“Supply Chain Management: A Data Envelopment Analysis (DEA) Based Approach”

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CERTIFICATE

Certified that Rohit bhadauriya (Roll. No. 1701302003) has carried out the research work presented in this thesis entitled " **Supply Chain Management -A Data Envelopment Analysis(DEA) based Approach***" for the award of Master of Technology from Integral University, Lucknow under our supervision. The thesis embodies results of original work, and studies are carried out by the student himself and the contents of the thesis do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution.*

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ABSTRACT

The economy of India is the sixth-largest in the world measured by nominal GDP and the third-largest by purchasing power parity (PPP). The country is classified as a newly industrialized country, and one of the G-20 major economies, with an average growth rate of approximately 7% over the last two decades. In this paper, we aim to make environmental efficiency analysis of India's regional industry. there is a growth rate of approximately 13% in pollution over the last 4 years. Data envelopment analysis (DEA) method is a constant return to scale measure (CRS) model considering undesirable outputs is introduced to measure the environmental efficiency of different regions. Big data is introduced in the collection and selection of the input and output data of the states and regions of India. Further, we evaluate the environmental efficiencies of India's industry using data from 2015 to 2019. The results show that apart from several developed provinces, the environmental efficiencies of India's industry are generally low. And the environmental efficiencies of the regions did not show any increasing trend through the past 4 years. Moreover, lager differences exist in environmental efficiencies between the regions in India. Finally, we suggest the Indian government to focus on the low environmental efficiencies and the unbalanced development of its regional industry.

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X_A	—	Input of seller
X_B	—	Input of buyer
Y_A	—	Output of seller
Y_B	—	Output of buyer
U	—	Output weights in fractional program
V	—	Input weights in fractional program
n	—	number of observations
μ	—	Output weights in linear program
ω	—	Input weights in linear program

Abbreviations

E_{AA}	—	Efficiency of sellers
E_{BB}	—	Efficiency of buyer
T	—	Number of decision making uni
E_{AA}^*	—	Maximum efficiency of seller
E_{BB}^*	—	Maximum efficiency of buyer
e_{AB}	—	Efficiency of supply chain

Chapter-1

Introduction

1.1 Supply Chain Management

Supply Chain Management (SCM) in simple words can be described as a network of facilities and distribution options. Wherein SCM involves functions such as material procurement, transformation of the material into intermediate and finished products, and then distribution of the finished product to consumer. Supply chains are found to exist in both service and manufacturing sectors, although the complexity of the supply chain may vary vastly from industry to industry and firm to firm, however it represents a logical advance in our evolving understanding of business performance (Smith and Budress, 2005).

Fierce competition in today's global markets, the introduction of products with shorter life cycles, and the heightened expectations of customers have forced business enterprises to invest in, and focus attention on, their supply chains. This, together with continuing advances in communications and transportation technologies (e.g., mobile communication, Internet, and overnight delivery), has motivated the continuous evolution of the supply chain and of the techniques to manage it effectively.

A supply chain consists of all stages involved, directly or indirectly, in fulfilling a customer request. The supply chain not only includes the manufacturer and suppliers, but also transporters, warehouses, retailers, and customers themselves. A supply chain is a network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers.

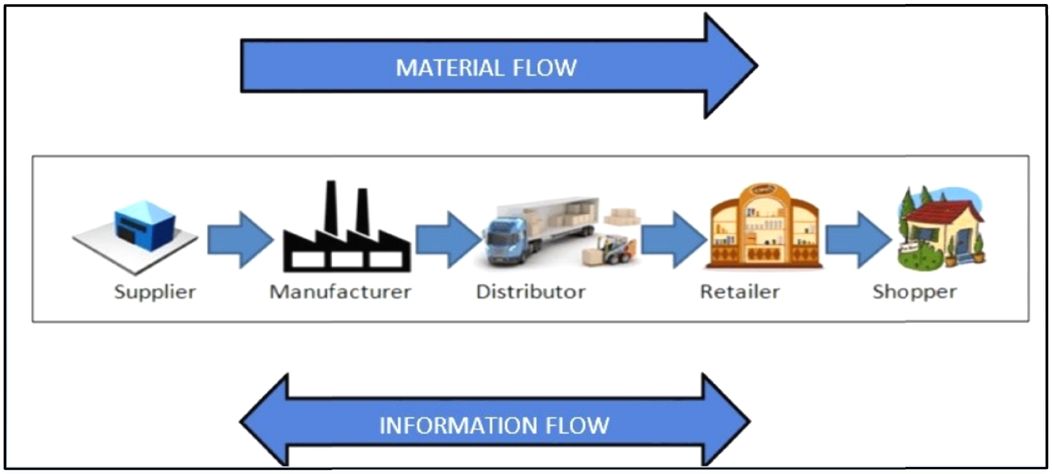


Figure 1.1 Components of a supply chain

The term "supply chain management" arose in the late 1980s and came into use in the 1990s. supply chain management is the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole. In other words, Supply chain management is the coordination of production, inventory, location, and transportation among the participants in a supply chain to achieve the best mix of responsiveness and efficiency for the market being served. Supply chain management views the supply chain and the organizations in it as a single entity. It brings a systems approach to understanding and managing the different activities needed to coordinate the flow of products and services to best serve the ultimate customer. This systems approach provides the framework in which to best respond to business requirements that otherwise would seem to be in conflict with each other. Effective supply chain management requires simultaneous improvements in both customer service levels and the internal operating efficiencies of the companies in the supply chain. The goal of supply chain management is to increase sales of goods and services to the final, end use customer while at the same time reducing both inventory and operating expenses.

Table 1.1 Definitions of supply chain management

Definition	**Author**
"A supply chain is a network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers".	Ganeshan and Harrison et al. (1995)
"A supply chain is the alignment of firms that bring products or services to market".	Lambert et al. (1998)
"The systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole".	Mentzer et al. (2001)
"A supply chain consists of all stages involved, directly or indirectly, in fulfilling a customer request. The supply chain not only includes the manufacturer and suppliers, but also transporters, warehouses, retailers, and customers themselves".	Chopra,2005
"Supply Chain Management is the systemic, strategic coordination of the traditional business function and tactics across these business functions within a particular company and across business within the supply chain, for the purpose of improving the long-term performance of the individual companies and the supply chain as a whole."	Sweeney,2007
"Supply Chain Management consists of developing a strategy to organize, control and motivate the resources involved in the flow of services and materials within the supply chain."	Krajewski et al. (2008)

"Supply Chain Management is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantity, to the right locations, and at the right time, in order to minimize system wide costs while satisfying service level requirements."	Lambert, 2008
"Supply Chain Management is the active management of supply chain activities and relationships in order to maximize customer value and achieve a sustainable competitive advantage."	Bozarth and Handfield (2008)
"Supply chain management is the coordination of production, inventory, location, and transportation among the participants in a supply chain to achieve the best mix of responsiveness and efficiency for the market being served".	Wiley, 2010

1.2 Importance of supply chain management

Supply Chain Management plays a vital role in organisation activities and an essential element to operational efficiency which can be applied to customer satisfaction and company's success. It is the backbone of an organisation which manages the critical issues of the business organisation such as rapid growth of multinational corporations, global expansion and environmental concerns which indirectly affects the corporate strategy.

Other benefits and importance of supply chain management are:

- Reduces inventory costs.
- Provides better medium for information sharing between partners.
- Improves customer satisfaction as well as service.
- Provides efficient manufacturing strategy.
- Improves process integration.
- Improves quality and gives higher profit margin.

1.3 Principles of Supply Chain Management

If supply-chain management has become top management's new "religion," then it needs a doctrine. Andersen Consulting has stepped forward to provide the needed guidance, espousing what it calls the "Seven Principles" of supply-chain management. When consistently and comprehensively followed, the consulting firm says, these seven principles bring a host of competitive advantages.

The seven principles as articulated by Andersen Consulting are as follows:

1.Segment customers based on service needs. Companies traditionally have grouped customers by industry, product, or trade channel and then provided the same level of service to everyone within a segment. Effective supply-chain management, by contrast, groups customers by distinct service needs--regardless of industry--and then tailors services to those particular segments.

2.Customise the Supply Chain Management network. In designing their Supply Chain Management network, companies need to focus intensely on the service requirements and profitability of the customer segments identified. The conventional approach of creating a "monolithic" Supply Chain Management network runs counter to successful supply-chain management.

3. Listen to signals of market demand and plan accordingly. Sales and operations planning must span the entire chain to detect early warning signals of changing demand in ordering patterns, customer promotions, and so forth. This demand-intensive approach leads to more consistent forecasts and optimal resource allocation.

4. Differentiate product closer to the customer. Companies today no longer can afford to stockpile inventory to compensate for possible forecasting errors. Instead, they need to postpone product differentiation in the manufacturing process closer to actual consumer demand.

5. Strategically manage the sources of supply. By working closely with their key suppliers to reduce the overall costs of owning materials and services, supply-chain management leaders enhance margins both for themselves and their suppliers. Beating multiple suppliers over the head for the lowest price is out, Andersen advises. "Gain sharing" is in.

6. Develop a supply-chain-wide technology strategy. As one of the cornerstones of successful supply-chain management, information technology must support multiple levels of decision making. It also should afford a clear view of the flow of products, services, and information.

7. Adopt channel-spanning performance measures. Excellent supply-chain measurement systems do more than just monitor internal functions. They adopt measures that apply to every link in the supply chain. Importantly, these measurement systems embrace both service and financial metrics, 0such as each account's true profitability.

1.4 Supply Chain Management Processes

Supply chain activities aren't the responsibility of one person or one company. Multiple people need to be actively involved in a number of different processes to make it work. It's kind of like baseball. While all the participants are called baseball players, they don't do whatever they want. Each person has a role – pitcher, catcher, shortstop, etc. – and must perform well at their assigned duties – fielding, throwing, and/or hitting – for the team to be successful. Of course, these players need to work well together. A hit-and-run play will only be successful if the base runner gets the signal and takes off running, while the batter makes solid contact with the ball. The team also needs a manager to develop a game plan, put people in the right positions, and monitor success. Winning the SCM "game" requires supply chain professionals to play similar roles. Each supply chain player must understand his or her role, develop winning strategies, and collaborate with their supply chain teammates. By doing so, the SCM team can flawlessly execute the following processes:

- **Planning** – Planning process seeks to create effective long- and short-range supply chain strategies. From the design of the supply chain network to the prediction of customer demand, supply chain leaders need to develop integrated supply chain strategies.
- **Procurement** –Procurement process focuses on the purchase of required raw materials, components, and goods.
- **Production** –Production involves the manufacture, conversion, or assembly of materials into finished goods or parts for other products. Supply chain managers provide production support and ensure that key materials are available when needed.

- **Distribution** – Distribution process manages the logistical flow of goods across the supply chain. Transportation companies, third party logistics firms, and others ensure that goods are flowing quickly and safely toward the point of demand.
- **Customer Interface** – The demand process revolves around all the issues that are related to planning customer interactions, satisfying their needs, and fulfilling orders perfectly.

1.5 Key issues in supply chain management

In this section, we introduce some of the supply chain management issues that we discuss in much more detail throughout the remaining chapters. These issues span a large spectrum of a firm's activities, from the strategic through the tactical to the operational level:

- The strategic level deals with decisions that have a long-lasting effect on the firm. This includes decisions regarding product design, what to make internally and what to outsource, supplier selection, and strategic partnering as well as decisions on the number, location, and capacity of warehouses and manufacturing plants and the flow of material through the logistics network.
- The tactical level includes decisions that are typically updated anywhere between once every quarter and once every year. These include purchasing and production decisions, inventory policies, and transportation strategies, including the frequency with which customers are visited.
- The operational level refers to day-to-day decisions such as scheduling, lead time quotations, routing, and truck loading.

1.6 Challenges in Supply Chain Management

Supply Chain Management (SCM) is an important way to track goods across departments in real-time, which can be a huge advantage. Despite this, there are several supply chain challenges that are faced with these management systems due to growing complexities.

- **SCM's can't do it all** - Unfortunately supply chain management systems cannot do all that companies may hope for. Be realistic about what can be achieved and research into how an SCM could help your business.
- **Demands** - Customers want their products immediately and at a good price, yet this is not always possible and puts companies under a great deal of pressure to provide customers with what they want. It is not always possible for companies to create both quick and remunerative methods due to the demands of the chain.
- **Globalisation** - Due to these demands, companies are often forced to collaborate with countries in which products can be produced at a lower cost. Despite this, delivery times take even longer, therefore may not be beneficial at all.
- **Market growth** - Increasing the customer base can be a hard challenge to tackle in order to expand distribution both at home and abroad. There are a number of factors to take into consideration when doing so, including trading policies, fees, and government policies, therefore is not always easy to get to grips with.
- **Inventory** - Most of the time, companies are unsure about what stock they own and confusion can arise surrounding whether products have been lost due to their SCM system being not as reliable as expected. Money can be lost easily though these false expectations as there is often too much stock to keep track of which as a result is not being sold.

