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ISSN: 0193-4120 Page No. 277-291

Assessing Supply Chain Performance: A DEA Approach

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Article Info
Volume 81
Page Number:277-291
Publication Issue:
September /October 2019

Article History
Article Received:*5 March 2019*
Revised: *18 May 2019*
Accepted: *24 September 2019*
Publication: *21 October 2019*

Abstract:
Supply chain faces challenges relating to the utilizations of resources as well as the competition. It is linked with supply chain members and hence the total system will be strengthened through integration and collaboration. In this globalisation era, it has been observed that there are growth and profit of an industry directly linked with a well-structured supply chain. The performance of supply chain management not only depends on the profit and growth but also linked with the customer satisfaction and long-term sustainability. For this problem, this study seeks to evaluate the measuring instrument for supply chain management that contribute towards the performance. So, performance of supply chain depends on the factors contributing towards logistic management, productivity management, customer service management as well as quality management.

This research employs both qualitative and quantitative methods. A focused group discussion has carried out for the qualitative analysis of the study. Data were analyzed through DEA technique to evaluate the supply chain performance. The DEA methodology is useful for supply chain organizations to identify their position in relation to their peers and to develop strategies for improvement through the right mix of inputs and outputs. Benchmarking is a better option for improving the performance of individual firms, which can be analyzed using DEA techniques.

Keywords: *Supply Chain, Data Envelopment Analysis, Performance management, Benchmarking*

1. INTRODUCTION

Supply Chain Management is critical to improving a company's performance. According to Simchi-Levi et al. (2000), supply chain management is a set of approaches used to effectively integrate suppliers, manufacturers, warehouses, and stores so that merchandise is produced and distributed in the right quantities, to the right locations, and at the right time, minimizing system-wide costs while meeting service level requirements. The supply chain is defined as a system that connects material suppliers, manufacturing facilities, distribution services, and customers through four processes: plan, source, make, and deliver. As a result, effective supply chain management is in charge of ensuring on-time and dependable delivery of high-quality products and services at the lowest possible cost. This is a critical cornerstone for organizations to develop a sustainable competitive advantage and remain at the forefront of excellence in a level playing field.

The evaluation of the entire supply chain is critical for achieving an efficient supply chain. This entails making the most efficient use of the supply chain members' combined resources in order to provide competitive and cost-effective products and services. As a result, "overall supply chain performance" is defined as the performance that considers multiple measures related to supply chain members, as well as their integration and coordination. As a result, managing the overall performance of the supply chain is a difficult and challenging task. According to Ross (1998), supply chain measurement systems were not in place at large corporations such as Sears and General Motors, which had large supply chain systems. It is critical to stress that the primary goal of this paper is to provide a realistic framework for studying supply chains. The author discusses an example with managerial implications. As a result, if a full scale of supply chain performance measurement is considered, incomplete and unavailability of data in many organizations may render the model inoperable. As a result, the scope of this paper's discussion of supply chain performance is limited to direct suppliers and customer relationships. In other words, only the first and second tiers of the supply chain are taken into account. The goal of the paper is to use all of the value chain activities to measure the supply chain within a manufacturing company. It's important to note that the goal is to focus on the supply chain activities within the manufacturing organization, not just the manufacturing processes. Despite the fact that the study does not cover the entire value chain, from the suppliers' suppliers to the final customer, the measure could still be referred to as supply chain performance within the context of the internal organization. Using Data Envelopment Analysis, this study will develop a tool to measure internal supply chain performance (DEA).

DEA is a nonparametric method for evaluating the efficiencies of the analyzed units that uses a linear programming technique. DEA can measure multiple inputs and outputs, as well as quantitatively and qualitatively evaluate the measures, allowing managers to make informed decisions about the performance of the analyzed units. We propose a DEA model to evaluate supply chain performance in various companies in this paper. This model aids management in identifying inefficient operations and recommending solutions for improving supply chain performance. The following is how the paper's chapter is organized in general. We begin by providing a brief overview of some of the traditional methods of measuring supply chain and the issues that come with them, followed by a discussion of DEA and its application in supply chain. The methodology and DEA models developed to measure supply chain performance are then explained.

2. Literature Review

Singh, Kumar, and Chand (2018) concentrated on a comprehensive approach to quantifying supply chain coordination for effective supply chain performance benchmarking in the Industry 4.0 era. Rather than Industry 4.0 technologies, top management appears to be focusing on organizational issues such as lean organizational structure, organisational culture, and responsiveness factors for improving supply chain coordination.

