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PROJECT REPORT

ON

"COMPARATIVE STUDY OF RETAIL STORES IN TERMS OF EFFICIENCY"

FOR

RELIANCE RETAIL LIMITED

SUBMITTED BY

RACHITA GROVER

IN

PARTIAL FULFILMENT OF THE REQUIREMENTS OF THE

DEGREE OF MASTER OF SCIENCE IN APPLIED OPERATIONAL RESEARCH

TO

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DEPARTMENT OF OPERATIONAL RESEARCH

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CERTIFICATE

This is to certify that this project entitled **“Comparative Study of Retail Stores in terms of Efficiency”** is my original work carried out at **Reliance Retail Limited** in the year 2020, and has been submitted for partial fulfilment of the requirements of the course M.Sc. Applied Operational Research. This project report has not been submitted earlier in full or in part for any other diploma or degree to any other university or institute to the best of my knowledge.

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CHAPTER 0

ABSTRACT

Retail industry is the most rapidly changing and dynamic industry in emerging economies like India. Indian retail industry is witnessing rapid growth due to vigorous investments, rise of multiformat retail, growing trends in e-commerce and m-commerce, and increasing penetration of internet. The growth in the sector is coupled with intense competition, shrinking revenues and rising expenditure on promotional activities, drawing attention of the decision makers towards efficient operations. It is imperative to develop methodologies for efficiency measurement to support planning and implementation of efficient operations.

In this study we propose an approach for measuring the efficiency of multiple retail stores based on self and peer evaluation using Data Envelopment Analysis (DEA) methodology. The study also present comparison between self and peer evaluation scores and suggest roadmap for inefficient stores to identify the inputs and outputs to be optimized with respect to the nearest efficient benchmark.

CHAPTER 1

INTRODUCTION TO OPERATIONAL RESEARCH

1.1 What is Operational Research?

Operational Research is a quantitative approach to decision making. It is a discipline that deals with the application of advanced analytical methods to help make better decisions. It is often considered to be a sub-field of mathematics. The terms management science and decision science are sometimes used as synonyms.

Operational Research is a discipline that deals with the application of advanced analytical methods to help make better decisions, to find the best solution which is profitable and cost effective.

As its name implies, operation research involves “research on operations”. Thus, operations research is applied to problems that concern how to conduct and coordinate the operations (i.e. the activities) within an organization. The nature of organization is essentially immaterial, and, in fact, or has been applied extensively in such diverse areas as manufacturing, transportation, construction, telecommunications, financial planning, health- care, the military and public services, to name just a few. The “research” part of the name that operations research uses that resembles the way research is conducted in established scientific (typically mathematical) model that attempts to abstract the essence of the real problem. It is then hypothesized that this model is sufficiently precise representation of the essential features of the situation that the conclusions (solution) obtained from the model are also valid for the real problem. An additional characteristic is that O.R. frequently attempts to find a best solution (optimal solution) for the problem under consideration.

Employing techniques from other mathematical sciences, such as mathematical modelling, statistical analysis, and mathematical optimization, operations research arrives at optimal or near-optimal solutions to complex decision-making problems. Operational research (OR) encompasses a wide range of problem-solving techniques and methods applied in the pursuit of improved decision-making and efficiency, such as

- Simulation
- Mathematical Optimization
- Queueing Theory
- Markov Decision Processes
- Econometric Methods

- Data Envelopment Analysis
- Neural Networks
- Analytic Hierarchy Process
- Decision Analysis

Nearly all of these techniques involve the construction of mathematical models that attempt to describe the system. Because of the computational and statistical nature of most of these fields, OR also has strong ties to computer science and analytics. Operational researchers faced with a new problem must determine which of these techniques are most appropriate given the nature of the system, the goals for improvement, and constraints on time and computing power.

1.2 Objectives of Operations Research:

- Decision making and improving the objective.
- Identify optimum solutions.
- Integrating the systems.
- Improving the objectivity of analysis.
- Minimising cost and maximising profit.
- Improving the productivity.
- Success in competition and market leadership.

1.3 History of Operational Research

While there is no clear date that marks the birth of O.R., it is generally accepted that the field originated in England during World War II. The impetus for its origin was the development of radar defence systems for the Royal Air Force, and the first recorded use of the term Operations Research is attributed to a British Air Ministry official named A. P. Rowe who constituted teams to do "operational researches" on the communication system and the control room at a British radar station. The studies had to do with improving the operational efficiency of systems (an objective which is still one of the cornerstones of modern O.R.). This new approach of picking an "operational" system and conducting "research" on how to make it run more efficiently soon started to expand into other arenas of the war. Perhaps the most famous of the groups involved in this effort was the one led by a physicist named P. M. S. Blackett which included physiologists, mathematicians, astrophysicists, and even a surveyor. This multifunctional team focus of an operations research project group is one that has carried forward to this day. Blackett's biggest contribution was in convincing the authorities of the need for a scientific approach to manage complex operations, and indeed he is regarded in many circles as the original operations research analyst.

O.R. made its way to the United States a few years after it originated in England. Its first presence in the U.S. was through the U.S. Navy's Mine Warfare Operations Research Group; this eventually expanded into the Antisubmarine Warfare Operations Research Group that was led by Phillip Morse, which later became known simply as the Operations Research Group. Like Blackett in Britain, Morse is widely regarded as the "father" of O.R. in the United States, and many of the distinguished scientists and mathematicians that he led went on after the end of the war to become the pioneers of O.R. in the United States.

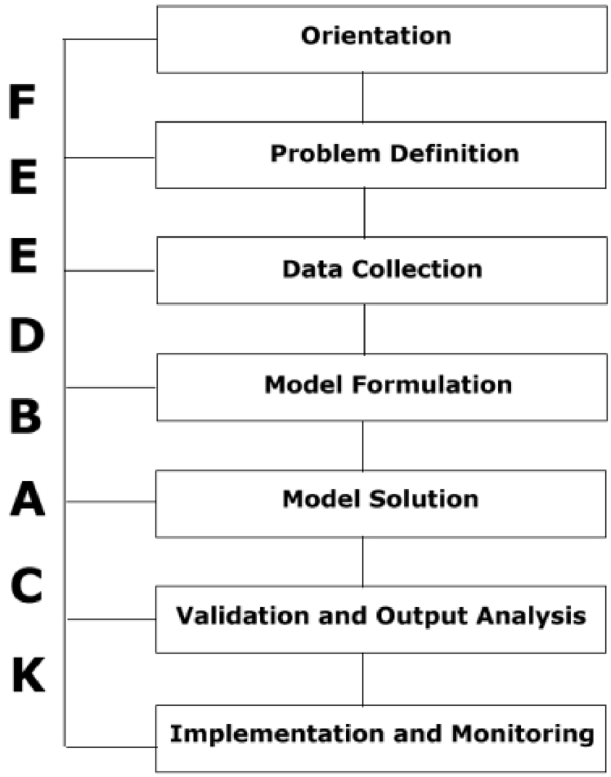
In the years immediately following the end of World War II, O.R. grew rapidly as many scientists realized that the principles that they had applied to solve problems for the military were equally applicable to many problems in the civilian sector. These ranged from short-term problems such as scheduling and inventory control to long-term problems such as strategic planning and resource allocation. George Dantzig, who in 1947 developed the simplex algorithm for Linear Programming (LP), provided the single most important impetus for this growth. To this day, LP remains one of the most widely used of all O.R. techniques and despite the relatively recent development of interior point methods as an alternative approach, the simplex algorithm (with numerous computational refinements) continues to be widely used. The second major impetus for the growth of O.R. was the rapid development of digital computers over the next three decades. The simplex method was implemented on a computer for the first time in 1950, and by 1960 such implementations could solve problems with about 1000 constraints. Today, implementations on powerful workstations can routinely solve problems with hundreds of thousands of variables and constraints. Moreover, the large volumes of data required for such problems can be stored and manipulated very efficiently.

Once the simplex method had been invented and used, the development of other methods followed at a rapid pace. The next twenty years witnessed the development of most of the O.R. techniques that are in use today including nonlinear, integer and dynamic programming, computer simulation, PERT/CPM, queuing theory, inventory models, game theory, and sequencing and scheduling algorithms.

Today, the impact of operation research can be seen in many areas. The number of academic institutions that are offering this field at all degree levels indicates this. A large number of management consultancy firms are currently engaged in operational research activities. The activities have gone beyond military and business applications to include hospitals, financial institutions, libraries, city planning, transportation system, and even crime investigation studies, to mention only a few. Despite its rapid growth, operations research is still a relatively young scientific activity. Its techniques and methods, and the areas to which they are applied, can be expected to continue to expand rapidly. Most of its history lies in the future

1.4 The Operations Research Approach

Given that O.R. represents an integrated framework to help make decisions, it is important to have a clear understanding of this framework so that it can be applied to a generic problem. To achieve this, the so-called *O.R. approach* is now detailed. This approach comprises the following seven sequential steps: (1) Orientation, (2) Problem Definition, (3) Data Collection, (4) Model Formulation, (5) Solution, (6) Model Validation and Output Analysis, and (7) Implementation and Monitoring. Tying each of these steps together is a mechanism for continuous feedback. The Figure below shows this schematically.



Step 1: Orientation:

The first step in the O.R. approach is referred to as problem orientation. The primary objective of this step is to constitute the team that will address the problem at hand and ensure that all its members have a clear picture of the relevant issues. This phase involves a study of documents and literature relevant to the problem in order to determine if others have encountered the same (or similar) problem in the past, and if so, to determine and evaluate what was done to address the problem.

The aim of the orientation phase is to obtain a clear understanding of the problem and its relationship to different operational aspects of the system, and to arrive at a consensus on what should be the primary focus of the project. In addition, the team should also have an appreciation for what (if anything) has been done elsewhere to solve the same (or similar) problem.

Step 2: Problem Definition:

This is the second step of the O.R. process. The objective here is to further refine the deliberations from the orientation phase to the point where there is a clear definition of the problem in terms of its scope and the results desired. This phase should not be confused with the previous one since it is much more focused and goal oriented; however, a clear orientation aids immeasurably in obtaining this focus. Moving from general goals such "increasing productivity" or "reducing quality problems" to more specific, well-defined objectives that will aid in meeting these goals.

Step 3: Data Collection:

In the third phase of the O.R. process, data is collected with the objective of translating the problem defined in the second phase into a model that can then be objectively analysed. Data typically comes from two sources – observation and standards.

The first corresponds to the case where data is actually collected by observing the system in operation and typically, this data tends to derive from the technology of the system. For instance, operation times might be obtained by time studies or work methods analysis, resource usage or scrap rates might be obtained by making sample measurements over some suitable interval of time, and data on demands and availability might come from sales records, purchase orders and inventory databases. Other data are obtained by using standards; a lot of cost related information tends to fall into this category. For instance, most companies have standard values for cost items such as hourly wage rates, inventory holding charges, selling prices, etc.; these standards must then be consolidated appropriately to compute costs of various activities. On occasion, data may also be solicited expressly for the problem at hand through the use of surveys, questionnaires or other psychometric instruments.

Step 4: Model Formulation:

This is the fourth phase of the O.R. process. It is also a phase that deserves a lot of attention since modelling is a defining characteristic of all operations research projects. Modelling is the process of capturing selected characteristics of a system or a process and then combining these into an abstract representation of the original. The main idea here is that it is usually far easier to analyse a simplified model than it is to analyse the original system, and as long as the model is a reasonably accurate representation, conclusions drawn from such an analysis may be validly extrapolated back to the original system.

Step 5: Model Solution:

The fifth phase of the O.R. process is the solution of the problem represented by the model. This is the area on which a huge amount of research and development in O.R. has been focused, and there is a plethora of methods for analysing a wide range of models. In recent years, a number of software systems have emerged which (at least in theory) are "black boxes" for solving various models. In applying a specific technique something that is important to keep in mind from a practitioner's perspective is that it is often sufficient to obtain a *good* solution even if it is not guaranteed to be the *best* solution. If neither resource-availability nor time were an issue, one would of course look for the optimum solution. However, this is rarely the case in practice, and timeliness is of the essence in many instances. In this context, it is often more important to quickly obtain a solution that is satisfactory as opposed to expending a lot of effort to determine the optimum one, especially when the marginal gain from doing so is small.

Step 6: Validation and Analysis:

Once a solution has been obtained two things need to be done before one even considers developing a final policy or course of action for implementation. The first is to verify that the solution itself makes sense. Oftentimes, this is not the case and the most common reason is that the model used was not accurate or did not capture some major issue. The process of ensuring that the model is an accurate representation of the system is called validation and this is something that (whenever possible) should be done before actual solution. The second part of this step in the O.R. process is referred to as post optimality analysis, or in layperson's terms, a "what-if" analysis. Recall that the model that forms the basis for the solution obtained is (a) a selective abstraction of the original system, and (b) constructed using data that in many cases is not 100% accurate.

Step 7: *Implementation and Monitoring*:

The last step in the O.R. process is to implement the final recommendation and establish control over it. Implementation entails the constitution of a team whose leadership will consist of some of the members on the original O.R. team. This team is typically responsible for the development of operating procedures or manuals and a time-table for putting the plan into effect. Once implementation is complete, responsibility for monitoring the system is usually turned over to an operating team. From an O.R. perspective, the primary responsibility of the latter is to recognize that the implemented results are valid only as long as the operating environment is unchanged and the assumptions made by the study remain valid.

1.5 Tools and Techniques of Operational Research

Operations Research uses any suitable tools or techniques available. The common frequently used tools/techniques are mathematical procedures, cost analysis, electronic computation. However, operations researchers given special importance to the development and the use of techniques like linear programming, game theory, decision theory, queuing theory, inventory models and simulation. In addition to the above techniques, some other common tools are non-linear programming, integer programming, dynamic programming, sequencing theory, Markov process, network scheduling (PERT/CPM), symbolic Model, information theory, and value theory. There are many other Operations Research tools/techniques also exists.

The brief explanations of some of the above techniques/tools are as follows:

1. Linear Programming: This is a constrained optimization technique, which optimize some criterion within some constraints. In Linear programming the objective function (profit, loss or return on investment) and constraints are linear. There are different methods available to solve linear programming.
2. Game Theory: This is used for making decisions under conflicting situations where there are one or more players/opponents. In this the motive of the players are dichotomized. The success of one player tends to be at the cost of other players and hence they are in conflict.
3. Decision Theory: Decision theory is concerned with making decisions under conditions of complete certainty about the future outcomes and under conditions such that we can make some probability about what will happen in future.
4. Queuing Theory: This is used in situations where the queue is formed (for example customers waiting for service, aircrafts waiting for landing, jobs waiting for processing in the computer system). The objective here is minimizing the cost of waiting without increasing the cost of servicing.
5. Inventory Models: Inventory model make a decision that minimize total inventory cost. This model successfully reduces the total cost of purchasing, carrying, and out of stock inventory. Simulation: Simulation is a procedure that studies a problem by creating a model. This is used in situations where the queue is formed (for example customers waiting for 14 service, aircrafts waiting for landing, jobs waiting for processing in the computer system). The objective here is minimizing the cost of waiting without increasing the cost of servicing.
6. Simulation: Simulation is a procedure that studies a problem by creating a model of the process involved in the problem and then through a series of organized trials and error solutions attempt to determine the best solution. Sometimes this is a

difficult/time consuming procedure. Simulation is used when actual experimentation is not feasible or solution of model is not possible.

7. Non-linear Programming: This is used when the objective function and the constraints are not linear in nature. Linear relationships may be applied to approximate non-linear constraints but limited to some range, because approximation becomes poorer as the range is extended. Thus, the nonlinear programming is used to determine the approximation in which a solution lies and then the solution is obtained using linear methods.
8. Dynamic Programming: Dynamic programming is a method of analysing multistage decision processes. In this each elementary decision depends on those preceding decisions and as well as external factors. Integer Programming: If one or more variables of the problem, take integral values only then dynamic programming method is used. For example, number or motor in an organization, number of passenger in an aircraft, number of generators in a power generating plant, etc.
9. Markov Process: Markov process permits to predict changes over time information about the behaviour of a system is known. This is used in decision making in situations where the various states are defined. The probability from one state to another state is known and depends on the current state and is independent of how we have arrived at that particular state.
10. Network Scheduling: This technique is used extensively to plan, schedule, and monitor large projects (for example computer system installation, R & D design, construction, maintenance, etc.). The aim of this technique is minimize trouble spots (such as delays, interruption, production bottlenecks, etc.) by identifying the critical factors. The different activities and their relationships of the entire project are represented diagrammatically with the help of networks and arrows, which is used for identifying critical activities and path. There are two main types of technique in network scheduling, they are:
    a. Program Evaluation and Review Technique (PERT) – is used when activities time is not known accurately/ only probabilistic estimate of time is available.
    b. Critical Path Method (CPM) – is used when activities time is known accurately.
11. Information Theory: This analytical process is transferred from the electrical communication field to O.R. field. The objective of this theory is to evaluate the effectiveness of flow of information with a given system. This is used mainly in communication networks but also has indirect influence in simulating the examination of business organizational structure with a view of enhancing flow of information.

1.6 Applications of Operational Research

Today, almost all fields of business and government utilizing the benefits of Operations Research. Although it is not feasible to cover all applications of O.R. in brief. The following are the abbreviated set of typical operations research applications to show how widely these techniques are used today:

1. Accounting:

- Assigning audit teams effectively
- Credit policy analysis
- Cash flow planning
- Developing standard costs
- Establishing costs for byproducts
- Planning of delinquent account strategy

2. Construction:

- Project scheduling, monitoring and control
- Determination of proper work force
- Deployment of work force
- Allocation of resources to projects

3. Facilities Planning:

- Factory location and size decision
- Estimation of number of facilities required
- Hospital planning
- International logistic system design
- Transportation loading and unloading
- Warehouse location decision

4. Finance:

- Building cash management models
- Allocating capital among various alternatives
- Building financial planning models
- Investment analysis
- Portfolio analysis
- Dividend policy making

5. Manufacturing:

- Inventory control
- Marketing balance projection
- Production scheduling
- Production smoothing

6. Marketing:

- Advertising budget allocation
- Product introduction timing
- Selection of Product mix
- Deciding most effective packaging alternative

7. Organizational Behavior / Human Resources:

- Personnel planning
- Recruitment of employees
- Skill balancing Training program scheduling
- Designing organizational structure more effectively

8. Purchasing:

- Optimal buying
- Optimal reordering
- Materials transfer

9. Research and Development:

- R & D Projects control
- R & D Budget allocation
- Planning of Product introduction

CHAPTER 2

COMPANY PROFILE

Reliance Retail Limited is a subsidiary company of Reliance Industries Limited. Founded in 2006, it is the largest retailer in India in terms of revenue. V Subramaniam is the CEO of the Venture.

Reliance Retail is the retail initiative of the group and an epicentre of our consumer facing businesses. It has in a short time forged strong and enduring bonds with millions of consumers by providing them unlimited choice, outstanding value proposition, superior quality and unmatched experience across all its retail stores.

Since its inception in 2006, Reliance Retail has grown to cater to millions of customers, and thousands of farmers and vendors. Reliance Retail serves over 100,000 customers every hour, and has the patronage of more than 117 million registered customers. Our nationwide network of retail outlets delivers a world-class shopping environment and unmatched customer experience powered by our state-of-the-art technology and seamless supply-chain infrastructure.

Reliance Retail has adopted a multi-prong strategy and operates neighbourhood stores, supermarkets, hypermarkets, wholesale cash & carry stores, specialty stores and online stores and has democratized access to all types of products and services across all segments for all Indian consumers.

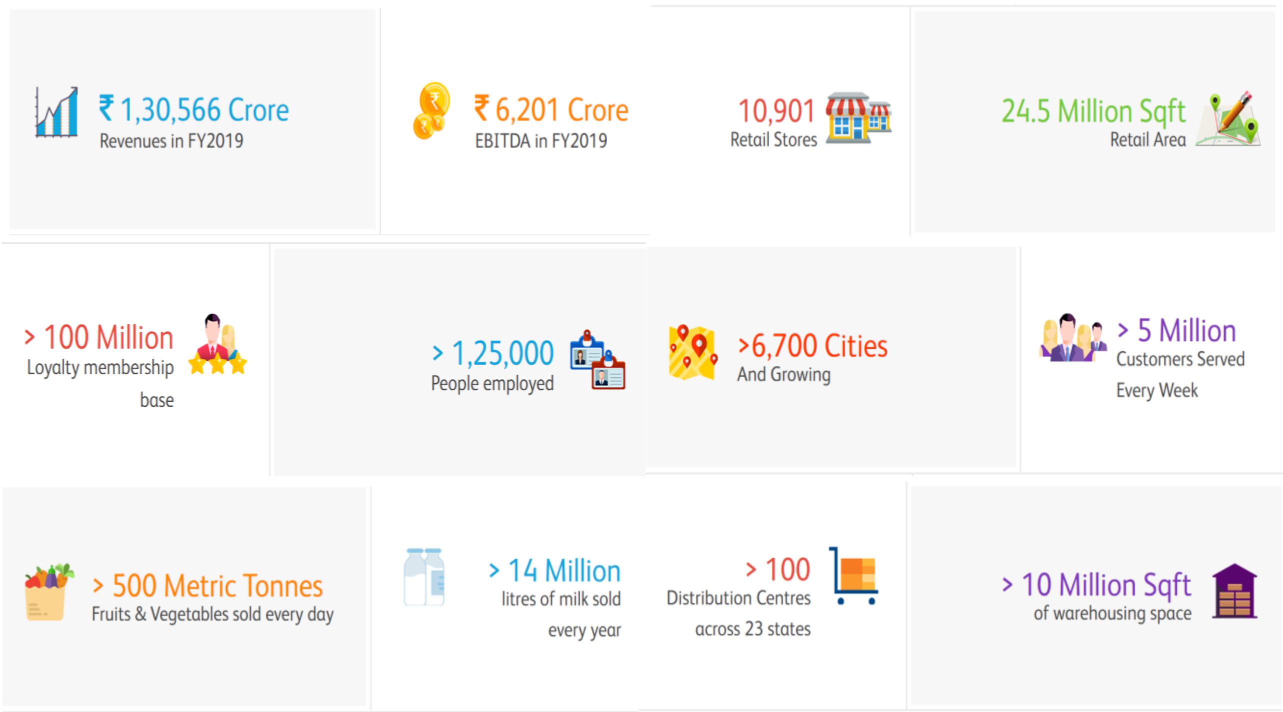
Serving the food and grocery category Reliance Retail operates Reliance Fresh, Reliance Smart and Reliance Market stores. In the customer electronics category, Reliance Retail operates Reliance Digital, Reliance Mini stores and Jio stores and in Fashion and lifestyle category, it operates Reliance Trends, Trends Women, Trends Man, Trends junior, Project Eve, Reliance Footprint, Reliance Jewels and AJIO.com in addition to a large number of partner brand stores across the country.

Reliance Retail has achieved the distinction of being the largest retailer in the country. Reliance Retail’s commitment to bettering lives has been embodied in its pursuit to make a difference on social socio-economic issues in India. The initiative has brought large number of farmers and small producers to the forefront of the retail revolution by partnering with them for growth.

Deep insight into India's economic, cultural and consumption diversity drives Reliance Retail's vision in the retail universe. The operating model is based on customer centricity, while leveraging common centres of excellence in technology, business processes and supply chain. More importantly, it has built a strong and unwavering foundation through its extraordinary people.

Reliance Retail has emerged as the partner of choice for international brands and has established exclusive partnerships with many revered international brands such as Armani Exchange, Burberry, Canali, Pottery Barn, Diesel, Superdry, Hamleys, Ermenegildo Zegna, Marks and Spencer, Paul & Shark, Brooks Brothers, Steve Madden, Grand Vision and many more.

Reliance Retail operates over 10,901 stores pan India with ~24.5 million square feet of retail space and is growing rapidly



DETAIL ABOUT RELIANCE FRESH AND RELIANCE SMART STORES

Reliance Fresh

Reliance fresh is the India's leading neighbourhood retail chain, synonymous with the freshness and savings. Reliance fresh is a one stop shop for fresh shopping, fresh savings and fresh happiness.

From fresh fruits and vegetables to diary, cereals to spices, processed food and beverages to home and personal care products, we have the entire gamut of your grocery needs covered. Across our stores, we retain a strong customer centric approach to meet all your shopping needs be it a routine or seasonal, well known brands and popular local products.

Reliance Smart

Reliance Smart is a new age supermarket serving the needs of today's smart and value seeking customers. Reliance Smart offers a one stop shopping experience by offering fresh produce, bakery, dairy products, home and personal care products, general merchandise and in many cases are co-located with our fashion and electronic stores Reliance Trends and Reliance Digital, making it a complete shopping destination. Reliance Smart's incredible value proposition rewards shoppers more and more for bigger purchase, every time they shop with 100% assortment being offered below the MRP all year round, while delivering a world class shopping experience.

CHAPTER 3

PROBLEM DESCRIPTION AND IT'S OBJECTIVES

Developments in service sector, increase in production amounts, shrinking product life cycles, increase in accessibility of variety of products reveals the importance of gaining competitive advantage in the market place. Therefore, continuous performance monitoring is essential for organizations to be successful. Different tools and techniques are used for measuring performance of organizations including balanced Scorecard, EFQM Excellence Model and Key Performance Indicators (KPI's).

Reliance Retail uses KPI measure to evaluate the performances of its retail stores. It is a measurable value that demonstrates how effectively a company is achieving its key business objectives and also to evaluate their success at reaching the targets.

Each department uses different KPI types to measure the success based on the specific business goals and targets. It was evident in reliance retail operations also, which took different KPIs under evaluation for different kind of stores.

Sales(% Achieved), NOB (% Like For Like), ABV(% Like For Like), NSO Sales(New store opening Sales- % Achieved), Always Open checkouts, Cleanliness and hygiene, Shelf Help, Customer Service and Interaction, Continuous WorkSmart Training, Price and Promotions, POG Compliance, F&V Loss, Non F&V Loss, Attrition are a few basic KPIs used in Reliance Retail Stores for evaluating the stores operations and its performance.

As one of a well-known mathematical model based technique, Data Envelopment Analysis (DEA) is a performance measuring technique which is used for comparing the performances of similar units of an organisation. These units for which we are doing the performance analysis are called Decision Making Units (DMU).

DEA has wide applications in all industries including hospitals, banks, universities etc. This technique calculates the efficiencies of all DMUs by taking a set of input and output variables (which are generally the most important business metrics of the organization) and then set a benchmark. DEA techniques are very popular in Operations Research and it uses concepts of Linear Programming to formulate and solve the problem at hand.