1.7 Functions of Supply Chain Management

The three major functions of SCM are:

- **Procurement** – It is purchasing of services, values, goods, raw material or information from the organizations.
- **Manufacturing** – These are operations used in transformation of raw materials to final products. It involves the calculation of credit risk in a venture capital and traditional factory tasks.
- **Distribution** – This function implies the delivery of end products at various levels i.e. from distributor to wholesaler, from wholesaler to retailer and from retailer to end customers.

1.8 Advantages of Supply Chain Management

The various advantages of supply chain management are as follows:

- Supply Chain Management helps to increase savings in labour and procurement costs.
- Supply Chain Management helps to achieve better inventory control.
- Supply Chain Management is used to get better control over suppliers.
- Supply Chain Management can increase market visibility.
- Chances of product failure rate can be reduced by Supply Chain Management.
- Supply Chain Management is used to provide better information on customer needs, tastes etc.
- Supply Chain Management helps to achieve regular and better communication with the customers.
- Supply Chain Management helps to improve customer care service.
- Supply Chain Management is used to achieve higher revenues.
- Supply Chain Management increases performance and profitability.
- Supply Chain Management is used to lower transportation, warehousing and packaging costs.
- Supply Chain Management increases capacity, capability or flexibility.
- Supply Chain Management enhance value for money.
- Supply Chain Management is used to improve reputation of brand in market.
- Supply Chain Management also increases the value of shareholder.
- Supply Chain Management is used for faster and more accurate order processing.
- Supply Chain Management allows higher discount on price to wholesaler due large order size.
- Supply Chain Management is also good for returns and recall management.
- Supply Chain Management is used for production tracking.

- Supply chain management helps to lower the labour costs as well as procurement costs.
- The customer care service can be increased with the help of supply chain management.
- Supply chain management increases the brand awareness for business.
- It is also seen that supply chain management helps to achieve better inventory control.

- By supply chain management process better control over suppliers can be seen.
- Supply chain management is good for both business as well as for customers.
- The supply chain management increases capacity as well as capability or flexibility of the flow of goods.
- The process of supply chain management helps to enhance value of money and profitability to increase revenue.
- Supply chain management also increases the value of shareholder.
- The performance as well as profitability can be increased by supply chain management strategy.
- The cost of transportation, warehousing as well as packaging cost can be reduced by applying supply chain management process

1.9 Disadvantages of Supply Chain Management

The various disadvantages of supply chain management are as follows:

- Sometimes Supply Chain Management can be very expensive to implement.
- Competitors can easily copy the strategy of Supply Chain Management.
- For better Supply Chain Management, proper skills and experience is required to achieve success.
- Sometimes in Supply Chain Management, various functions may be difficult to manage.

1.10 Data Envelopment Analysis (DEA)

William W. Cooper (1978): "Data envelopment analysis is a method for evaluating decision making units within an organization, by using imputed shadow prices. These prices are computed using a fractional program that is solved by reducing it to a linear program."

- Data Envelopment Analysis (DEA) measures the relative efficiencies of organizations with multiple inputs and multiple outputs. The organizations are called the decision-making units, or DMUs.

- DEA is a mathematical programming approach to provide a relative efficiency assessment (called DEA efficient) for a group of decision-making units (DMU) with multiple number of inputs and outputs.

- DEA assigns weights to the inputs and outputs of a DMU that give it the best possible efficiency. It thus arrives at a weighting of the relative importance of the input and output variables that reflects the emphasis that appears to have been placed on them for that particular DMU.

- It concerned with evaluations of performance and it is especially concerned with evaluating the activities of organizations such as business firms, government agencies, hospitals, educational institutions, etc.

In DEA, there are a number of producers. The production process for each producer is to take a set of inputs and produce a set of outputs. Each producer has a varying level of inputs and gives a varying level of outputs. For instance, consider a set of banks. Each bank has a certain number of tellers, a certain square footage of space, and a certain number of managers (the inputs). There are a number of measures of the output of a bank, including number of checks cashed, number of loan applications processed, and so on (the outputs). DEA attempts to determine which of the banks are most efficient, and to point out specific inefficiencies of the other banks.

A fundamental assumption behind this method is that if a given producer, A, is capable of producing Y(A) units of output with X(A) inputs, then other producers should also be able to do the same if they were to operate efficiently. Similarly, if producer B is capable of producing Y(B) units of output with X(B) inputs, then other producers should also be capable of the same production schedule. Producers A, B, and others can then be combined to form a composite producer with composite inputs and composite outputs. Since this composite producer does not necessarily exist, it is typically called a virtual producer.

The heart of the analysis lies in finding the "best" virtual producer for each real producer. If the virtual producer is better than the original producer is by either making more output with the same input or making the same output with less input then the original producer is inefficient. The subtleties of DEA are introduced in the various ways that producers A and B can be scaled up or down and combined.

1.10.1 Objective of Data Envelopment Analysis

The objective of data envelopment analysis is to find the efficiency of the various DMU’s to arrange or selection the best DMU. The objective of any selection procedure is to identify appropriate selection criteria, and obtain the most appropriate combination of criteria in conjunction with the real requirement. The DEA is also used to find the most desirable alternatives from a set of available alternatives based on the selected criteria. In DEA, alternatives are ranked from best to worst based on their efficiency. Selection criterions are often called as attributes and they are either given by industry or taken from literature.

1.10.2 Strengths of DEA

DEA can be a powerful tool when used wisely. A few of the characteristics that make it powerful are:

- DEA can handle multiple input and multiple output models.
- It does not require an assumption of a functional form relating inputs to outputs.
- DMUs are directly compared against a peer or combination of peers.
- Inputs and outputs can have very different units. For example, X1 could be in units of lives saved and X2 could be in units of lives saved and X2 could be in units of dollars without requiring an a priori tradeoff between the two.

1.10.3 Drawback

- A drawback of this technique is that model specification and inclusion/exclusion of variables can affect the results

1.10.4 Applications

- It is most useful when a comparison is sought against "best practices" where the analyst does not want the frequency of poorly run operations to affect the analysis. DEA has been applied in many situations such as: health care (hospitals, doctors), education (schools, universities), banks, manufacturing, benchmarking, management evaluation, fast food restaurants, and retail stores.

- The analyzed data sets vary in size. Some analysts work on problems with as few as 15 or 20 DMUs while others are tackling problems with over 10,00 DMUs.

1.10.5 Mathematical Models

Consider a buyer-seller supply chain as described in Fig. 1, where X_A is the input vector of the seller, and Y_A is the seller's output vector. Y_A is also an input vector of the buyer, along with X_B, with Y_B being the buyer's output vector.

Suppose there are *n* such supply chains or observations on one supply chain. The Charnes, Cooper and Rhodes (CCR) DEA efficiency of the supply chain is measured as (Charnes et al., 1978; CCR)

Before introducing the method and the models that will be used, we first define the symbols that will be used

X_A = Input of seller

X_B = Input of buyer

Y_A = Output of seller

Y_B = Output of buyer

U = Output weights in fractional program

V = Input weights in fractional program

n = number of observation

μ = Output weights in linear program

ω = Input weights in linear program

T = Number of decision making unit

E_{AA} = Efficiency of sellers

E_{BB} = Efficiency of buyer

E^*_{AA} = Maximum efficiency of sellers

E^*_{BB} = Maximum efficiency of buyer

e_{AB} = Efficiency of supply chain

$$\text{Max } \frac{U^T Y_{B0}}{V^T (X_{A0}, X_{B0})}$$

$$\text{s.t} \frac{U^T Y_{Bj}}{V^T (X_{Aj}, X_{Bj})} \leq 1 \qquad j = 1, 2 \ldots\ldots\ldots, n$$

(1)

$$U^T, V^T \geq 0$$

Zhu (2003) shows that DEA model (1) fails to correctly characterize the performance of supply chains, because it only considers the inputs and outputs of the supply chain system and ignores measures $Y_A$associated with supply chain members. Zhu (2003) also shows that if $Y_A$are treated as both input and output measures in model (1), all supply chains become efficient.

Zhu (2003) further shows that an efficient performance indicated by model (1) does not necessarily indicate efficient performance in individual supply chain members. Consequently, improvement to the best-practice can be distorted. i.e., the performance improvement of one supply chain member affects the efficiency status of the other, because of the presence of intermediate measures.

Alternatively, we may consider the average efficiency of the buyer and seller as in the following DEA model

$$\text{Max } \frac{1}{2}\left[\frac{U_A^T Y_{A0}}{V_A^T X_{A0}} + \frac{U_B^T Y_{B0}}{V_B^T (X_{B0}, Y_{A0})}\right]$$

$$\text{s.t } \frac{U_A^T Y_{Aj}}{V_A^T X_{Aj}} \leq 1 \qquad j = 1,2,\ldots\ldots n \qquad (2)$$

$$\frac{U_B^T Y_{Bj}}{V_B^T (X_{Bj}, Y_{Aj})} \leq 1 \qquad j = 1,2,\ldots\ldots n$$

$$U_A^T, V_A^T, U_B^T, V_B^T \geq 0$$

Although model (2) considers Y_A, it does not reflect the relationship between the buyer and the seller. The weights of $Y_A$as inputs of the buyer may not be equal to the weights of $Y_A$as outputs of the seller. Model (2) treats the seller and the buyer as two independent units. This does not reflect an ideal supply chain operation.

We next develop several models that can directly evaluate the performance of the supply chain as well as its members while considering the relationship between the buyer and the seller. Our modeling processes are based upon the concept of non-cooperative and cooperative games (see, e.g., Simaan and Cruz, 1973; Li, Huang, and Ashley, 1995; Huang, 2000).

Based upon Li, Huang and Ashley (1995), we suppose the seller-buyer interaction is viewed as a two-stage noncooperative game with the seller as the leader and the buyer as the follower. For example, in the case of non-cooperative advertising between the manufacture (seller) and the retailer (buyer), Toyota automobile company decides that it wants to promote sales of a particular model and directs and subsidizes its local dealers. The local dealers then react to Toyota's strategy by adjusting the amount they spend on advertising and promotion.

First, we use the CCR model to evaluate the efficiency of the seller, as the leader

$$\text{Max } \frac{U_A^T Y_{A0}}{V_A^T X_{A0}} = \mathrm{E}_{\mathrm{AA}}$$

$$\text{s.t. } \frac{U_A^T Y_{Aj}}{V_A^T X_{Aj}} \leq 1 \qquad j = 1,2,\ldots\ldots n$$

(3)

$$U_A^T, V_A^T \geq 0$$

This model is equivalent to the following standard DEA multiplier model:

$$\text{Max } \mu_A^T Y_{A0} = E_{AA}$$

$$\text{s.t.} \omega_A^T X_{Aj} - \mu_A^T Y_{Aj} \geq 0 \qquad j=1,2,\ldots\ldots n$$

(4)

$$\omega_A^T X_{A0} = 1$$

$$\omega_A^T, \mu_A^T \geq 0$$

Suppose we have an optimal solution of model (4) $\omega_A^{T*}, \mu_A^{T*}$,and E_{AA}^* and denote the seller's efficiency as E_{AA}^*. We then use the following model to evaluate the buyer's efficiency:

$$\text{Max } \frac{U_B^T Y_{B0}}{V_B^T X_{B0} + D \times \mu_A^T Y_{A0}} = E_{AB}$$

$$\text{s.t. } \frac{U_B^T Y_{Bj}}{V_B^T X_{Bj} + D \times \mu_A^T Y_{Aj}} \leq 1 \qquad j = 1,2,\ldots\ldots n \qquad (5)$$

$$\mu_A^T Y_{A0} = E_{AA}^*$$

$$\omega_A^T X_{Aj} - \mu_A^T Y_{Aj} \geq 0 \quad j = 1,2,\ldots\ldots n$$

$$\omega_A^T X_{A0} = 1$$

$$\omega_A^T, \mu_A^T, U_B^T, V_B^T, D \geq 0$$

Note that in model (5), we try to determine the buyer's efficiency given that the seller's efficiency remains at E_{AA}^*. Model (5) is equivalent to the following non-linear model:

$$\text{Max } \mu_B^T Y_{B0} = E_{AB}$$

$$\text{s.t. } \omega_B^T X_{Bj} + d\mu_A^T Y_{Aj} - \mu_B^T Y_{Bj} \geq 0 \qquad j = 1,2,\ldots\ldots n \qquad (6)$$

$$\omega_B^T X_{B0} + d\mu_A^T Y_{A0} = 1$$

$$\mu_A^T Y_{A0} = E_{AA}^*$$

$$\omega_A^T X_{Aj} + \mu_A^T Y_{Aj} \geq 0 \qquad j = 1,2,\ldots\ldots n$$

$$\omega_A^T X_{A0} = 1$$

$$\omega_A^T, \mu_A^T, \omega_B^T, \mu_B^T, d \geq 0$$

Note that $\omega_B^T X_{B0} + d\mu_A^T Y_{A0} = 1$ and $\mu_A^T Y_{A0} = E_{AA}^*$. Thus, we have $0 \leq d \leq \frac{1}{\mu_A^T Y_{A0}} = \frac{1}{E_{AA}^*}$, i.e, we have the upper and lower bounds on *d*. Therefore, *d* can be treated as a parameter and model (6) can be solved as a linear program. In computation, we set the initial d value as the upper bound, namely, $d_0 = \frac{1}{E^*_{AA}}$, and solve the resulting linear program. We then start to decrease d according to $d_t = \frac{1}{E^*_{AA}} - \varepsilon \times t$ for each step t, where ε is a small positive number. We solve each linear program of model (6) corresponding to d_t and denote the optimal objective value as $E^*_{BA}(d_t)$.