(Balakannan et al., 2016) used a balance score card to evaluate supply chain performance. A balanced score card is a management tool that includes information and proposes a new way to assess the performance of manufacturing industries based on four broad aspects that overlap and overlap with design and development, manufacturing, financial requirements, and consumer needs. PSPP software was used to perform a reliability analysis of four evaluative perspectives for the supply chain performance score i.e design and execution, policies and firm coordination, information technology and shipment effectiveness. Lisrel software was used to conduct a structure analysis for supply chain and logistics performance score card. The authors confirmed that it is critical to establish long-term cooperative relationships with customers and suppliers, as well as to provide effective worker training. (Junior, Ensslin, and Ensslin, 2011) created a supply chain performance evaluation model capable of reflecting decision makers' values and preferences and providing them with the support they need to make decisions that improve the company's operations. The theoretical framework was built using bibliographic research, and the Multicriteria Decision Aid Methodology – Constructivist was chosen as the intervention tool (MCDA-C). The MACBETH's pair-to-pair comparison method was chosen to define the conversion rates in this paper because it allows the decision maker to express his preferential judgments using a semantic scale. The three stages of this case study were structuring, evaluation, and recommendations. Kusrini, Subagyo, and Masruroh

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(2014) investigated how to assess a supply chain performance model. The survey was conducted using a random sampling technique to distribute questionnaires to SCM actors. The respondents to the survey were SCM actors who were capable of evaluating the level of efficiency and effectiveness in a variety of Indonesian businesses, including services, manufacturing, mining and electricity. They classified the criteria into two groups: efficient and effective. Three sub-criteria made up the efficient criteria: not too much data, low cost, and output presented in a simple format. The following criteria were found to be effective: validity, clarity, responsiveness, comprehensiveness, and dynamics, in that order. Using pairwise comparisons and an analytical Hierarchy Process model to analyse the data, it was discovered that efficient criteria outweighed effective criteria.

Sillanpaa (2012) proposed that the supply chain measurement framework for the manufacturing industry define which data should be measured and validate the measurement framework in the case company's supply chain. The author discovered the measurement framework's key elements, which are profitability, time, managerial analysis order book analysis. According to Sirsath, Dalu (2015), performance measurement helps with strategy planning and goal setting. The process of developing strategic plans and goals is less meaningful without the ability to measure performance and progress. Based on their literature review, he discovered that the SCOR Model of SC Evaluation is more practical than other models. Chena and Gong (2013) proposed a new supply chain design and evaluation method that can be used to model a real-world supply chain network design process and determine the best scheme. The cost factors are the most important index, and they are divided into four categories: disruption costs, production costs, vulnerability costs and coordination costs. Liu (2013) focused on green supply chain performance, which includes three key financial, operational, and environmental indicators. He discovered that the financial aspect of the supply chain must be improved in order for the entire supply chain's performance to improve. According to Khan(2013), a model of supply chain management performance that integrates all supply chain functions and measures overall supply chain performance is needed. AHP, Fuzzy, and DEA multi-criteria decision-making tools can be useful in developing models that evaluate overall supply chain management performance because overall supply chain management is dependent on many criteria. Sarkis and Dou (2015) used the DEMATEL method and adopted a multi-criteria decision-making model that focused on the identification of relational practises in the supply chain environment. The concept of big data was introduced by Brinch and et al. (2017). He looked at big data and its application in SCM from the standpoint of business processes, which can assist the supply chain community in determining where big data's value can be applied. This study employs a sequential mixed-methods approach. First, a Delphi study was conducted to gain insight into big data terminology, and then applications of big data in SCM were identified using an adjusted SCOR process framework. Following that, a survey of supply chain executives was conducted to clarify the Delphi study findings and assess the practical application of big data. Jamkhaneh et al. (2017) focused on the importance of each criterion and the relationship between them in the Iranian services supply chain (SSC). He investigated using the DEMATEL method. Finally, the final weight of each criterion was calculated using the DANP method. According to the findings, using the process of SSC 19 evaluation criteria have been identified in Iran. These criteria were divided into four categories based on their nature and the "Deming Excellence Model and ISO 9004 standards: Plan, Do, Check, and Act". Furthermore, the Act dimension, which has a weight of 0.275, is the most important, while the Plan dimension, which has a weight of 0.219, is the least important.