3.1 Objectives of the Project

The objectives of the project are:

- Evaluate and rank the stores based on their performance using the DEA Models
- Determine the peers and their respective weights for all the under-performing stores
- Determine target values for all the inefficient employees as opposed to the actual values
- Based on the targets draw recommendations to be imposed by the management personnel to enhance the performance of all the stores that are underperforming.

3.2 Practical Usage of the Project

Within-chain comparative store efficiency is a key factor in a number of important strategic management decisions.

- First, the evaluation, promotion and development store management personnel relies on assumptions about factors affecting store financial performance.
- Second, strategic resource-allocation decisions—such as advertising budgets, store expansions and store closings—are based on top management's understanding of what drives store performance. For instance, if the factors that contribute to low performance are deemed to be unalterable or prohibitively expensive to modify, management may choose to close the store.
- Third, adopting a 'best practices' approach to continuous improvement and corporate learning requires ongoing monitoring of store management procedures and their influence on store performance.

This study describes an evaluation process, based on Data Envelopment Analysis DEA, to assess the efficiency of individual stores within a chain. DEA is particularly appropriate for this evaluation because it integrates a variety of performance metrics and provides a structured methodology for evaluating retail store performance.

CHAPTER 4

LITERATURE OVERVIEW

4.1 Definition of DEA

Data envelopment analysis (DEA), occasionally called frontier analysis is a nonparametric method in operations research and economics for the estimation of production frontiers. It is used to empirically measure productive efficiency of decision making units (DMUs). Here, a DMU is a distinct unit within an organisation that has flexibility with respect to some of the decisions it makes, but not necessarily absolute freedom with respect to these decisions.

Although DEA has a strong link to production theory in economics, the tool is also used for benchmarking in operations management, where a set of measures is selected to benchmark the performance of manufacturing and service operations. In benchmarking, the efficient DMUs, as defined by DEA, may not necessarily form a “production frontier”, but rather lead to a “best-practice frontier”

Data envelopment analysis (DEA) is a linear programming methodology to measure the efficiency of multiple decision-making units (DMUs) when the production process presents a structure of multiple inputs and outputs

"The framework has been adapted from multi-input, multi-output production functions and applied in many industries. DEA develops a function whose form is determined by the most efficient producers. This method differs from the Ordinary Least Squares (OLS) statistical technique that bases comparisons relative to an average producer.

Like Stochastic Frontier Analysis (SFA), DEA identifies a "frontier" which are characterized as an extreme point method that assumes that if a firm can produce a certain level of output utilizing specific input levels, another firm of equal scale should be capable of doing the same. The most efficient producers can form a 'composite producer', allowing the computation of an efficient solution for every level of input or output. Where there is no actual corresponding firm, 'virtual producers' are identified to make comparisons"

4.2 History of DEA

In an article which represents the inception of DEA, Farrell (1957) was motivated by the need for developing better methods and models for evaluating productivity. He argued that while attempts to solve the problem usually produced careful measurements, they were also very restrictive because they failed to combine the measurements of multiple inputs into any satisfactory overall measure of efficiency. Responding to these inadequacies of separate indices of labour productivity, capital productivity, etc., Farrell proposed an activity analysis approach that could more adequately deal with the problem. His measures were intended to be applicable to any productive organization. In the process, he extended the concept of "productivity" to the more general concept of "efficiency".

Farrell (1957) attempted to measure the efficiency of production in the single input and output case. Farrell's applied the model to estimate the efficiency of US agricultural output relative to other countries. But he failed to summarize all the various inputs and outputs into a single virtual input and single virtual output.

Charnes, Cooper and Rhodes (1978) extended Farrell's idea and proposed a model which generalizes the single input, single output measure of efficiency of a Decision Making Unit (DMU) to a multiple input, multiple output setting by constructing a relative efficiency score as the ratio of a single virtual output to a single virtual input. Thus, DEA become a new tool in operational research for measuring technical efficiency under the assumption of constant returns to scale.

Banker, Charnes, Cooper (1984) intended the idea from constant returns to scale to include variable returns to scale. So, the basic DEA models are known as CCR and BCC.

Since 1978 over 1000 articles, books and dissertation have been published and DEA has rapidly extended to returns to scale, dummy or categorical variables, discretionary and non-discretionary variables, incorporating value judgments, longitudinal analysis, weight restrictions, stochastic DEA, non-parametric Malmquist indices, technical change in DEA and many other topics.

4.3 Applications of DEA

DEA measure has been used to evaluate and compare the performance efficiency in various sectors including educational departments (schools, colleges and universities), health care (hospitals, clinics) prisons, agricultural production, banking, armed forces, sports, market research, transportation (highway maintenance), courts, benchmarking, index number construction and many others where there is a relatively homogeneous set of units. The summary of some studies in DEA is given in the following table along with the sector, focused area and the method used.

Author(s)	Sector	Focused area	Method
Banker et al.	Healthcare	Comparing about hospital cost and production from 2 estimation models	Translog joint cost function, Output Oriented CCR Model
Weber	Production	Evaluating the 6 vendor supplying an item to a baby food manufacturer	Input-Oriented CCR
Jemric and Vujcic	Finance	Analysing bank efficiencies in Croatia between 1995 and 2000	Both Output-Oriented BCC and CCR Models
Johnes	Education	Measurement of universities' performance in UK, 1993	Ordinary least squares method, stochastic frontier analysis model, multilevel model
Avkiran	Financial Service	The multi stakeholder perspective on benchmarking rates firms' performance	Input-Oriented and Output-Oriented CCR Model
Johnes	Education	Measuring the content of higher education in England, 2000–2001	Output-Oriented BCC Model
Johnes and Li	Education	Examining the efficiency in the production of 109 Chinese regular universities in 2003 and 2004	Output-Oriented BCC Model
Nayar and Ozcan	Healthcare	Performance measurements of quality in Virginia hospitals	Input-Oriented CCR Model

Author(s)	Sector	Focused area	Method
Staub et al.	Finance	Evaluating cost, technical and allocative efficiencies for Brazilian bank between 2000–2007	Regression model
Ram Jat and Sebastian	Healthcare	Measuring technical efficiency of 40 public district hospital in India	Input-Oriented BCC Model
Thomas et al.	Industry	Operational and environmental efficiencies of 47 prefectures in Japan	Input-Oriented CCR
Paradi and Zhu	Finance	Surveying 80 published DEA applications in 24 countries that focus on bank branches	Additive and slack based models (8 of them), BCC and CCR models (72 of them)
Mirhedayatian et al.	Production	Evaluating 10 Iranian soft drinks companies in terms of green supply chain management	Output-oriented network slack based model
Kawaguchi et al.	Healthcare	Evaluating 9000 private and public hospitals in Japan	Dynamic network and black box model
Othman et al.	Finance	Measuring relative efficiency of banks	Both CCR and BCC Models

DEA is also commonly applied in the electric utilities sector. For instance, a government authority can choose data envelopment analysis as their measuring tool to design an individualized regulatory rate for each firm based on their comparative efficiency. The input components would include man-hours, losses, capital (lines and transformers only), and goods and services. The output variables would include number of customers, energy delivered, length of lines, and degree of coastal exposure.

DEA is also regularly used to assess the efficiency of public and not-for-profit organizations, e.g. hospitals, police forces, or liberal arts colleges.

Since this study focuses on performance measurement in retail sector by using DEA, in the following section, studies that used DEA in retail sector are investigated.

4.4 DEA in Retail Sector

DEA method is a useful technique for performance evaluation in retail sector in terms of measuring multiple inputs and outputs. From retail perspective, DEA is used to ensure better service to customers over time in consequence of input-output analysis to perform new policies in line with the outcomes.

Nowadays, there is a perceptible rise and growth in competition in retail sector, therefore, increasing the performance of retail stores to gain competitive advantage and investigating the causes of bottlenecks are essential. In order to do that, measuring current performance is necessary. For efficiency analysis, DEA is very suitable in terms of evaluating multiple inputs and outputs. According to the needs of research, inputs and outputs that are used in DEA may vary.

Various studies have been adopted for evaluating the performance efficiency using DEA. The following table shows some of the studies done by various authors along with the method used and various input and outputs used for the analysis.

Author(s)	**Methods**	**Inputs**	**Outputs**
Kamakura et al.	Output-Oriented CCR	Labour, and customer service area	Cash Deposits, Other Deposits Pays (Volume of transit in branch), and MREV (Service fee)
Thomas et al.	Input-Oriented CCR	Labour, experience, location related costs, and internal processes	Sales and profit
Donthu and Yoo	Input-Oriented CCR	Environmental conditions, customers factors, retail firms managerial efforts, and employees factors	Financial or economic outcomes, and behavioural outcomes
Gemici	DEA and AHP	Quality management applications and systems, internal check documentation, capacity of process and production, company management, design and development opportunities, and performance of cost reduction	Quality, cost, delivery, performance of cost reduction

Author(s)	Methods	Inputs	Outputs
Mishra	Output-Oriented CCR	Value of stock, floor space and recurrent costs	Annual sales, and customer satisfaction
Mostafa	Output-Oriented CCR	Employees, and assets	Revenue, earn share, and market value
Lau	Input-Oriented CCR and BCC	Equivalent number of vehicles used for delivery, and total transport cost	Number of customers served, number of orders filled, and total revenue
Gandhi and Shankar	CCR and BCC	Cost of labour, and capital employed	Profit, and sales
Geyikçi and Bal	Output-Oriented CCR and BCC	Current ratio, stock turnover, and financial lever	Net profit margin, and marketing value

4.5 <u>Strengths and Weaknesses of DEA</u>

Some of the strengths of DEA are:

- DEA can handle multiple input and multiple output models.
- DEA identifies the possible peers as role models who have an efficiency score of 1 and sets improvement targets for them.
- By providing improvement targets DEA acts as an important tool for benchmarking
- The possible sources of inefficiency can be determined using DEA

Some of the weaknesses of DEA are:

- As DEA is deterministic rather than stochastic DEA produces results that are particularly sensitive to measurement errors. If an input of a DMU is understated or the output is overstated then the organization can become the outlier that significantly distorts the shape of frontier and reduces the efficiency score of nearby organization.
- DEA score is sensitive to input and output specifications and the size of the sample. Increasing the size of the sample will tend to reduce the average efficiency score, as more DMUs provide greater score for DEA to find similar comparison partners. Conversely too small DMUs relative to the number of inputs and outputs can artificially inflate the efficiency score.

4.6 Concept of DEA

Data envelopment analysis (DEA) is a linear programming based technique for measuring the relative performance of organizational units called DMU where the presence of multiple inputs and outputs makes comparisons difficult. It aims to measure how efficiently a DMU uses the resources available to generate the set of outputs.

DEA is a multi-factor productivity analysis model for measuring the relative efficiency of a homogenous set of DMU's. For every inefficient DMU's, DEA identifies a set of corresponding efficient DMUs that can be utilized as benchmarks for improvement of performance and productivity called the Peer group or Reference Set.

DEA developed based on two scale of assumptions viz., Constant Return to Scale (CRS) model and Variable Return to Scale (VRS) model.

The usual measure of efficiency is

$$\text{Efficiency}=\frac{\text{Output}}{\text{Input}}$$

is often inadequate due to the existence of multiple inputs and outputs related to different resources, activities and environmental factors. Hence, such measure is referred to as 'partial productivity measure'. This terminology is attempted to distinguish from the 'total productivity measure' as the latter takes into account multiple inputs and outputs.

Thus, for moving from partial to total productivity, virtual inputs and outputs are created for each DMU by combining the inputs and outputs and assigning weights to each input and output values.

Let x and y represent the inputs and outputs respectively and the subscripts i and j represent the particular inputs and outputs respectively. Let I and J represent the total number of inputs and outputs used in the analysis. Here, I and J is greater than 0. Therefore, we have,

$$\text{Efficiency}=\frac{\text{Virtual output}}{\text{Virtual input}}$$

Virtual input$=\sum_{i=1}^{I} u_i x_i$

Virtual output$=\sum_{j=1}^{J} v_j y_j$

Where u_i is the weight assigned to the input x_i during aggregation. $u_i \geq 0$

And, v_j is the weight assigned to the output y_j during aggregation. $v_j \geq 0$

The most important issue now is to decide the weights for inputs and outputs. This is a little bit tricky as there is no unique set of weights.

There are several ways to estimate the efficiency rate as defined above, namely multicriterial decision methods and data envelopment analyses (DEA). These approaches differ in how they obtain input and output weights.

• Multicriterial decision methods usually expect the user to define the weights v_j and u_i upfront, i.e. the user determines the significance of individual inputs and outputs in the analysis. Such an analysis yields the rate of utility of given units. It reflects the relative importance of inputs and outputs represented by their respective weights. Based on this analysis, units can be ranked from the worst to the best performer.

• DEA models derive input and output weights by means of an optimising calculation. Based on that, units can be classified into efficient and inefficient. In inefficient units, they tell us target values of inputs and outputs which would lead to efficiency.

We shall use the DEA models to estimate the input and output weights which are explained in the following section.

4.7 DEA Models

Numerous methods have been proposed for evaluating retail efficiency for a single location retailer, retailers in a specific category, and the retail industry as a whole. There is a paucity of research, however, on the measurement and evaluation of individual store productivity within a large, multi-store multi-market chain operation.

DEA is a methodology that evaluates relative efficiency of DMUs (i.e., retail stores in a large chain) when there are multiple inputs and outputs. This approach first establishes an 'efficient frontier' formed by a set of Decision Making Units (DMUs) that exhibit best practices and then assigns the efficiency level to other non-frontier units according to their distances to the efficient frontier.

Although, there are different methods under DEA and integration between other methods is possible, CCR (Charnes, Cooper, Rhodes) and BCC (Banker, Charnes, Cooper) are the most well-known DEA methods.

CCR model assumes that constant returns to scale i.e, it is based on the assumption that the input and output ratios do not change with size. It is named after the first letters of the authors Charnes, Cooper, and Rhodes whereas BCC model considers that variable returns to scale i.e, it is a model that is applied when the ratio of input and output varies with size. It is named after Banker, Charnes, and Cooper who first introduced this model. Because of this differentiation, CCR and BCC models are separated from each other.

In addition, DEA has three orientations in efficiency analysis (Charnes 1994):

- Input oriented models are models where DMUs are deemed to produce a given amount of output with the smallest possible amount of input.
- Output Oriented models are models where DMUs are deemed to produce the highest possible amount of output with the given amount of input.
- Base oriented models are models where DMUs are deemed to produce the optimal mix of input and output.

After CCR and BCC models were introduced, many variations of these models like Additive sum model, Non-discretionary variable model, Non-controllable variable model, Slack based model, super efficiency model, stochastic DEA, Network DEA etc. have been developed. Some of these variations are explained in the next section.

4.8 Mathematical Formulation of DEA Models

According to the identified inputs and outputs, model of the problem needs to be generated. Model selection is one of the problems to be considered in DEA including the choices of multiple models (or methods) used.

If we cannot identify the characteristics of the production frontiers by preliminary surveys, it may be risky to rely on only one particular model. If the application has an important consequence it is wise to try different models and methods, compare the results and utilize the expert knowledge of the problem before arriving at the definitive conclusion.

Some of the DEA models are explained below:

4.8.1 The CCR model

CCR Model is a basic DEA Model which was developed by Charnes, Cooper, Rhodes. A number of different versions of this basic DEA model have been developed to addresss a series of potential shortcomings of the original DEA model. We will examine the variations of DEA models in the subsequent sections. We shall first address the basic model as formulated below:

Assume that there are n DMUs, and each DMU_j, produces s outputs (y_{1j}, ..., y_{sj}) by using m inputs (x_{1j}, ..., x_{mj}). We measure the efficiency of each DMU once and hence we need n optimizations, one for each DMU_j to be evaluated. Let the DMU_j to be evaluated on any trial be assigned as DMU_q where q ranges from 1, 2, ……. n.

We solve the following fractional programming problem to obtain the values for the input weights (u_i, i=1,2,....m) and the output weights (v_r, r=1,2,....s)

$$\left.\begin{array}{ll} \text{Maximise} & \theta = \dfrac{v_1 y_{1q} + v_2 y_{2q} + \dots\dots\dots + v_s y_{sq}}{u_1 x_{1q} + u_2 x_{2q} + \dots\dots\dots + u_m x_{mq}} \\ \text{Subject to} & \dfrac{v_1 y_{1j} + v_2 y_{2j} + \dots\dots\dots + v_s y_{sj}}{u_1 x_{1ij} + u_2 x_{2j} + \dots\dots\dots + u_m x_{mj}} \le 1 \quad \text{for all } j=1,2,\dots n \\ & u_i \ge 0,\ i=1,2,\dots.m \\ & v_r \ge 0,\ r=1,2,\dots.s \end{array}\right\} \quad (P1)$$

The constraints mean that the ratio of virtual output and virtual input should not exceed 1 for every DMU. The objective is to obtain the input weights (u_i, i=1,2,....m) and the output weights (v_r, r=1, 2,.... s) that maximise the efficiency ratio for $DMU_{q,}$ the DMU being evaluated.

By virtue of the constraint, the optimal objective value θ^* is at most 1.

The non-negativity constraints assume that all the inputs and outputs have some non-zero worth and thus, it is reflected in the weights being assigned some positive value.

Hence, DMU_q is called CCR efficient if $\theta^* = 1$ and there at least one optimal value (u*,v*) with u*>0 and v*>0. Otherwise, it is CCR inefficient.

We now replace the above fractional problem to the linear programming problem as:

$$\left.\begin{array}{ll} \text{Maximise} & \theta = v_1 y_{10q} + v_2 y_{2q} + \dots\dots\dots + v_s y_{sq} \\ \text{Subject to} & u_1 x_{1q} + u_2 x_{2q} + \dots\dots\dots + u_m x_{mq} = 1 \\ & \dfrac{v_1 y_{1j} + v_2 y_{2j} + \dots\dots\dots + v_s y_{sj}}{u_1 x_{1ij} + u_2 x_{2j} + \dots\dots\dots + u_m x_{mj}} \le 1 \quad \text{for all } j=1,2,\dots n \\ & v_i \ge 0,\ i=1,2,\dots.m \\ & u_r \ge 0,\ r=1,2,\dots.n \end{array}\right\} \quad (P2)$$

The above model can thus be transformed into a matrix form as:

$$\left.\begin{array}{ll} \text{Maximize} & z = v^T y_q \\ \text{Subject to} & u^T x_q = 1 \\ & v^T Y - u^T X \le 0 \\ & u \ge 0,\ v \ge 0 \end{array}\right\} \quad (P3)$$

For any linear problem (LP) as defined above, it is possible to formulate a partner LP using the same data and the solution to either LP (the primal) or the partner (the dual) provides the same information about the problem being modelled.

The dual model is constructed by assigning the variable (dual variable) to each constraint of the primal model and constructing a new model on these variables.

The dual model for model (P3) above can be states as follows:

$$\left.\begin{array}{ll} \text{Minimize} & \theta \\ \text{Subject to} & Y\lambda - s^{+} = y_q \\ & X\lambda + s^{-} = \theta x_q \\ & \lambda, s^{+}, s^{-} \geq 0 \text{ and } \theta \text{ is unrestricted} \end{array}\right\} \quad \text{(D1)}$$

where θ is a real variable, $\lambda = (\lambda_1, \lambda_2, ..., \lambda_n)$, $\lambda \geq 0$ is a vector assigned to individual decision making units and s^- and s^+ are vectors consisting of slack values for input and output variables respectively.

We can interpret the constraints in the above model as follows:

- In the first constraint, the weighted sum of all the DMU's is taken on LHS and the output of the reference unit DMU_q on RHS. This constraint states that the dual variable λ should be chosen in such a way that the weighted combinations of all the outputs of the DMU's is at least equal to the output of the reference unit DMU_q.
- The second constraint states that the weighted combination of all inputs of the DMU's cannot be more than the input of the reference unit DMU_q.

A unit DMU is CCR efficient, if:

1. the value of variable θ^* is 1
2. the values of all additional slack variables s^{+*} and s^{-*} equal zero

For inefficient units θ is less than one. This value shows the need for a proportional reduction of inputs for unit DMUq to become efficient. The advantage of the DEA model is that it advises how the unit evaluated should mend its behaviour to reach efficiency.

Models (P3), (P4) and (D1) are output maximisation (input oriented) model.

Similarly, We have input minimisation model (output oriented) which can be formulated as:

$$\left.\begin{array}{ll} \text{Minimize} & z = u^T x_q \\ \text{Subject to} & v^T y_q = 1 \\ & v^T Y - u^T X \leq 0 \\ & u \geq 0,\ v \geq 0 \end{array}\right\} \quad \text{(P4)}$$

Such a model's dual could be written as follows:

$$\left.\begin{array}{ll} \text{Maximize} & \phi \\ \text{Subject to} & Y\lambda - s^+ = \phi\, y_q \\ & X\lambda + s^- = x_q \\ & \lambda,\ s^+,\ s^- \geq 0 \text{ and } \phi \text{ is unrestricted.} \end{array}\right\} \quad \text{(D2)}$$

This model can be interpreted as follows: unit DMU_q is CCR efficient if the optimal value of the objective function in model (P6) equals one, $\phi^* = 1$. If the value of the function is greater than one, the unit is inefficient. The variable ϕ indicates the need for reducing input to achieve efficiency. For the optimal solution to the CCR model, the values of objective functions should be inverted, i.e. $\phi^* = 1/\theta^*$.

Note: <u>Comparison between Primal and Dual Problems</u>

- The optimal value for primal and dual are the same.
- The no. of constraints of the primal depends on the no. of DMU while the no. of constraints in dual depends upon the input and output variables.

The computational efficiency depends on the no of constraints on a greater extent than the no. of variables. Thus, in general, the dual problems are computationally advantageous than primal to solve.

<u>Note</u>*: Primal problem which assigns the weights to the input and output of the DMU's is also called as Multiplier DEA model. On the other hand, Dual problem which assign weights to the DMU's is also called the Envelopment Model.*

4.8.2 BCC Model

As described in the earlier section, BCC model developed by Banker, Charnes, Cooper is an extension of CCR model which assumes variable returns to scale characteristics with increasing returns to scale occurring in the first solid line segment followed by decreasing returns to scale in the second segment and constant returns to scale occurring at the point where the transition from the first segment to the second segment is made. Thus, the bcc model has its production frontiers by the convex hull of the existing DMUs.

The introduction of an additional convexity constraint, $e^T\lambda = 1$ in the CCR model makes it a BCC model ensuring that the firms operating at different scales (see next section) are recognised as efficient. Therefore, the envelopment model is formed by the multiple convex combination of the best possible firms.

Input-oriented BCC model

The input-oriented BCC model evaluates the efficiency of DMU_q, q=1,2,….n by solving the following (envelopment form) linear program can be formulated as:

$$\left.\begin{array}{ll}\text{Minimize} & \theta \\ \text{Subject to} & Y\lambda - s^{+} = y_q \\ & X\lambda + s^{-} = \theta x_q \\ & e^T\lambda = 1 \\ & \lambda, s^{+}, s^{-} \geq 0 \text{ and } \theta \text{ is unrestricted}\end{array}\right\} \quad (D3)$$

The corresponding dual multiplier form of this linear program can be expressed as:

$$\left.\begin{array}{ll}\text{Maximize} & z=v^Ty_q-v_q \\ \text{Subject to} & u^Tx_q=1 \\ & v^TY - u^TX-v_qe \leq 0 \\ & u\geq 0,\ v\geq 0,\ v_q \text{ is free in sign}\end{array}\right\} \quad (P5)$$

The equivalent BCC fractional program is obtained from the dual program as:

$$\left.\begin{array}{ll}\text{Maximize} & z=\dfrac{v^Ty_q-v_q}{u^Tx_q} \\ \text{Subject to} & \dfrac{v^Ty_j-v_q}{u^Tx_j} \leq 1 \\ & u\geq 0,\ v\geq 0,\ v_q \text{ is free in sign}\end{array}\right\} \quad (P6)$$

Output-oriented BCC model

The output-oriented BCC model evaluates the efficiency of DMU_q , q=1,2,....n by solving the following (envelopment form) linear program can be formulated as

$$\left.\begin{array}{ll} \text{Maximise} & \phi \\ \text{Subject to} & Y\lambda - s^{+} = \phi\, y_q \\ & X\lambda + s^{-} = x_q \\ & e^{T}\lambda = 1 \\ & \lambda, s^{+}, s^{-} \geq 0 \text{ and } \phi \text{ is unrestricted} \end{array}\right\} \quad \text{(D4)}$$

The corresponding dual multiplier form of this linear program can be expressed as:

$$\left.\begin{array}{ll} \text{Minimize} & z = u^{T}x_q - u_q \\ \text{Subject to} & v^{T}y_q = 1 \\ & v^{T}Y - u^{T}X - u_q e \leq 0 \\ & u \geq 0,\ v \geq 0,\ u_q \text{ is free in sign} \end{array}\right\} \quad \text{(P7)}$$

The equivalent BCC fractional program is obtained from the dual program as:

$$\left.\begin{array}{ll} \text{Maximize} & z = \dfrac{u^{T}x_q - u_q}{v^{T}y_q} \\ \text{Subject to} & \dfrac{u^{T}x_q - u_q}{v^{T}y_q} \leq 1 \\ & u \geq 0,\ v \geq 0,\ u_q \text{ is free in sign} \end{array}\right\} \quad \text{(P8)}$$

A unit DMU is BCC efficient, if:

1. the value of variable θ^* is 1
2. the values of all additional slack variables s^{+*} and s^{-*} equal zero
   Otherwise, it is BCC inefficient

If a DMU is BCC efficient then, it will be CCR efficient also, but the converse may not hold.

**Returns to scale (concept)

We can extend the BCC envelopment model by relaxing the convexity condition $e^T\lambda = 1$ to,

$L \le e^T\lambda \le U$ where L ($0 \le L \le 1$) and U ($0 \le U \le 1$) are the upper and lower bounds for $e^T\lambda$.

Notice that L=0 and U= ∞ correspond to the CCR model and L=U=1 correspond to the BCC model. Some typical extensions can be described as follows:

The case when L=1 and U= ∞ or $e^T\lambda < 1$ is called **Increasing Returns to Scale (IRS).** The condition L=1 assumes that we cannot reduce the scale of DMU but it is possible to expand the scale to infinity. It occurs when the proportional increase in output is always atleast as great as the related proportional increase in input.

$\frac{\Delta y/y}{\Delta x/x} \ge 1$ where Δx and Δy are the increases to be made from a frontier point with coordinates (x, y)

The case when L=0 and U=1 or $e^T\lambda > 1$ is called **Decreasing Returns to Scale (DRS).** By the condition U=1, scaling up of DMU's is interdicted, while scaling down is permitted.