Let E^*_{BA} = Max $E^*_{BA}(d_t)$. Then we obtain a best heuristic search solution E^*_{BA} to model (6). This E^*_{BA} represents the buyer's efficiency when the seller is given thepre-emptive priority to achieve its best performance. The efficiency of the supply chain can then be defined as

$$e_{AB} = \frac{1}{2}(E^*_{AA} + E^*_{AB})$$

Similarly, one can develop a procedure for the situation when the buyer is the leader and the seller the follower. For example, in the October 6, 2003 issue of the Business Week, its cover story reports that Walmart dominates its suppliers and not only dictates delivery schedules and inventory levels, but also heavily influences product specifications.

We first evaluate the efficiency of the buyer using the standard CCR ratio model

$$\text{Max } \frac{U_B^T Y_{B0}}{V_B^T X_{B0} + V^T Y_{Aj}} = E_{BB}$$

$$\text{s.t. } \frac{U_B^T Y_{Bj}}{V_B^T X_{Bj} + V^T Y_{Aj}} \leq 1 \quad j = 1,2,\ldots\ldots n \tag{7}$$

$$U_B^T, V_B^T, V^T \geq 0$$

Model (7) is equivalent to the following standard CCR multiplier model

$$\text{Max } \mu_B^T Y_{B0} = E_{BB}$$

$$\text{s.t. } \omega_B^T X_{Bj} + \mu^T Y_{Aj} - \mu_B^T Y_{Bj} \geq 0 \quad j = 1,2,\ldots\ldots\ldots,n \tag{8}$$

$$\omega_B^T X_{B0} + \mu^T Y_{A0} = 1$$

$$\omega_B^T, \mu_B^T, \mu^T \geq 0$$

Let $\omega_B^{T*}, \mu_B^{T*}, \mu^{T*}, E_{BB}^*$an optimal solution from model (8) where E_{BB}^*represents the buyer's efficiency score.

1.11 Problem statement

Supply chain of a company consist of various manufacturers and suppliers. The suppliers supply the raw material to the manufacturer as per the demand and the producer produces the product for the customer. There are number of suppliers who provide raw material at different cost, which affects the manufacturing cost and quality. In the supply chain network, there are several factors which affect the inputs and outputs thus making the calculation of these types of problems very complex and the consideration of each affecting variable will not be possible. DEA technique provides the solution of such type of problem, it includes the entire affecting variable and provide the most efficient supply chain network through which we get minimum input and maximum output.

In the present work, problem of a gear manufacturing company has been considered and efficiency of two-stage supplier and producer supply chain has been determined by developing continuous CCR ratio DEA model using DEA Solver 8.0 software along with MS Excel. Company have n homogeneous supply chain operations. Each supply chain observation had considered a DMU. It is assumed that each supplier $S_j$in DMU_j: j = 1,...,n has m inputs x_{ij}: i = 1,...,m and s outputs y_{rj}: r = 1,..., s. These outputs can become the inputs to the manufacturer M_j. The manufacturer $M_j$has its own inputs Z_{dj}: d = 1,..., D. The final outputs from manufacturer are Q_{lj}: l = 1,..., L. This type of problem came into the two-stage supply chain, supplier-manufacturer supply chain.

1.12 Objective of research

The objective of the present research work are as follows: -

- Identification of opportunities to improve the existing supply chain to make it more flexible.
- Development of case study of gear manufacturing company.
- Development a hierarchal model of various suppliers and manufacturers then identifying and ranking the efficiency of suppliers

and manufacturers in supply chains.

- Development of efficient supply chain network using DEA (Data Envelopment Analysis).

1.13 Scope of work

This study covers the complete supply chain of ABC Ltd. The main purpose of this work to find out the most efficient supply chain network by finding out the efficiency or various suppliers and manufacturers using DEA (Data Envelopment Analysis). This study covers the thorough analysis of the company and thus helps in finding out the relationship between the suppliers and manufacturing. Data Envelopment Analysis is a modern management tool it is also used to construct a most efficient and effective supply chain network among all. This study is carried out on one of the leading piston manufacturing company in near capital region of India and to remain in the market the company is implementing sustainability in their supply chain

.

1.14 Research Methodology

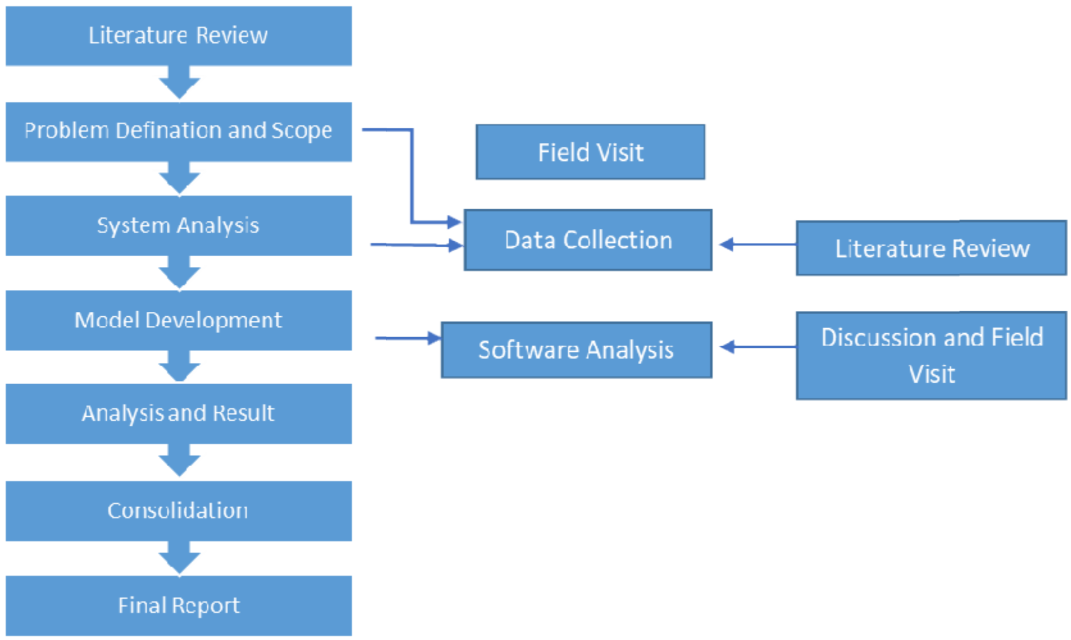


Figure 1.2 Flow diagram of work done

1.15 Organization of report

This thesis is being organized into six chapters as summarized below: -

1. Chapter 1 covers the introduction of supply chain management and green supply chain management. It also covers introduction of DEA (Data Envelopment Analysis). It also covers problem statement and research objective with scope of the work.

2. Chapter 2 includes the literature survey on applications of data envelopment analysis (DEA) approach in different areas of supply chain management. It also covers research gaps and future research directions.

3. Chapter 3 covers the system analysis of the company taken into consideration for the purpose of study. It also includes detailed company's profile, what kind of product it manufactures, how these are manufactured and what kind of risk are involved during its manufacturing. It also covers the strength, weakness, opportunities and threats of the company.

4. Chapter 4 includes the research methodologies used in this research work. Data envelopment analysis (DEA) approach has been used to analyse the supply chain networks and the best supply chain network has been selected amongst all.

5. Chapter 5 covers summary of work done, limitations of work done, scope for future work and concluding remarks.

1.16 Summary

In this chapter, thesupply chain management and various advantages and disadvantages of supply chain management along with the key themes of SCM is discussed. The data envelopment analysis also discussed along with their advantages, disadvantages and mathematical model. Finally, the problem statement, objectives and scope of work is discussed in this chapter.

Chapter 2

Literature Review

2.1 Introduction

Data envelopment analysis is a new futuristic tool which is widely used in several areas such as manufacturing system, Business and management, Energy and environment management etc.

It is a linear programming-based technique for measuring the relative performance of organizational units where the presence of multiple inputs and outputs makes comparisons difficult? Supply chain management has become an imperative research agenda among the researchers/practitioners to achieve most efficient network for the financial benefits. Supply chain management and data envelopment analysis published in various major journal during 1995 to 2017 have been studied. The journal include European Journal of Operational Research, Indian Journal of Science and Technology, Procedia - Social and Behavioral Sciences, Journal of Cleaner Production, Transportation Research, Sustainable Cities and Society, Expert Systems With Applications, Computers and Operations Research, IMA Journal of Management Mathematics, Computers & Industrial Engineering, Omega, Renewable Energy, International Journal of Data Envelopment Analysis, Journal of Computers, The Stata Journal and Energy Economics were used to find the related literature. This paper gives a futuristic literature review on DEA provisions what's more methodologies. In this research, around 50 journal publication have been reviewed. A review is intended for researchers wishing to understand deeply the existing theory on data envelopment analysis.

2.2 Supply chain management and Data envelopment analysis

Charnes et al. (1981)

- The points that have just been made should suffice to indicate some of the possibilities that our DEA approach may offer. Here we have presented this approach in terms of an illustrative application to Program Follow Through. It is not to be regarded as limited to this Program, however, or even to education programs.

Bruce et al. (1982)

- The strong growth of DEA research in recent years has increased the DEA literature to a scale in which it is not easy to conduct a general review without quantitative methodologies. We survey the DEA literature with the assistance of the main path method. The method is quantitative and citation based. It helps identifies significant paths, important papers, and recent active subareas in DEA development

Banker (1984)

- The relation between the most productive scale size (mpss) for input and output mixes and returns to scale for multiple-inputs multiple-outputs situations is explicitly developed. This relation is then employed to extend the applications of Data Envelopment Analysis (DEA) introduced by Charnes. Cooper and Rhodes (CCR) to the estimation of most productive scale sizes for convex production possibility sets. It is then shown that in addition to productive inefficiencies at the actual scale size. the CCR efficiency measure also reflects any inefficiencies due to divergence from the most productive scale size.

Daniel & Gabriela (1987)

- Author propose a simple statistical heuristic procedure that will allow practitioners to identify potential endogenous inputs when they suspect that there might be some significant positive endogeneity in their setting.

Chukova (1994)

- Supply chain management is an important competitive strategy used by modern enterprises. Effective design and management of supply chains assists in the production and delivery of a variety of products at low costs, high quality, and short lead times. Recently, data envelopment analysis (DEA) has been extended to examine the efficiency of supply chain operations. The current paper develops a DEA model for measuring the performance of suppliers and manufacturers in supply chain operations. Additive efficiency decomposition for suppliers and manufacturers in supply chain operations is proposed.

Bae (1996)

- Today, many academic researchers recognize Stata as one of the leading packages for statistical analysis; however, there are still uncovered areas that managerial organizations are interested in. In particular, optimization procedures in Stata can be further developed to fill in the gaps between parametric and nonparametric analysis. The DEA command introduced in this article is a new application in Stata and is a powerful managerial tool for measuring the efficiency and productivity of DMUs.

Hwang & Chang (2003)

- Author used data envelopment analysis (DEA), developed by Charnes et al. (Eur.J. Oper. Res. 2(6) (1978) 429), and the Malmquist productivity index expressed by F.are et al. (J. Product Anal. 3(1) (1992) 85), to measure the managerial performance of 45 hotels in 1998 and the efficiency change of 45 Hotels from 1994 to 1998. The results revealed that there was a significant difference in efficiency change due to difference in sources of customers and management styles. In addition, this paper showed that the managerial efficiency of international tourist hotels in Taiwan is related to the level of internationalization of hotels. Moreover, the entire industry can be partitioned into six clusters based on relative managerial efficiency and efficiency change.

Takahashib et al. (2005)

- To evaluate the management efficiency of Japanese regional banks, there is a limit in traditional simple DEA model. It is because the management situation of Japanese regional banks has been diversified. This study applies a slack-based measure network DEA (NSBM-DEA) model to evaluate the management efficiency of Japanese regional banks. The objective of this research is to evaluate overall and divisional efficiencies of Japanese regional banks. This study contributes to understand management efficiency of the divisions when regional banks evaluate their management efficiency

Cook et al. (2006)

- It is shown that a supply chain can be deemed as efficient while its members may be inefficient in DEA-terms. The current study develops several DEA-based approaches for characterizing and measuring supply chain efficiency when intermediate measures are incorporated into the performance evaluation. The models are illustrated in a seller-buyer supply chain context, when the relationship between the seller and buyer is treated first as one of leader-follower, and second as one that is cooperative.