Asmussen et al. (2018) explored how management attention and supply chain complexity affect supply chain design (SCD) decision-making

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and cost estimation accuracy. He said that as the complexity of “supply chain decision-making” grows, the accuracy of cost estimation declines. The degree to which “supply chain decision-making” complexity is readily recognized has an impact on the tactics used for information search and analysis, as well as the cost estimating inaccuracies that occur. The paper also demonstrates the relevance of management attention for cost estimating accuracy, particularly when conflicting goals promote behaviours that improve estimation ability. Mor and Singh (2017) focused on dairy supply chain performance indicators. The authors of this study used an ISM-based model to benchmark supply chain procedures and MICMAC analysis to classify PIs. Based on a literature review and expert opinion, performance indicators (PIs) have been identified as variables. These include: 1) Effective quality management, 2) Effective product marketing, 3) Supplier relationship management, 4) Brand management and featured products, 5) Traceability systems, 6) Effective cold chain infrastructure, 7) Information-technology enabled support system, 8) Milk wastages management, 9) Shipment accuracy 10) Production Operation Management, and 11) Support for technological innovations.

The important PIs in the dairy industry sector include effective information technology, brand management, waste control, and responsiveness in shipment and accuracy according to the model. The next main PIs are effective traceability systems, cold chain infrastructure, quality management, and support for technological advancements. In MICMAC analysis, there is no autonomous PI, demonstrating the relevance of the discovered PIs in the case study. Jharkharia, Das (2018) analysed the relevant literature on “low carbon supply chain management” (LCSCM) and classified it according to context. In LCSCM, they discovered important decision-making concerns. By incorporating emissions-related challenges into all supply chain operations, such as inventory planning, network design, supplier selection, and logistic decisions, all supply chain tasks have been redefined. This study highlights the findings of previous studies on low carbon transportation planning, inventory control, location selection, and coordination of supply chain. Simangunsong et al. (2016) looked at successful management solutions for 14 different types of supply chain uncertainty, with a focus on ethical uncertainties and strategies. Three ethical difficulties are highlighted empirically: first, “supplier collaboration to ration supply and raise prices”; second, “unethical influences on government policy”; and third, huge merchants' "abuse of power at the expense of smaller competitors”. Large food sellers have been reported to engage in anti-competitive behavior. Joint purchase has been proposed as a crucial technique for addressing the first of these ethical concerns. Forslund (2015) investigated and created hypotheses about the elements that influence the degree of integration of performance management processes in retail supply chains. Two retail supply chains' performance management processes were investigated. The daily grocery supply chain is covered in the first segment, and the home decorating supply chain is covered in the second. Five proposals are generated as a result of differences in the degree of performance management process integration and influencing factors. The degree of performance management process integration appears to be positively connected to brand importance, dependability, performance demand, business process integration, and the existence of a performance management standard in the relationship. Performance management process integration in particular and process integration in general are both considered. When "performance management managers" need to convey integration aspirations with other managers within and beyond their own firm, knowledge of influencing factors comes in handy. AL-Shboul et al. (2016) looked at the best supply chain management practices used by medium and large Gulf industrial companies. flexibility with partners, supplier collaboration, use of the Internet, lean production, customer focus, quality management and internal integration, were all investigated in this study. It

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assumes that the top-performing companies are those that use the best practices. The best practices used by medium and large-sized Gulf manufacturing enterprises were determined using a T-test and multiple linear regression analysis. The findings revealed that in Gulf manufacturing enterprises, customer focus, quality management, and supplier collaboration are deemed to be the best supply chain management techniques. Rudolf and Spinler (2018) verified a specific supply chain risk portfolio of large-scale engineering and construction projects, and developed and contextualized SCRM to make it more useful for large-scale project application and support management practices, leading to a higher success rate of major projects. The findings explored into four key categories: supplier, supply chain coordination and management, environment, behavior and cooperation, and environment, which are all relevant to large-scale projects. The identified risk portfolio deviates greatly from generic projects and reveals a large-scale project's intrinsic risk exposure to be extremely high. Behavioral risks, in particular, have been highlighted as critical. Gligor et al. (2018) discovered that 15 theories were used in almost 95 percent of supply chain management research that used formal theories. Second, the writers identified the most often utilized marketing and management theories (217 theories). Third, while it is hard to provide a detailed account of each of the 217 theories due to space constraints, the authors choose 30 theories that they believe are most relevant to supply chain study and identify areas where supply chain academics might use these theoretical views. (Schniederjans, 2016) focused on the role of business process innovation in the interaction between social quality management and supply chain performance. Among these relation the result is positive effect. (Kitsis, Chen, and Chen, Kitsis, 2016) created a framework and propositions to promote sustainable supply chain management research and practice (SSCM). Stakeholder pressures, moral motives, and management commitment are all linked to relational behaviors in SSCM implementation. (Al-Shboul, Barber, Garza-Reyes, Kumar, Abdi, 2017) theorized and developed seven dimensions (i.e. level of information sharing, strategic supplier partnership, quality of information sharing, customer service management, internal lean practices, total quality management and postponement) into a “supply chain management” (SCM) practices (SCMPs) construct, and investigated its link to the conceptualized constructs of supply chain performance (SCP) and manufacturing firm (MFP) . The causal link between SCP and MFP was investigated by the authors. (Jordan, Bak, 2016) discovered that supply chain skills needs are best understood in the context of a higher education institution which is UK-based comprising graduates, academics, and employers. Time management, cooperation, collaborative learning, and problem solving are underlined as key graduate skills demands, with the inclusion of two supply chain skill categories, namely specialized training and the knowledge and application of rules. (Liu et al., 2019) gave a behavioral operations viewpoint on the evolution of “service supply chain management”, pointing out future study areas for scholars. In terms of the “service supply chain” link, the authors found that existing literature focuses mostly on service coordination management and service supply, with less emphasis on integration management and service demand. In terms of behavioral characteristics, most focus on classic behavior factors, with developing behavior factors receiving less attention. In this study auhors proposed five research agendas: demand-oriented management and integrated supply chain-oriented behavioral research; broadening the scope of behavioral operations; incorporating the most recent service industry backgrounds and trends into the research; increased focus on behavioural operations in service sub-industries; and To delve into interesting research problems, multimethod combinations are encouraged to be used. (Holsapple and Goldsby, 2019) looked into how the supply chain management team of a multidivisional business (MDF) contributes to supply chain agility. The authors discovered four structural elements that

