A significant body of work exists in algorithmic trading, market microstructure, and the search for liquidity in securities markets. Another interesting area of research could be the integration of the various objectives for improving operations in financial services in which interactions among components can be viewed and modelled holistically. It is of great interest to the financial services industry that these interdependencies are well understood. Pricing and revenue management of financial services could be an area that is ripe for academic research with a potential short-term payoff that may be large. Operations researchers could leverage related work in economics, finance, and may adapt revenue management principles to develop novel pricing methodologies for financial services. Operations research may also be key in enabling visionary ideas for reforming corporate governance. Application of the techniques and models specified in this paper can result in significant improvement in processes and decisions. However, recent trends indicate that a high degree of digitalization, automation and technological advancement will likely change the face of this industry causing major transformation not only in the models but also the reality itself.

VIII. CHALLENGES

- Dependence on Software: O.R. techniques try to find out an optimal solution taking into account all the factors. In the financial services industry, these factors are extremely diverse and may not always be in the required form thus, establishing relationships among these require voluminous calculations that can only be handled by complex softwares.
- Non-Quantifiable Factors: O.R. techniques provide a solution only when all the elements related to a problem can be quantified. All relevant variables do not lend themselves to quantification. Factors affecting financial services that cannot be quantified find no place in O.R. models.
- Distance between Manager and Operations Researcher: O.R. requires expertise and precision and the person in charge of the financial services may be not be a specialist when it comes to forming O.R. models to facilitate a given service.
- Money and Time Costs: When financial data is subjected to frequent changes, incorporating them into the O.R. models is a costly affair. Moreover, a fairly good solution at present may be more desirable than a perfect O.R. solution available after sometime.

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