Prieto & Zofi (2007)

- DEA allows us to model the different sub technologies corresponding to alternative production processes, to assess efficient resource allocation among them, and to determine potential output gains if inefficiencies were dealt with. The proposed model optimizes the underlying multi-stage technologies that the input–output system comprises identifying the best practice economies.

Zhou et al. (2008)

- Author discuss the environmental DEA technologies that exhibit non-increasing returns to scale (NIRS) and variant returns to scale (VRS). The pure measures under different situations and a mixed measure under the VRS environmental DEA technology for measuring environmental performance are proposed. For the measures that deal with nonlinear programming models, we also give their linear programming equivalents. Finally, a study on measuring the carbon emission performance of eight world regions is presented.

Chiang (2008)

- Author clarified the two concepts of efficiency decomposition and efficiency aggregation widely applied to measuring the system and division efficiencies in network DEA. A relational model using the efficiency decomposition approach to measure the system and division efficiencies at the same time is developed.

Zhu et al. (2009)

- Author investigate an interactive parallel system by a data envelopment analysis game approach. In this system, one sub process invests some of its outputs to another stage and also consumes some outputs of the other sub-process. We first built a centralized model for measuring the efficiency of a DMU in a centralized mode. This non-linear program can be considered as a parametric program and solved via searching the best value during an interval. Based on this, we give an algorithm for solving it.

Chen et al. (2009)

- Rural transportation management is of crucial importance to today's society due to the increasing demand and the limited operations resources available. It is also an area which has received little attention from the research community. In this paper, we develop a new methodology for analyzing the resource scarcity and equity issues in rural transportation management.

Romero et al. (2010)

- Author evaluated the effect of feed allocation and energetic efficiency on technical and economic efficiency of broiler breeder hens using the data envelope analysis methodology and quantified the effect of variables affecting technical efficiency.

Saranga & Moser (2010)

- Author conclude the contributes to the PSM performance evaluation literature in two major aspects. In order to address the problems associated with the traditional, questionnaire-based surveys with respect to the measurement of implemented PSM activities and actual performance outcomes, a new approach to data collection is proposed, which incorporates data from a variety of sources via different evaluation techniques including external performance reviews and hence avoids common method bias and problems associated with perceptual measures. Second, the two-stage value chain DEA method is applied to the PSM performance evaluation incorporating precise as well as imprecise data for the first time in the PSM literature.

Chen & Yan (2011)

- Author constructs an alternative network DEA model that embodies the internal structure for supply chain performance evaluation. We take the perspective of organization mechanism to deal with the complex interactions in supply chain. Three different network DEA models are introduced under the concept of centralized, decentralized and mixed organization mechanisms, respectively. Efficiency analysis including the relationship between supply chain and divisions, and the relationship among the three different organization mechanisms are discussed. As a further extension, we investigate internal resource waste in supply chain.

Liang et al. (2011)

- Author defined two types of supply chain production possibility sets, which have been proved to be equivalent to each other. Based upon the production possibility set, a supply chain CRS DEA model is advanced to appraise the overall technical efficiency of supply chains. The major advantage of the model lies on the fact that it can help to find out the most efficient production abilities in supply chains, by replacing or improving inefficient subsystems (supply chain members).

Chen & Jia (2011)

- The author take the undesirable outputs into consideration to measure the efficiency of 31 regions' industry since undesirable outputs have significance impacts on Chinese environment directly and most part waste and pollution come from the industries.

Piskunov & Lychev (2011)

- The DEA approach makes it possible to visualize operational ways of the production unit's development in the multi-dimensional space of inputs and outputs.

Lozanod et al. (2012)

- Author proposes a novel fuzzified DEA framework that handles fuzzy input and output data and computes fuzzy efficiency scores as well as fuzzy input and output targets. The CRS and VRS cases are considered. FFDEA weakly efficient and FFDEA efficient) depending on whether all inputs, only some inputs or outputs or none of the inputs or outputs can be improved.

Mishra (2012)

- Author conclude this paper an attempt has been taken to measure the efficiency of supply chain has been measured by taking input and output. The average technical efficiency score obtained through CRS model is 0.868, indicating scope for lot of improvement for the Pharmaceutical companies.

Sanei et al. (2013)

- Over the years, we have witnessed the growing importance of supply chain operations and supply chain management (SCM), as supply chains play a major role in every step of the product life cycle. Therefore, this paper will DEA-based performance evaluation approaches for overall supply chain can be categorized. Future perspectives and challenges are discussed.

Chaowarat et al. (2013)

- The objective of the author should review the application of Data Envelopment Analysis (DEA) in Supply Chain Management (SCM) research including different perspectives and research topics. In this review, academic databases used were Science Direct, Scopus and Google Scholar. The latter database was included to identify unpublished studies, conference proceedings and other types of unpublished studies. Practical review criteria are used for the inclusion or exclusion of the pertinent literature.

Lu & Lin (2013)

- It helps identifies significant paths, important papers, and recent active subareas in DEA development. The method first assigns a search path count to each citation and then traces the paths with the largest search path counts. Search path count is the exhausted count of the routes for knowledge in all the sources to disseminate to all the sinks. The local, global, and multiple main paths are examined. Each of them provides us with different views on the DEA evolution.

Saneia & Chatghayeh (2013)

- Over the years, we have witnessed the growing importance of supply chain operations and supply chain management (SCM), as supply chains play a major role in every step of the product life cycle. Therefore, this paper will DEA-based performance evaluation approaches for overall supply chain can be categorized. Future perspectives and challenges are discussed.

Leu et al. (2014)

- Author researched covers an application of data envelopment analysis (DEA) slacks based model to a multinational chemical manufacturer to minimize both input and bad output variables of both the environmental aspect, covering energy consumption, water intake, carbon dioxide (CO2), volatile organic compound(VOC), solid waste, and the social aspect covering employees' working hours and total recordable (injury and illness) rate. The model also maximizes the good output, finished good products, to satisfy customers and other stakeholders

Mukherjee et al. (2015)

- Author performed experimental investigation has been carried out on four different types of air pollutants or aerosols (commonly found in Indian environment) for their impact on performance of PV cells.

Mirbolouki (2015)

- The main goal of the paper is a consideration of cost efficiency evaluation models related to some supply chain when dealing with imprecise data. Data envelopment analysis (DEA) method is a non-parametric mathematical programming approach to assess the performance. This method is proposed for deterministic data and it can be generalized to inaccurate data, while considering real world applications. Here we consider data as random variables and after reviewing and introducing new models to evaluate cost eSciences related to the special circumstances of the supply chain using DEA, these models are developed to probabilistic form.

Marbini & Mehdi (2015)

- The author first made an attempt to improve discriminating power as well as to provide more realistic weight dispersion within the MCDEA models.

Ghosh & Mukherjee (2015)

- The author investigated, experimental investigation has been carried out on four different types of air pollutants or aerosols (commonly found in Indian environment) for their impact on performance of PV cells.

Zhang et al. (2015)

- Evaluate eco-efficiency level of 40 industrial parks in China based on DEA model. Results show that 20% of the parks (e.g. NCHID, SCHTD) are relatively efficient in overall efficiency. 47% of the parks being inefficient in SE show decreasing returns to scale. CQYCIP is the lowest efficient park in both CCR and BCC model.

Eskelinen (2015)

- This study has demonstrated that the implications may concern not only the efficiency scores and rankings of individual DMUs, but also the importance that the variables and their logical groups have in the efficiency evaluation.

Yousefi & Saen (2015)

- Author ran ANN to forecast inputs, outputs, and links of green suppliers. After that, to evaluate suppliers in multiple periods, dynamic DEA was run. Finally, for the first time, the green suppliers were ranked based on both overall efficiency scores and slope of the efficiency trend.

Khoshnevis (2016)

- A review of the literature shows that there are many gaps in the theory and application of supplier selection with sustainable sourcing. For example, there are essentially no supplier assessment decision support systems that integrate sustainability criteria with conventional criteria such as price, quality, flexibility, etc.

Vyas & Jha (2016)

- Author studied proposes a method by which a green building index can be increased by using the attributes that contribute more green points at less of a cost. It is possible to benchmark green building attributes with respect to cost by applying the DEA. The data envelopment analysis helps identify the efficiency of the green building attributes, which are selected based on the cost. The DEA model chosen for this project is the CRS –CCR formulation input-oriented model. In this model, the output increases by the same proportional change of each proportional increase in the input.

Boudaghi & Saen (2016)

- Author predict group membership of suppliers in terms of sustainability, we developed a new DEA–DA model. We discussed that Sue Yoshi did not care about inputs, outputs, and efficiency factors. To the best of our knowledge, none of the DEA–DA models has considered the nature of factors in predicting the observations' group membership.

Aparicio et al. (2016)

- As in DEA the new approach assumes a common technology, offering novel analytical possibilities to researchers interested in this field by introducing the ability of performing efficiency evaluation. An outstanding feature of the new approach is, therefore, the possibility of estimating the technical coefficients in the evaluation process, the re by determining the under lying relationship between each pair of inputs and outputs.

Khoshnevis et al. (2016)

- Sustainable sourcing is a recent priority for firms considering customer behavior and societal norms with respect to the supply chain. Customer attitudes, particularly in the developed countries, are affected by the perceived sustainability of products or services regarding environmental, social and economic aspects.

Majkut et al. (2016)

- Author develop a new methodology for rural transportation management which takes into consideration of both the equity and cost factors under multiple objectives. We conceptualize and define equity in rural transportation management with the development of new performance measures and an analytical model for decision making with multiple desirable and undesirable objectives. We also develop a heuristic procedure based on data envelopment analysis for characterizing and analyzing the route design choices on the frontier between costs and multi-objective measures of equity.

Vyas & Jha (2016)

- The present study focuses on developing appropriate constructs to benchmark green building attributes in construction such that, with limited funds, the sustainable performance of the building is improved. In this study, Indian green building assessment tools, such as Green Rating for Integrated Habitat

Assessment (GRIHA), Indian Green Building Council (IGBC), eco-housing, and a newly developed rating system, are reviewed.

Chen & Li (2016)

- The current paper develops an additive efficiency decomposition approach wherein the overall efficiency is expressed as a (weighted) sum of the efficiencies of the individual stages. This approach can be applied under both CRS and variable returns to scale (VRS) assumptions. The case of Taiwanese non-life insurance companies is revisited using this newly developed approach.

Yadav et al. (2016)

- One of the biggest challenges before the world today is to find a trade-off between high energy demand and mitigation of greenhouse gas emissions. Researchers and energy policy makers around the world are now resorting to renewable energy (RE), as a solution to this crisis with special focus on solar energy, as it is the most abundantly available resource.

Chen et al. (2016)

- The assumptions of strong and weak disposability for undesirable outputs have long dominated studies of data envelopment analysis for environmental assessments. Unfortunately, these assumptions cannot de- scribe the diverse technical features of different undesirable outputs during the actual production process. Thus, we introduce a non-disposal degree to develop a new semi-disposability assumption, which can re- place the assumptions of strong and weak disposability in environmental assessments. This assumption ensures that decision makers can address undesirable outputs freely within the scope of current production technology; otherwise, they must reduce desirable outputs in the same proportion to decrease undesirable outputs.

2.3 Research gaps

Future research paths might focus on the following problems, questions: -

i. There is a requirement to enhance DEA models' capabilities in supplier evaluation by combining goal programming, dynamic programming, and DEA simultaneously.

ii. Data envelopment analysis discriminant analysis (DEA-DA) and goal programming can be integrated to forecast the trend of efficiency of DMUs.

iii. Future research can also possible by taking customer satisfaction, the delivery efficiency as outputs.

2.4 Summary

This chapter presents a literature survey of DEA applications in five areas

1. Supply chain and logistics management

2. Manufacturing systems and design engineering

3. Business and management

4. Energy and environment management

5. And other useful areas,

In this chapter, different research papers published in the journals of national and international repute were studied. Different authors have developed different models by DEA technique in the field of supply chain management. Based on the literature survey it can be inferred that many firms have utilized these models in various fields. In recent years, these models which have been developed using Data Envelopment Analysis (DEA) methodology are now being validated using DEA Solver software.

Chapter-3

System analysis of Company

3.1 Company profile

XYZ ltd was established in the year 1951 as The Pioneers in the manufacturing of Industrial Geared motors and Reducers, Material Handling Equipment, Mining equipment, casting processes etc. XYZ ltd is one of the largest manufacturers of Material Handling Equipments and Industrial Gears in Asia. XYZ ltd had set up a separate Gear Division in 1976. First in India to manufacture sophisticated equipment for bulk Material Handling and a product range that caters to almost every Industrial sector in India. It has 6 manufacturing plants, 16 marketing offices, 3 repair and refurbishment center, more than 25 dealers and almost 20 corporate representatives in different part of world.