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have a positive impact on the supply chain agility of a multidivisional firm (MDF): Hierarchical position of the divisional top supply chain executive , the scope of divisional supply chain operations, the headquarters' top supply chain executive's hierarchy, and the headquarters' role in SCM coordination . According to (Kumar et al., (2018) manufacturing risk and supplier risk management are both critical for business performance in Chinese manufacturing. Although there is a strong link between business and manufacturing risk management performance, no significant impact of supplier dependency, production, systematic purchasing, and supply chain maturity, or human resources was discovered. Despite previously being regarded as key influencers of supply and manufacturing risk management performance. Supply chain of Chinese manufacturing, factors such as flexibility, supplier and customer orientation, supply risk and production, all have a strong correlation with business performance. There were 103 valid survey replies and six semi-structured interviews among the findings. (Forslund, 2015) investigated logistics "performance management" strategies in two textile supply chains in order to identify best practices and impediments. In the "logistics performance" management process, differences in practices, priorities, and teamwork were discovered. There were no practices particular to the textile industry discovered. A method of exchanging action plans between the actors is an intriguing best practice that allows for improvement projects to be carried out over large distances. Barriers were discovered in the form of challenges in establishing a collaborative culture; however, IT support appears to no longer be a barrier. With security culture as a moderator, (Zailan et al., 2013) investigated the relationship between security practices and security operational performance. The authors chose service provider organizations in the logistics industry that operate in Malaysia for their study. According to the findings of this study, facility management, cargo management, information management and human resource management all have a positively significant impact on "supply chain" security operational performance. And the relationship between supply chain security performance and facility management practices only confirmed the moderating impact of security culture.

Beamon (1999) focused an overview and review of the performance metrics which used in "supply chain models", as well as a framework for the selection of industrial supply chain performance measurement systems. The categorization of "supply chain performance" measures led in the recognition of three types of performance metrics: resource, output, and flexibility, which are all required components of any "supply chain performance measurement system". This study also discusses existing methods for new product flexibility, and mix flexibility as well as developing volume and Supply chain delivery flexibility measures. System dynamics (SD) and the autoregressive integrated moving average are employed.

(Ip, Chan, and Lam, 2011) mentioned an integrated approach to modelling and measuring "supply chain performance" and stability (ARIMA). employee fulfilment, product reliability, customer fulfilment, profit growth, on-time delivery, and working efficiency were the most significant factors in "supply chain performance", with six corresponding indicators (employee fulfilment, product reliability, customer fulfilment, profit growth, on-time delivery, and working efficiency). The combined model's findings show that the case company's supply chain performance is adequate (average OPIN 14 0.64) and stable, but not exceptional. In order to enhance performance, it is recommended that continuous improvement, particularly in supply chain efficiency, be pursued. (Grover, 2015) created a clear picture of how the retail supply chain functions, stating that performance criteria should encompass both financial and non-financial performance. In four primary categories, the study found the following major indicators for retail supply chain performance: information technology optimization, transportation optimization, resource optimization, inventory

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optimization. The most important aspects of the retail supply chain are transportation and inventory management, which are related to information sharing at many levels for resource management.