The case when L= U=1 or $e^T\lambda = 1$ is called **Constant Returns to Scale (CRS).**

Thus, $\theta^*_{CCR} \le \theta^*_{IRS}$, $\theta^*_{DRS} \le \theta^*_{BCC}$

Note that beyond a limit, IRS does not hold. For example, if the manufacturer needs to produce billion units of the item, he might find it difficult to produce that amount because of the storage problems and limits on the supply of raw materials. In this case, he is said to be operating under DRS

Combining the two extremes IRS and DRS would necessitate variable returns to scale. This property signifies that in a production process, the operations will follow IRS or DRS for different ranges of output.

Note that IRS changes from DRS at a particular point of production represented. At this point, a DMU is said to be operating at its **most productive scale size** because it enjoys the maximum possible economy of scale. In this case, CCR score = BCC score and hence 100% efficient.

Thus, the DMU's operating at a lower scale size are said to be operating under IRS because they can achieve greater economies of scale if they increase their volume of operation. On the other hand, the DMU's operating at a higher scale size are said to be operating under DRS.

4.8.3 Scale Efficiency Model

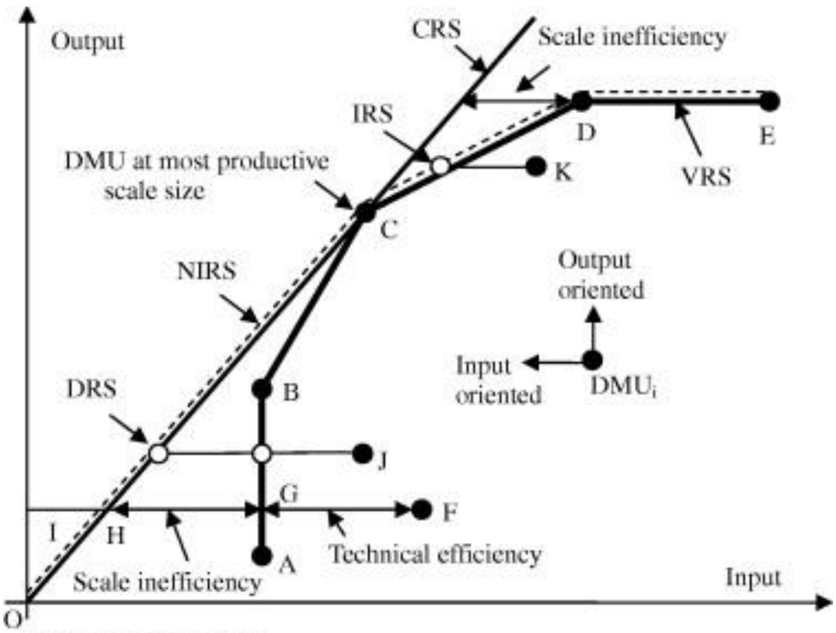
It is interesting to investigate the sources of inefficiency that a DMU might have. For this purpose, comparison of CCR and BCC scores deserves consideration. The CCR model assumes constant returns to scale production possibility set and hence the CCR score is called **Global Technical Efficiency.**

On the other hand, the BCC model assumes that the convex combinations of the DMU's form the production possibility set and the BCC score is called **Local Pure Technical Efficiency.**

If a DMU has full BCC efficiency but a low CCR score, then it is operating locally efficiently but not globally efficiently due to the scale size of the DMU. Thus, it is reasonable to characterise the **scale efficiency** of a DMU by the ratio of the two scores.

$$\mathbf{SE} = \frac{\theta^*_{CCR}}{\theta^*_{BCC}}$$

SE is less than 1 always as $\theta^*_{CCR} \leq \theta^*_{BCC}$. For a BCC efficient DMU, with CRS characteristics, i.e., in the most productive scale size , its SE=1.



RTS: returns to scale
OC and ABCDE: CRS and VRS frontiers, respectively.
NIRS: non-increasing RTS
IRS and DRS: increasing and decreasing RTS, respectively

Along with the efficiency values, DEA model also provides,

- **Efficient Peers:** The number of peers that the unit has, if any. Zero are assigned for the units which are deemed efficient.

- **Lambda values:** It is defined as the raw weights assigned to the peer UNITS when solving the DEA model. They are most easily interpreted via the dual formulation of the DEA model.
- **Slack and Target values:** *Explained in the section below.*

****<u>Input and Output Slack and Target Values (Concept)</u>**

The aim of DEA analysis is not only to determine the efficiency rate of the units reviewed, but in particular to find target values for inputs and outputs for an inefficient unit. After reaching these values, the unit would arrive at the threshold of efficiency.

Suppose the DMU A is the most efficient, we can set Performance Targets for the inefficient firms to enable them to reach 100 % relative efficiency. Since the DMU A has operated under similar environment and hence using its performance as benchmark is realistic. We are not assigning unrealistic targets.

<u>Input Target</u>: The input target for an inefficient unit is the amount of input which shall be used by the inefficient DMU to produce the same level of output so as to make the DMU efficient one.

$$\text{Input Target}=\frac{\text{Actual Input * Relative Efficiency}}{100}$$

<u>Input Slack</u>: For inefficient firms, Input target will be smaller than actual input. The difference between actual input and input target is usually called the Input Slack.

Input Slack for an inefficient DMU = Actual Input – Input Target

<u>Input Slack Percentage:</u> For the inefficient DMU's, Input Slack Percentage give the percentage by which the input should be decreased to be efficient.

$$\text{Input Slack Percentage} = \frac{\text{Input Slack}}{\text{Actual Intput}} \text{x100}$$

Using a similar logic, we can compute Output Targets, Slacks and Percentages as:

$$\text{Output Target} = \frac{\text{Actual Output}}{\text{Relative Efficiency}} \text{x100}$$

Output Slack = Output Target – Actual Output

$$\text{Output Slack Percentage} = \frac{\text{Output Slack}}{\text{Actual Output}} \text{x100}$$

NOTE: *Choosing input minimization, the DEA solutions (results) sometimes also indicate the DMU can optimize their outputs too. It would expect that output is fixed and only input improvements can be made. The other way around, choosing for output maximization, some results say the DMU should change their input as well. The reason is due to the optimization that is done to show each unit in its best possible light. The linear program finds an optimal position relative to the efficient frontier which gives the unit its score. However, in doing so, it can also determine that to achieve that position, it does not need to use as much resource as it is using, or could produce more output (depending on the mode of operation). It can be argued that such improvements should not be shown since that is not what is being looked for, but it is useful information and tells you a little more about the DMU's.*

4.8.4 Non-Controllable Variable Model

Data Envelopment Analysis (DEA) has been used to measure the productive efficiency and the potential areas of improvement of decision making units (DMUs) with multiple input and output. However, in real life, the ways to improve efficiency of DMUs is impractical because some of the inputs or outputs are uncontrollable. Thereby, using the non-controllable input output oriented model is an attempt to improve the efficiency score and derive the input-output target strategy and at the same time to prove that the uncontrollable input cannot be reduce but the value should be fixed. It is discovered the new input-output target and the results obtained indicate that the impact of uncontrollable variables is relatively significant.

The non-controllable variable model can be formulated as below:

Minimize θ

Subject to $Y^C\lambda - s^+ = y_q^C$

$X^C\lambda + s^- = \theta x_q^C$

$Y^N\lambda = y_q^N$

$X^N\lambda = x_q^N$

$L \leq e^T\lambda \leq U$

$\lambda, s^+, s^- \geq 0$ and θ is unrestricted

Here, we are using the matrix vector formulation in which X^C, Y^C refer to the matrices of "controllable" variables and x_q^C and y_q^C refer to the corresponding vectors of the observed values for the DMU_q being evaluated. The matrices X^N, Y^N, on the other hand, refers to the data on the uncontrollable variables that are to be evaluated relative to the vectors x_q^N and y_q^N for the same $DMU_{q.}$ Finally, the last constraint imposes an upper bound U and a lower bound L on the variable choices with $e^T\lambda$ which is used to indicate the economies of scale.

4.8.5 Additive Model

In basic models of DEA, we distinguish between input-oriented and output-oriented models. In this model, we combine both orientations in a single model, called Additive model. This model has the same production possibility set as the BCC and CCR models and their variants but treats the slacks (the input excesses and output shortfalls) directly in the objective function.

Maximize $z = (e^T s^+ + e^T s^-)$

Subject to $Y\lambda - s^+ = y_q$

$X\lambda + s^- = x_q$

$e\lambda = 1$

$\lambda, s^+, s^- \geq 0$

DMU_q is said to be additive efficient iff $s^+ = s^- = 0$

Note: DMU_q is ADD efficient iff it is BCC efficient.

4.8.6 Super Efficiency (SE) Model

Data Envelopment Analysis (DEA) evaluates the relative efficiency of decision-making units (DMUs) but does not allow for a ranking of the efficient units themselves. A modified version of DEA called super-efficiency model was introduced by Andersen and Andersen (1993). The super-efficiency (SE) model is identical to the standard model, except that the unit under evaluation is excluded from the reference set. This model has been used in ranking efficient units, identifying outliers, sensitivity and stability analysis, measuring productivity changes, and solving two-player games. This model can result in values which are regarded as according to the DMU under evaluation being "super-efficient". These values are then used to rank the DMU's and thereby eliminate some of the ties that occur for efficient DMU's.

Excluding the column vector correspond to DMUq from the LP coefficients matrix of model BCC Output Oriented Model, super-efficiency model is defined as follows:

Output oriented SE model:

Maximize ϕ

Subject to $\sum_{j=1, j\neq q}^{n} \lambda_j x_j + s^- = x_q$

$\sum_{j=1, j\neq q}^{n} \lambda_j y_j - s^+ = \phi\, y_q$

$\phi, \lambda_j, s^-, s^+ \geq 0$

Input oriented SE model:

Minimize θ

Subject to $\sum_{j=1, j\neq q}^{n} \lambda_j x_j + s^- = \theta\, x_q$

$\sum_{j=1, j\neq q}^{n} \lambda_j y_j - s^+ = y_q$

$\phi, \lambda_j, s^-, s^+ \geq 0$ for $j \neq q$

For SE-CCR append nothing.

For SE-BCC append $\sum_{j=1, j\neq q}^{n} \lambda_j = 1$

Notice that the vectors x_q, y_q are omitted from the expression on the left-hand side in the constraints. The data associated with the DMU_q being evaluated on the right-hand side of the constraints is therefore omitted from the production possibility set. Note that in the output-oriented version, the optimal $\phi^* = 1/\theta^*$.

Inefficient DMUs are assigned an index of efficiency less than 1 that could be interpreted as the minimum increase in output vector that is required to make a DMU efficient. Efficient DMUs have an index of efficiency equal to or more than 1. It represents the maximum possible proportional decrease in an output vector retaining DMU efficiency. It is worth emphasizing that we can solve the proposed super-efficiency model to find efficient DMUs as well as rank them. This derives from this fact that efficient DMUs have efficiency score more than or equal to 1. Therefore, DMUs with super-efficiency score greater than 1 are efficient.

Other uses of this approach are also proposed. Wilson(1993) suggest 2 uses of these measures in which each DMU is ranked according to its influence in either or both of the following 2 senses:

- The no. of observations that experience a change in their measure of technical efficiency as a result of these eliminations from the solution set., and
- The magnitude of these changes.

There are troubles with these “super-efficiency” measures which can range from a lack of units invariance for these measures and extend to the non-solution possibilities when convexity constraints are to be dealt as in the BCC model. However, the underlying concept is important so we shall review this approach to ranking the DMU’s.

CHAPTER 5

IMPLEMENTATION OF THE STUDY

Implementation of the study was conducted for all the Reliance Smart and Reliance Fresh stores located in Delhi NCR and mathematical DEA models was structured based on a real-life problem.

Retail sector is a dynamic sector and the changes in inputs or outputs do not affect the other linearly. In other words, changing the values of inputs do not cause a change in outputs in the same amount. Therefore, a model which allows variable return to scale is needed because we could not assume that there were no economies of scale for the efficiency of stores. From this point of view, BCC model is more appropriate for retail sector.

Furthermore, It is argued that, in competitive markets, it is desirable to apply the output-oriented DEA model because private firms operating in a competitive market environment aim to maximize their outputs rather than minimize their inputs.

For this reason, OUTPUT-oriented BCC model was chosen.

In the following subsections the data collection for the analysis is provided followed by the selection of inputs and outputs for the study and the results after implementing the DEA models as described in the previous section are given.

5.1 Data Collected

The focal organization for this study is the largest retailer in India in terms of revenue, with over 3000 stores. The DMUs for this study are the individual stores. In DEA, the homogeneity of DMUs should be assumed. Therefore, to ensure homogeneity as much as possible, we selected stores through the following process.

First, in order to secure regional homogeneity, we selected stores located in Delhi NCR, the capital city of India.

In Delhi NCR, Reliance Retail currently has 19 Reliance Smart stores and 45 Reliance Fresh stores in different locations. In this study, separate analysis is done for Reliance Smart and Reliance Fresh stores because of their difference in operations to ensure homogeneity.

The data points in the data represents the monthly record for the month of January, 2020.

5.2 <u>Selection of Inputs and Outputs in the Model</u>

As mentioned in the literature overview chapter, there are many different inputs and outputs related to retail sector that can be used to evaluate efficiencies of DMU's.

In order to apply DEA successfully, the choice of input and output variables is critical. Input and output variables for DEA should be chosen such that they accurately reflect the retail firm's goals, objectives, and sales situation.

Suppose that there are n DMUs. Some of the common input and output measures for each DMU can be selected as follows:

- Numerical data are available for each input and output with the data assumed to be positive for all DMU's. if there is any variable in the model which consists of negative values, the values should be converted into positive values by adding a common number which can make all the negatives into positive values.
- The items (inputs, outputs and choice of DMUs) should reflect the analyst's or a manager's interest in the components that will enter into a relative evaluation of DMUs.
- In principle, smaller inputs are preferable and larger output amounts are preferable so that the efficiency scores should reflect these principles.
- The measurement units of the different inputs and outputs need not be congruent. Some may involve the number of persons, or areas of floor space, money expended etc. The optimal values for efficiency is independent of the units in which the inputs and outputs are measured but provided that these units are same for every DMU. This is called the Units Invariance property.

In this study, the input and output variables were selected with consideration of the variables used in previous studies and the key performance indicators (KPIs) used within the company. This is intended to include variables that are commonly used in retailers' efficiency analyses, as well as variables that reflect the company's strategic goals, sales situation, and performance management

Through this process, the following input and output variables are used:

(Note that all the rupee value variables are in Lakhs for the month of January,2020)

<u>For Reliance Smart Stores</u>, 3 inputs and 3 outputs were selected

Inputs:

- Rental Cost: Cost incurred by the businesses to utilize the property or location for doing their operations.
- Staff Cost: Salaries and benefits related to the payment of personnel per month.

- Utilities cost: It includes the monthly expenditures of electricity, heat(gas), sewer and water.

Outputs:

- Sales: It contains amount of sales for each store. It is one of the most important KPIs in most companies. In this study, the daily average sales revenue was used.
- EBITDA: It stands for Earnings before Interest, Tax, Depreciation and Amortization. It is a measure of a company's overall financial performance.
- Ratings: Customer rating for a particular store at a five-point scale.

For Reliance Fresh Stores, 6 inputs and 5 outputs were selected *****Note below.***

Inputs:

- Rental Cost: Cost incurred by the businesses to utilize the property or location for doing their operations.
- Staff Cost: Salaries and benefits related to the payment of personnel per month.
- Utilities cost: It includes the monthly expenditures of electricity, heat(gas), sewer and water.
- Sales Promotion and Advertising Cost: An activity or series of activities that boost the sales of the product. Examples include discount coupons, temporary price reductions etc.
- Housekeeping and Pest Control Cost: Cost of housekeeping and maintaining the control of pests in stores which are outsourced by the organisation.
- Repairs and Maintenance Cost: Cost incurred to bring an asset back to an earlier condition or to keep the asset operating at its present condition.

Outputs:

- Sales: It contains amount of sales for each store. It is one of the most important KPIs in most companies. In this study, the daily average sales revenue was used.
- NOB: It stands for No of Bills in a month.
- ABV: It stands for Average Basket Value of each customer per month.
- EBITDA: It stands for Earnings before Interest, Tax, Depreciation and Amortization. It is a measure of a company's overall financial performance.
- Ratings: Customer rating for a particular store at a five-point scale.

From the above input and output variables we assume that the input variable of Rental cost over which the store manager had little influence, but greatly impact the efficiency of their store. Thus, this variable is assumed to be a non-controllable variable in the analysis.

Also, the output variable of EBITDA consist of some negative values and since, DEA needs all the positive values in the analysis, we add a constant value to this variable in order to make all the data points in this variable a positive value.

Note: DEA results are influenced by the size of the sample. In the envelopment model, the number of degrees of freedom will increase with the number of DMUs and decrease with the number of inputs and outputs. A rough rule of thumb in the envelopment model is as follows:

n>=max(mxs,3(m+s))

Where n = number of DMUs, m = number of inputs and s = number of outputs

If the number of DMUs is less than the product of the number of inputs and outputs or less than 3 times their sum, a large portion of the DMUs will be identified as efficient and the efficiency discrimination among the DMUs is questionable due to an inadequate number of degrees of freedom. This situation is analogous to when a manager notes that almost every store can excel on some performance criteria if a large enough array of criteria are considered. Thus, the selection of input and output variables is crucial for the successive application of DEA

The use of input and output efficiency measures for practical managerial evaluative purposes, however, raises additional problems.

- Relevant individual store differences must be considered within the model to take into account advantages and disadvantages of particular stores.
- Motivating and rewarding store personnel is much more effective when specific practices can be observed and transferred to other stores. Efficient practices should be identified, described, and used as benchmarks for less efficient stores.
- A distinction must be made between resources under the control of store personnel vs. those they have little or no influence over e.g., Rental Cost in our case.
- More than one outcome usually needs to be considered because stores are responsible for multiple and sometimes conflicting performance measures e.g., sales and profits. An appropriate balance must be achieved so that one measure does not dominate the evaluation process.

5.3 Descriptive Statistics for Input and Output Variables

The descriptive statistics for input and output variables used in the model are displayed as below:

For Reliance Smart Stores:

Variables	vars	n	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se
Rental Cost	1	19	12.00	4.86	11.82	12.01	4.88	3.33	20.51	17.18	-0.21	-1.04	1.11
Staff Cost	2	19	11.91	4.01	10.34	11.74	4.03	6.62	20.04	13.42	0.60	-1.04	0.92
Utilities Cost	3	19	3.73	1.62	3.70	3.67	1.96	1.53	7.01	5.48	0.40	-1.11	0.37
Sales	1	19	284.18	152.22	274.86	265.78	100.46	89.20	791.84	702.64	1.77	3.89	34.92
EBITDA	2	19	-8.52	17.33	-11.99	-10.04	15.61	-34.08	42.90	76.98	1.13	1.67	3.98
Ratings	3	19	4.09	0.16	4.10	4.11	0.15	3.70	4.30	0.60	-1.27	1.09	0.04

For Reliance Fresh Stores:

Variables	vars	n	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se
Rental Cost	1	45	2.49	1.38	2.16	2.24	0.77	0.97	8.04	7.07	2.11	5	0.21
Staff Cost	2	45	3.51	0.8	3.34	3.42	0.62	2.19	6.08	3.89	1.24	1.78	0.12
Utilities Cost	3	45	1.2	0.4	1.1	1.16	0.33	0.57	2.39	1.82	0.86	0.22	0.06
Sales and Promotion Cost	4	45	0.42	0.07	0.42	0.41	0.06	0.21	0.57	0.36	-0.05	0.62	0.01
House Keeping and Pest Control Cost	5	45	0.27	0.05	0.27	0.26	0.01	0.19	0.53	0.34	3	14.54	0.01
Repairs and Maintainance Cost	6	45	0.35	0.14	0.3	0.33	0.1	0.14	0.72	0.58	0.99	0.07	0.02
Sales	1	45	88.33	24.56	83.84	85.84	19.97	52	167.31	115.31	1.03	1.1	3.66
NOB	2	45	676.69	135	661	675.19	155.67	403	952	549	0.16	-0.84	20.12
ABV	3	45	462.8	106.56	434	456.11	112.68	302	690	388	0.49	-0.96	15.89
EBITDA	4	45	-0.47	2.73	-0.62	-0.75	2.49	-4.15	8.32	12.47	0.94	0.82	0.41
Ratings	5	45	3.85	0.2	3.9	3.88	0.15	3	4.1	1.1	-2.03	5.84	0.03

5.4 Correlation Matrix for Input and Output Variables

Correlation matrix of the input and output variables used in the model are displayed as below

For Reliance Smart Stores:

Correlation	Rental Cost	Staff Cost	Utilities Cost	Sales	EBITDA	Ratings
Rental Cost	1					
Staff Cost	0.2636	1				
Utilities Cost	0.2640	0.8265	1			
Sales	0.0063	0.6159	0.4463	1		
EBITDA	-0.4685	0.0481	-0.1319	0.7565	1	
Ratings	0.3830	0.6054	0.6542	0.4435	-0.0250	1

For Reliance Fresh Stores:

-

Correlation	Rental Cost	Staff Cost	Utilities Cost	Sales and..	House K..	Repairs..	Sales	NOB	ABV	EBITDA	Ratings
Rental Cost	1										
Staff Cost	0.4965	1									
Utilities Cost	-0.1246	-0.0642	1								
Sales and Promotion Cost	0.4142	-0.0278	0.0873	1							
House Keeping and Pest Control Cost	0.0523	0.5839	0.0523	-0.2598	1						
Repairs and Maintainance Cost	-0.0739	-0.1115	0.0033	0.0845	-0.1244	1					
Sales	0.6212	0.7121	0.0566	0.3916	0.3725	-0.0245	1				
NOB	0.3136	0.5890	0.1762	0.1646	0.2243	0.1042	0.5655	1			
ABV	0.4325	0.2807	-0.0488	0.3171	0.1867	-0.1379	0.6703	-0.2108	1		
EBITDA	0.2390	0.5092	-0.1006	0.1946	0.2928	-0.1351	0.7885	0.3941	0.5780	1	
Ratings	0.0625	0.2477	0.2017	-0.0418	0.3187	-0.3482	0.3367	0.1427	0.3059	0.3776	1

Selection of input and output variables should be such that, they should be reflecting the efficiency of store. To rightly select the input and output variables for the study Pearson correlation test has been used.

In this study, we have assumed that a correlation is considered to be strong if its value is above 0.85. Thus, as we observe the entire matrix given above cell by cell we do not find any strong correlations among the variables that can possibly hinder the further analysis.

5.5 Implementing the DEA Models

In this phase of the process was allow the DEA program to assign weights to inputs and outputs. DEA assumes complete substitutability of inputs and outputs and will assign weights to derive the highest efficiency score possible for each unit analysed.

In constructing the DEA model, a strategy of continuous involvement of top management was utilized to maintain their understanding of the process and results. At each step of the process, the executive team was asked to evaluate the reasonableness of the results. When the results were found to be unrealistic and not representative of top management’s decisions, additional input was sought from the executive team and incorporated into the model.

Implementation of the DEA models is conducted in R programming language. Refer to the appendix at the end of this project for its code along with the explanations for each model implementation. Also, the traditional way of writing the code as in LINGO software is provided in appendix for a clear understanding.

The numerical results after implementing various models explained in the earlier sections are given in the following subsections:

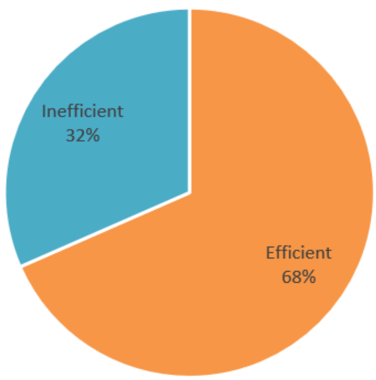
5.5.1 BCC Efficiency

BCC Output Oriented DEA model is used to find the efficiency values under variable returns to scale assumption. Also, since we have Rental Cost as an input variable in the model, we let the model treat this variable as a non controllable input. The nature column is used to denote whether the corresponding DMU is efficient based upon it efficiency score. Along with this, a pie chart and table is shown to represent the frequency and percentage of both efficient and inefficient stores in our study.

For Reliance Smart Stores:

Store Code	DMU- Store Name	BCC Efficiency	Nature
2364	Jharsa Road	0.98256	Inefficient
2995	Meenakshi Garden	1	Efficient
6205	Crown Interiors Mall	1	Efficient
6239	Dwarka	1	Efficient
6701	Dlf Mega Mall	1	Efficient
6708	Ansal Plaza	1	Efficient
6727	Bmg Mall	1	Efficient
T913	Jaipuria Mall	1	Efficient
T915	Signature Street	1	Efficient
T918	Cloud 9 Ghaziabad	1	Efficient
TH86	Beta Plaza	0.98818	Inefficient
TL30	Vikaspuri	1	Efficient
TP06	Aggarwal Prestige Mall	1	Efficient
TU21	G3S Mall Rohini	1	Efficient
TH89	Aero Tower	0.99151	Inefficient
TU11	Smart Najafgarh	0.98460	Inefficient
TC74	Iris Broadway	0.99560	Inefficient
TB22	Galaxy Diamond Plaza	0.97222	Inefficient
TDC1	Smart Palwal	1	Efficient

BCC Efficiency for Reliance Smart Stores



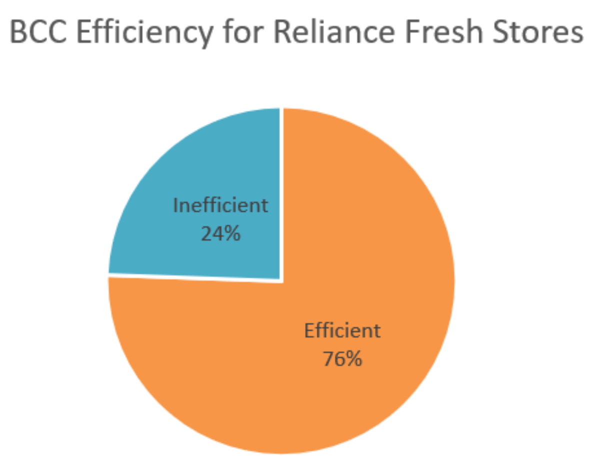
Nature	Count	Percentage
Efficient	13	68.42%
Inefficient	6	31.58%
Grand Total	**19**	**100.00%**

From the table and pie chart shown above, it is evident that the stores with 6 stores located at Jharsa Road, Beta plaza, Aero Tower, Smart Najafgarh, Iris Broadway, and Galaxy Diamond Plaza are relatively inefficient and they need to improve their output to be as efficient as the rest of them.