The company operates through two divisions, material handling equipments(MHE) and industrial gears. For FY10, MHE segment contributed 59% to the total revenue, while industrial gears constituted the remaining 41%.

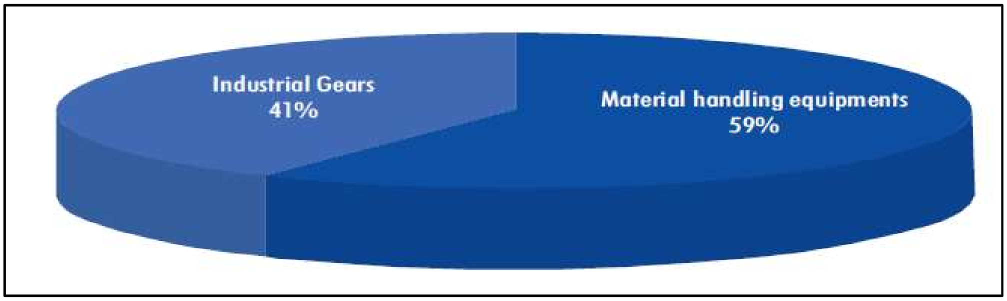


Figure 3.1 Division of company on the basis of total revenue

Number of Gear manufacturing plants- 1

Employee strength- 2220

Main plant area – 1,73,098 sq. mt

- Product profile:- Helical Gears
- Spiral Bevel Helical Gears
- Worm reduction Gears units
- Couplings
- Gear boxes for highly specialized and precision applications
- Belt Conveyors
- Lift gears

The latest additions to their production line are planetary gear boxes for marine and other applications which have already been delivered for use on the off-shore patrol vessels of the Indian Coast Guard. These are very compact, high precision gear boxes, capable of transmitting up to 23,000 KW of power

Yearly production volume: This division has a capacity of producing more than 25,0000 gear unit yearly, out of which 90% share for worm speed reduction gear units and remaining share in helical speed reduction gear unit.

Work schedule operations: three shifts

Work timings- 8:00 to 16:00 (1st shift)

16:00 to 00:00 (2nd shift)

00:00 to 8:00 (3rd shift)

International accreditation: ISO 9001

3.2 Organizational structure of XYZ ltd.

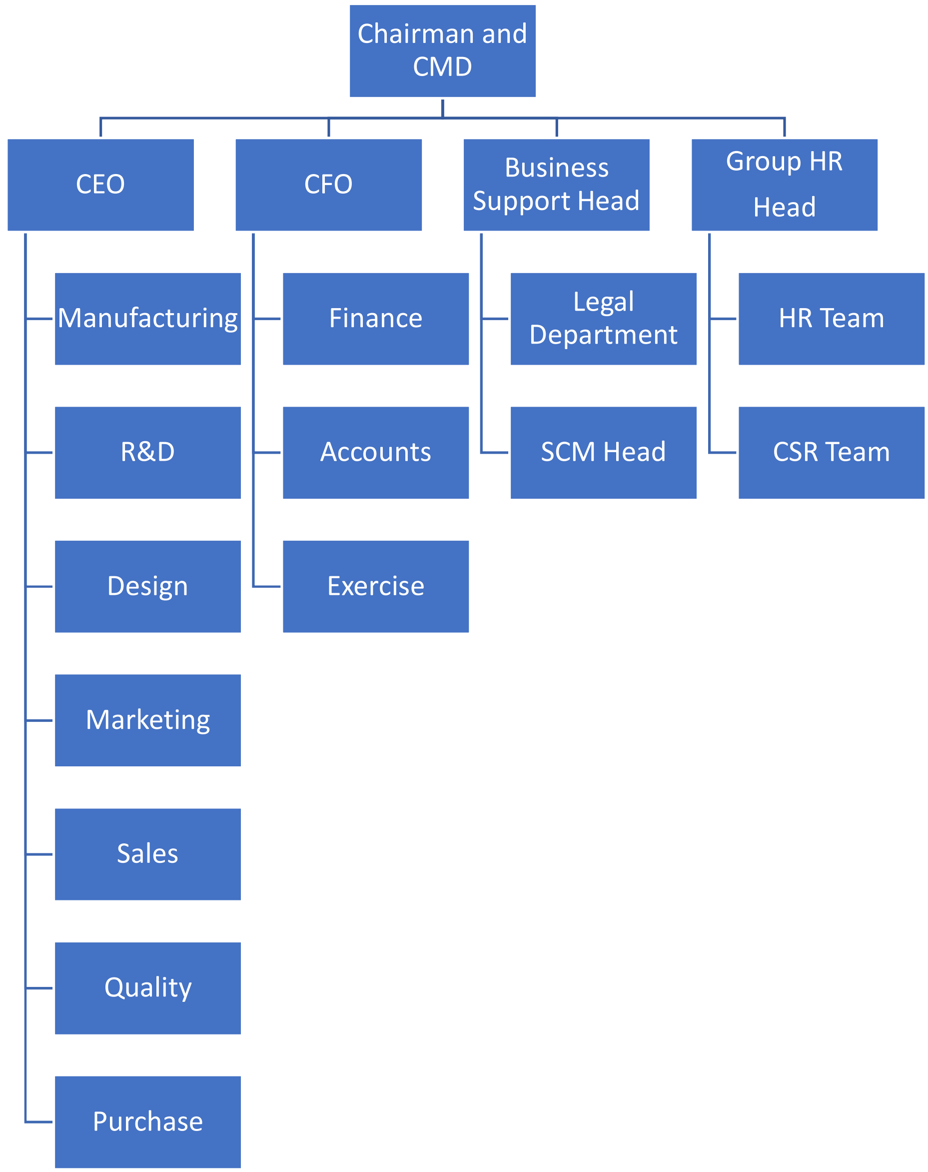


Figure 3.2 Organization structure of XYZ ltd.

3.3 Customer base

The products of XYZ ltd. are being supplied to various customers in India and abroad.

Some of the important customers are as follows:

Table 3.1 List of customers of the company

S.No.	Customer
1	L&T
2	BHEL
3	NTPC
4	NBBC
5	Indian Navy
6	Coal India Limited
7	GAIL (India) Limited
8	Indian Oil Corporation Limited
9	Oil & Natural Gas Corporation Limited
10	Steel Authority of India Limited and many more govt and private sector OEM's and end users

3.4 Types of products

3.4.1 Helical Gear units and Bevel helical gear units

Table 3.2 Helical gears and bevel helical gears technical specifications

	Helical gear specifications	Bevel helical gear specifications
Ratio	1.25......560	1.25......560
Power	1.7......4825 Kw	0.8......1850 kW
Torque	132000 Nm	132000 Nm

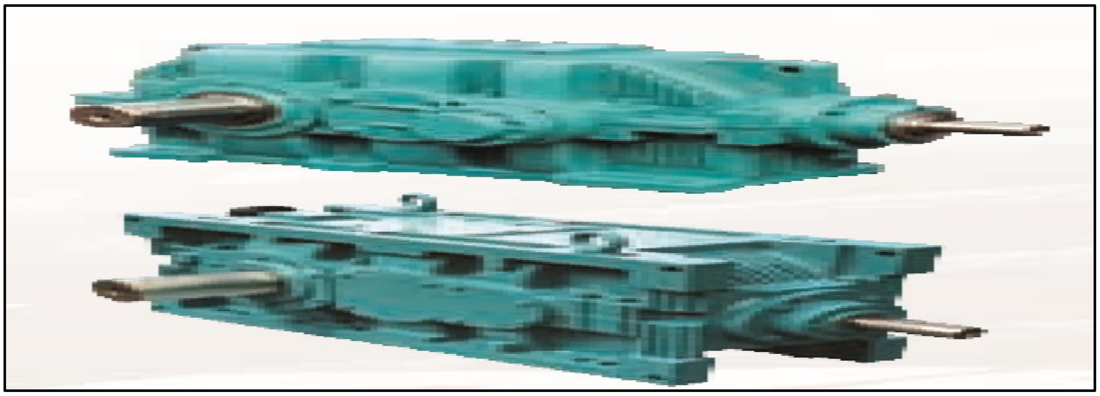


Figure 3.3 Helical Gear units and Bevel helical gear units

3.4.2 Worm geared motor- SWM

Worm geared motors are single-stage angular geared motors with high-performance worm gearing.

Sizes: 1 , 2 , 3, 4

Ratio: Min. 5 : 1 to Max. 70 : 1

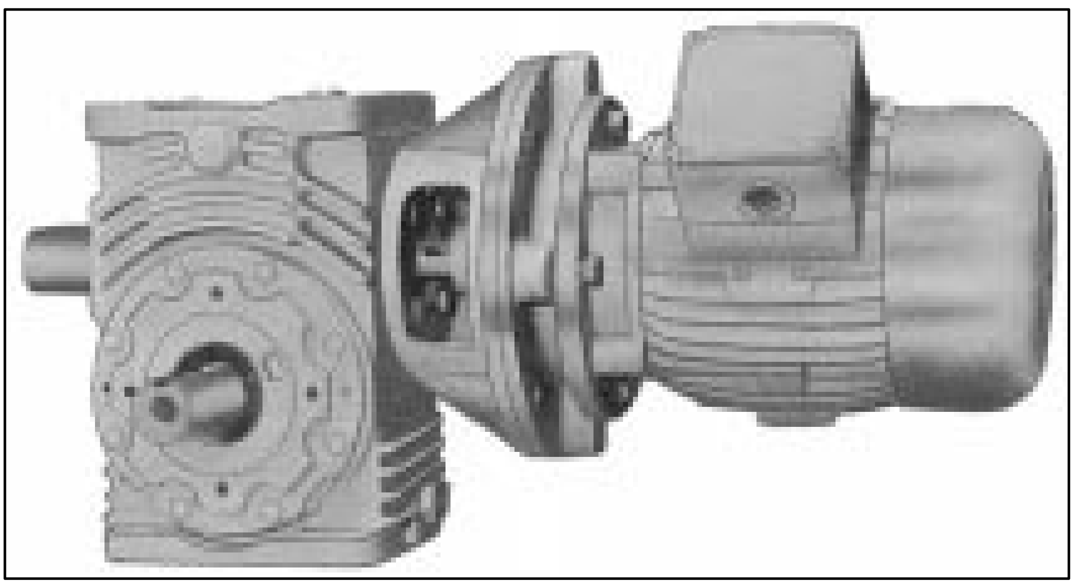


Figure 3.4 Worm geared motor- SWM

3.4.3 Double reduction units (helical/worm)

Model & Type: Combination with First pair helical gear unit and Second pair with worm gear unit.

Sizes: 7, 8, 9, 10.5, 12, 14

Ratio: Max. 440 : 1

Power Capacity to 70 KW.

Figure 3.5 HSSM

3.4.4 Heavy Duty Stirrer Units

Heavy Duty stirrer unit incorporates an extended bearing housing to accommodate a larger bottom bearing and increased shaft size, thereby enhancing the unit capacity to absorb the high bending loads imposed during stirrer applications. This gear unit is compact with facility of top mounted pivoted platform where electric motor can be directly mounted above the gear unit using belt tensioning device.

Model & Type: SNU–CVDM

Sizes: 4, 5, 6, 7, 8, 9, 10.5

Model & Type: CVDM

Sizes: 12, 14, 17

Ratio: Min. 5 : 1 to Max, 70 : 1

Power Capacity to 350 KW

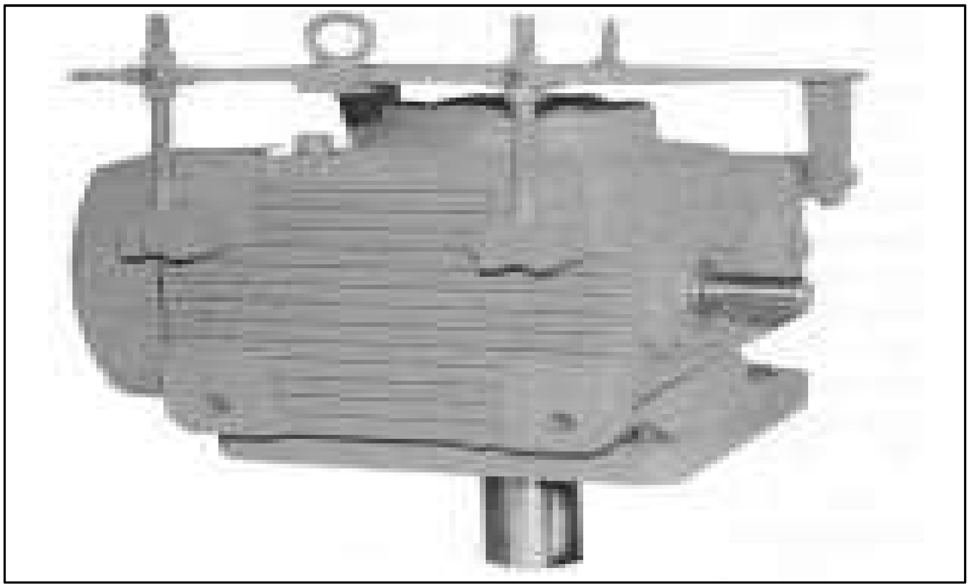


Figure 3.6 SNU-CVDM/CVDM

3.4.5 Cooling Tower Fan Drive Gear Unit

Cooling Tower Fan Drive Gear Unit incorporates an extended top bearing housing to accommodate the larger wheel shaft bearing. Length of the output shaft extension are manufactured to client's requirements and to suit fan hub mounting. Lubrication is entirely contained by splash and lower bearing dip in the oil bath while oil is pumped to the top wheel shaft bearing by mean of a built-in plunger mechanism. All exposed parts other than the extensions are applied with corrosion resistant paint.