(Supatn, Banomyong, 2011) proposed a “supply chain performance” evaluation tool that evaluates a firm's core activities of supply chain across many performance aspects. The tool's results provide a description of a company's internal supply chain activity. The “supply chain performance” framework in use is capable of isolating each supply chain activity. (Vaidya and Hudnurkar, 2013) discussed a method for evaluating “supply chain performance” using multiple criteria. An eight-step technique for performance evaluation is developed using a “multi-criteria decision-making” tool, such as the “analytic hierarchy process”. The research leads to the calculation of the supply chain performance number (SCPN), which ranges from 0 to 1. The benchmark (goal) value is one of the most important aspects of the analysis. (Xia and Tang, 2011) investigated the issues of “supply chain management” and proposed a triple-C (stop-control-combine) solution for the supply chain management of the North American car sector. The authors used management theories, gathered data from managers at all levels of the car industry's supply chain management, and built a new theoretical model of supply chain management sustainability for the auto sector. The authors stated that the present supply chain approach of outsourcing to low-cost countries is not only unsustainable, but also irresponsible for the car industry and society. For the car industry's supply chain management, a triple-C (stop-control-combine) solution is offered There is a scarcity of empirical evidence to back up the claimed benefits of supply chain management integration, particularly beyond the dyadic level. According to (Näslund and Hulthen, 2012), who identified limited empirical studies covering SCM integration beyond the dyadic level. There are also few specific frameworks and concrete proposals for improving supply chain integration. In fact, there is a lot of misunderstanding about the term "supply chain management integration," hence the study provides a definition.

Hassini (2008) introduced a special edition that examines how supply chain management might help businesses gain a competitive advantage. The author offered a four-dimensional assessment of the papers' important features: methodology, supply chain management concerns, competitive factors, and contributions. The papers in this special issue illustrated how, through conceptual models and empirical research, organizations may gain a competitive edge by developing and operating efficient supply chains with the use of information technology. Customer pleasure and service are believed to last longer than cost savings, according to (Fawcett, Magnan, and McCarter,2008). Technology, information, and measurement systems are all important roadblocks to successful supply chain collaboration, according to all managers. People concerns, on the other hand, such as culture, trust, aversion to change, and desire to work, are more difficult to resolve. People are the most important link in a successful collaborative innovation process, and they should not be forgotten while firms invest in supply chain enablers like technology, data, and measurement systems.

(Khamseha and Zahmatkesh, 2015) assessed the performance of supply chains (SCs) in the face of uncertainty using a variety of metrics including operational costs, direct costs, , transaction expenditures, product adaptability, order lead time, and net profit. The performance of supply chain problems can be measured using a “data envelopment analysis” (DEA). The robust optimization strategy, on the other hand, is a powerful technique for dealing with issues that are subject to a variety of environmental uncertainties. (Olugu and Wong, 2009) investigated the scope of research in “supply chain performance” measurement and used fuzzy logic to identify knowledge gaps in supply chain performance measurement. The use of fuzzy logic to quantify supply chain performance has been identified as a new path in measuring the uncertainty and ambiguity that surrounds supply network performance

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monitoring.

(Carter and Rogers, 2008) introduced the notion of sustainability to the logistics literature, defining it as "the integration of environmental, social, and economic criteria that allow an organization to attain long-term economic viability." They place sustainability within the SSCM umbrella. They established a framework for "sustainable supply chain management" (SSCM) and developed research proposals based on resource dependency theory, population ecology, transaction cost economics, and the firm's resource-based outlook.

3. Objectives Of The Study

- To measure the supply chain performance of manufacturing firms
- To assess the importance of supply chain management strategies of manufacturing firms for managerial decision making.

4. Methodology

The supply chain performance of 41 manufacturing enterprises that produce steel, aluminum, sugar, paper, cement, and auto component manufacturing industries with revenues of more than 100 million rupees (Rs.) is evaluated. Data for the five parameters indicated in Table-1 were gathered from a variety of secondary sources. Industry Reports, Industry Manuals, and Annual Reports of Companies are examples of secondary sources. Based on the nature of DEA, the data collected on the following parameters is divided into two categories. The criteria for selecting inputs and outputs are subjective, and there is no set rule for establishing how inputs and outputs should be chosen (Ramanathan, 2001). Table 2 gives a description of the inputs and outcomes.

5. Concept of DEA

5.1. The CCR Model

This model is an extension of the ratio technique used in traditional approaches to measuring efficiency. The maximum of a weighted output to weighted input ratio for any DMU (Decision Making Unit) is obtained, subject to the condition that similar ratios for each DMU be less than or equal to unity.

We define the following notations to develop the DEA model mathematically.