For Reliance Fresh Stores:

Store Code	DMU- Store Name	BCC efficiency	Nature
2072	Narela	1	Efficient
2350	Nit 1&2	1	Efficient
2355	Inderpuri	1	Efficient
2356	Kakrola	1	Efficient
2360	Tamur Nagar	1	Efficient
2363	Pataudi Road	1	Efficient
2365	Huda Mrkt Sec 23	1	Efficient
2366	Shubham Hall	1	Efficient
2367	Shahnai Banquet	1	Efficient
2368	Sargar Villa	1	Efficient
2380	Mauj Purjhonda	1	Efficient
2425	Mohan Garden	1	Efficient
2429	Bali Nagar	0.96845	Inefficient
2440	Nit 3	1	Efficient
2441	Huda Mrkt Sec 28	1	Efficient
2442	Dayanand Colony	1	Efficient
2507	Mansarovar Garden	1	Efficient
2508	Gangavihar	1	Efficient
2513	Dilshad Garden	1	Efficient
2605	South Najafgarh	0.95122	Inefficient
2608	Shasti Park	1	Efficient
2609	Arjun Nagar	0.93755	Inefficient
2610	Madhurmilan	0.93529	Inefficient

Store Code	DMU- Store Name	BCC efficiency	Nature
2611	Paschim Vihar	0.99542	Inefficient
2614	North Ghonda	1	Efficient
2625	Madhuban Road	0.99176	Inefficient
2635	Tuglaquabad	0.96738	Inefficient
2636	Fateh Nagar	0.94232	Inefficient
2648	Lado Sarai	1	Efficient
2651	Dayal Bagh Road	1	Efficient
2756	Jittar Nagar	1	Efficient
2761	Sultanputi Nangloi Road	1	Efficient
2762	Acharya Niketan	1	Efficient
2763	Khichripur East	1	Efficient
2766	Nangloi Najafgarh	0.96879	Inefficient
2799	Savitri Nagar	1	Efficient
2800	Sector 31, Gurgaon	1	Efficient
2801	Huda Mrkt 2, Sec 4 , Gurgaon	1	Efficient
2844	Kathmandi	1	Efficient
2845	PLA Hisar	1	Efficient
2856	Hassan Pur	0.96586	Inefficient
2865	Mandoli Main Road	1	Efficient
3062	Nagloi Saiyed	0.93585	Inefficient
3079	Ansal Plaza Palam	1	Efficient
TA90	Dashmesh Palace	1	Efficient



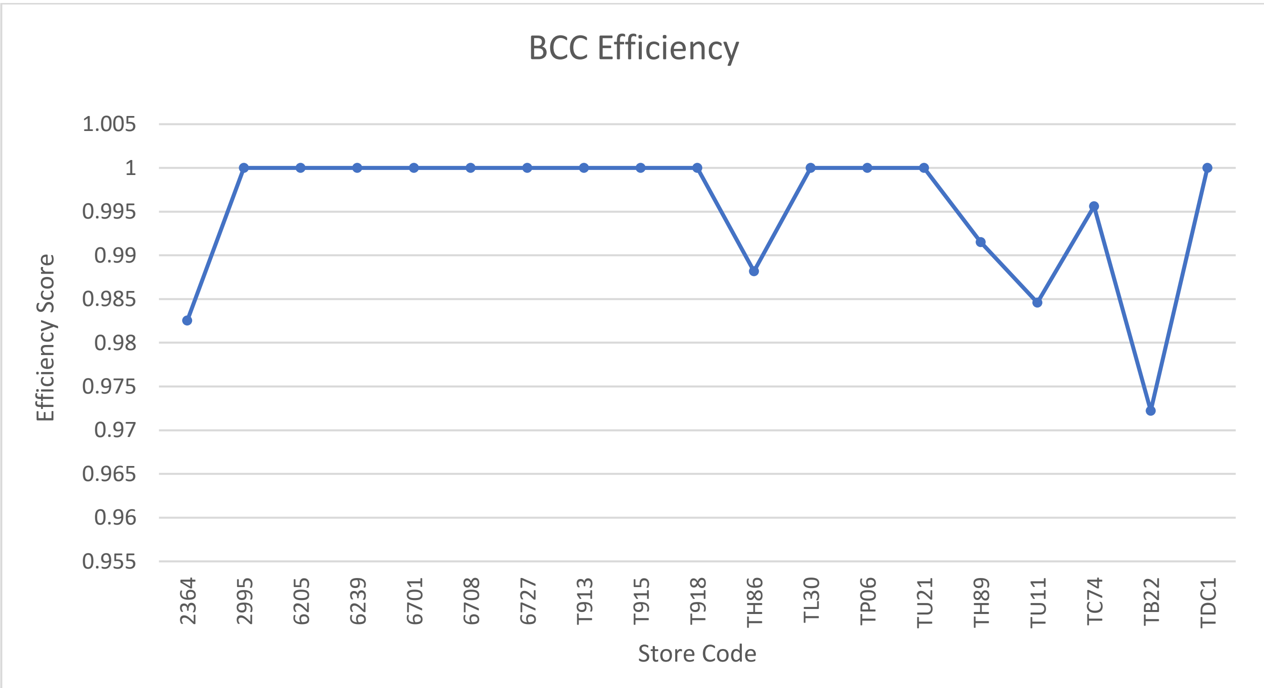
Nature	Count	Percentage
Efficient	34	75.56%
Inefficient	11	24.44%
Grand Total	**45**	**100.00%**

From the table it is evident that the stores with 11 stores located at Bali Nagar, South Najafgarh, Arjun Nagar, Madhurmilan, Paschim Vihar, Madhuban Road, Tuglaquabad, Fateh Nagar, Nagloi Najafgarh, HassanPur, Nagloi Saiyed are relatively inefficient and they need to improve their output to be as efficient as the rest of them.

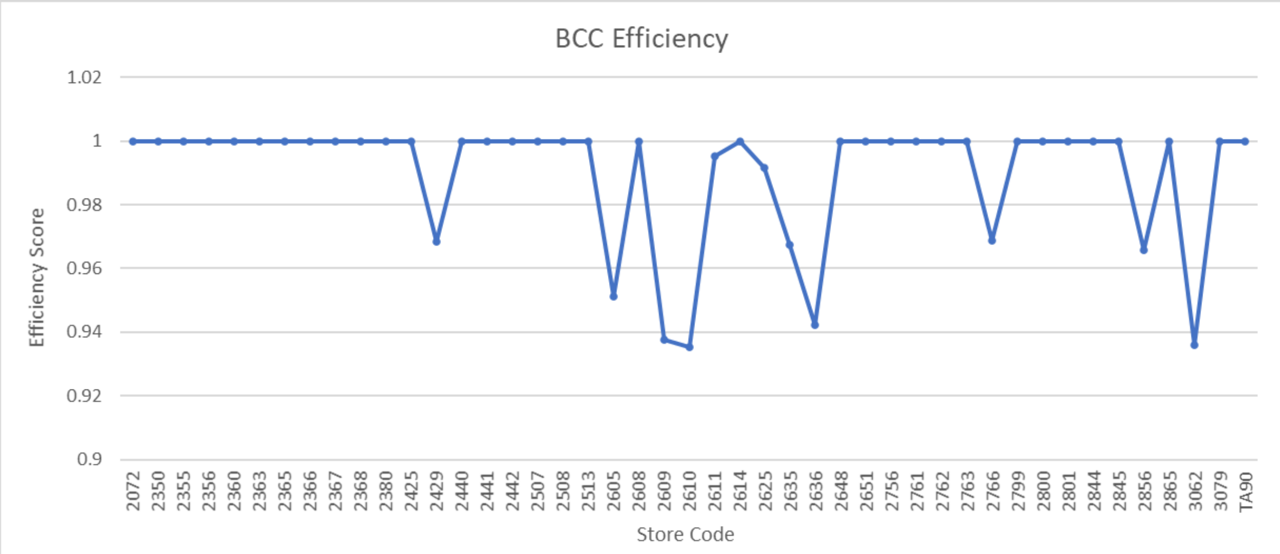
5.5.2 <u>Graphical Representation of BCC Efficiency Scores</u>

The following graphs depicts the efficiency score of stores with output orientation under variable returns to scale. Thus, the ones with a drop in the line of efficiency score being equal to 1 and those who needs improvement to become as efficient as the rest of them are all efficient stores.

<u>For Reliance Smart Stores:</u>



For Reliance Fresh Stores:



5.5.3 Peers Table

Peers table extracts the reference set for each DMU along with weights for each of its peers. The column headings are used to represent the store code rather than the store name to make the results understandable and clear.

Peers in the tables below represent the combination of efforts that the individual store needs to perform to achieve the efficiency score of 1. Fellows with the technical efficiency of 1 do not have others in their peer group.

For Reliance Smart Stores:

DMU- Store Name	Store Code	TP06	6708	6727	T918	6205	6701	6239	TU21	2995	T915
Jharsa Road	**2364**	0.2711	0	0	0.0838	0	0.645	0	0	0	0
Meenakshi Garden	**2995**	0	0	0	0	0	0	0	0	1	0
Crown Interiors Mall	**6205**	0	0	0	0	1	0	0	0	0	0
Dwarka	**6239**	0	0	0	0	0	0	1	0	0	0
Dlf Mega Mall	**6701**	0	0	0	0	0	1	0	0	0	0
Ansal Plaza	**6708**	0	1	0	0	0	0	0	0	0	0
Bmg Mall	**6727**	0	0	1	0	0	0	0	0	0	0
Jaipuria Mall	**T913**	0	0	0	0	0	0	0	0	0	0
Signature Street	**T915**	0	0	0	0	0	0	0	0	0	1
Cloud 9 Ghaziabad	**T918**	0	0	0	1	0	0	0	0	0	0
Beta Plaza	**TH86**	0	0	0.5286	0.4061	0.0422	0	0	0	0	0.0231
Vikaspuri	**TL30**	0	0	0	0	0	0	0	0	0	0
Aggarwal Prestige Mall	**TP06**	1	0	0	0	0	0	0	0	0	0
G3S Mall Rohini	**TU21**	0	0	0	0	0	0	0	1	0	0
Aero Tower	**TH89**	0.3572	0	0	0.3183	0	0.3244	0	0	0	0
Smart Najafgarh	**TU11**	0	0	0	0	0	0	0.8284	0.1716	0	0
Iris Broadway	**TC74**	0	0.1259	0.4011	0	0.1026	0	0	0	0.0061	0.3643
Galaxy Diamond Plaza	**TB22**	0.2729	0	0	0.5559	0	0	0.1712	0	0	0
Smart Palwal	**TDC1**	0	0	0	0	0	0	0	0	0	0

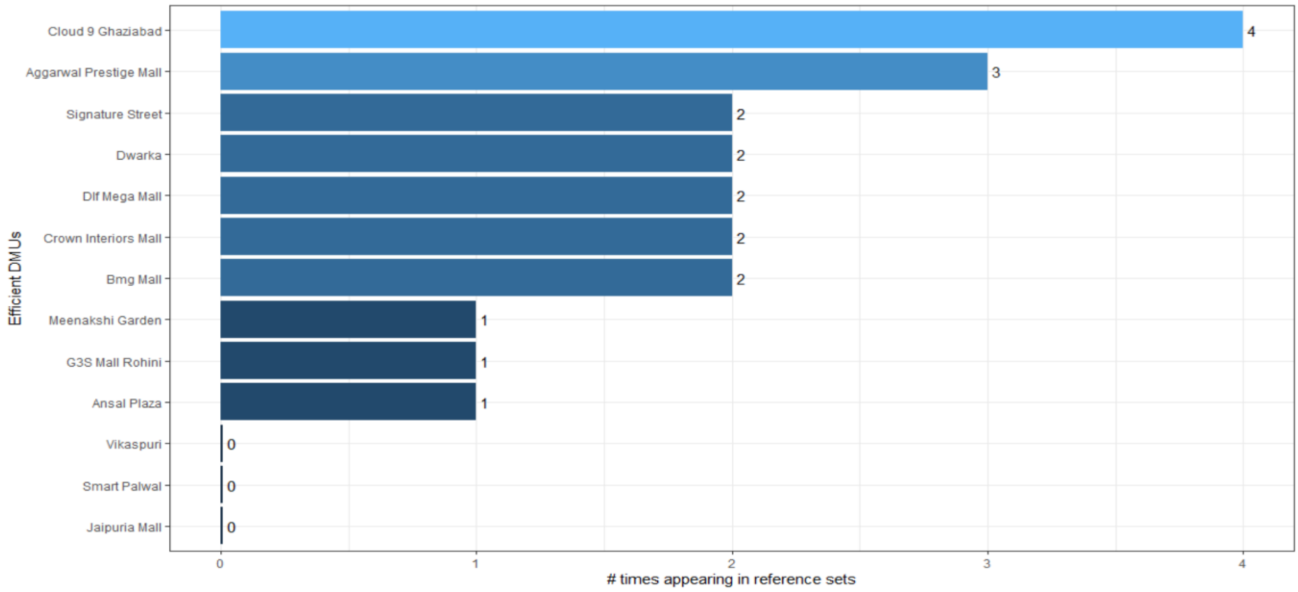
For Reliance Fresh Stores:

DMU- Store Name	Store Code	3079	TA90	2651	2513	2508	2365	2355	2356	2844	2763	2648	2865	2380	2072	2440	2614	2845	2368	2799	2608	2360
Narela	2072	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Nit 1&2	2350	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inderpuri	2355	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kakrola	2356	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Tamur Nagar	2360	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pataudi Road	2363	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Huda Mrkt Sec 23	2365	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shubham Hall	2366	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shahnai Banquet	2367	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sargar Villa	2368	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Mauj Purjhonda	2380	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Mohan Garden	2425	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bali Nagar	2429	0	0	0	0	0	0	0.2436	0	0	0	0.1474	0	0.261	0.0089	0.0105	0	0.1362	0	0.1547	0	0.0376
Nit 3	2440	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Huda Mrkt Sec 28	2441	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dayanand Colony	2442	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mansarovar Garden	2507	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gangavihar	2508	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dilshad Garden	2513	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
South Najafgarh	2605	0	0.0175	0	0	0	0	0	0	0	0	0	0	0.5455	0	0	0	0	0	0.4371	0	0
Shasti Park	2608	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Arjun Nagar	2609	0.1692	0	0	0	0	0.0115	0	0	0	0	0	0	0.3938	0.1073	0	0	0.0547	0.2636	0	0	0
Madhurmilan	2610	0.1269	0	0	0	0	0	0.6794	0	0	0	0.1147	0	0	0.0335	0	0	0	0	0	0.0456	0
Paschim Vihar	2611	0	0	0.1198	0	0	0.1048	0	0	0.1881	0	0	0.5223	0	0.0064	0	0	0.0586	0	0	0	0
North Ghonda	2614	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Madhuban Road	2625	0	0	0	0	0	0.1188	0	0.05	0	0	0	0	0.4219	0.1461	0.1499	0	0	0	0	0.1134	0
Tuglaquabad	2635	0.1855	0	0	0	0	0	0	0	0	0	0	0	0	0.1686	0	0.1452	0.3361	0	0.1645	0	0
Fateh Nagar	2636	0.1088	0	0	0	0.0233	0.0416	0	0	0	0.3064	0	0	0.2151	0	0	0.0435	0.2612	0	0	0	0
Lado Sarai	2648	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Dayal Bagh Road	2651	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jittar Nagar	2756	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sultanputi Nangloi Road	2761	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acharya Niketan	2762	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Khichripur East	2763	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Nangloi Najafgarh	2766	0.1022	0	0	0.0965	0	0	0	0	0	0.0681	0	0	0	0.2776	0	0	0.4555	0	0	0	0
Savitri Nagar	2799	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Sector 31, Gurgaon	2800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Huda Mrkt 2, Sec 4 , Gur	2801	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kathmandi	2844	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
PLA Hisar	2845	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Hassan Pur	2856	0	0	0	0	0	0.0533	0	0	0	0.2167	0	0	0.2273	0.1861	0	0.1117	0.2048	0	0	0	0
Mandoli Main Road	2865	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Nagloi Saiyed	3062	0	0	0	0	0.2891	0	0	0	0.0748	0	0	0	0.5443	0.0311	0	0	0.0606	0	0	0	0
Ansal Plaza Palam	3079	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dashmesh Palace	TA90	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

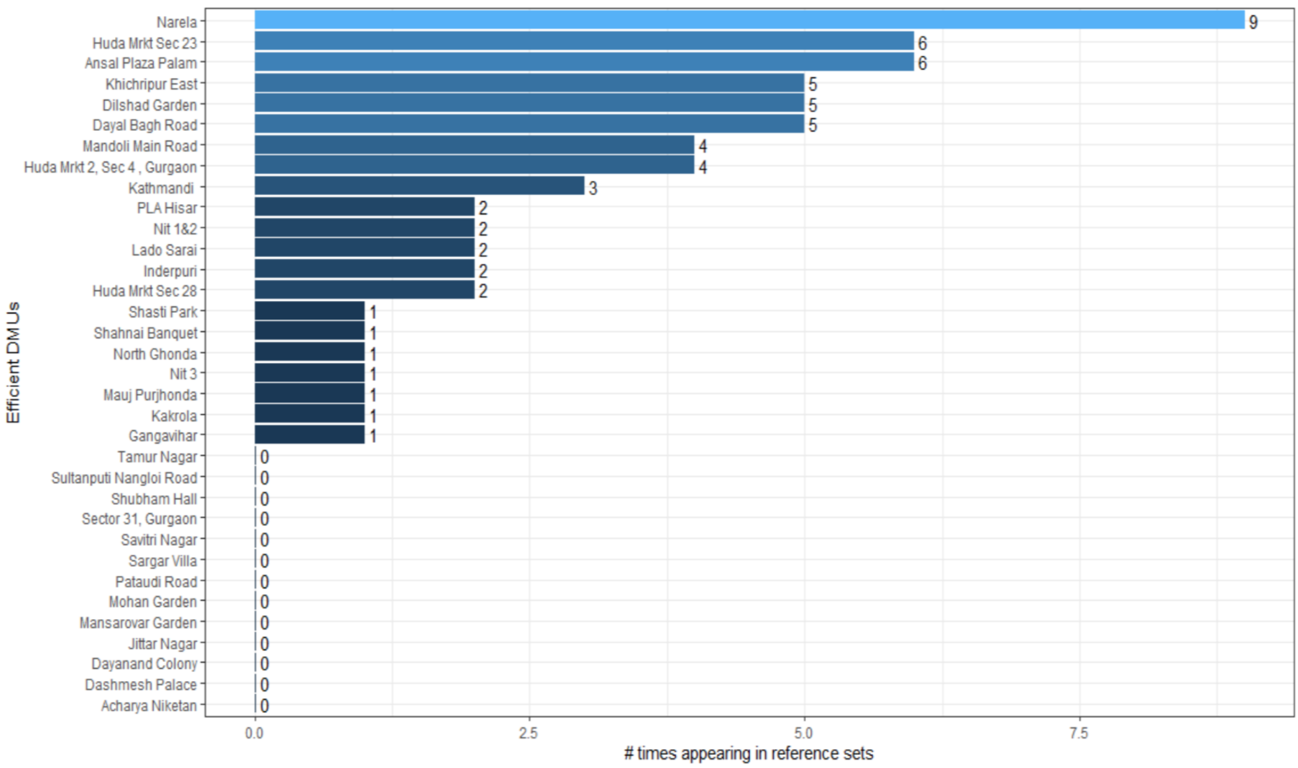
5.5.4 Graphical Representation of Peers Count

The following graphs are used to display then number of times an efficient DMU is a part of the inefficient DMUs reference set.

For Reliance Smart Stores:



For Reliance Fresh Stores:

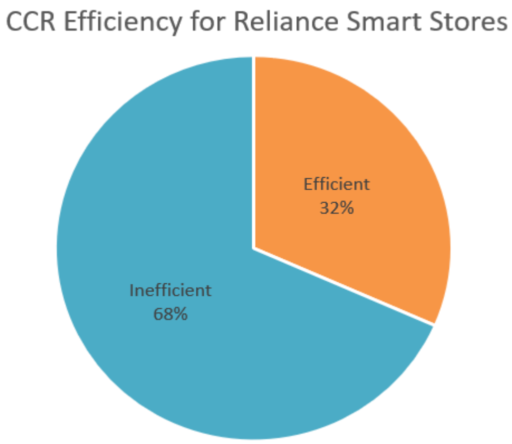


5.5.5 CCR Efficiency

The efficiency scores for each DMU are calculated under the assumption of constant returns to scale are shown (for the comparison with BCC efficiency results) in the table below along with the pie chart and table representing the frequency and percentage of efficient and inefficient DMU's. Also, since we have Rental Cost as an input variable in the model, we let the model treat this variable as a non controllable input. The nature column is used to denote whether the corresponding DMU is efficient based upon it efficiency score. Note that the number of efficient DMU's in CCR model are less than those in the BCC model as it is more restricted according to the variable returns to scale.

For Reliance Smart Stores:

Store Code	DMU- Store Name	CCR Efficiency	Nature
2364	Jharsa Road	0.86060	Inefficient
2995	Meenakshi Garden	1	Efficient
6205	Crown Interiors Mall	1	Efficient
6239	Dwarka	0.68203	Inefficient
6701	Dlf Mega Mall	1	Efficient
6708	Ansal Plaza	1	Efficient
6727	Bmg Mall	1	Efficient
T913	Jaipuria Mall	0.81362	Inefficient
T915	Signature Street	0.89265	Inefficient
T918	Cloud 9 Ghaziabad	0.94696	Inefficient
TH86	Beta Plaza	0.81579	Inefficient
TL30	Vikaspuri	0.59395	Inefficient
TP06	Aggarwal Prestige Mall	0.65637	Inefficient
TU21	G3S Mall Rohini	0.68093	Inefficient
TH89	Aero Tower	0.78946	Inefficient
TU11	Smart Najafgarh	0.43162	Inefficient
TC74	Iris Broadway	0.89821	Inefficient
TB22	Galaxy Diamond Plaza	0.66586	Inefficient
TDC1	Smart Palwal	1	Efficient



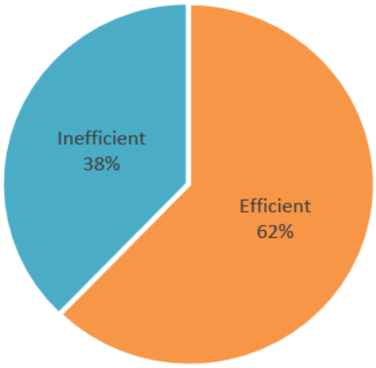
Nature	Count	Percentage
Efficient	6	31.58%
Inefficient	13	68.42%
Grand Total	**19**	**100.00%**

For Reliance Fresh Stores:

Store Code	DMU- Store Name	CCR Efficiency	Nature
2072	Narela	1	Efficient
2350	Nit 1&2	1	Efficient
2355	Inderpuri	1	Efficient
2356	Kakrola	1	Efficient
2360	Tamur Nagar	1	Efficient
2363	Pataudi Road	1	Efficient
2365	Huda Mrkt Sec 23	1	Efficient
2366	Shubham Hall	0.99082	Inefficient
2367	Shahnai Banquet	1	Efficient
2368	Sargar Villa	1	Efficient
2380	Mauj Purjhonda	1	Efficient
2425	Mohan Garden	0.98311	Inefficient
2429	Bali Nagar	0.93414	Inefficient
2440	Nit 3	1	Efficient
2441	Huda Mrkt Sec 28	0.90525	Inefficient
2442	Dayanand Colony	0.99557	Inefficient
2507	Mansarovar Garden	0.99417	Inefficient
2508	Gangavihar	1	Efficient
2513	Dilshad Garden	1	Efficient
2605	South Najafgarh	0.80216	Inefficient
2608	Shasti Park	1	Efficient
2609	Arjun Nagar	0.85154	Inefficient
2610	Madhurmilan	0.93107	Inefficient

Store Code	DMU- Store Name	CCR Efficiency	Nature
2611	Paschim Vihar	0.97673	Inefficient
2614	North Ghonda	1	Efficient
2625	Madhuban Road	0.98567	Inefficient
2635	Tuglaquabad	0.90920	Inefficient
2636	Fateh Nagar	0.92194	Inefficient
2648	Lado Sarai	1	Efficient
2651	Dayal Bagh Road	1	Efficient
2756	Jittar Nagar	1	Efficient
2761	Sultanputi Nangloi Road	1	Efficient
2762	Acharya Niketan	0.98101	Inefficient
2763	Khichripur East	1	Efficient
2766	Nangloi Najafgarh	0.95203	Inefficient
2799	Savitri Nagar	1	Efficient
2800	Sector 31, Gurgaon	1	Efficient
2801	Huda Mrkt 2, Sec 4 , Gurgaon	1	Efficient
2844	Kathmandi	1	Efficient
2845	PLA Hisar	1	Efficient
2856	Hassan Pur	0.95522	Inefficient
2865	Mandoli Main Road	1	Efficient
3062	Nagloi Saiyed	0.86322	Inefficient
3079	Ansal Plaza Palam	1	Efficient
TA90	Dashmesh Palace	1	Efficient

CCR Efficiency for Reliance Fresh Stores



Nature	Count	Percentage
Efficient	28	62.22%
Inefficient	17	37.78%
Grand Total	**45**	**100.00%**

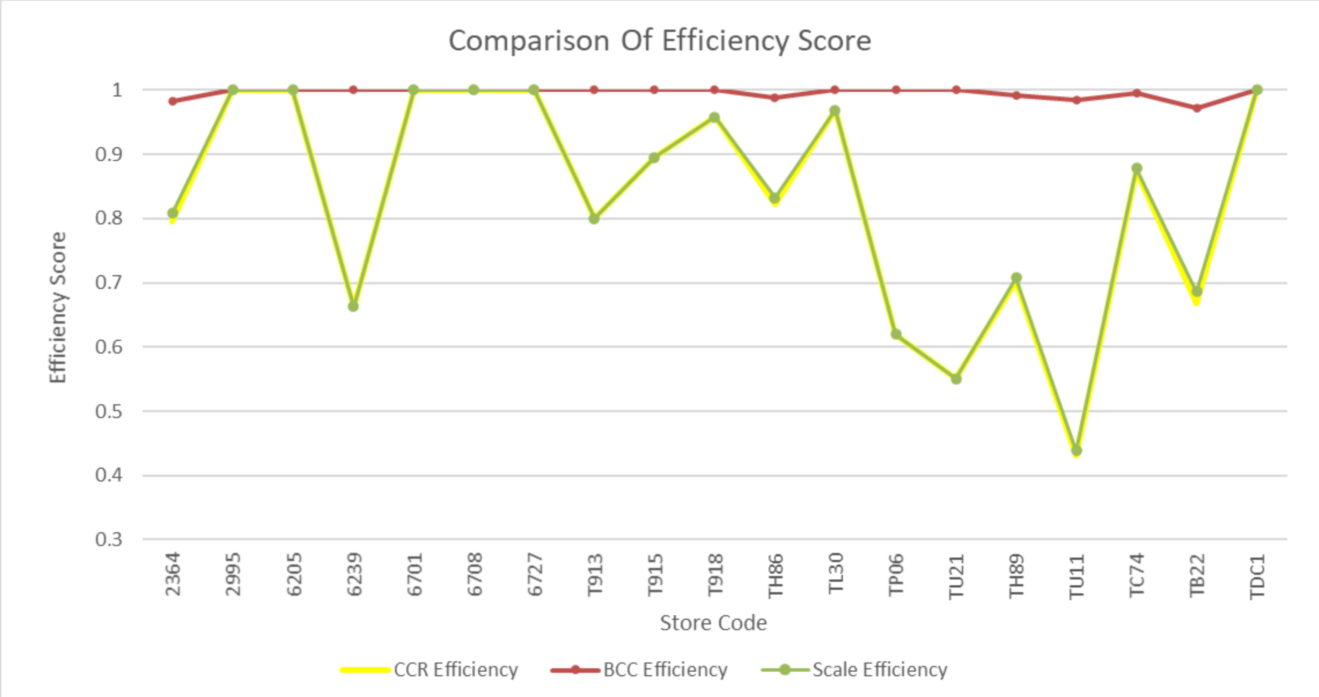
5.5.6 Scale Efficiency Model

Scale Efficiency is used to investigate the sources of inefficiency that a DMU might have, we calculate scale efficiency. As mentioned in the theory sections, the stores with CCR efficiency equal to Scale Efficiency and hence BCC efficiency of 1 are those stores which are locally efficient but not globally. These stores are those located at Dwarka, Jaipuria Mall, Signature Street, Cloud 9 Ghaziabad, Vikaspuri, Aggarwal Prestige Mall, and G3S Mall Rohini.