Model & Type: SNU–CTU

Sizes: 4, 5, 6, 7, 8, 9, 10.5

Model & Type : CTU

Sizes: 12, 14, 17

Rato: Min. 5 : 1 to Max. 70 : 1

Power Capacity: 350 KW

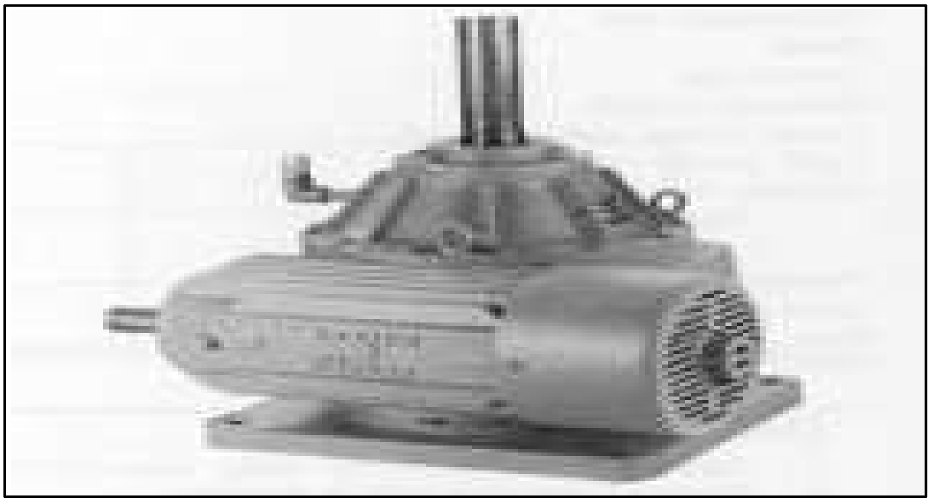


Figure 3.7 SNU-CTU/CTU

3.4.6 Fluid couplings

A fluid coupling or hydraulic coupling is a hydrodynamic device used to transmit rotating mechanical power. It also has widespread application in marine and industrial machine drives, where variable speed operation and controlled start-up without shock loading of the power transmission system is essential.

Sizes:185.........760

Power: 0.20.......950 kW

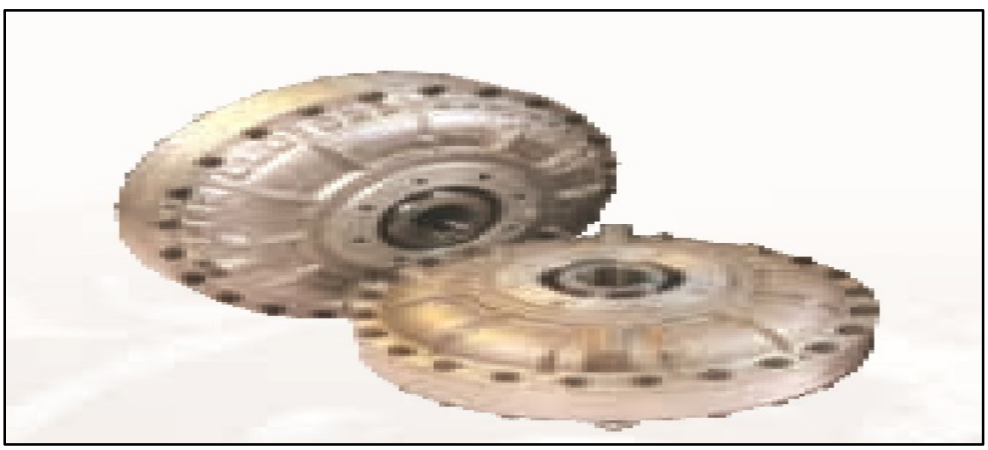


Figure 3.8 Fluid coupling

3.4.7 Flexible Coupling

Flexible couplings are usually used to transmit torque from one shaft to another when the two shafts are slightly misaligned. They can accommodate varying degrees of misalignment up to 3° and some parallel misalignment

Torque: 70 Nm......4,30,000 Nm

Power: 0.007 kW/rpm.....44.77 kW/rpm

Figure 3.9 Flexible coupling

3.5 Gearbox Manufacturing processes

Manufacture of gears needs several processing operations in sequential stages depending upon the material and type of the gears and quality desired. Those stages generally are shown in the form of flowchart below:

Figure 3.10 Process flow diagram for gear manufacturing

3.6 Supply chain of XYZ ltd.

XYZ ltd. has different departments like engineering or R&D, purchase, quality, Production, Quality etc.

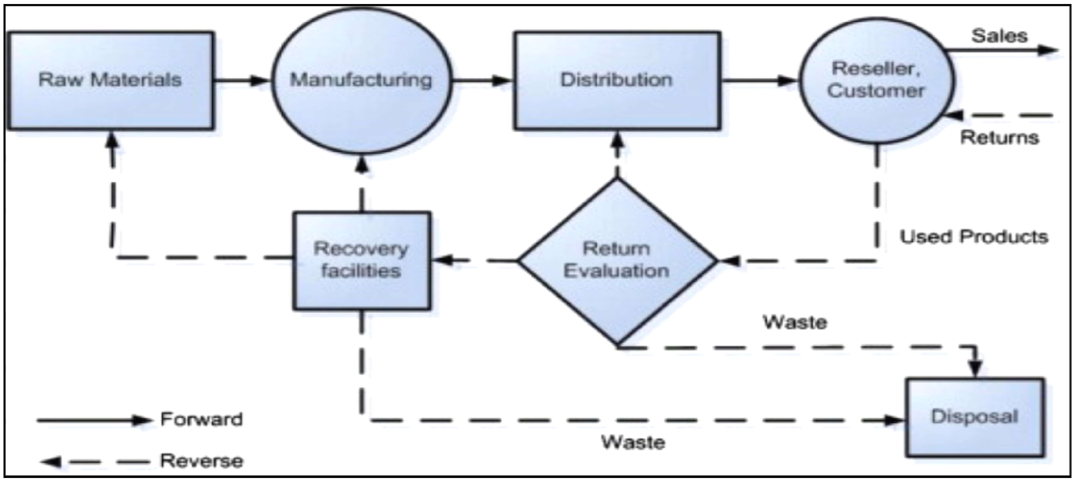


Figure 3.11 Supply chain of XYZ ltd.

3.7 Quality Policy (ISO 9001:2008)

To be a customer focussed organisation all the time, the XYZ did the following:

- Understanding customer needs and providing optimum solution. Fulfilling commitment made towards supply, reliability and trouble-free usage.
- Upgrading technology of products and services.

It will be endeavour of the company to continuously improve and exceed customer expectations through engineering excellence so that the XYZ ltd was benchmarked amongst the very best. XYZ ltd will ensure that, while excel in their business operations, also comply with all applicable standards & norms.

3.8 Product safety information

XYZ ltd gear units will operate safely provided that they are selected, installed, used and maintained property. As with any equipment consists of rotating shafts and transmitting power, adequate guarding is necessary to eliminate the possibility of physical contact with rotating shafts or coupling.The following points should be noted and brought to attention to the persons involved in the installation, use and maintenance of equipment.

- For lifting of gear unit eye-bolts or lifting points (on larger units) should be used.
- Check the grade and quantity of lubrication before commissioning. Read and carry out all instructions on lubricant plate and in the installation and maintenance manual literature.

- Installation must be performed in accordance with the manufacturer's instruction and be undertaken by suitably qualified personnel.
- Ensure the proper maintenance of gearboxes in operation.
- The oil level should be examined periodically, if required the oil should be filled again.
- The operating speeds, transmitting powers, generated torques or the external loads must not exceed the design values.
- The driving and the driven equipment must be correctly selected to ensure that the complete installation of the machinery will perform satisfactorily e.g. avoiding system critical speeds, system torsional vibration etc.

3.9 SWOT analysis

SWOT analysis is a tool for auditing an organization and its environment. It is the first stage of planning and helps marketers to focus on key issues. *SWOT* stands for strengths, weaknesses, opportunities, and threats. Strengths and weaknesses are internal factors. Opportunities and threats are external factors. A strength is a positive internal factor. A weakness is a negative internal factor. An opportunity is a positive external factor. A threat is a negative external factor. The main purpose of the analysis is to add value to the company products and services so that a company can recruit new customers, retain loyal customers, and extend products and services to customer segments over the long-term.

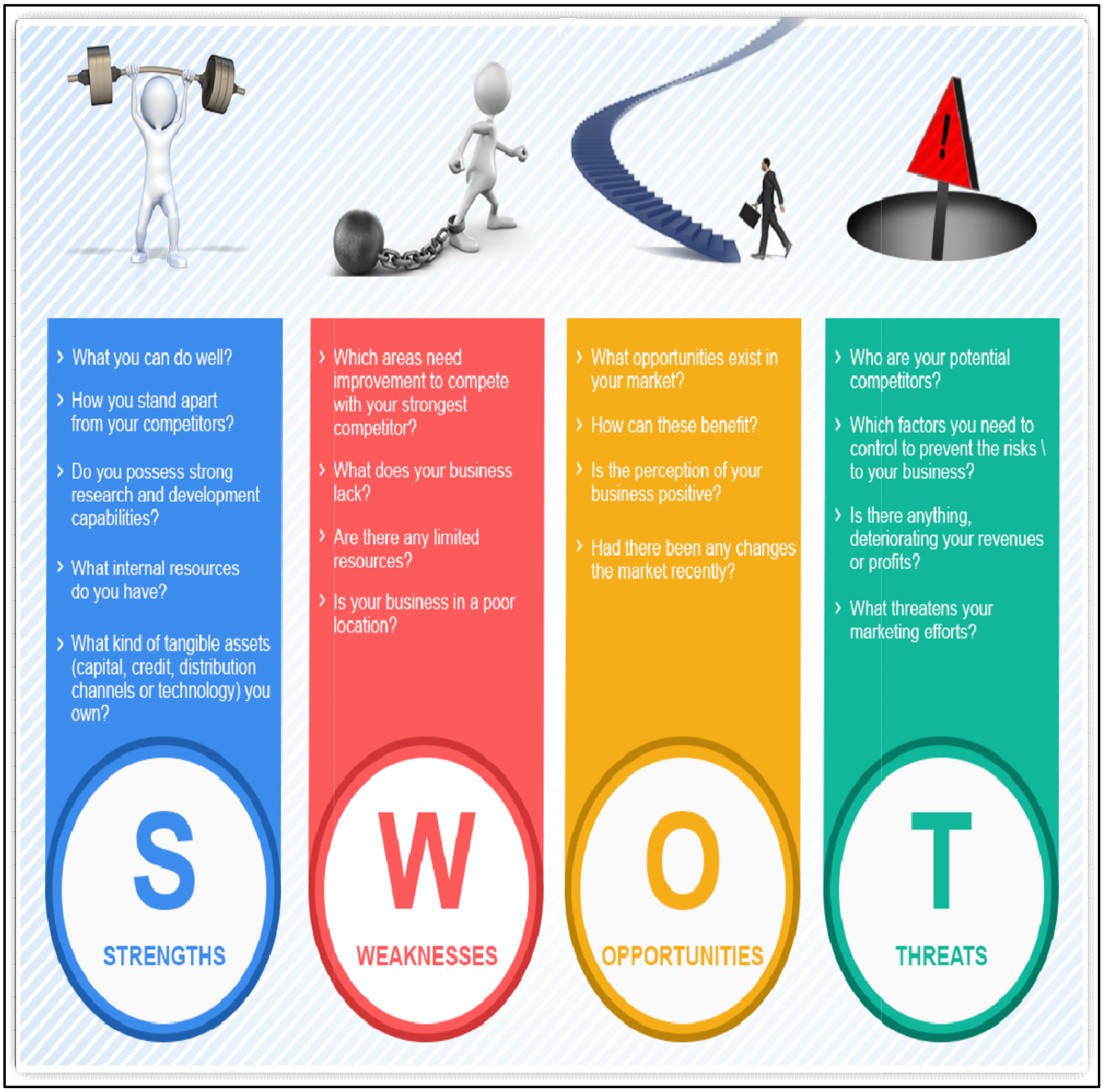


Figure 3.12 SWOT analysis

An overview of the four factors (Strengths, Weaknesses, Opportunities and Threats) is given below-

- **Strengths -** Strengths are the qualities that enable us to accomplish the organization’s mission. These are the basis on which continued success can be made and continued/sustained.