5.2 Notations

To develop the DEA model, we use the following parameters and variables:

n= Number of DMU $\{j = 1,2,...,n\}$
s = Number of outputs $\{r = 1,2,\dots,s\}$
m = Number of inputs $\{i = 1,2,\dots,m\}$
y_{rj}= Quantity of r^{th} output of j^{th} DMU
x_{ij}= Quantity of i^{th} input of j^{th} DMU
u_r= weight of r^{th} output
v_i = weight of i^{th} input

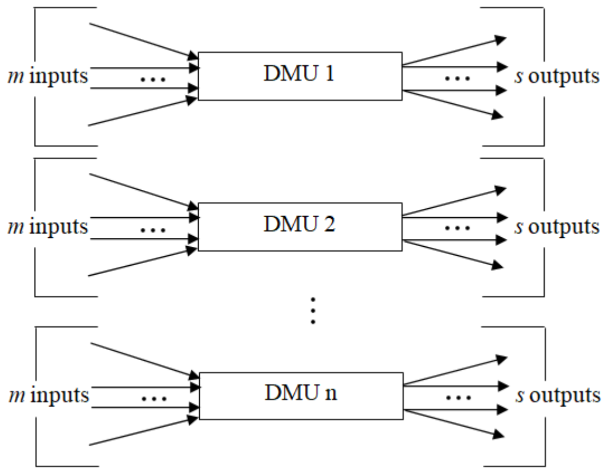

Figure 1: DMU and Homogeneous Units

5.3. Data Envelopment Analysis Model

The relative efficiency score of DMU is given by Maximize the efficiency of unit, j_0Subject to the efficiency (output / input) of all units being ≤ 1

Or, output - input ≤ 0

The model can be written algebraically as

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$$\max\ h_{j_0}(u,v)=\frac{\sum_{r=1}^{s}u_r y_{rj_0}}{\sum_{i=1}^{m}v_i x_{ij_0}}$$

$$subject\quad to\quad \sum_{r=1}^{s}u_r y_{rj}-\sum_{i=1}^{m}v_i x_{ij}\le 0\qquad j=1,2,\ldots,n$$

$$u_r, v_i \ge 0\ \forall\ r, i$$

$$u=(u_1,u_2,\ldots,u_r,\ldots u_s)$$

$$v=(v_1,v_2,\ldots,v_i,\ldots v_m) \tag{1}$$

The weights are the variables in the above problem, and the solution produces the weights that are most favourable to the unit, j-0, as well as a measure of efficiency. The decision variables and are the weights assigned to the s outputs and the m inputs, respectively. For,j-0.DMU, the numerator of the objective function in (1) is the weighted sum of output and the denominator is the weighted sum of input. In the constraint section, we write the difference between the weighted sum of output and the weighted sum of input for each of the n DMUs one by one. The model is solved n times, one unit at a time, to obtain the relative efficiencies of all the units. As shown below, the fractional programme (1) can be reduced to a Linear Programming Problem (LPP):

$$\max\ h_{j_0}=\sum_{r=1}^{s}u_r y_{rj_0}$$

$$subject\quad to\quad \sum_{i=1}^{m}v_i x_{ij_0}=1 \tag{2}$$

$$\sum_{r=1}^{s}u_r y_{rj}-\sum_{i=1}^{m}v_i x_{ij}\le 0\qquad j=1,2,\ldots,n$$

$$u_r, v_i \ge 0\ \forall\ r, i$$

This is known as the CCR output maximisation DEA model.

For illustration - say we have four DMUs with two inputs and three outputs as shown below

DMU	Input 1	Input 2	Output 1	Output 2	Output 3
DMU_1	5	7	3	6	8
DMU_2	3	8	4	7	8
DMU_3	4	5	6	3	5
DMU_4	4	6	9	8	7

The efficiency score of DMU_1 can be calculated using (3) and the LP model can be written as:

$$max\, h_1 = 3u_1 + 6u_2 + 8u_3 \tag{4}$$

$$subject to 5v_1 + 7v_2 = 1 \tag{5}$$

$$3u_1 + 6u_2 + 8u_3 - 5v_1 - 7v_2 \le 0 (for DMU_1) \tag{6}$$

$$4u_1 + 7u_2 + 8u_3 - 3v_1 - 8v_2 \le 0 (for DMU_2) \tag{7}$$

$$6u_1 + 3u_2 + 5u_3 - 4v_1 - 5v_2 \le 0 (for DMU_3) \tag{8}$$

$$9u_1 + 8u_2 + 7u_3 - 4v_1 - 6v_2 \le 0 (for DMU_4) \tag{9}$$

$$u_1, u_2, u_3, v_1, v_2 \ge 0 \tag{10}$$

The objective function (3.6) maximizes the weighted output of DMU_1 whereas (3.7) unitizes the weighted inputs of DMU_1. Equations from (3.8) to (3.11) state that the efficiencies of DMU_1 to DMU_4 lies within 0 and 1 respectively. Equation (3.12) is the non-negativity restriction on weights of both inputs and outputs.