For Reliance Smart Stores:

Store Code	DMU- Store Name	CCR Efficiency	BCC Efficiency	Scale Efficiency
2364	Jharsa Road	0.79457	0.98256	0.80867
2995	Meenakshi Garden	1	1	1
6205	Crown Interiors Mall	1	1	1
6239	Dwarka	0.66340	1	0.66340
6701	Dlf Mega Mall	1	1	1
6708	Ansal Plaza	1	1	1
6727	Bmg Mall	1	1	1
T913	Jaipuria Mall	0.80035	1	0.80035
T915	Signature Street	0.89529	1	0.89529
T918	Cloud 9 Ghaziabad	0.95794	1	0.95794
TH86	Beta Plaza	0.82279	0.98818	0.83264
TL30	Vikaspuri	0.96865	1	0.96865
TP06	Aggarwal Prestige Mall	0.61962	1	0.61962
TU21	G3S Mall Rohini	0.55040	1	0.55040
TH89	Aero Tower	0.70160	0.99151	0.70760
TU11	Smart Najafgarh	0.43181	0.98460	0.43856
TC74	Iris Broadway	0.87459	0.99560	0.87846
TB22	Galaxy Diamond Plaza	0.66740	0.97222	0.68647
TDC1	Smart Palwal	1	1	1

We compare the above three efficiency score results by visualizing the line graph as below. Notice that the variation in the values of efficiency score in case of CCR model is higher in case of than that of BCC model whose values are close to 1 thus, the line graph for CCR model overlaps with the scale efficiency line graph.

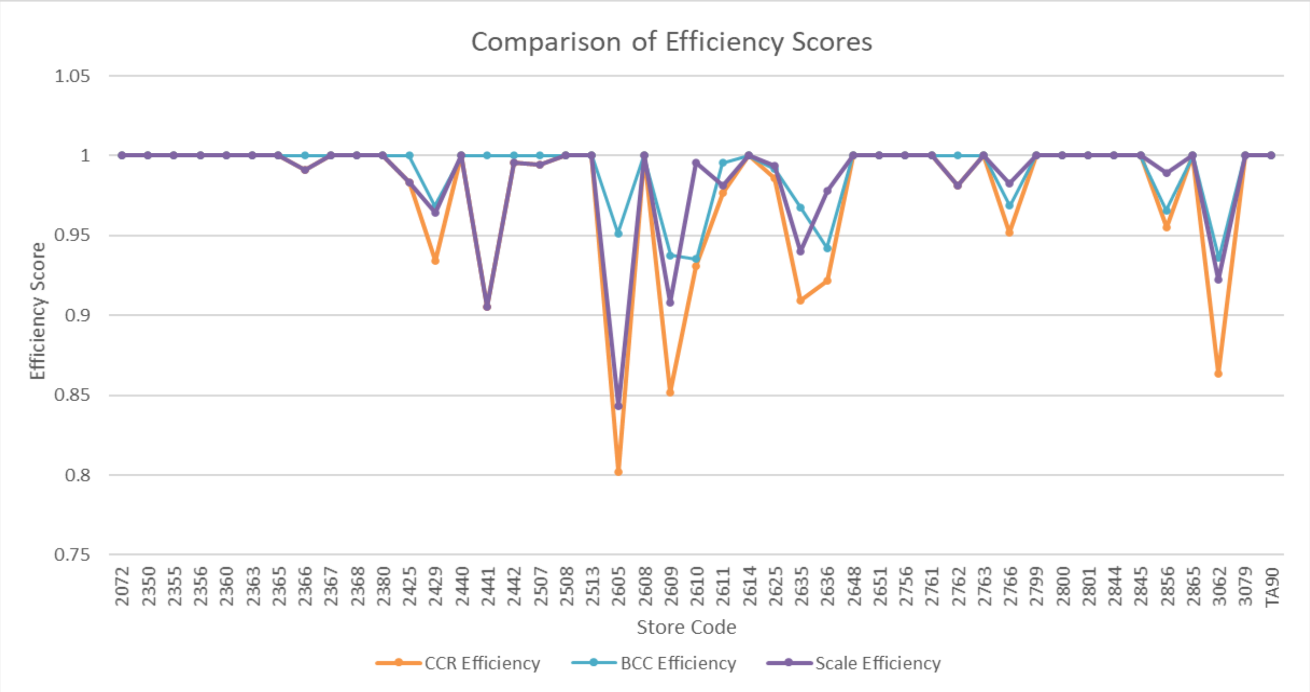


For Reliance Fresh Stores:

Store Code	DMU- Store Name	CCR Efficiency	BCC Efficiency	Scale Efficiency
2072	Narela	1	1	1
2350	Nit 1&2	1	1	1
2355	Inderpuri	1	1	1
2356	Kakrola	1	1	1
2360	Tamur Nagar	1	1	1
2363	Pataudi Road	1	1	1
2365	Huda Mrkt Sec 23	1	1	1
2366	Shubham Hall	0.99082	1	0.99082
2367	Shahnai Banquet	1	1	1
2368	Sargar Villa	1	1	1
2380	Mauj Purjhonda	1	1	1
2425	Mohan Garden	0.98311	1	0.98311
2429	Bali Nagar	0.93414	0.96845	0.96458
2440	Nit 3	1	1	1
2441	Huda Mrkt Sec 28	0.90525	1	0.90525
2442	Dayanand Colony	0.99557	1	0.99557
2507	Mansarovar Garden	0.99417	1	0.99417
2508	Gangavihar	1	1	1
2513	Dilshad Garden	1	1	1
2605	South Najafgarh	0.80216	0.95122	0.84329
2608	Shasti Park	1	1	1
2609	Arjun Nagar	0.85154	0.93755	0.90826
2610	Madhurmilan	0.93107	0.93529	0.99549

Store Code	DMU- Store Name	CCR Efficiency	BCC Efficiency	Scale Efficiency
2611	Paschim Vihar	0.97673	0.99542	0.98123
2614	North Ghonda	1	1	1
2625	Madhuban Road	0.98567	0.99176	0.99386
2635	Tuglaquabad	0.90920	0.96738	0.93986
2636	Fateh Nagar	0.92194	0.94232	0.97837
2648	Lado Sarai	1	1	1
2651	Dayal Bagh Road	1	1	1
2756	Jittar Nagar	1	1	1
2761	Sultanputi Nangloi Road	1	1	1
2762	Acharya Niketan	0.98101	1	0.98101
2763	Khichripur East	1	1	1
2766	Nangloi Najafgarh	0.95203	0.96879	0.98270
2799	Savitri Nagar	1	1	1
2800	Sector 31, Gurgaon	1	1	1
2801	Huda Mrkt 2, Sec 4 , Gurgaon	1	1	1
2844	Kathmandi	1	1	1
2845	PLA Hisar	1	1	1
2856	Hassan Pur	0.95522	0.96586	0.98899
2865	Mandoli Main Road	1	1	1
3062	Nagloi Saiyed	0.86322	0.93585	0.92240
3079	Ansal Plaza Palam	1	1	1
TA90	Dashmesh Palace	1	1	1

We compare the above three efficiency score results by visualizing the line graph as below.



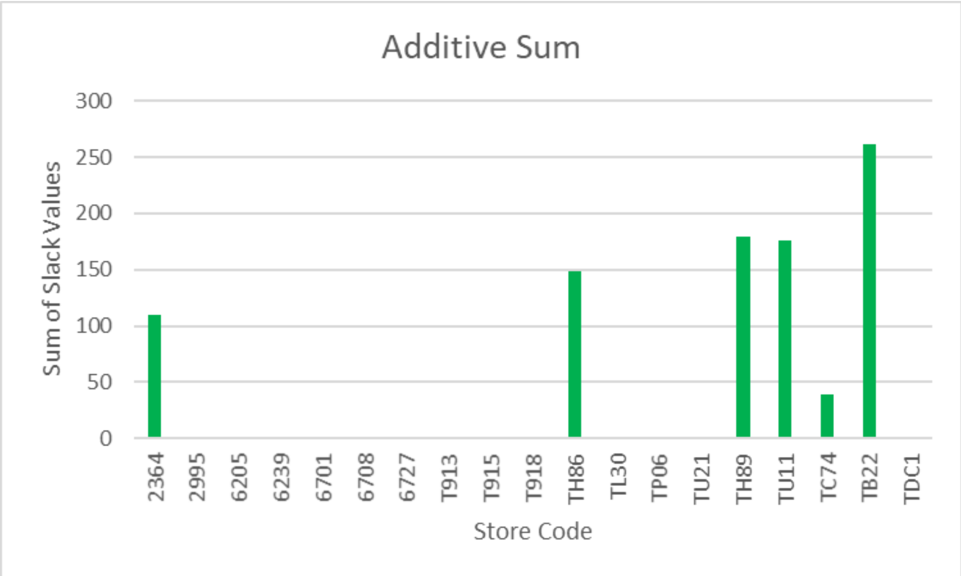
5.5.7 Additive Sum

Additive model is solved wherein it is possible to solve input-oriented, output-oriented, and non-oriented additive DEA model under variable returns to scale. In this model, the efficiency score is the sum of the slacks. Therefore, a DMU is efficient when the objective value is zero. Along with the sum of slack the following tables show slack values for each input and output variable separately.

For Reliance Smart Stores:

Store Code	DMU- Store Name	Additive Sum	Rental Cost	Staff Cost	Utilities Cost	Sales	EBITDA	Ratings
2364	Jharsa Road	110.06933	0	0	1.80017	92.22353	16.01026	0.03537
2995	Meenakshi Garden	0	0	0	0	0	0	0
6205	Crown Interiors Mall	0	0	0	0	0	0	0
6239	Dwarka	0	0	0	0	0	0	0
6701	Dlf Mega Mall	0	0	0	0	0	0	0
6708	Ansal Plaza	0	0	0	0	0	0	0
6727	Bmg Mall	0	0	0	0	0	0	0
T913	Jaipuria Mall	0	0	0	0	0	0	0
T915	Signature Street	0	0	0	0	0	0	0
T918	Cloud 9 Ghaziabad	0	0	0	0	0	0	0
TH86	Beta Plaza	148.68059	0	0	0	130.50982	18.17077	0
TL30	Vikaspuri	0	0	0	0	0	0	0
TP06	Aggarwal Prestige Mall	0	0	0	0	0	0	0
TU21	G3S Mall Rohini	0	0	0	0	0	0	0
TH89	Aero Tower	179.84137	0	0	0.33875	159.11697	20.38564	0
TU11	Smart Najafgarh	176.01883	0	3.43320	2.16791	147.94946	22.46827	0
TC74	Iris Broadway	39.49361	0	0	0	38.68994	0.80367	0
TB22	Galaxy Diamond Plaza	261.71495	0	0	1.66705	229.58802	30.43035	0.02953
TDC1	Smart Palwal	0	0	0	0	0	0	0

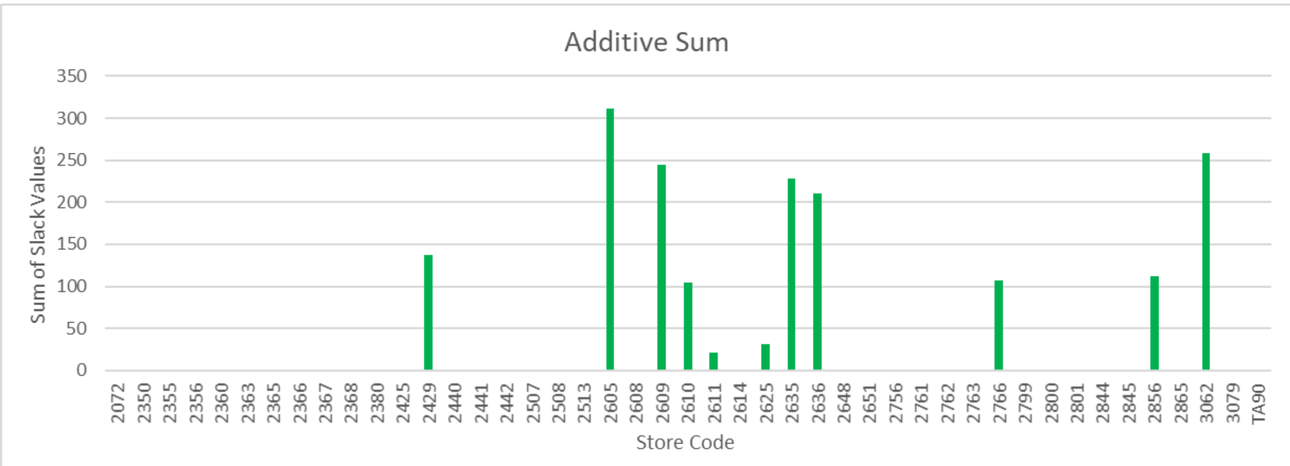
The total sum of slack values to show the improvement that needs to be made for the inefficient stores to make them efficient is depicted below:



For Reliance Fresh Stores:

Store Code	DMU- Store Name	Additive Sum	Rental Cost	Staff Cost	Utilities Cost	Sales and..	House Keep..	Repairs and..	Sales	NOB	ABV	EBIDTA	Ratings
2072	Narela	0	0	0	0	0	0	0	0	0	0	0	0
2350	Nit 1&2	0	0	0	0	0	0	0	0	0	0	0	0
2355	Inderpuri	0	0	0	0	0	0	0	0	0	0	0	0
2356	Kakrola	0	0	0	0	0	0	0	0	0	0	0	0
2360	Tamur Nagar	0	0	0	0	0	0	0	0	0	0	0	0
2363	Pataudi Road	0	0	0	0	0	0	0	0	0	0	0	0
2365	Huda Mrkt Sec 23	0	0	0	0	0	0	0	0	0	0	0	0
2366	Shubham Hall	0	0	0	0	0	0	0	0	0	0	0	0
2367	Shahnai Banquet	0	0	0	0	0	0	0	0	0	0	0	0
2368	Sargar Villa	0	0	0	0	0	0	0	0	0	0	0	0
2380	Mauj Purjhonda	0	0	0	0	0	0	0	0	0	0	0	0
2425	Mohan Garden	0	0	0	0	0	0	0	0	0	0	0	0
2429	Bali Nagar	137.6983	0	0	0	0.1074	0	0	18.5562	0	112.6261	6.3513	0.0572
2440	Nit 3	0	0	0	0	0	0	0	0	0	0	0	0
2441	Huda Mrkt Sec 28	0	0	0	0	0	0	0	0	0	0	0	0
2442	Dayanand Colony	0	0	0	0	0	0	0	0	0	0	0	0
2507	Mansarovar Garden	0	0	0	0	0	0	0	0	0	0	0	0
2508	Gangavihar	0	0	0	0	0	0	0	0	0	0	0	0
2513	Dilshad Garden	0	0	0	0	0	0	0	0	0	0	0	0
2605	South Najafgarh	311.9910	0	0	0.0414	0.0857	0.0511	0	42.3253	120.9839	140.4171	8.0189	0.0676
2608	Shasti Park	0	0	0	0	0	0	0	0	0	0	0	0
2609	Arjun Nagar	245.0354	0	0.2332	0	0	0	0.0625	34.8894	98.3189	105.9088	5.4324	0.1903
2610	Madhurmilan	105.0888	0	0	0	0	0.0058	0	15.3167	0	88.7161	0.4138	0.6364
2611	Paschim Vihar	20.7439	0	0	0	0	0.0229	0.3697	0.6324	0	16.6377	2.9113	0.1700
2614	North Ghonda	0	0	0	0	0	0	0	0	0	0	0	0
2625	Madhuban Road	30.9027	0	0	1.0182	0	0.0182	0	2.5358	0	24.6117	2.6022	0.1166
2635	Tuglaquabad	227.9269	0	0	0.3699	0	0.0302	0	30.5141	143.6077	50.4282	2.9538	0.0229
2636	Fateh Nagar	210.9072	0	0	0	0	0.0202	0	25.4988	59.2885	120.5346	5.3957	0.1694
2648	Lado Sarai	0	0	0	0	0	0	0	0	0	0	0	0
2651	Dayal Bagh Road	0	0	0	0	0	0	0	0	0	0	0	0
2756	Jittar Nagar	0	0	0	0	0	0	0	0	0	0	0	0
2761	Sultanputi Nangloi Road	0	0	0	0	0	0	0	0	0	0	0	0
2762	Acharya Niketan	0	0	0	0	0	0	0	0	0	0	0	0
2763	Khichripur East	0	0	0	0	0	0	0	0	0	0	0	0
2766	Nangloi Najafgarh	106.4109	0	0	1.0178	0	0.0740	0.1373	12.7851	86.0188	0	6.2482	0.1297
2799	Savitri Nagar	0	0	0	0	0	0	0	0	0	0	0	0
2800	Sector 31, Gurgaon	0	0	0	0	0	0	0	0	0	0	0	0
2801	Huda Mrkt 2, Sec 4 , Gurgaon	0	0	0	0	0	0	0	0	0	0	0	0
2844	Kathmandi	0	0	0	0	0	0	0	0	0	0	0	0
2845	PLA Hisar	0	0	0	0	0	0	0	0	0	0	0	0
2856	Hassan Pur	111.8959	0	0	0.1318	0	0.0256	0.2064	13.1170	52.6293	42.9156	2.8277	0.0424
2865	Mandoli Main Road	0	0	0	0	0	0	0	0	0	0	0	0
3062	Nagloi Saiyed	258.1392	0	0	0.2394	0.0253	0.0671	0	23.3205	169.4423	59.8624	5.1183	0.0640
3079	Ansal Plaza Palam	0	0	0	0	0	0	0	0	0	0	0	0
TA90	Dashmesh Palace	0	0	0	0	0	0	0	0	0	0	0	0

The total sum of slack values to show the improvement that needs to be made for the inefficient stores to make them efficient is depicted below:



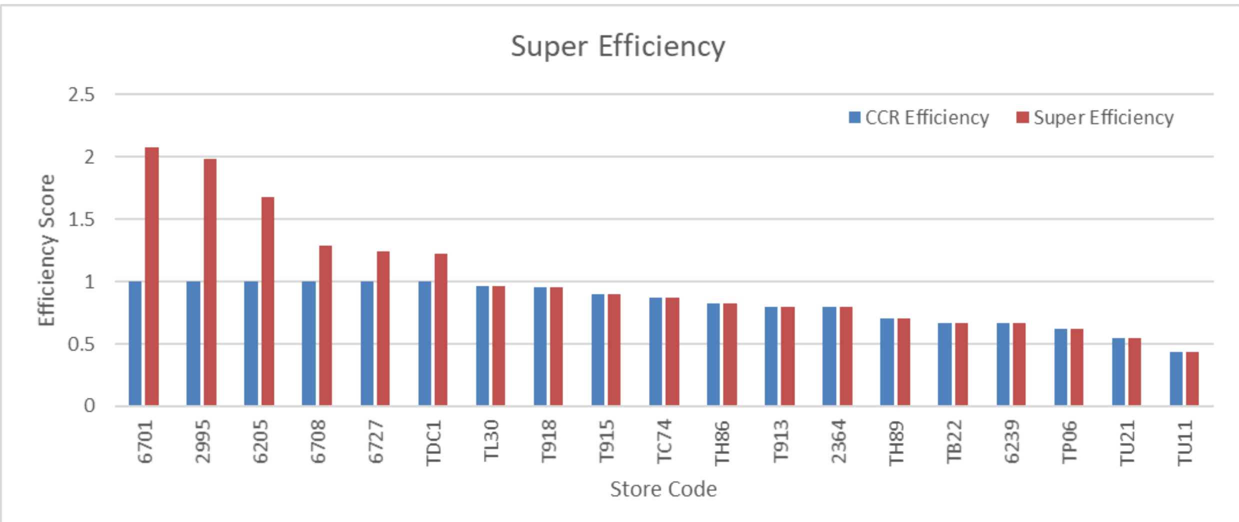
5.5.8 **Super Efficiency**

Super efficiency model is used to identify both the efficient and inefficient stores in order to rank them accordingly. The below table gives different the super efficiency scores for each store and thus the ranking of all the stores are provided with the most efficient to the least efficient units. Note that the super efficiency model under the assumption of variable, non-increasing and non-decreasing returns to scale (VRS, NIRS, NDRS), the SE model may be infeasible for some efficient DMUs. Hence, we have used super efficiency model under constant returns to scale to make the rankings correctly.

For Reliance Smart Stores:

Store Code	DMU - Store Name	CCR Efficiency	Super Efficiency	Rank
6701	Dlf Mega Mall	1	2.07744	1
2995	Meenakshi Garden	1	1.98768	2
6205	Crown Interiors Mall	1	1.68121	3
6708	Ansal Plaza	1	1.28682	4
6727	Bmg Mall	1	1.24649	5
TDC1	Smart Palwal	1	1.22522	6
TL30	Vikaspuri	0.96865	0.96865	7
T918	Cloud 9 Ghaziabad	0.95794	0.95794	8
T915	Signature Street	0.89529	0.89529	9
TC74	Iris Broadway	0.87459	0.87459	10
TH86	Beta Plaza	0.82279	0.82279	11
T913	Jaipuria Mall	0.80035	0.80035	12
2364	Jharsa Road	0.79457	0.79457	13
TH89	Aero Tower	0.70160	0.70160	14
TB22	Galaxy Diamond Plaza	0.66740	0.66740	15
6239	Dwarka	0.66340	0.66340	16
TP06	Aggarwal Prestige Mall	0.61962	0.61962	17
TU21	G3S Mall Rohini	0.55040	0.55040	18
TU11	Smart Najafgarh	0.43181	0.43181	19

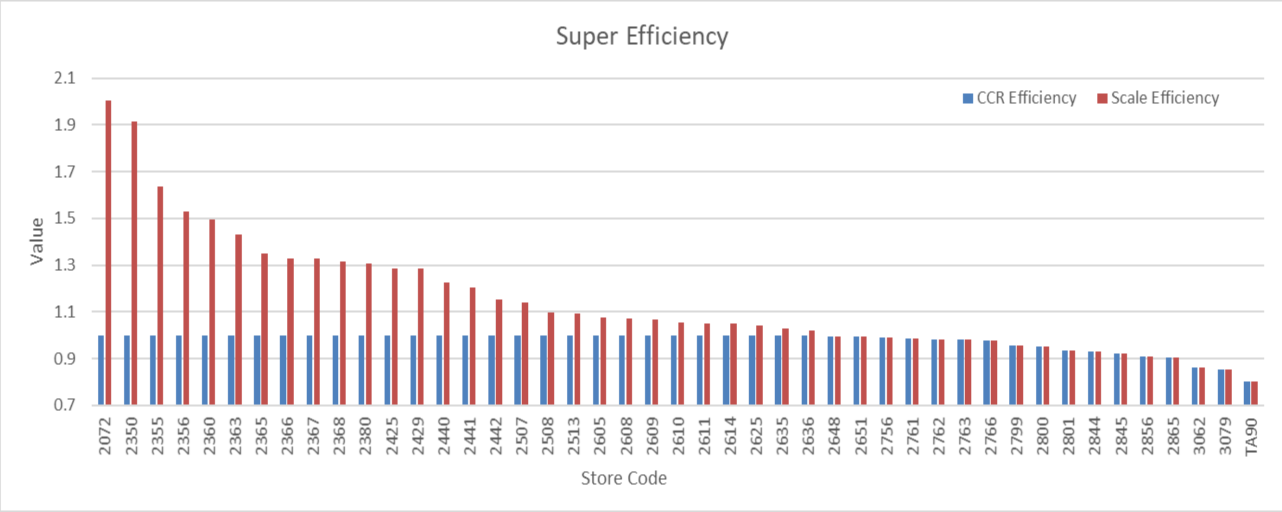
The following graph thus provides the different super efficiency scores for each of the stores. The score values are above 1 for efficient units reflecting how much efficient is each unit. And the inefficiency scores less than 1 remains unchanged



For Reliance Fresh Stores:

Store Code	DMU - Store Name	CCR Efficiency	Scale Efficiency	Rank
2072	Ansal Plaza Palam	1	2.00619	1
2350	Narela	1	1.91630	2
2355	Dashmesh Palace	1	1.63535	3
2356	Inderpuri	1	1.53139	4
2360	PLA Hisar	1	1.49341	5
2363	Dilshad Garden	1	1.42939	6
2365	Pataudi Road	1	1.34822	7
2366	Huda Mrkt Sec 23	1	1.33041	8
2367	Dayal Bagh Road	1	1.33003	9
2368	Kathmandi	1	1.31375	10
2380	Tamur Nagar	1	1.30830	11
2425	Lado Sarai	1	1.28720	12
2429	Nit 3	1	1.28518	13
2440	Sector 31, Gurgaon	1	1.22384	14
2441	Sargar Villa	1	1.20275	15
2442	Gangavihar	1	1.15319	16
2507	Khichripur East	1	1.13951	17
2508	Shahnai Banquet	1	1.09633	18
2513	Kakrola	1	1.09286	19
2605	Nit 1&2	1	1.07428	20
2608	Mauj Purjhonda	1	1.07188	21
2609	Jittar Nagar	1	1.06627	22
2610	Shasti Park	1	1.05572	23
2611	Savitri Nagar	1	1.05054	24
2614	North Ghonda	1	1.04958	25
2625	Sultanputi Nangloi Road	1	1.04361	26
2635	Mandoli Main Road	1	1.02863	27
2636	Huda Mrkt 2, Sec 4 , Gurgaon	1	1.02193	28
2648	Dayanand Colony	0.99557	0.99557	29
2651	Mansarovar Garden	0.99417	0.99417	30
2756	Shubham Hall	0.99082	0.99082	31
2761	Madhuban Road	0.98567	0.98567	32
2762	Mohan Garden	0.98311	0.98311	33
2763	Acharya Niketan	0.98101	0.98101	34
2766	Paschim Vihar	0.97673	0.97673	35
2799	Hassan Pur	0.95522	0.95522	36
2800	Nangloi Najafgarh	0.95203	0.95203	37
2801	Bali Nagar	0.93414	0.93414	38
2844	Madhurmilan	0.93107	0.93107	39
2845	Fateh Nagar	0.92194	0.92194	40
2856	Tuglaquabad	0.90920	0.90920	41
2865	Huda Mrkt Sec 28	0.90525	0.90525	42
3062	Nagloi Saiyed	0.86322	0.86322	43
3079	Arjun Nagar	0.85154	0.85154	44
TA90	South Najafgarh	0.80216	0.80216	45

The following graph thus provides the different super efficiency scores for each of the stores. The score values are above 1 for efficient units reflecting how much efficient is each unit. And the inefficiency scores less than 1 remains unchanged



5.5.9 Target Values

Target values are calculated for each of the DMU's in a BCC DEA model are detailed in the table below as opposed to the actual values.