Strengths can be either tangible or intangible. These are what you are well-versed in or what you have expertise in, the traits and qualities your employees possess (individually and as a team) and the distinct features that give your organization its consistency.

Strengths are the beneficial aspects of the organization or the capabilities of an organization, which includes human competencies, process capabilities, financial resources, products and services, customer goodwill and brand loyalty. Examples of organizational strengths are huge financial resources, broad product line, no debt, committed employees, etc.

- **Weaknesses -** Weaknesses are the qualities that prevent us from accomplishing our mission and achieving our full potential. These weaknesses deteriorate influences on the organizational success and growth. Weaknesses are the factors which do not meet the standards we feel they should meet.

  Weaknesses in an organization may be depreciating machinery, insufficient research and development facilities, narrow product range, poor decision-making, etc. Weaknesses are controllable. They must be minimized and eliminated. For instance - to overcome obsolete machinery, new machinery can be purchased. Other examples of organizational weaknesses are huge debts, high employee turnover, complex decision making process, narrow product range, large wastage of raw materials, etc.

- **Opportunities -** Opportunities are presented by the environment within which our organization operates. These arise when an organization can take benefit of conditions in its environment to plan and execute strategies that enable it to become more profitable. Organizations can gain competitive advantage by making use of opportunities.

  Organization should be careful and recognize the opportunities and grasp them whenever they arise. Selecting the targets that will best serve the clients while getting desired results is a difficult task. Opportunities may arise from market, competition, industry/government and technology. Increasing demand for telecommunications accompanied by deregulation is a great opportunity for new firms to enter telecom sector and compete with existing firms for revenue.

- **Threats -** Threats arise when conditions in external environment jeopardize the reliability and profitability of the organization's business. They compound the vulnerability when they relate to the weaknesses. Threats are uncontrollable. When a threat comes, the stability and survival can be at stake. Examples of threats are - unrest among employees; ever changing technology; increasing competition leading to excess capacity, price wars and reducing industry profits; etc

3.9.1 Advantages of SWOT Analysis

SWOT Analysis is instrumental in strategy formulation and selection. It is a strong tool, but it involves a great subjective element. It is best when used as a guide, and not as a prescription. Successful businesses build on their strengths, correct their weakness and protect against internal weaknesses and external threats. SWOT Analysis helps in strategic planning in following manner-

- It is a source of information for strategic planning.
- Builds organization's strengths.
- Reverse its weaknesses.
- Maximize its response to opportunities.
- Overcome organization's threats.
- It helps in identifying core competencies of the firm.
- It helps in setting of objectives for strategic planning.
- It helps in knowing past, present and future so that by using past and current data, future plans can be chalked out.

3.9.2 Limitations of SWOT Analysis

SWOT Analysis is not free from its limitations. It may cause organizations to view circumstances as very simple because of which the organizations might overlook certain key strategic contact which may occur. Moreover, categorizing aspects as strengths, weaknesses, opportunities and threats might be very subjective as there is great degree of uncertainty in market. SWOT Analysis does stress upon the significance of these four aspects, but it does not tell how an organization can identify these aspects for itself.

There are certain limitations of SWOT Analysis which are not in control of management. These include-

- Price increase;
- Inputs/raw materials;
- Government legislation;
- Economic environment;

Searching a new market for the product which is not having overseas market due to import restrictions; etc.

Internal limitations may include-

- Insufficient research and development facilities;
- Faulty products due to poor quality control;
- Poor industrial relations;
- Lack of skilled and efficient labour; etc

3.10 SWOT analysis of the company

3.10.1 Strength

XYZ ltd is one of the largest gear manufacturer with a market share of 26%. The company has a strong foothold in worm gears, helical gears, different types of couplings and customized power transmission products and has executed prestigious orders like large size planetary gearboxes, supply of marine gears for battle ship, etc. XYZ ltd is topping the market in terms of market share as compared to the competitor like Shanthi gear, Premium, Flender and others.

Some other strengths of the company are listed below:

- Strong financial background.
- Staff is technically skilled.
- Fast diversifying company.

- Equipped with world class manufacturing technology.
- Order inflows are relative stable

3.10.2 Weakness

XYZ ltd working capital block is higher than its peers, primarily on account of higher inventory days (required for gear division). It maintains inventory of 110 days as compared to 40 days maintained by peer group. Advances from customers are 8 % of sales for XYZ ltd as compared to peers who receive 20% of sales, since advances are not received on all gear orders by XYZ ltd. This stretches the working capital requirement. Some other weaknesses are as follows:

- Unable to adjust with the uncertain demands of the customer.
- Waiting time for product is high.

3.10.3 Opportunities

Growth in the economy is not only strong but also broad based with large number of sectors contributing to growth. The Capital goods and consumer durables have contributed the most to industrial growth. Consistent good performance of capital goods sector suggests investments activities gaining momentum and growing confidence in the economy. XYZ ltd is not only witnessing announcements of fresh projects but also increase in projects under implementation, indicating conversion of announcements in to investments.

3.10.4 Threats

- There is huge competition in the market due to large number of suppliers in the market like Shanthi gear, Premium, Flender and others organised players.
- Revenues are largely dependent on capital investments made by user industries. Hence, any deceleration in industrial capex has an adverse impact on growth of the company.
- Demand for customized product is increasing day by day.
- Manpower is going expensive day by day.
- Changes in the government policies

3.11 Summary

In this chapter, the study of the company XYZ ltd has been described in detail. The various processes flow diagrams are used to explain the various activities within the company. The main focus is to study the supply chain structure of the company XYZ Limited. So, a detailed model is being provided which clearly defines the various flaws within the supply chain of the company. SWOT analysis is conducted to determine the strength, weakness and opportunities of the company.

Chapter 4

Application of DEA Approach for Performance Evaluation of Suppliers and Manufacturer

4.1 Problem statement

Supply chain of a company consist of various manufacturers and suppliers. The suppliers supply the raw material to the manufacturer as per the demand and the producer produces the product for the customer. There are number of suppliers who provide raw material at different cost which affects the manufacturing cost and quality. In the supply chain network, there are several factors which affect the inputs and outputs thus making the calculation of these types of problems very complex and the consideration of each affecting variable will not be possible. DEA technique provides the solution of such type of problem, it includes all the affecting variable and provide the most efficient supply chain network through which we get minimum input and maximum output.

In the present work, problem of a gear manufacturing company has been considered and efficiency of two stage supplier and producer supply chain has been determined by developing continuous CCR ratio DEA model using DEA Solver 8.0 software along with MS Excel. Company have n homogeneous supply chain operations. Each supply chain observation had considered to be a DMU. It is assumed that each supplier $S_j$in DMU_j: j = 1,...,n has m inputs x_{ij}: i = 1,...,m and s outputs y_{rj}: r = 1,..., s. These outputs can become the inputs to the manufacturer M_j. The manufacturer $M_j$has its own inputs Z_{dj}: d = 1,..., D. The final outputs from manufacturer are Q_{lj}: l = 1,..., L. This type of problem came into the two-stage supply chain, supplier-manufacturer supply chain.

4.2 Mathematical Model of DEA

Consider a buyer-seller supply chain, *XA* is the input vector of the seller, and *YA* is the seller's output vector. *YA* is also an input vector of the buyer, along with *XB*, with *YB* being the buyer's output vector.

Suppose there are *n* such supply chains or observations on one supply chain. The CCR DEA efficiency of the supply chain is measured as (Charnes et al., 1978; CCR)

Before introducing the method and the models that will be used, we first define the symbols that will be used

X_A = Input of seller

X_B = Input of buyer

Y_A = Output of seller

Y_B = Output of buyer

U = Output weights in fractional program

V = Input weights in fractional program

n = number of observation

μ = Output weights in linear program

ω = Input weights in linear program

T = Number of decision-making unit

E_{AA} = Efficiency of sellers

E_{BB} = Efficiency of buyer

E_{AA}^{*} = Maximum efficiency of sellers

E_{BB}^{*} = Maximum efficiency of buyer

e_{AB} = Efficiency of supply chain

$$\text{Max } \frac{U^T Y_{B0}}{V^T(X_{A0}, X_{B0})}$$

$$\text{s.t} \quad \frac{U^T Y_{Bj}}{V^T(X_{Aj}, X_{Bj})} \leq 1 \qquad j = 1, 2\ldots\ldots\ldots, n$$

(9)

$$U^T,\ V^T \geq 0$$

Zhu (2003) shows that DEA model (1) fails to correctly characterize the performance of supply chains, because it only considers the inputs and outputs of the supply chain system and ignores measures *YA* associated with supply chain members. Zhu (2003) also shows that if *YA* are treated as both input and output measures in model (1), all supply chains become efficient.

Zhu (2003) further shows that an efficient performance indicated by model (1) does not necessarily indicate efficient performance in individual supply chain members. Consequently, improvement to the best-practice can be distorted. i.e., the performance improvement of one supply chain member affects the efficiency status of the other, because of the presence of intermediate measures.

Alternatively, we may consider the average efficiency of the buyer and seller as in the following DEA model

$$\text{Max } \frac{1}{2}\left[\frac{U_A^T Y_{A0}}{V_A^T X_{A0}} + \frac{U_B^T Y_{B0}}{V_B^T (X_{B0}, Y_{A0})}\right]$$

$$\text{s.t } \frac{U_A^T Y_{Aj}}{V_A^T X_{Aj}} \leq 1 \qquad j = 1,2,\ldots\ldots n$$

(10)

$$\frac{U_B^T Y_{Bj}}{V_B^T (X_{Bj}, Y_{Aj})} \leq 1 \qquad j = 1,2,\ldots\ldots n$$

$$U_A^T, V_A^T, U_B^T, V_B^T \geq 0$$

Although model (2) considers Y_A, it does not reflect the relationship between the buyer and the seller. The weights of $Y_A$as inputs of the buyer may not be equal to the weights of $Y_A$as outputs of the seller. Model (2) treats the seller and the buyer as two independent units. This does not reflect an ideal supply chain operation.

We next develop several models that can directly evaluate the performance of the supply chain as well as its members while considering the relationship between the buyer and the seller.

Based upon Li, Huang and Ashley (1995), we suppose the seller-buyer interaction is viewed as a two-stage noncooperative game with the seller as the leader and the buyer as the follower. For example, in the case of non-cooperative advertising between the manufacture (seller) and the retailer (buyer), Toyota automobile company decides that it wants to promote sales of a particular model and directs and subsidizes its local dealers. The local dealers then react to Toyota's strategy by adjusting the amount they spend on advertising and promotion.

First, we use the CCR model to evaluate the efficiency of the seller, as the leader

$$\text{Max } \frac{U_A^T Y_{A0}}{V_A^T X_{A0}} = E_{AA}$$

$$\text{s.t. } \frac{U_A^T Y_{Aj}}{V_A^T X_{Aj}} \leq 1 \qquad j = 1, 2\ldots\ldots n$$

(11)

$U_A^T, V_A^T \geq 0$

This model is equivalent to the following standard DEA multiplier model:

$$\text{Max } \mu_A^T Y_{A0} = E_{AA}$$

$$\text{s.t.} \omega_A^T X_{Aj} - \mu_A^T Y_{Aj} \geq 0 \qquad j=1, 2\ldots\ldots n$$

(12)

$$\omega_A^T X_{A0} = 1$$

$$\omega_A^T, \mu_A^T \geq 0$$

Suppose we have an optimal solution of model (4) $\omega_A^{T*}, \mu_A^{T*}$,and E_{AA}^* and denote the seller's efficiency as E_{AA}^*. We then use the following model to evaluate the buyer's efficiency:

$$\text{Max } \frac{U_B^T Y_{B0}}{V_B^T X_{B0} + D\times \mu_A^T Y_{A0}} = E_{AB}$$

$$\text{s.t. } \frac{U_B^T Y_{Bj}}{V_B^T X_{Bj} + D\times \mu_A^T Y_{Aj}} \leq 1 \qquad j = 1,2,\ldots\ldots..n$$

(13)

$$\mu_A^T Y_{A0} = E_{AA}^*$$

$\omega_A^T X_{Aj} - \mu_A^T Y_{Aj} \geq 0$j = 1,2,……..n

$$\omega_A^T X_{A0} = 1$$

$$\omega_A^T, \mu_A^T, U_B^T, V_B^T, D \geq 0$$

Note that in model (5), we try to determine the buyer's efficiency given that the seller's efficiency remains at E_{AA}^*. Model (5) is equivalent to the following non-linear model:

Max $\mu_B^T Y_{B0} = E_{AB}$

s.t. $\omega_B^T X_{Bj} + d\mu_A^T Y_{Aj} - \mu_B^T Y_{Bj} \geq 0$ j = 1,2,……n

(14)

$$\omega_B^T X_{B0} + d\mu_A^T Y_{A0} = 1$$

$$\mu_A^T Y_{A0} = E_{AA}^*$$

$\omega_A^T X_{Aj} + \mu_A^T Y_{Aj} \geq 0$ j = 1,2,……n

$$\omega_A^T X_{A0} = 1$$

$$\omega_A^T, \mu_A^T, \omega_B^T, \mu_B^T, d \geq 0$$

Note that $\omega_B^T X_{B0} + d\mu_A^T Y_{A0} = 1$ and $\mu_A^T Y_{A0} = E_{AA}^*$. Thus, we have 0≤ d ≤ $\frac{1}{\mu_A^T Y_{A0}} = \frac{1}{E_{AA}^*}$, i.e, we have the upper and lower bounds on *d*. Therefore, *d* can be treated as a parameter and model (6) can be solved as a linear program. In computation, we set the initial *d* value as the upper bound, namely,$d_0 = \frac{1}{E_{AA}^*}$, and solve the resulting linear program. We then start to decrease *d* according to $d_t = \frac{1}{E_{AA}^*} - \varepsilon \times t$for each step *t*, where ε is a small positive number. We solve each linear program of model (6) corresponding to $d_t$and denote the optimal objective value as $E_{BA}^*(d_t)$.