Similarly the second program can be written to find the efficiency of DMU_2 and so on for all the four DMUs. The number of LPP to be formulated is same as the number of DMUs under consideration. DEA routine computation can be done with either generalized LP software or specialized DEA software. Non-computational aspects play an important role in the DEA application procedure.

5.4. INPUT AND OUTPUT ORIENTATION

The DEA models discussed can have either an input orientation or an output orientation. Input orientation denotes the amount by which inputs will be reduced while maintaining the same level of output. However, the corresponding output-oriented question — by how much outputs will be increased while keeping the level of inputs constant — could be equally important. The latter question may be more relevant for many government service providers, particularly those providing human services, because the community frequently wants more of these services while budgetary constraints make increasing inputs difficult (Steering Committee for the Review of Commonwealth/State Service Provision, 1997). The returns to scale (RTS) assumption is another DEA model variation. It is possible to use constant, decreasing, increasing, and variable returns to scale assumptions. Constant RTS

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implies that doubling inputs will result in an exact double of outputs. Reduced RTS implies that doubling inputs will result in less-than-doubling outputs. Increasing RTS implies that doubling inputs will result in outputs that are more than doubled. Variable RTS enables a mix of constant, increasing, and decreasing regions along the frontier.

In a CCR model, "if an activity (x,y) is feasible, then for every positive scalar t, the activity (tx, ty) is also feasible." For example, if the number of tellers in a bank doubled, we would expect the number of services to double as well. The CCR model is based on a CRS. In the VRS case, the frontier is generated by forming a convex hull with the most efficient DMUs on the outside. By connecting these relatively efficient DMUs with linear segments, the efficient frontier is built. The term variable returns-to-scale refers to the fact that the returns-to-scale of these various linear segments can be decreasing, increasing, or constant. For example, if the number of teachers in a school district doubles, we would not expect the number of students graduating to double as well.

The disadvantage of the previously discussed CCR model is that it only compares DMUs based on overall efficiency, assuming constant returns to scale. It ignores the possibility of different DMUs operating at different scales. To address this shortcoming, Banker, Charnes, and Cooper (Banker et al., 1984) created the BCC model, which takes variable returns to scale into account and compares DMUs solely on technical efficiency.

5.5. THE BCC MODEL

The CRS assumption is only valid when all DMUs are operating at their optimal scale. Imperfect competition, financial constraints, and other factors may cause a DMU to operate at a lower-than-optimal scale. Banker, Charnes, and Cooper proposed an extension of the CRS DEA model to account for Variable Return to Scale (VRS) situations (Banker et al. 1984). When the CRS specification is used when not all DMUs are operating at optimal scale, it results in a measure of Technical Efficiency (TE) that is muddled by scale efficiencies (SE). The use of VRS specifications will allow the calculation of TE without regard to these SE effects (Coelli, www.une.edu.au / econometrics. cepa.htm). The primary distinction between this model and the CCR model is how returns to scale are treated. The CCR version evaluates based on constant returns to scale. The BCC version is more adaptable, with variable returns to scale. The model is depicted below.

The difference between the CCR model and the BCC model (3.14), is now limited to a single digit. This removes the constraint in the CCR model that DMUs must be scale efficient. As a result, the BCC model allows for variable returns to scale and only measures technical efficiency for each DMU. That is, a DMU must be both scale and technical efficient in order to be considered CCR efficient. A DMU only needs to be technically efficient to be considered BCC efficient.

Table 1. Classification of Inputs and Outputs

Inputs	Outputs
Manufacturing capacity	Profit
Cycle time	On-time delivery rate
Cost	

Table 2: Explanation of Inputs and Outputs Parameters

Sl. No.	Parameters	Abbreviations	Explanation
1	Manufacturing capacity	MC	Total production capacity per day
2	Cycle time	CT	The time it takes for a supply chain to deliver goods or services to customers.
3	Cost	CO	Cost associated with supply chain
4	Profit	PT	Overall profit in a year
5	On-time delivery rate	OTD	Number of accurate delivery (as per percentage)

Table 3: Descriptive Statistics on Inputs and Outputs data

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	MC (days)	CT (hour)	CO (in Crore)	PT (in Crore)	OTD (in Crore)
Max,	32	141	0.55	2.8	98
Min,	4	2	0.02	0.022	92
Avg.	25.5	22.22	0.05	1.12	95
SD	8.25	25,35	0.11	0.78	2.04

6. RESULT AND DISCUSSION

As previously stated, the CCR-DEA model is based on constant RTS and does not consider the size of manufacturing units when calculating efficiency.