For Reliance Smart Stores:

		Sales		EBITDA		Ratings	
Store Code	**DMU- Store Name**	**Actual**	**Target**	**Actual**	**Target**	**Actual**	**Target**
2364	Jharsa Road	277.22	287.04	-12.60	-8.51	4.0	4.1
2995	Meenakshi Garden	292.83	292.83	12.79	12.79	3.7	3.7
6205	Crown Interiors Mall	791.84	791.84	42.90	42.90	4.3	4.3
6239	Dwarka	418.58	418.58	-11.99	-11.99	4.3	4.3
6701	Dlf Mega Mall	317.62	317.62	-1.46	-1.46	4.0	4.0
6708	Ansal Plaza	207.10	207.10	-10.32	-10.32	4.1	4.1
6727	Bmg Mall	274.86	274.86	-1.25	-1.25	4.1	4.1
T913	Jaipuria Mall	431.45	431.45	-2.64	-2.64	4.2	4.2
T915	Signature Street	251.31	251.31	1.11	1.11	4.1	4.1
T918	Cloud 9 Ghaziabad	89.20	89.20	-20.53	-20.53	4.2	4.2
TH86	Beta Plaza	218.11	220.72	-12.40	-7.16	4.1	4.1
TL30	Vikaspuri	346.40	346.40	-3.96	-3.96	4.2	4.2
TP06	Aggarwal Prestige Mall	275.48	275.48	-21.56	-21.56	4.2	4.2
TU21	G3S Mall Rohini	206.41	206.41	-34.08	-34.08	4.1	4.1
TH89	Aero Tower	175.96	229.85	-23.28	-14.71	4.1	4.1
TU11	Smart Najafgarh	269.63	382.17	-30.05	-15.78	4.2	4.3
TC74	Iris Broadway	283.41	310.91	3.07	3.08	4.1	4.1
TB22	Galaxy Diamond Plaza	174.85	196.42	-23.12	-19.35	4.1	4.2
TDC1	Smart Palwal	97.11	97.11	-12.49	-12.49	3.7	3.7

For Reliance Fresh Stores:

		Sales		NOB		ABV		EBITDA		Ratings	
Store Code	DMU- Store Name	Actual	Target	Actual	Target	Actual	Target	Actual	Target	Actual	Target
2072	Narela	112.61	112.61	654	654	614	614	4.92	4.92	4.0	4.0
2350	Nit 1&2	74.12	74.12	525	525	502	502	-0.24	-0.24	3.9	3.9
2355	Inderpuri	71.38	71.38	709	709	348	348	-0.58	-0.58	3.9	3.9
2356	Kakrola	92.29	92.29	772	772	418	418	-3.02	-3.02	3.8	3.8
2360	Tamur Nagar	131.69	131.69	873	873	524	524	3.83	3.83	3.9	3.9
2363	Pataudi Road	86.91	86.91	598	598	510	510	1.24	1.24	3.6	3.6
2365	Huda Mrkt Sec 23	105.26	105.26	849	849	426	426	-1.27	-1.27	3.9	3.9
2366	Shubham Hall	64.29	64.29	530	530	433	433	-1.86	-1.86	3.5	3.5
2367	Shahnai Banquet	113.74	113.74	661	661	620	620	1.62	1.62	3.8	3.8
2368	Sargar Villa	113.85	113.85	696	696	578	578	4.04	4.04	4.1	4.1
2380	Mauj Purjhonda	84.41	84.41	812	812	369	369	0.76	0.76	4.1	4.1
2425	Mohan Garden	85.20	85.20	854	854	347	347	-1.28	-1.28	3.8	3.8
2429	Bali Nagar	88.33	91.21	725	749	426	443	-3.17	0.68	3.9	4.0
2440	Nit 3	131.91	131.91	841	841	558	558	4.75	4.75	4.0	4.0
2441	Huda Mrkt Sec 28	64.38	64.38	556	556	405	405	-3.57	-3.57	3.0	3.0
2442	Dayanand Colony	83.84	83.84	553	553	533	533	0.53	0.53	3.8	3.8
2507	Mansarovar Garden	70.37	70.37	729	729	334	334	-3.73	-3.73	3.8	3.8
2508	Gangavihar	54.66	54.66	641	641	302	302	-1.06	-1.06	4.0	4.0
2513	Dilshad Garden	80.29	80.29	448	448	636	636	0.02	0.02	3.9	3.9
2605	South Najafgarh	74.96	95.18	600	739	441	466	-3.50	0.83	3.9	4.1
2608	Shasti Park	109.42	109.42	900	900	430	430	1.06	1.06	3.8	3.8
2609	Arjun Nagar	97.49	107.21	694	740	489	522	-0.75	2.43	3.8	4.1
2610	Madhurmilan	74.47	86.71	700	748	367	404	0.02	0.19	3.3	3.9
2611	Paschim Vihar	79.40	79.77	673	676	409	422	-2.90	-0.02	3.7	3.9
2614	North Ghonda	61.78	61.78	661	661	330	330	-2.28	-2.28	4.0	4.0
2625	Madhuban Road	100.52	101.36	799	806	439	449	-0.62	1.57	3.9	4.0
2635	Tuglaquabad	82.55	107.91	536	640	546	599	-1.32	1.71	3.9	4.0
2636	Fateh Nagar	70.54	85.83	571	606	434	508	-4.15	-0.09	3.8	4.0
2648	Lado Sarai	93.74	93.74	952	952	345	345	0.28	0.28	4.0	4.0
2651	Dayal Bagh Road	75.67	75.67	790	790	333	333	0.45	0.45	3.8	3.8
2756	Jittar Nagar	80.41	80.41	795	795	355	355	-0.32	-0.32	3.9	3.9
2761	Sultanputi Nangloi Road	52.12	52.12	446	446	416	416	-3.74	-3.74	3.9	3.9
2762	Acharya Niketan	71.70	71.70	549	549	457	457	-2.10	-2.10	3.8	3.8
2763	Khichripur East	52.00	52.00	403	403	457	457	-2.76	-2.76	4.0	4.0
2766	Nangloi Najafgarh	93.53	105.33	539	586	617	637	-3.89	2.28	3.9	4.0
2799	Savitri Nagar	105.74	105.74	641	641	579	579	0.62	0.62	4.1	4.1
2800	Sector 31, Gurgaon	96.17	96.17	894	894	368	368	-2.98	-2.98	3.7	3.7
2801	Huda Mrkt 2, Sec 4 , Gurgaon	62.94	62.94	607	607	360	360	-3.44	-3.44	3.8	3.8
2844	Kathmandi	94.64	94.64	615	615	552	552	1.01	1.01	4.0	4.0
2845	PLA Hisar	104.71	104.71	565	565	666	666	1.82	1.82	4.1	4.1
2856	Hassan Pur	82.46	85.38	607	628	475	493	-0.96	0.54	3.9	4.0
2865	Mandoli Main Road	67.03	67.03	650	650	365	365	-0.51	-0.51	3.8	3.8
3062	Nagloi Saiyed	66.78	78.68	591	728	364	389	-3.18	0.45	3.8	4.1
3079	Ansal Plaza Palam	147.45	147.45	746	746	690	690	2.66	2.66	3.9	3.9
TA90	Dashmesh Palace	167.31	167.31	901	901	659	659	8.32	8.32	4.1	4.1

CHAPTER 6

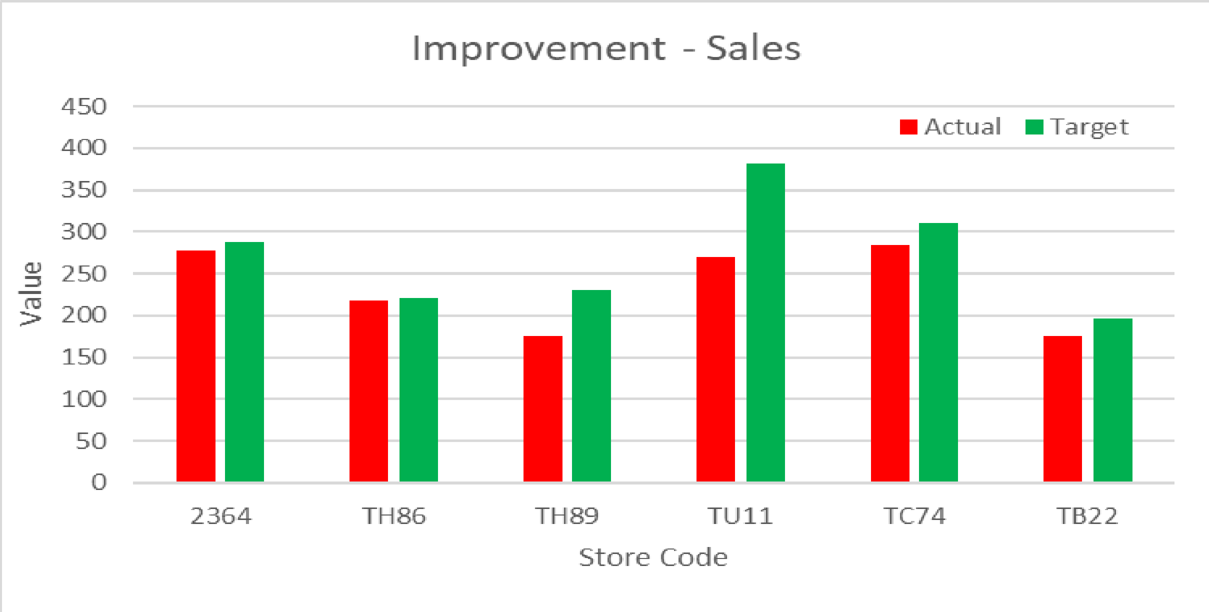
RECOMMENDATIONS

For only the inefficient DMU's the actual versus target output values and their representation and shown as below. Note that the Targets have been recommended from a theoretical point of view on the basis of the data provided. In practice, the targets may not be achievable. Moreover, as mentioned earlier, the results of DEA are very sensitive to the inputs/outputs selected as well as errors in measurement or other random errors.

For Reliance Smart Stores:

		Sales		EBITDA		Ratings	
Store Code	**DMU- Store Name**	**Actual**	**Target**	**Actual**	**Target**	**Actual**	**Target**
2364	Jharsa Road	277.22	287.04	-12.60	-8.51	4.0	4.1
TH86	Beta Plaza	218.11	220.72	-12.40	-7.16	4.1	4.1
TH89	Aero Tower	175.96	229.85	-23.28	-14.71	4.1	4.1
TU11	Smart Najafgarh	269.63	382.17	-30.05	-15.78	4.2	4.3
TC74	Iris Broadway	283.41	310.91	3.07	3.08	4.1	4.1
TB22	Galaxy Diamond Plaza	174.85	196.42	-23.12	-19.35	4.1	4.2

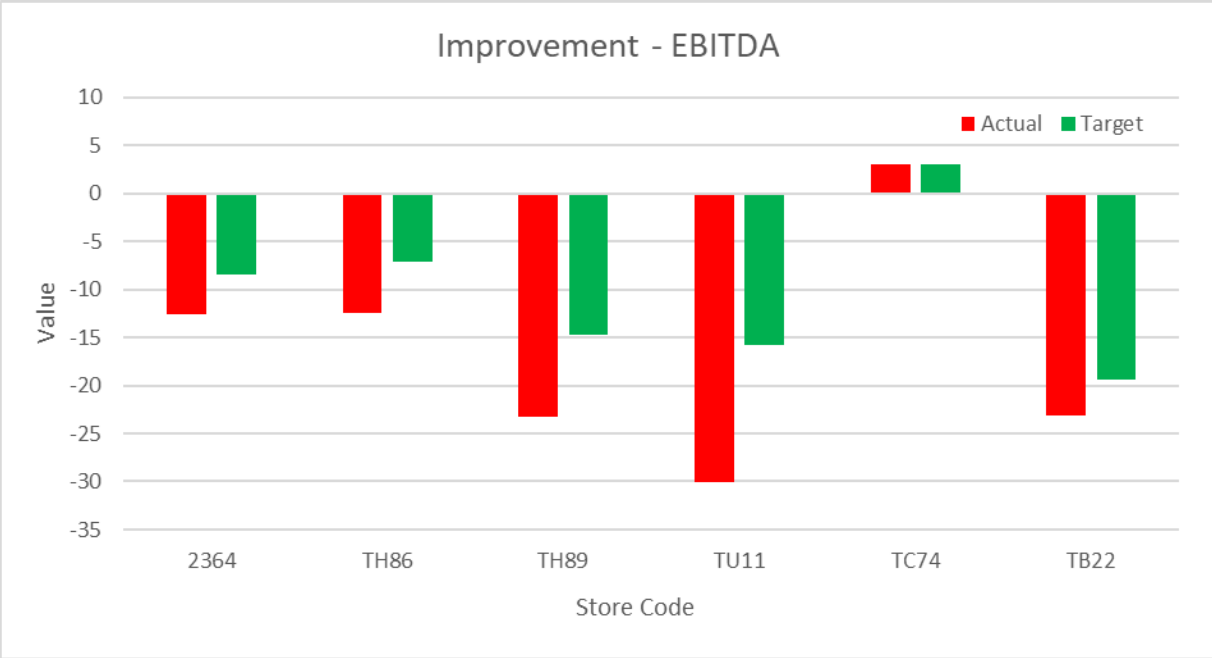
The following graphs with their recommendations are given in the next page for the possible improvement in the output variables for inefficient firms in Reliance Smart Stores.



The following Reliance Smart stores must increase its Sales to become efficient.

1. Store Code: 2364
   Store Name: Jharsa Road
   Improvement needed: from 277.22 Lakhs to 287.04 Lakhs end of the month.
2. Store Code: TH86
   Store Name: Beta Plaza
   Improvement needed: from 218.11 Lakhs to 220.72 Lakhs end of the month.
3. Store Code: TH89
   Store Name: Aero Tower
   Improvement needed: from 175.96 Lakhs to 229.85 Lakhs end of the month.
4. Store Code: TU11
   Store Name: Smart Najafgarh
   Improvement needed: from 269.63 Lakhs to 382.17 Lakhs end of the month.
5. Store Code: TC74
   Store Name: Iris Broadway
   Improvement needed: from 283.41 Lakhs to 310.91 Lakhs end of the month.
6. Store Code: TB22
   Store Name: Galaxy Diamond Plaza
   Improvement needed: from 174.85 Lakhs to 196.42 Lakhs end of the month.

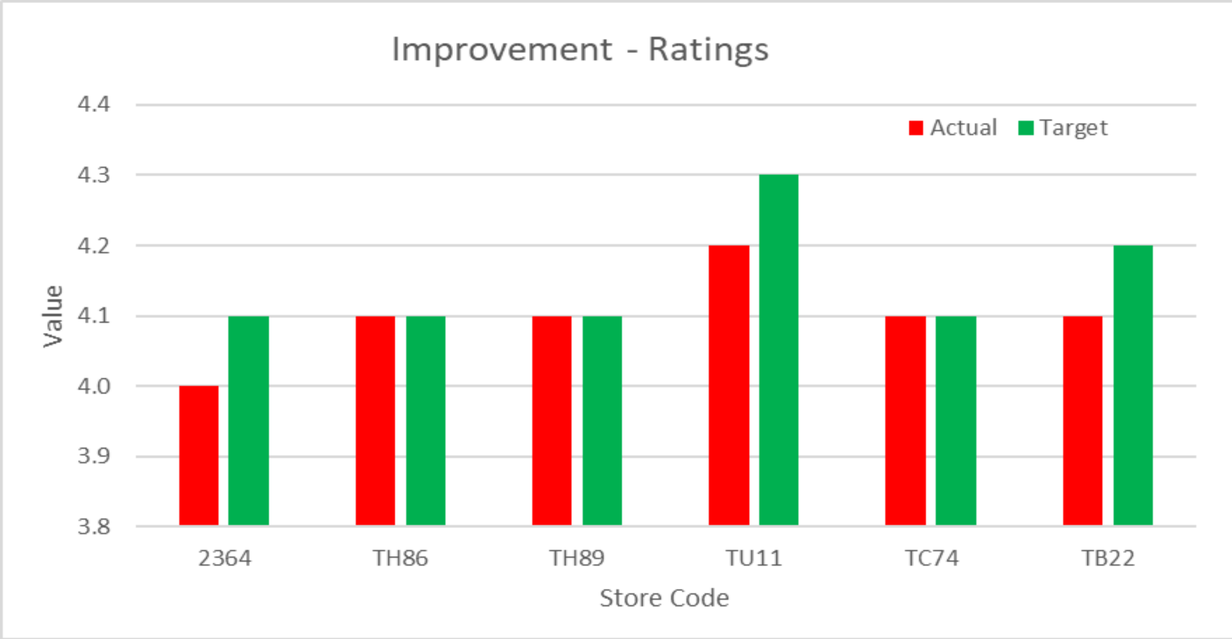
The store located at Smart Najafgarh needs to work the most in terms of its Sales followed by Aero Tower.



The following Reliance Smart stores must improve its EBITDA to become efficient.

1. Store Code: 2364
   Store Name: Jharsa Road
   Improvement needed: from -12.60 Lakhs to -8.51 Lakhs end of the month.
2. Store Code: TH86
   Store Name: Beta Plaza
   Improvement needed: from -12.40 Lakhs to -7.16 Lakhs end of the month.
3. Store Code: TH89
   Store Name: Aero Tower
   Improvement needed: from -23.28 Lakhs to -14.71 Lakhs end of the month.
4. Store Code: TU11
   Store Name: Smart Najafgarh
   Improvement needed: from -30.05 Lakhs to -15.78 Lakhs end of the month.
5. Store Code: TC74
   Store Name: Iris Broadway
   Improvement needed: from 3.07 Lakhs to 3.08 Lakhs end of the month.
6. Store Code: TB22
   Store Name: Galaxy Diamond Plaza
   Improvement needed: from -23.12 Lakhs to -19.35 Lakhs end of the month.

The store located at Smart Najafgarh needs to work the most in terms of its EBITDA



The following Reliance Smart stores must improve upon its Customer Ratings to become efficient.

1. Store Code: 2364
   Store Name: Jharsa Road
   Improvement needed: from 4 to 4.1
2. Store Code: TU11
   Store Name: Smart Najafgarh
   Improvement needed: from 4.2 to 4.3
3. Store Code: TB22
   Store Name: Galaxy Diamond Plaza
   Improvement needed: from 4.1 to 4.2

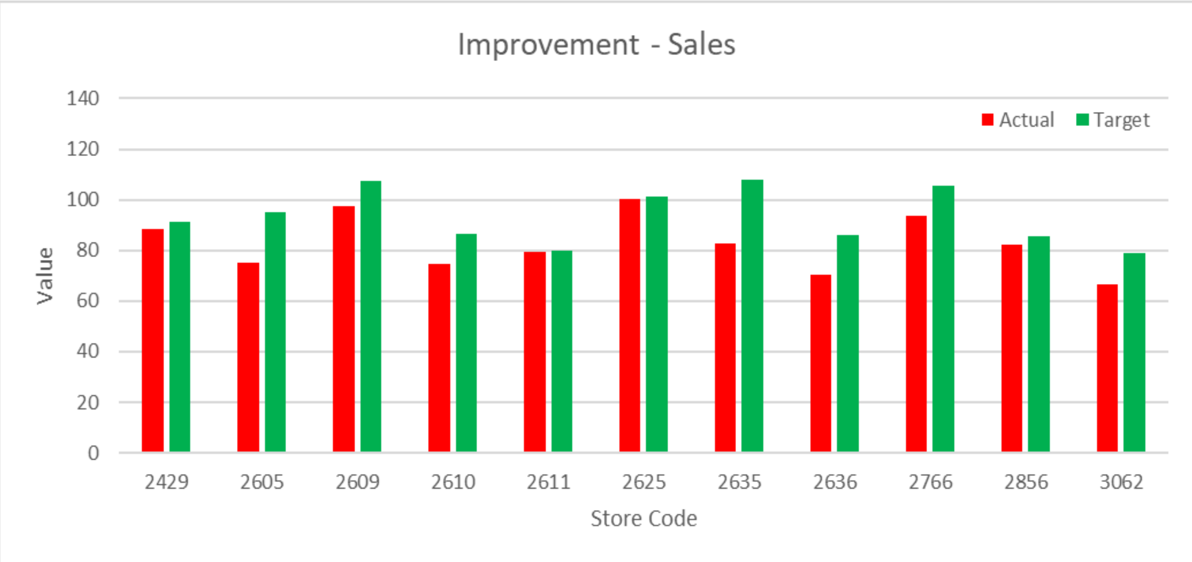
The store located at Galaxy Diamond Plaza needs to work the most in terms of its Customer Ratings.

To enhance the customer rating, the store must consider improving some of the general aspects such as the facilities, services, service time, waiting time, ambience, look/feel etc. to provide the customer with wholesome experience.

Thus, for Reliance smart stores, we see that the inefficient stores need to mainly work on their EBITDA. They should improve considerable in order to be as efficient as the rest of the efficient stores.

For Reliance Fresh Stores:

		Sales		NOB		ABV		EBITDA		Ratings	
Store Code	DMU- Store Name	Actual	Target	Actual	Target	Actual	Target	Actual	Target	Actual	Target
2429	Bali Nagar	88.33	91.21	725	749	426	443	-3.17	0.68	3.9	4.0
2605	South Najafgarh	74.96	95.18	600	739	441	466	-3.50	0.83	3.9	4.1
2609	Arjun Nagar	97.49	107.21	694	740	489	522	-0.75	2.43	3.8	4.1
2610	Madhurmilan	74.47	86.71	700	748	367	404	0.02	0.19	3.3	3.9
2611	Paschim Vihar	79.40	79.77	673	676	409	422	-2.90	-0.02	3.7	3.9
2625	Madhuban Road	100.52	101.36	799	806	439	449	-0.62	1.57	3.9	4.0
2635	Tuglaquabad	82.55	107.91	536	640	546	599	-1.32	1.71	3.9	4.0
2636	Fateh Nagar	70.54	85.83	571	606	434	508	-4.15	-0.09	3.8	4.0
2766	Nangloi Najafgarh	93.53	105.33	539	586	617	637	-3.89	2.28	3.9	4.0
2856	Hassan Pur	82.46	85.38	607	628	475	493	-0.96	0.54	3.9	4.0
3062	Nagloi Saiyed	66.78	78.68	591	728	364	389	-3.18	0.45	3.8	4.1

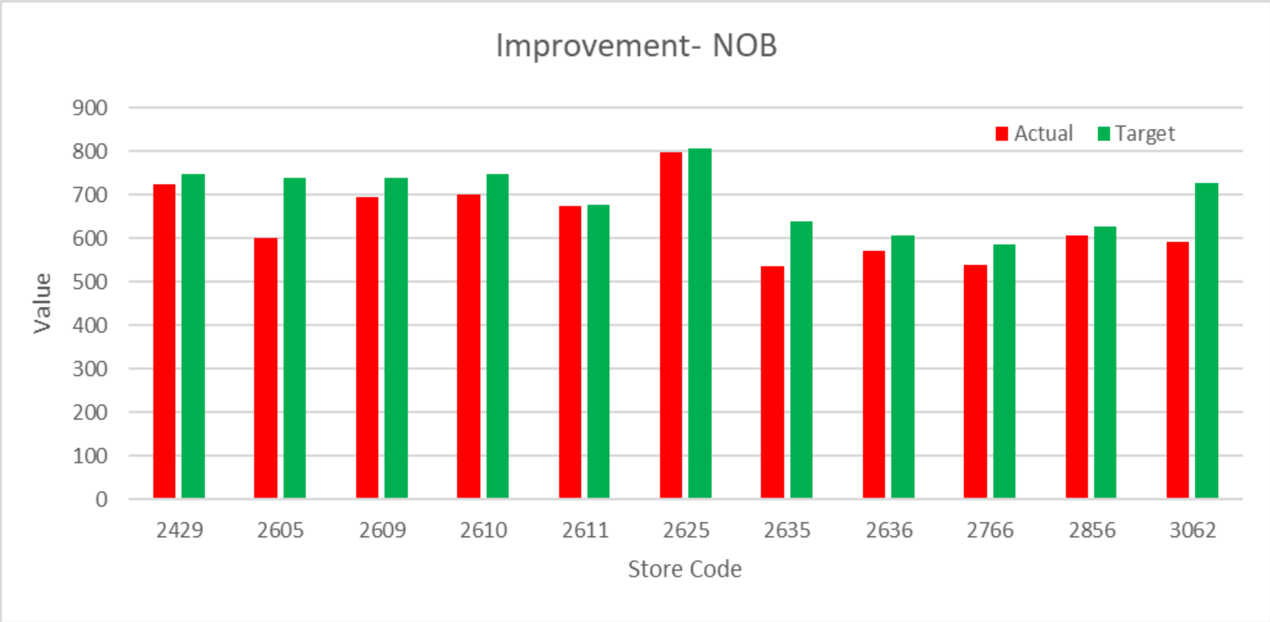


The following Reliance Fresh stores must increase its Sales to become efficient.

1. Store Code: 2429
   Store Name: Bali Nagar
   Improvement needed: from 88.33 Lakhs to 91.21 Lakhs end of the month.
2. Store Code: 2605
   Store Name: South Najafgarh
   Improvement needed: from 74.96 Lakhs to 95.18 Lakhs end of the month.
3. Store Code: 2609
   Store Name: Arjun Nagar
   Improvement needed: from 97.49 Lakhs to 107.21 Lakhs end of the month.

4. Store Code: 2610
   Store Name: Madhurmilan
   Improvement needed: from 74.47 Lakhs to 86.71 Lakhs end of the month.
5. Store Code: 2611
   Store Name: Paschim Vihar
   Improvement needed: from 79.40 Lakhs to 79.77 Lakhs end of the month.
6. Store Code: 2625
   Store Name: Madhuban Road
   Improvement needed: from 100.52 Lakhs to 101.36 Lakhs end of the month.
7. Store Code: 2635
   Store Name: Tuglaquabad
   Improvement needed: from 82.55 Lakhs to 107.91 Lakhs end of the month.
8. Store Code: 2636
   Store Name: Fateh Nagar
   Improvement needed: from 70.54 Lakhs to 85.83 Lakhs end of the month/.
9. Store Code: 2766
   Store Name: Nagloi Najafgarh
   Improvement needed: from 93.53 Lakhs to 105.33 Lakhs end of the month.
10. Store Code: 2856
    Store Name: Hassan Pur
    Improvement needed: from 82.46 Lakhs to 85.38 Lakhs end of the month.
11. Store Code: 3062
    Store Name: Nagloi Saiyed
    Improvement needed: from 68.78 Lakhs to 78.68 Lakhs end of the month.

The store located at Tuglaquabad needs to work the most in terms of its Sales followed by South Najafgarh and Fateh Nagar

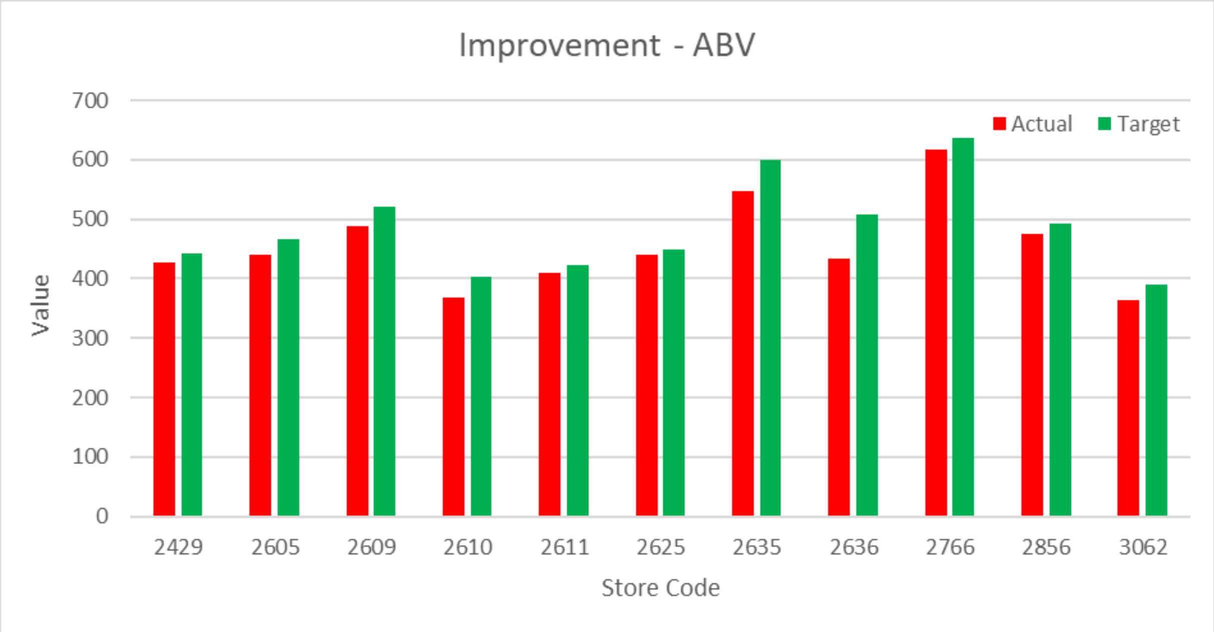


The following Reliance Fresh stores must increase its NOB (Number Of Bills) value to become efficient.

1. Store Code: 2429
   Store Name: Bali Nagar
   Improvement needed: from 725 to 749 end of the month.
2. Store Code: 2605
   Store Name: South Najafgarh
   Improvement needed: from 600 to 739 end of the month.
3. Store Code: 2609
   Store Name: Arjun Nagar
   Improvement needed: from 694 to 740 end of the month.
4. Store Code: 2610
   Store Name: Madhurmilan
   Improvement needed: from 700 to 748 end of the month.
5. Store Code: 2611
   Store Name: Paschim Vihar
   Improvement needed: from 673 to 676 end of the month.
6. Store Code: 2625
   Store Name: Madhuban Road
   Improvement needed: from 799 to 806 end of the month.
7. Store Code: 2635
   Store Name: Tuglaquabad
   Improvement needed: from 536 to 640 end of the month.

8. Store Code: 2636
   Store Name: Fateh Nagar
   Improvement needed: from 571 to 606 end of the month.
9. Store Code: 2766
   Store Name: Nagloi Najafgarh
   Improvement needed: from 539 to 586 end of the month.
10. Store Code: 2856
    Store Name: Hassan Pur
    Improvement needed: from 607 to 628 end of the month.
11. Store Code: 3062
    Store Name: Nagloi Saiyed
    Improvement needed: from 591 to 728 end of the month.

The store located at South Najafgarh and Nagloi Saiyed needs to work the most in terms of its NOB (Number Of Bills) followed by Tuglaquabad

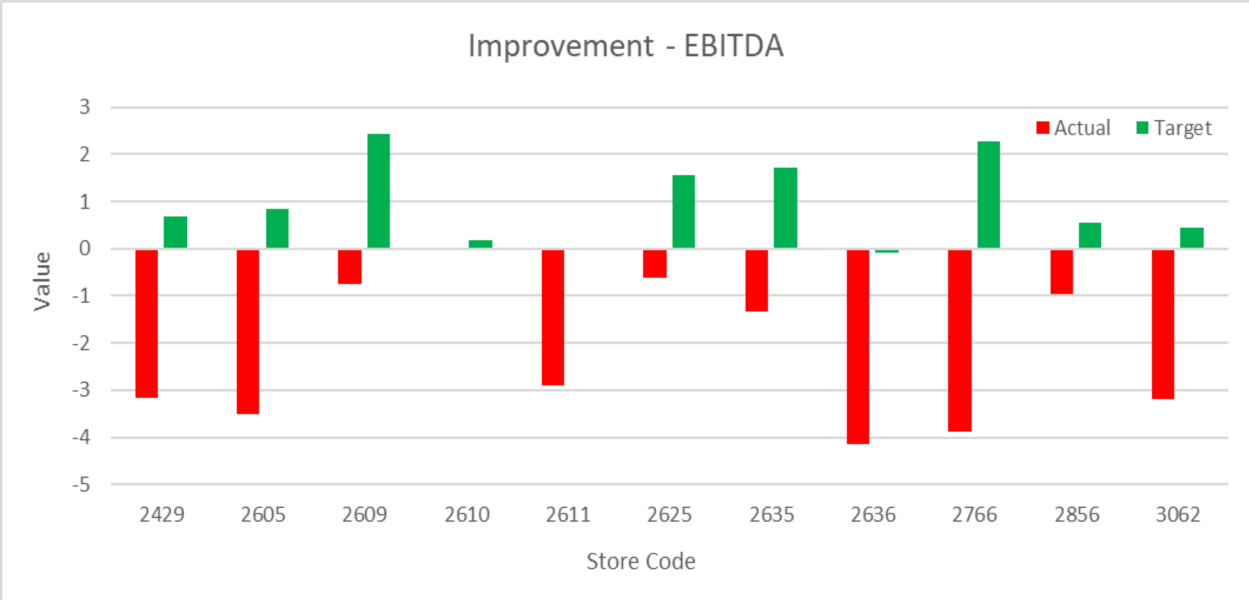


The following Reliance Fresh stores must increase its ABV (Average Basket Value) to become efficient.

1. Store Code: 2429
   Store Name: Bali Nagar
   Improvement needed: from 426 to 443 end of the month.
2. Store Code: 2605
   Store Name: South Najafarh
   Improvement needed: from 441 to 466 end of the month.
3. Store Code: 2609
   Store Name: Arjun Nagar
   Improvement needed: from 489 to 522 end of the month.
4. Store Code: 2610
   Store Name: Madhurmilan
   Improvement needed: from 367 to 404 end of the month.
5. Store Code: 2611
   Store Name: Paschim Vihar
   Improvement needed: from 409 to 422 end of the month.
6. Store Code: 2625
   Store Name: Madhuban Road
   Improvement needed: from 439 to 449 end of the month.
7. Store Code: 2635
   Store Name: Tuglaquabad
   Improvement needed: from 546 to 599 end of the month.

8. Store Code: 2636
   Store Name: Fateh Nagar
   Improvement needed: from 434 to 508 end of the month.
9. Store Code: 2766
   Store Name: Nagloi Najafgarh
   Improvement needed: from 617 to 637 end of the month.
10. Store Code: 2856
    Store Name: Hassan Pur
    Improvement needed: from 475 to 493 end of the month.
11. Store Code: 3062
    Store Name: Nagloi Saiyed
    Improvement needed: from 364 to 389 end of the month.

The store located at Fateh Nagar needs to work the most in terms of its ABV (Average Basket Value) followed by Tuglaquabad and Madhurmilan

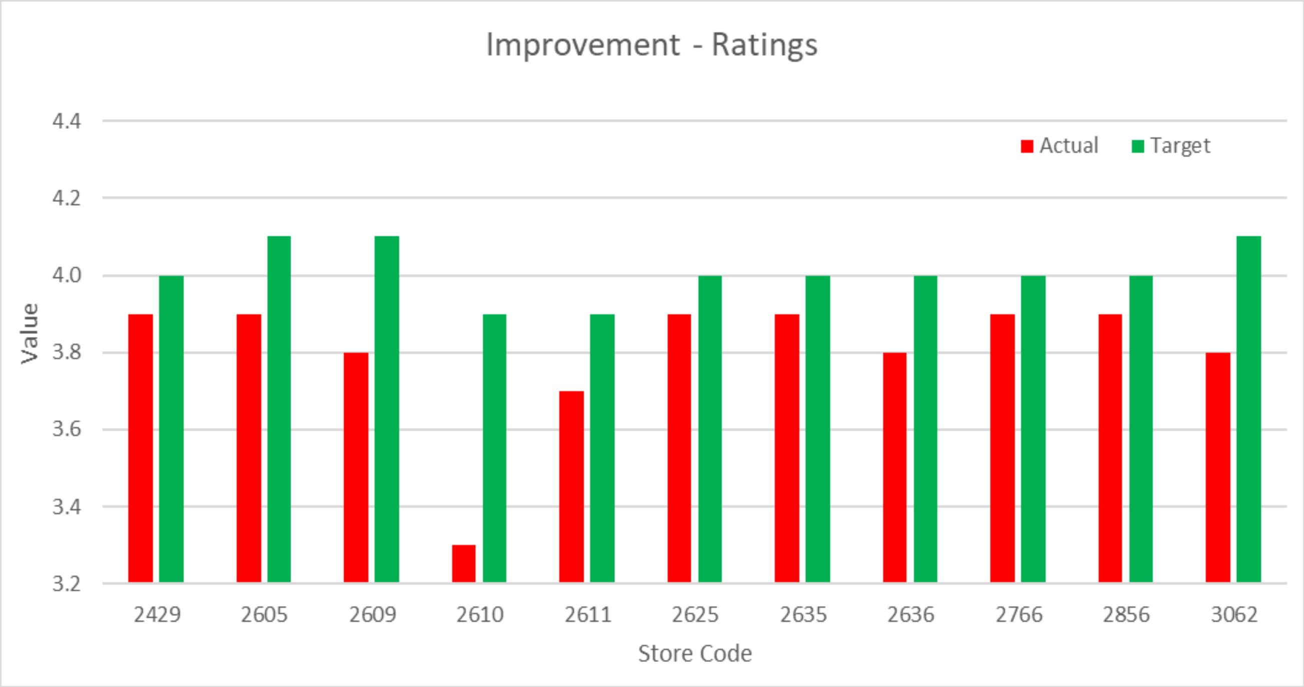


The following Reliance Fresh stores must improve its EBITDA to become efficient.

1. Store Code: 2429
   Store Name: Bali Nagar
   Improvement needed: from -3.17 Lakhs to 0.68 Lakhs end of the month.
2. Store Code: 2605
   Store Name: South Najafarh
   Improvement needed: from -3.50 Lakhs to 0.83 Lakhs end of the month.
3. Store Code: 2609
   Store Name: Arjun Nagar
   Improvement needed: from -0.75 Lakhs to 2.43 Lakhs end of the month.
4. Store Code: 2610
   Store Name: Madhurmilan
   Improvement needed: from 0.02 Lakhs to 0.19 Lakhs end of the month.
5. Store Code: 2611
   Store Name: Paschim Vihar
   Improvement needed: from -2.90 Lakhs to -0.02 Lakhs end of the month.
6. Store Code: 2625
   Store Name: Madhuban Road
   Improvement needed: from -0.62 Lakhs to 1.57 Lakhs end of the month.
7. Store Code: 2635
   Store Name: Tuglaquabad
   Improvement needed: from -1.32 Lakhs to 1.71 Lakhs end of the month.
8. Store Code: 2636
   Store Name: Fateh Nagar
   Improvement needed: from -4.15 Lakhs to -0.09 Lakhs end of the month.

9. Store Code: 2766
   Store Name: Nagloi Najafgarh
   Improvement needed: from -3.89 Lakhs to 2.28 Lakhs end of the month.
10. Store Code: 2856
    Store Name: Hassan Pur
    Improvement needed: from -0.96 Lakhs to 0.54 Lakhs end of the month.
11. Store Code: 3062
    Store Name: Nagloi Saiyed
    Improvement needed: from -3.18 Lakhs to 0.45 Lakhs end of the month.

The store located at Nagloi Najafgarh needs to work the most in terms of its EBITDA followed by South Najafarh and Fateh Nagar



The following Reliance Fresh stores must improve its Ratings to become efficient.

1. Store Code: 2429
   Store Name: Bali Nagar
   Improvement needed: from 3.9 to 4.0
2. Store Code: 2605
   Store Name: South Najafarh
   Improvement needed: from 3.9 to 4.1
3. Store Code: 2609
   Store Name: Arjun Nagar
   Improvement needed: from 3.8 to 4.1
4. Store Code: 2610
   Store Name: Madhurmilan
   Improvement needed: from 3.3 to 3.9
5. Store Code: 2611
   Store Name: Paschim Vihar
   Improvement needed: from 3.7 to 3.9
6. Store Code: 2625
   Store Name: Madhuban Road
   Improvement needed: from 3.9 to 4.0
7. Store Code: 2635
   Store Name: Tuglaquabad
   Improvement needed: from 3.9 to 4.0

8. Store Code: 2636
   Store Name: Fateh Nagar
   Improvement needed: from 3.8 to 4.0
9. Store Code: 2766
   Store Name: Nagloi Najafgarh
   Improvement needed: from 3.9 to 4.0
10. Store Code: 2856
    Store Name: Hassan Pur
    Improvement needed: from 3.9 to 4.0
11. Store Code: 3062
    Store Name: Nagloi Saiyed
    Improvement needed: from 3.8 to 4.1

The store located at Madhurmilan needs to work the most in terms of its customer ratings followed by Nagloi Saiyed and Arjun Nagar.

To enhance the customer rating, the store must consider improving some of the general aspects such as the facilities, services, service time, waiting time, ambience, look/feel etc. to provide the customer with wholesome experience.

Thus, for Reliance Fresh stores, we see that the inefficient stores need to mainly work on their EBITDA and Sales. They should improve considerably in order to be as efficient as the rest of the efficient stores.

CHAPTER 7

DISCUSSIONS AND CONCLUSION

During the meeting with the operating manager of Reliance retail chain, it was told that Meenakshi Garden and Crown Interiors Mall gives the best returns and are proven to be most profitable. The numerical results of this study are found in line with these.

Although, some results in our study were not in line with the manager. This, might be because in this study we didn't take some important factors considering these to be taken into account like location, no of competitive stores, etc. If some of these would have been taken into account, the results might have been more accurate.

Also, the data was taken for only the month of January,2020. Some distortion in the results might be due to this month data and hence, yearly data could have been taken.

In conclusion, this study aimed to make a performance evaluation in a Reliance retail chain by using DEA method. In future studies, performance evaluation can be conducted for all the stores of the retail chain and moreover, number of inputs and outputs can be increased.

Retailers must be aware about good customer service, so that they not only enhance, attract and retail customer but also customer delight can be achieved which is an asset to the company.

The long-term prospects of each retail stores cannot be ascertained from its historical sales alone. Historical sales may not reflect the potential of the market of a retail store which better management could exploit.

7.1 Limitations of the Study

This study also identifies practical limitations for applying DEA in a retail setting.

1. Input and Output Variables considered in the model
   DEA relies on the availability of valid and reliable archival data. While management was comfortable with the certain input factors considered in this study, other inputs, if available, could have been considered. It is interesting if one can take the non-discretionary inputs like location, manager's experience and others to measure the performance of the stores.
   Furthermore, future studies may consider increasing the involvement of store managers in the input and output variable selection process since much of the

analysis reflects on activities occurring at the store-level. It should also be noted that DEA is particularly sensitive to measurement error since there is no process currently available within DEA to identify or deal with measurement error. As a result, future researchers should be cautious when using subjectively derived survey data whose psychometric properties cannot be determined.

2. Number of input and output variables considered in the model.
   Stable DEA results require a large number of observations particularly as the number of inputs and outputs are increased. As a result, DEA may not be appropriate for smaller retail chains. For smaller chains, the number of total inputs and outputs used may have to be reduced, thus rendering the results less valuable for the management.
3. Weights restrictions- Bounded variable model
   If the weights assigned by the DEA program are not reflective of management's "mental map" of intended store operating procedures or of the company's strategic performance objectives. To produce more representative results, management's judgments should have been more explicitly incorporated into the DEA model. Expert judgments involve placing assurance restrictions which constraint weights the model places on various inputs and outputs to capture the intellectual discrimination, managerial biases, and strategic operating orientations of the organization's top management team.
4. DEA with Categorical Variables
   There are some managerial situations over which managers of a particular organisation do not have total control. For example, in evaluating the performance of a branch store of a supermarket, it is necessary to consider the sales environment of a store including whether it has a severe competition, is in a normal business condition or in a relatively advantageous one.
   If we evaluate the efficiency of the above supermarkets as "scratch" players, the evaluation would be unfair to the stores in a highly competitive situation and would be too indulgent to the stores in the advantageous one. Hence, we need to provide something in the way of a "handicap" when evaluating them.
   A hierarchical category is suitable for handling such situations. As for the supermarket example, we classify the stores facing severe competition as category 1, in a normal situation as category 2 and in an advantageous one as category 3. Then, we evaluate the stores in category 1 only within the group, stores in category 2 with reference to the stores in category 1 and 2 and stores in category 3 within all the stores in the model. Thus, we evaluate the stores under operating handicaps which takes into account their particular environments, and we also use this information to evaluate the stores in higher categories.

7.2 <u>Summary</u>

An efficiency evaluation process incorporating DEA is presented as an approach for assessing store efficiency within a large retail chain. While there has been a sizable body of literature on retail efficiency, very little has been published on the efficiency of individual stores within multi-store, multi-market retail chains. Issues to be addressed in measuring individual store efficiency include weighting multiple inputs and outputs, taking into consideration many factors influencing productivity that are likely to vary from store to store, developing a single index of store efficiency, and establishing the performance capability of each store.

DEA is offered as one approach for addressing these problems. It derives for each store a single summary index of efficiency relative to other comparable stores in the analysis. DEA incorporates the strategic decision making recommendations of senior management regarding inputs and outcomes. In addition, factors not under the control of store management may be incorporated to ensure equity in the evaluation of individual store efficiency and management's strategic emphasis. In focusing on frontiers rather than central tendencies, as in ordinary least squares regression, DEA identifies the limits of each store's outcome producing capabilities given certain resources, rather than the average performance. Efficiency scores estimated using DEA is relative to the best performing DMU. The best performing DMU is given the efficiency score of unity and the performance of other DMU's vary between 0 and unity relative to its best performing unit.

The DEA methodology permitted us to isolate those decisions over which the store manager had little influence, but greatly impacted the efficiency of their store. Some factors like location related costs, age of store, and compensation level of hourly employees could also been taken into analysis as a non-controllable variables but the ones affecting the efficiency of the stores.

Management's goal is to get the best possible performance out of each unit. Determining what that means and how to measure store performance is often a problem. With bar codes, modems, microchips and other advances in information technology, the challenge of today's manager is to extract insight from the numbers. One can study and compare stores in terms of their outputs, inputs, key ratios and even use econometric techniques to find out how each variable is affected by the others. However, managers will still be using overall average performance as the benchmark. DEA not only helps make sense of the data in deriving an overall efficiency index, but also identifies the best practice stores within the organization by focusing on the efficiency frontier.

7.3 Software Used

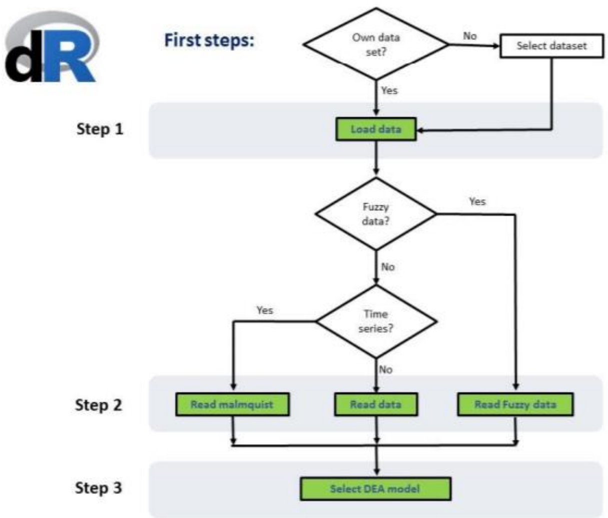
This paper aims to present an implementation of DEA models in R programming software, a free software and open source, highly extensible that offers a variety of functions and graphical routines for data analysis.

Various R packages are built to solve DEA models in the software like Frontier Efficiency Analysis with R – FEAR, Benchmarking, lpSolve, rDEA, etc.

A new R package for DEA called deaR was presented in the 16th International Conference on Data Envelopment Analysis This package allows to run a wide variety of models based on DEA:

- Conventional DEA models: CCR, BCC, directional distance function multiplier, additive, non-radial, SBM, radial super efficiency, additive super efficiency, SBM super efficiency, cross efficiency, bootstrapping, etc.
- Malmquist index
- Fuzzy DEA models: some possibilistic DEA models.

In the flow chart below,
we can see the steps to perform any DEA (Data Envelopment Analysis) with deaR.



This study used deaR package in R software to perform the analysis and modelling

Also, Microsoft Excel software *was used to provide the results along with the visualization of graphs for better interpretation of results.*

LINGO software *was used to develop the tradition understanding behind the models. LINGO is a comprehensive tool to solve linear, non-linear, quadratic, and many other optimisation models faster, easier and efficiently.*

7.4 References

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2. Data Envelopment Analysis: A handbook of Models and Methods
   By: Joe Zhu

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   By: Richard S. Barr, William L. Cron and John Slocum.

4. Efficiency Analysis of Retail Chain Stores in Korea
   By: Kyungwan Ko, Meehyang Chang, Eun-Song Bae and Daecheol Kim

5. Efficiency Analysis in Retail Sector: Implementation of Data Envelopment Analysis in a Local Supermarket Chain
   By: Ceren Kahraman, İrem Uluğ, Can Burak Othan, Yeşim Deniz Özkan-Özen(&) , and Yiğit Kazançoğlu.

6. Benchmarking scheme for Retail Stores Efficiency
   By: Rohita Kumar Mishra

7. An investigation of Returns to Scale
   By: Lawrence M. Seiford, Joe Zhu

8. Implementing DEA models in the R program
   By: José Francisco Moreira Pessanha, Alexandre Marinho, Luiz da Costa Laurencel Janeiro, Marcelo Rubens dos Santos do Amaral

9. Data Envelopment Analysis: Theory and Applications
   By: Rajiv Banker, Ali Emrouznejad, Ana Lucia Miranda Lopes, Mariana Rodrigues de Almeida

10. Usage of DEA Technique for measuring productivity of Grocery Retail Outlets.
    By: Sanjiv Mittal, Akanksha Gupta, Gokulananda Patel.

CHAPTER 8

APPENDIX

Implementing DEA Models Using R

R-code for implementing various DEA models is given below. Note that the rental cost variable taking as a non comtrollable input variable. Also, the EBITDA variable was dealt with in the data itself.

For Reliance Smart Stores:

R-code for implementing BCC output oriented model is given below.

```
# installing package
install.packages('deaR')
library(deaR)

# reading the data
smart=read.csv('data- rel smart in csv.csv')
colnames(smart)

# BCC model
dt <- read_data(smart,ni= 2:4,no=5:7,inputs=2:4,outputs=5:7,nc_inputs=1)
dea_vrs<- model_basic(dt,orientation="oo",rts = "vrs")

# finding the efficiency values
eff=efficiencies(dea_vrs)
eff
bcc=1/eff
bcc

# Peer DMU's and their weights
references(dea_vrs)

#Target values
targets(dea_vrs)

# exporting the data to Excel file
summary(dea_vrs, exportExcel = TRUE,filename='bcc smart results.csv')
```

Explaination:

read_data() function creates, from a data frame, a deadata structure, which is as list with fields input, output, dmunames, nc_inputs, nc_outputs, nd_inputs, nd_outputs.