However, the size of a unit can frequently have an impact on its ability to produce more efficiently. As a result, we have evaluated the VRS model for our research. It should be noted that the Banker, Charnes, and Cooper (BCC) model supports VRS but only evaluates TE for each DMU, whereas a DMU is CCR efficient if it is both scale and technically efficient. Based on the VRS assumption, the BCC score evaluates the pure TE.

The CCR scores are calculated using the constant RTS (CRS) assumption and are made up of a non-additive combination of pure TE and scale efficiency. When the CCR model is used, the average score for a firm is 0.566 with a standard deviation of 0.315. Similarly, the BCC model yields an average score of 0.751 with a standard deviation of 0.246. The rank-order correlation coefficient between the efficiency rankings obtained by CCR and BCC models is 0.763 ($p = 0.000$), which is statistically significant. The scale efficiency is defined as the ratio of the TE of the CRS model to the TE of the VRS model. In the CRS model, the average TE of DMUs is 0.565. In the VRS model, the average TE of DMUs is 0.751. The correlation coefficient is computed for each ranking. The correlation coefficient between the two DEA rankings using the CRS and VRS model is 0.763, and the correlation coefficient between the CRS and Scale efficiency is 0.855. These are all statistically significant correlations. The 'Paired-sample t-test' is used to compare the ranks obtained by different models. The hypotheses are as follows:

H_{01} The efficiency score of DEA-CRS is equal to DEA-VRS.

H_{11} The efficiency score of DEA-CRS is different from DEA-VRS.

When the DEA-CRS and DEA-VRS models' efficiency scores are tested using a paired sample t-test. As a result of our analysis, we get a very low p value of 0.003. In this case, we rule out the null hypothesis (Type-I error). This enables us to accept the alternative hypothesis that the DEA-CRS and DEA-VRS models assign significantly different ranks. The peer group of inefficient manufacturing firms identifies the efficient manufacturing firm with whom the inefficient manufacturing firms are most similar in terms of inputs and outputs. It's also worth noting that there are multiple DMUs with the same efficiency score in both the CCR and BCC scores, resulting in a tie. The best manufacturing firm is the one that appears as a peer the most times in the above table. The infrequently occurring efficient DMUs in the peer group of other inefficient DMUs are likely to have a very unusual input/output combination and thus are not appropriate examples for other inefficient manufacturing firms. To determine the robustness of the model, a sensitivity analysis must now be performed.

7. CONCLUSION

One of the top priorities for policymakers is the expansion of Indian manufacturing enterprises. This means that manufacturing industries have a lot of room to grow. India's manufacturing companies will grow as a result of innovation and capacity utilisation. In this scenario, the manufacturing company should pay close attention to their fundamental strategy in terms of cost, production capacity, and cost. The purpose of this study is to show how learning from best practises can assist manufacturing units develop strategies and become more competitive. Profit is used as an output metric for sustainability, because a manufacturing firm can only survive if it makes a profit. For manufacturing businesses, cost minimization through optimal resource use is critical, which can only be accomplished by learning and developing solutions.

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The identification and control method is critical to the business's long-term viability. The goal of doing business is to remain vigilant, and in this case, supply chain performance monitoring can help manufacturing companies design alternative strategies. The Efficiency score is used to rank businesses. DMU 3, DMU 5, DMU 6, DMU 12, DMU 21, DMU 26, DMU 34, DMU 35, DMU 36, DMU 37, DMU 40, and DMU 41 are found to be relatively efficient in the CRS model. DMU 15 and DMU 39 are also efficient in the VRS model, which includes the entire efficient DMUs of the CRS model. The model can be repeated for an unlimited number of firms. The best firm, or a combination of enterprises, can serve as a model for other businesses to improve upon. The use of DEA is used to assess the efficiency of businesses in this study. For calculations, the DEA solver 5.0 is utilised. The TE score was determined using both the Constant RTS (CRS) and VRS assumptions. The average TE score obtained using the CRS model is 0.565, indicating that the firms have room for improvement. The average efficiency score obtained by the VRS model is 0.751, which is higher than the CRS. Again, the performance of each manufacturing unit varies depending on its resources and capabilities. It's due to a shortage of resources or an innovative approach to business management. Firms can use the DEA approach to determine their position in relation to their peers and to develop strategies for improvement using the optimal combination of inputs and outputs. Although the concept of benchmarking is beneficial in terms of enhancing individual unit performance, it is distinguished by a lack of transparency in data sharing as well as data dependability. In the future, a larger number of firms may be considered for an extended period of time to gain a deeper understanding of the situation.

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