The read_data() function takes the following arguments:

- datadea: It is the dataset (It must be a dataframe).
- dmus: Number of the column where the DMUs are. By default, deaR considers DMU s are in the first column of the dataset.
- ni: It is the number of inputs.
- no: It is the number of outputs.
- inputs: We can indicate the numbers of the columns where the inputs are instead of indicating the number of inputs.
- Outputs: We can indicate the numbers of the columns where the outputs are instea d of indicating the number of outputs.
- nc_inputs: If we have non-controllable inputs, we can indicate which are them.
- nc_outputs: If we have non-controllable outputs, we can indicate which are them.
- nd_inputs: If we have non-discretionary inputs, we can indicate which are them.
- nd_outputs: If we have non-discretionary outputs, we can indicate which are them.
- ud_inputs: If we have undesirable (bad) inputs, we can indicate which are them.

Once we have adapted the data to the reading format in deaR, the next step is to select the DEA model and run it.

Various Conventional DEA models are available in DeaR package.

- Basic (radial) models (envelopment and multiplier forms)
- Directional distance function model
- (Weighted) Additive model
- Super-efficiency additive model
- Radial Super-efficiency model (Weighted)
- Non-radial model
- Preference Structure model (Weighted)
- Slack-based model (Weighted)
- Super-efficiency slack-based model
- Cross-efficiency (crs12 and vrs13)
- Bootstrapping (Simar and Wilson algorithm)
- FDH model

model_basic() *is* used to solve the input and output oriented basic DEA models (envelopment form) constant returns to scale(CCR DEA), variable returns to scale(BCC DEA), non- increasing, non- decreasing and generalised returns to scale. By default, models are solved in a two staged process (DEA slacks are maximised).

The model_basic function allows us to deal with the non-discretionary, non- cintrollable and undesirable inputs and output variables. It can also be used to solve the directionary DEA model by specifying the orientation="dir".

Note

(1) With undesirable inputs/outputs and non-directional orientation, you should select "vrs" returns to scale (BCC model) in order to maintain translation invariance (Seiford and Zhu, 2002). If deaR detects that you are not specifying rts = "vrs", it makes the change to "vrs" automatically.

(2) With undesirable inputs and non-directional orientation use input-oriented BCC model, and with undesirable outputs and non-directional orientation use output-oriented BCC model. Alternatively, you can also treat the undesirable outputs as inputs and then apply the input-oriented BCC model (similarly with undesirable inputs).

(3) With orientation = "dir" (directional distance function model), efficient DMUs are those for which beta = 0.

efficiencies() function is used to extract the efficienies from a dea object defined as dea_vrs above. It will give the value 1 for efficient DMUs and less than 1 for inefficient DMUs. So , as mentioned in the literature overview chapter, we will take the reciprocal of these values to get the efficiency scores for each store which is between 0 and 1.

references() function is used to extract the reference set for each DMU (inefficient DMUs and efficicent DMUs that are combination of other efficient DMUs) from a DEA model solution.

targets() function is used to extract the input and output targets of the DMUs from a dea solution.

summary() function gives the summary of the results obtained by a DEA model. It helps in exporting them into excel file for more convenience.

R-code for implementing CCR output oriented model is given below.

```
# CCR model
dt <- read_data(smart,ni= 2:4,no=5:7,inputs=2:4,outputs=5:7,nc_inputs=1)
dea_crs<- model_basic(dt,orientation="oo",rts = "crs")

# finding the efficiency values
eff=efficiencies(dea_crs)
eff
bcc=1/eff
bcc

# exporting the data to Excel file
summary(dea_crs, exportExcel = TRUE,filename='ccr smart results.csv')
```

Similarly, R-code for implementing Additive and Super Efficiency model is given below.

```
#Read the DEA data
dt <- read_data(smart,
                ni= 2:4,no=5:7,inputs=2:4,outputs=5:7,nc_inputs=1)
#ADDITIVE MODEL
dea_add<- model_additive(dt,rts = "vrs")
summary(dea_add, exportExcel = TRUE,filename='add smart result.csv')

#SUPER EFFICIENCY MODEL
dea_se<- model_supereff(dt,orientation = "oo",rts = "crs")
summary(dea_se, exportExcel = TRUE,filename='SE smart result.csv')
```

<u>Explanation:</u>

model_additive() is used to solve the additive model at Charnes et al. (1985) under the assumption of variable returns to scale. In addition, the user can define the weights for input and output slacks in this function to solve weighted additive models.

model_supereff() is used to solve Andersen and Petersen radial Super-efficiency DEA model.

<u>Note</u>

(1) Radial super-efficiency model under variable (vrs, nirs, ndrs, grs) returns to scale can be infeasible for certain DMUs.

(2) DMUs with infeasible solution are not shown in the results.

On the similar lines,

For Reliance Fresh Stores:

R-code for implementing BCC output oriented model is given below.

```
# reading the data
fresh=read.csv('data- rel fresh in csv.csv')
colnames(fresh)

# BCC model
dt <- read_data(fresh,ni= 2:7,no=8:12,inputs=2:7,outputs=8:12,nc_inputs=1)
dea_vrs<- model_basic(dt,orientation="oo",rts = "vrs")

# finding the efficiency values
eff=efficiencies(dea_vrs)
eff
bcc=1/eff
bcc

# exporting the data to Excel file
summary(dea_vrs, exportExcel = TRUE,filename='bcc fresh results.csv')
```

R-code for implementing CCR output oriented model is given below.

```
# reading the data
fresh=read.csv('data- rel fresh in csv.csv')
colnames(fresh)

# CCR model
dt <- read_data(fresh,ni= 2:7,no=8:12,inputs=2:7,outputs=8:12,nc_inputs=1)
dea_crs<- model_basic(dt,orientation="oo",rts = "crs")

# finding the efficiency values
eff=efficiencies(dea_crs)
eff
bcc=1/eff
bcc

# exporting the data to Excel file
summary(dea_crs, exportExcel = TRUE,filename='ccr fresh results.csv')
```

Similarly, R-code for implementing Additive and Super Efficiency model is given below.

```
#Read the DEA data
dt <- read_data(fresh,ni= 2:7,no=8:12,inputs=2:7,outputs=8:12,nc_inputs=1)

#ADDITIVE MODEL
dea_add<- model_additive(dt,rts = "vrs")
summary(dea_add, exportExcel = TRUE,filename='add fresh result.csv')

#SUPER EFFICIENCY MODEL
dea_se<- model_supereff(dt,orientation = "oo",rts = "crs")
summary(dea_se, exportExcel = TRUE,filename='SE fresh result.csv')
```

Implementing DEA Models Using LINGO CODE-

The LINGO-code for computing the BCC output-oriented efficiency for one store in each of Reliance Smart store (Jharsa Road) and Reliance Fresh store (Narela) is given as an example below. Similar code can be used for computing the efficiency of other DMU stores by changing the RHS of the constraints. Note that here,

- The dual optimisation model is used,
- The rental cost variable constraint has an equality to depict that it is a non-controllable variable and,
- The variable of EBITDA has the coefficients values as the original value plus some constant value in order to get rid of the negative values in the output variable for computing DEA.

For Reliance Smart stores:

Note that here, the initials for each store are used to indicate the lambda values for each store.

```
! For Jharsa Road-jr (Reliance Smart store);
max= Ejr;

! Input constraint for Rent(in lakhs)- Non controllable variable;
16.90*jr+4.08*mg+8.14*cim+14.80*dw+18.15*dlf+10.24*ap+13.59*bmg+15.11*jm+8.92*ss
+8.61*cg+11.23*bp+4.89*vp+16.49*apm+20.51*gmr+14.52*at+15.78*sn+10.85*ib+11.82*g
dp+3.33*sp=16.90;

! Input constraint for Staff cost(in lakhs);
10.34*jr+8.83*mg+18.57*cim+16.61*dw+9.34*dlf+6.62*ap+9.39*bmg+14.22*jm+9.50*ss
+7.62*cg+10.42*bp+17.27*vp+13.56*apm+15.50*gmr+10.30*at+20.04*sn+10.02*ib+10.78*
gdp+7.34*sp<=10.34;
```

```
! Input constraint for Utilities(in lakhs);
4.28*jr+1.53*mg+5.83*cim+6.16*dw+2.04*dlf+2.84*ap+1.64*bmg+5.23*jm+2.38*ss
+3.33*cg+2.52*bp+4.84*vp+3.97*apm+3.71*gmr+3.70*at+7.01*sn+2.49*ib+5.14*gdp+2.23
*sp<=4.28;

! Output constraint for Sales;
277.22*jr+292.83*mg+791.84*cim+418.58*dw+317.62*dlf+207.10*ap+274.86*bmg+431.45*
jm+251.31*ss+89.20*cg+218.11*bp+346.40*vp+275.48*apm+206.41*gmr+175.96*at+269.63
*sn+283.41*ib+174.85*gdp+97.11*sp>=277.22*Ejr;

! Output constraint for EBITDA;
22.48*jr+47.87*mg+77.98*cim+23.09*dw+33.62*dlf+24.76*ap+33.83*bmg+32.44*jm+36.19
*ss+14.55*cg+22.68*bp+31.12*vp+13.52*apm+1*gmr+11.08*at+5.03*sn+38.15*ib+11.96*g
dp+22.59*sp>=22.48*Ejr;

! Output constraint for Ratings;
4.0*jr+3.7*mg+4.3*cim+4.3*dw+4.0*dlf+4.1*ap+4.1*bmg+4.2*jm+4.1*ss+4.2*cg+4.1*bp+
4.2*vp+4.2*apm+4.1*gmr+4.1*at+4.2*sn+4.1*ib+4.1*gdp+3.7*sp>=4*Ejr;

! for variable returns to scale;
jr+mg+cim+dw+dlf+ap+bmg+jm+ss+cg+bp+vp+apm+at+gmr+sn+ib+gdp+sp=1;
! non negativity constraints;
jr>=0;
mg>=0;
cim>=0;
dw>=0;
dlf>=0;
ap>=0;
bmg>=0;
jm>=0;
ss>=0;
cg>=0;
bp>=0;
vp>=0;
apm>=0;
at>=0;
gmr>=0;
sn>=0;
ib>=0;
gdp>=0;
sp>=0;
end
```

The result is depicted as below. With the Objective value as $\phi^* = 1/\theta^*$ for θ^* being the efficiency value between 0 and 1, as mentioned in the literature overview chapter. Along with this, the table consisting of the values for each variable in the model is given below depicting the weights called as lambda in the dual variable model. Also, the slack or surplus variable are given below the weights table indicating the improvement value that can be done for each row in the linear program depicted above.

```
Global optimal solution found.
Objective value:                              1.017749
Infeasibilities:                              0.000000
```

```
Total solver iterations:                              14
Elapsed runtime seconds:                            0.08

Model Class:                                          LP

Total variables:                     20
Nonlinear variables:                  0
Integer variables:                    0

Total constraints:                   27
Nonlinear constraints:                0

Total nonzeros:                     156
Nonlinear nonzeros:                   0



Variable    Value            Reduced Cost
EJR        1.017749             0.000000
JR         0.000000             0.1774945E-01
MG         0.000000             0.1672635
CIM        0.000000             0.7830496E-01
DW         0.000000             0.1451454E-01
DLF        0.6450109            0.000000
AP         0.000000             0.4632834E-02
BMG        0.000000             0.6869462E-02
JM         0.000000             0.1553788E-01
SS         0.000000             0.4004500E-01
CG         0.8384747E-01        0.000000
BP         0.000000             0.3253955E-01
VP         0.000000             0.1138131
APM        0.2711416            0.000000
GMR        0.000000             0.1503618E-01
AT         0.000000             0.8779051E-02
SN         0.000000             0.6410887E-01
IB         0.000000             0.3150183E-01
GDP        0.000000             0.3176509E-01
SP         0.000000             0.1588136

Row    Slack or Surplus      Dual Price
1        1.017749            1.000000
2        0.000000           -0.6888714E-02
3        0.000000            0.9138563E-02
4        1.608533            0.000000
5        4.901148            0.000000
6        3.692074            0.000000
7        0.000000           -0.2500000
8        0.000000            1.039676
9        0.000000            0.000000
10       0.000000            0.000000
11       0.000000            0.000000
12       0.000000            0.000000
13       0.6450109           0.000000
14       0.000000            0.000000
15       0.000000            0.000000
```

```
16       0.000000          0.000000
17       0.000000          0.000000
18       0.8384747E-01     0.000000
19       0.000000          0.000000
20       0.000000          0.000000
21       0.2711416         0.000000
22       0.000000          0.000000
23       0.000000          0.000000
24       0.000000          0.000000
25       0.000000          0.000000
26       0.000000          0.000000
27       0.000000          0.000000
```

For Reliance Fresh stores:

Note that here, the lambda values for each store as sk for k=1,2,3,…….45. and e1 represents the efficiency score to be maximised as in case of output orientation for the first store. similarly, we will have e2, e3…. e45 after creating the similar kind of linear programming problems

```
! For Narela-s1 (Reliance Fresh store);
max= e1;

! Input Variable- Rent- non controllable variable;
1.81*s1+2.58*s2+1.14*s3+1.86*s4+5.23*s5+1.12*s6+6.45*s7+1.77*s8+3.08*s9+3.15*s10
+1.46*s11+1.51*s12+2*s13+2.38*s14+2.28*s15+1.82*s16+2.63*s17+0.97*s18+2.19*s19+1
.96*s20+2.68*s21+3.20*s22+2.21*s23+2.18*s24+1.01*s25+2.40*s26+3.38*s27+2.90*s28+
2.03*s29+1.17*s30+2.14*s31+1.58*s32+1.56*s33+1.90*s34+3.05*s35+2.52*s36+5.05*s37
+2.11*s38+1.66*s39+3.04*s40+2.16*s41+1.65*s42+1.44*s43+8.04*s44+3.56*s45=1.81;

! Input Variable- Staff Cost;
4.43*s1+2.85*s2+2.96*s3+3.13*s4+6.08*s5+3.51*s6+3.75*s7+2.64*s8+3.03*s9+3.27*s10
+3.54*s11+3.44*s12+4.16*s13+3.87*s14+2.54*s15+3.22*s16+3.65*s17+3.02*s18+3.24*s1
9+4.13*s20+4.74*s21+4.46*s22+3.46*s23+2.85*s24+2.92*s25+3.86*s26+3.56*s27+3.21*s
28+4.19*s29+2.74*s30+3.54*s31+2.78*s32+3.13*s33+3*s34+3.4*s35+4.13*s36+4.02*s37+
2.64*s38+2.19*s39+2.61*s40+3.34*s41+2.94*s42+3.26*s43+4.54*s44+5.88*s45<=4.43;

! Input Variable- Utilities;
0.89*s1+0.98*s2+0.57*s3+1.99*s4+0.76*s5+0.97*s6+1.29*s7+1.39*s8+1.27*s9+1.49*s10
+1.39*s11+1.49*s12+1.09*s13+1.57*s14+0.85*s15+0.86*s16+0.65*s17+1.10*s18+1.05*s1
9+1.19*s20+1.32*s21+1.29*s22+0.82*s23+1.11*s24+1.82*s25+2.39*s26+1.54*s27+0.97*s
28+1.96*s29+1*s30+1.11*s31+1.71*s32+0.88*s33+0.72*s34+1.89*s35+0.95*s36+0.89*s37
+0.88*s38+1.65*s39+0.73*s40+1.30*s41+0.95*s42+1.27*s43+0.93*s44+0.95*s45<=0.89;

! Input Variable- SP&A;
0.21*s1+0.43*s2+0.40*s3+0.41*s4+0.47*s5+0.45*s6+0.46*s7+0.52*s8+0.56*s9+0.57*s10
+0.35*s11+0.42*s12+0.42*s13+0.49*s14+0.42*s15+0.34*s16+0.41*s17+0.33*s18+
0.34*s19+0.42*s20+0.38*s21+0.43*s22+0.41*s23+0.41*s24+0.33*s25+0.37*s26+0.43*s27
+0.4*s28+0.44*s29+0.43*s30+0.35*s31+0.39*s32+0.34*s33+0.32*s34+0.41*s35+0.44*s36
+0.46*s37+0.42*s38+0.53*s39+0.54*s40+0.36*s41+0.34*s42+0.41*s43+0.50*s44+
0.43*s45<=0.21;
```

```
! Input Variable- HK & PT;
0.27*s1+0.20*s2+0.26*s3+0.27*s4+0.3*s5+0.2*s6+0.23*s7+0.22*s8+0.22*s9+0.24*s10+
0.28*s11+0.28*s12+0.27*s13+0.23*s14+0.22*s15+\0.26*s16+0.28*s17+0.27*s18+
0.28*s19+0.3*s20+0.29*s21+0.26*s22+0.27*s23+0.27*s24+0.28*s25+0.28*s26+0.28*s27+
0.27*s28+0.28*s29+0.19*s30+0.29*s31+0.27*s32+0.27*s33+0.28*s34+0.32*s35+0.29*s36
+0.22*s37+0.22*s38+0.23*s39+0.23*s40+0.28*s41+0.27*s42+0.28*s43+0.25*s44+
0.53*s45<=0.27;

! Input Variable- R & P;
0.3*s1+0.32*s2+0.24*s3+0.22*s4+0.3*s5+0.6*s6+0.42*s7+0.22*s8+0.25*s9+0.29*s10+
0.37*s11+0.58*s12+0.28*s13+0.45*s14+0.71*s15+0.23*s16+0.29*s17+0.24*s18+0.17*s19
+0.38*s20+0.28*s21+0.43*s22+0.23*s23+0.72*s24+0.24*s25+0.36*s26+0.24*s27+0.3*s28
+0.23*s29+0.47*s30+0.27*s31+0.21*s32+0.42*s33+0.33*s34+0.43*s35+0.23*s36+0.61*s3
7+0.27*s38+0.55*s39+0.27*s40+0.58*s41+0.25*s42+0.43*s43+0.14*s44+0.38*s45<=0.3;

! Output Variable- Sales;
112.61*s1+74.12*s2+71.38*s3+92.29*s4+131.69*s5+86.91*s6+105.26*s7+64.29*s8+
113.74*s9+113.85*s10+84.41*s11+85.20*s12+88.33*s13+131.91*s14+64.38*s15+83.84*s1
6+70.37*s17+54.66*s18+80.29*s19+74.96*s20+109.42*s21+97.49*s22+74.47*s23+
79.4*s24+61.78*s25+100.52*s26+82.55*s27+70.54*s28+93.74*s29+75.67*s30+80.41*s31+
52.12*s32+71.70*s33+52*s34+93.53*s35+105.74*s36+96.17*s37+62.94*s38+94.64*s39+
104.71*s40+82.46*s41+67.03*s42+66.78*s43+147.45*s44+167.31*s45>=112.61*e1;

! Output Variable- NOB;
654*s1+525*s2+709*s3+772*s4+873*s5+598*s6+849*s7+530*s8+661*s9+696*s10+812*s11+8
54*s12+725*s13+841*s14+556*s15+553*s16+729*s17+641*s18+448*s19+600*s20+900*s21+6
94*s22+700*s23+673*s24+661*s25+799*s26+536*s27+571*s28+952*s29+790*s30+795*s31+4
46*s32+549*s33+403*s34+539*s35+641*s36+894*s37+607*s38+615*s39+565*s40+607*s41+6
50*s42+591*s43+746*s44+901*s45>=654*e1;

! Output Variable- ABV;
614*s1+502*s2+348*s3+418*s4+524*s5+510*s6+426*s7+433*s8+620*s9+578*s10+369*s11+3
47*s12+426*s13+558*s14+405*s15+533*s16+334*s17+302*s18+636*s19+441*s20+430*s21+4
89*s22+367*s23+409*s24+330*s25+439*s26+546*s27+434*s28+345*s29+333*s30+355*s31+
416*s32+457*s33+457*s34+617*s35+579*s36+368*s37+360*s38+552*s39+666*s40+475*s41+
365*s42+394*s43+690*s44+659*s45>=614*e1;

! Output Variable- EBITDA;
10.07*s1+4.91*s2+4.57*s3+2.13*s4+8.98*s5+6.39*s6+3.88*s7+3.29*s8+6.77*s9+
9.19*s10+5.91*s11+3.87*s12+1.98*s13+9.9*s14+1.58*s15+5.68*s16+1.42*s17+4.09*s18+
5.17*s19+1.65*s20+6.21*s21+4.4*s22+5.17*s23+2.25*s24+2.87*s25+4.53*s26+3.83*s27+
1*s28+5.43*s29+5.6*s30+4.83*s31+1.41*s32+3.05*s33+2.39*s34+1.26*s35+5.77*s36+
2.17*s37+1.71*s38+6.16*s39+6.97*s40+4.19*s41+4.64*s42+1.97*s43+7.81*s44+13.47*s4
5>=10.07*e1;

! Output Variable- Ratings;
4*s1+3.9*s2+3.9*s3+3.8*s4+3.9*s5+3.6*s6+3.9*s7+3.5*s8+3.8*s9+4.1*s10+4.1*s11+3.8
*s12+3.9*s13+4*s14+3*s15+3.8*s16+3.8*s17+4*s18+3.9*s19+3.9*s20+3.8*s21+3.8*s22+
3.3*s23+3.7*s24+4*s25+3.9*s26+3.9*s27+3.8*s28+4*s29+3.8*s30+3.9*s31+3.9*s32+3.8*
s33+4*s34+3.9*s35+4.1*s36+3.7*s37+3.8*s38+4*s39+4.1*s40+3.9*s41+3.8*s42+3.8*s43+
3.9*s44+4.1*s45>=4*e1;
```

```
! variable returns to scale;
s1+s2+s3+s4+s5+s6+s7+s8+s9+s10+s11+s12+s13+s14+s15+s16+s17+s18+s19+s20+s21+s22+s
23+s24+s25+s26+s27+s28+s29+s30+s31+s32+s33+s34+s35+s36+s37+s38+s39+s40+s41+s42+s
43+s44+s45=1;

! non negative constraints;
s1>=0;
s2>=0;
s3>=0;
s4>=0;
s5>=0;
s6>=0;
s7>=0;
s8>=0;
s9>=0;
s10>=0;
s11>=0;
s12>=0;
s13>=0;
s14>=0;
s15>=0;
s16>=0;
s17>=0;
s18>=0;
s19>=0;
s20>=0;
s21>=0;
s22>=0;
s23>=0;
s24>=0;
s25>=0;
s26>=0;
s27>=0;
s28>=0;
s29>=0;
s30>=0;
s31>=0;
s32>=0;
s33>=0;
s34>=0;
s35>=0;
s36>=0;
s37>=0;
s38>=0;
s39>=0;
s40>=0;
s41>=0;
s42>=0;
s43>=0;
s44>=0;
s45>=0;
end
```

The result is depicted as below. With the Objective value as $\phi^* = 1/\theta^*$ for θ^* being the efficiency value between 0 and 1, as mentioned in the literature overview chapter. Along with this, the table consisting of the values for each variable in the model is given below depicting the weights called as lambda in the dual variable model. Also, the slack or surplus variable are given below the weights table indicating the improvement value that can be done for each row in the linear program depicted above.

```
Global optimal solution found.
Objective value:                              1.000000
Infeasibilities:                              0.000000
Total solver iterations:                             7
Elapsed runtime seconds:                          0.71

Model Class:                                        LP

Total variables:                     46
Nonlinear variables:                  0
Integer variables:                    0

Total constraints:                   58
Nonlinear constraints:                0

Total nonzeros:                     591
Nonlinear nonzeros:                   0



Variable        Value           Reduced Cost
E1             1.000000           0.000000
S1             1.000000           0.000000
S2             0.000000           0.2797303
S3             0.000000           0.3235204
S4             0.000000           0.6050151
S5             0.000000           0.5571251
S6             0.000000           0.2769983
S7             0.000000           0.5798507
S8             0.000000           0.4352215
S9             0.000000           0.1867206
S10            0.000000           0.000000
S11            0.000000           0.2887985
S12            0.000000           0.5002282
S13            0.000000           0.8360938
S14            0.000000           0.1934414E-01
S15            0.000000           0.5424120
S16            0.000000           0.2415770
S17            0.000000           0.7825401
S18            0.000000           0.3541068
S19            0.000000           0.2963386
S20            0.000000           0.8626903
S21            0.000000           0.5185849
S22            0.000000           0.6617215
```

```
S23            0.000000            0.3710439
S24            0.000000            0.5354732
S25            0.000000            0.4546782
S26            0.000000            0.5001048
S27            0.000000            0.5331010
S28            0.000000            0.7336940
S29            0.000000            0.5080742
S30            0.000000            0.1885714
S31            0.000000            0.3960477
S32            0.000000            0.5960749
S33            0.000000            0.4842264
S34            0.000000            0.5146049
S35            0.000000            0.7469776
S36            0.000000            0.4619623
S37            0.000000            0.8052294
S38            0.000000            0.5500828
S39            0.000000            0.6180842E-01
S40            0.000000            0.7201353E-01
S41            0.000000            0.4226459
S42            0.000000            0.2872287
S43            0.000000            0.6476585
S44            0.000000            0.3689846
S45            0.000000            0.5326920E-01


Row    Slack or Surplus      Dual Price
1         1.000000            1.000000
2         0.000000            0.000000
3         0.000000            0.2058048
4         0.000000            0.000000
5         0.000000            0.4204036
6         0.000000            0.000000
7         0.000000            0.000000
8         0.000000            0.000000
9         0.000000            0.000000
10        0.000000            0.000000
11        0.000000           -0.9930487E-01
12        0.000000            0.000000
13        0.000000            0.000000
14        1.000000            0.000000
15        0.000000            0.000000
16        0.000000            0.000000
17        0.000000            0.000000
18        0.000000            0.000000
19        0.000000            0.000000
20        0.000000            0.000000
21        0.000000            0.000000
22        0.000000            0.000000
23        0.000000            0.000000
24        0.000000            0.000000
25        0.000000            0.000000
26        0.000000            0.000000
27        0.000000            0.000000
28        0.000000            0.000000
29        0.000000            0.000000
```

30	0.000000	0.000000
31	0.000000	0.000000
32	0.000000	0.000000
33	0.000000	0.000000
34	0.000000	0.000000
35	0.000000	0.000000
36	0.000000	0.000000
37	0.000000	0.000000
38	0.000000	0.000000
39	0.000000	0.000000
40	0.000000	0.000000
41	0.000000	0.000000
42	0.000000	0.000000
43	0.000000	0.000000
44	0.000000	0.000000
45	0.000000	0.000000
46	0.000000	0.000000
47	0.000000	0.000000
48	0.000000	0.000000
49	0.000000	0.000000
50	0.000000	0.000000
51	0.000000	0.000000
52	0.000000	0.000000
53	0.000000	0.000000
54	0.000000	0.000000
55	0.000000	0.000000
56	0.000000	0.000000
57	0.000000	0.000000
58	0.000000	0.000000