Let E_{BA}^{*} = Max E_{BA}^{*}(d_t). Then we obtain a best heuristic search solution $E_{BA}^{*}$to model (6). This E_{BA}^{*}represents the buyer's efficiency when the seller is given thepre-emptive priority to achieve its best performance. The efficiency of the supply chain can then be defined as

$$e_{AB} = \frac{1}{2}(E_{AA}^{*} + E_{AB}^{*})$$

Similarly, one can develop a procedure for the situation when the buyer is the leader and the seller the follower. For example, in the October 6, 2003 issue of the Business Week, its cover story reports that Walmart dominates its suppliers and not only dictates delivery schedules and inventory levels, but also heavily influences product specifications.

We first evaluate the efficiency of the buyer using the standard CCR ratio model

$$\text{Max } \frac{U_B^T Y_{B0}}{V_B^T X_{B0} + V^T Y_{Aj}} = E_{BB}$$

$$\text{s.t.} \quad \frac{U_B^T Y_{Bj}}{V_B^T X_{Bj} + V^T Y_{Aj}} \leq 1 \qquad j = 1,2,\ldots\ldots n$$

(15)

$$U_B^T, V_B^T, V^T \geq 0$$

Model (7) is equivalent to the following standard CCR multiplier model

$$\text{Max } \mu_B^T Y_{B0} = E_{BB}$$

$$\text{s.t.} \quad \omega_B^T X_{Bj} + \mu^T Y_{Aj} - \mu_B^T Y_{Bj} \geq 0 \qquad j = 1,2,\ldots\ldots\ldots,n$$

(16)

$$\omega_B^T X_{B0} + \mu^T Y_{A0} = 1$$

$$\omega_B^T, \mu_B^T, \mu^T \geq 0$$

Let $\omega_B^{T*}, \mu_B^{T*}, \mu^{T*}, E_{BB}^{*}$an optimal solution from model (8) where E_{BB}^{*}represents the buyer's efficiency score.

The efficiency of the supply chain network can then be defined as

$$E_{AB} = \frac{1}{2}(E_{AA}^{*} + E_{BB}^{*})$$

We now illustrate the DEA procedures with eight supply chain operations (DMUs) given in Table 1. The supplier has three inputs, X_1(labour cost), X_2(operating cost) and X_3(shippingcost)andtwooutputs,Y_1(Shipping of Cast aluminum alloy) and Y_2(Shipping of stainless steel). The buyer has another input Z_1(labour cost) in addition to Y_1, $Y_2$and two outputs: Q_1(sales) and Q_2(profit).

4.3 DEA Model

In the present work, we use continuous CCR ratio DEA model which is obtained by DEA Solver 8.0 software along with MS Excel.

Steps to develop DEA model using DEA Solver 8.0 software are as follows:

Step1: Open DEA software and click on start button followed by OK button.

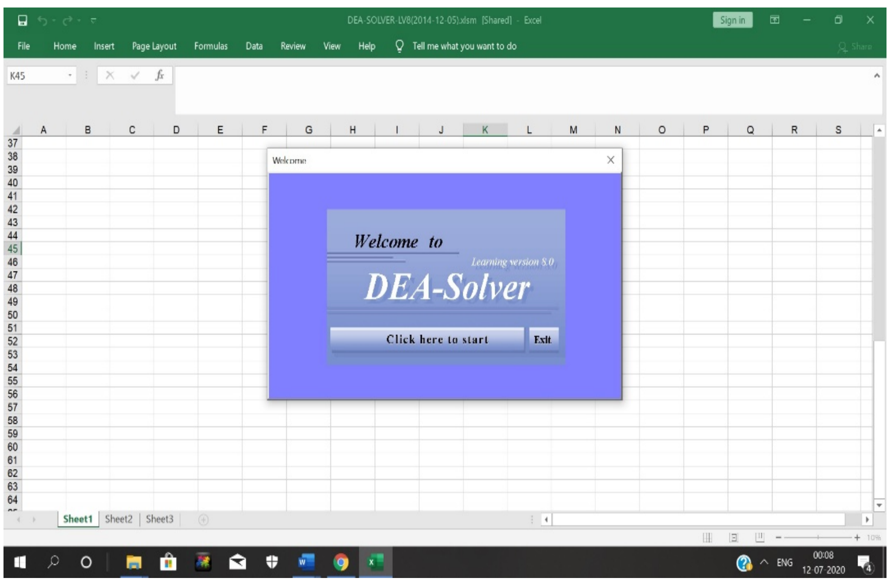


Figure 4.1: Screenshot showing DEA starting Interface

Step2: Select DEA Model type

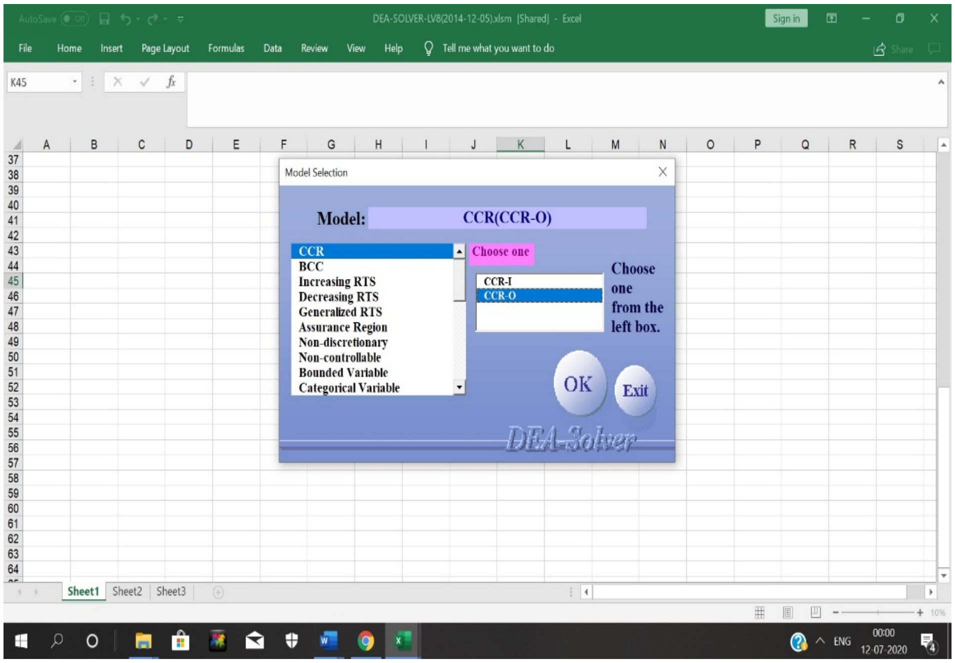


Figure 4.2: Screenshot showing various models available in DEA software

Step3: Select the Input data via excel sheet and press OK button.

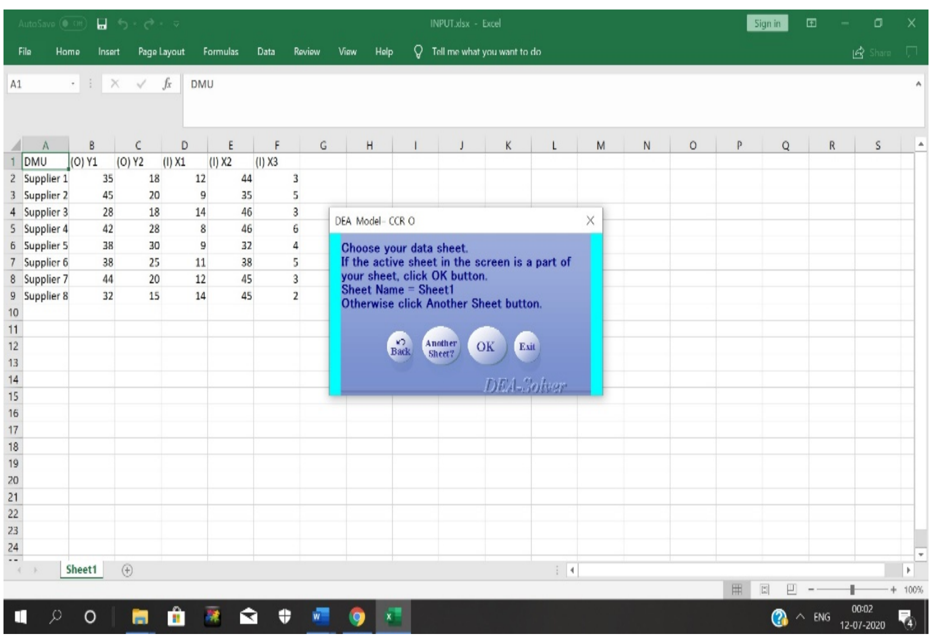


Figure 4.3: Screenshot showing how data is entered in software

Step4: Select the location to save the data of DEA after computation and press RUN button.

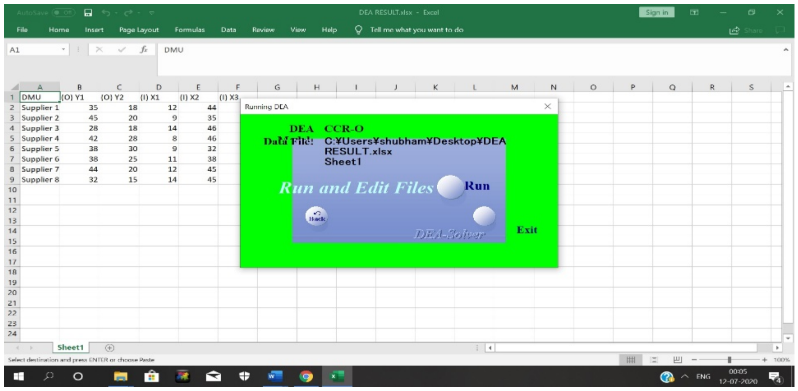


Figure 4.4: Screenshot showing the allocating the location for DEA computation

Step5: Press EXIT and DEA computation will obtain.

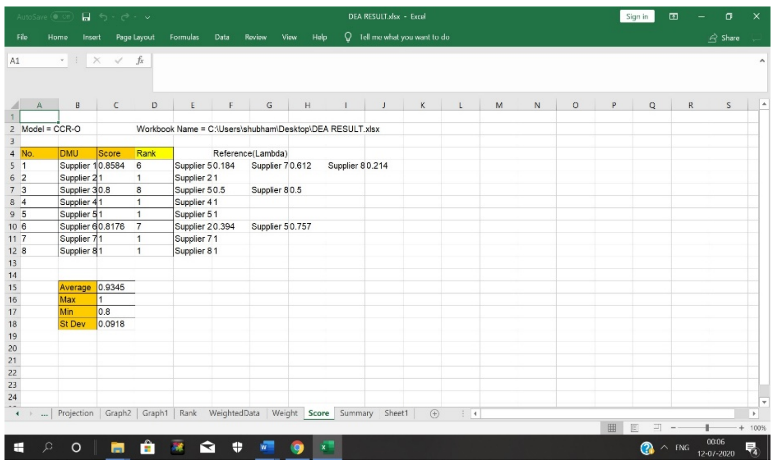


Figure 4.5: Screenshot showing DEA computation results

4.4 DEA Model Formulation using DEA Solver software

4.4.1: Approach

In the present work, following parameters has been taken into consideration to construct the models

X_1 =Labor cost (Lakh Rs)

X_2 = Operating cost (Lakh Rs)

X_3 = Shippingcost (Lakh Rs)

Y_1 = Shipping cost of product A (Cast aluminum alloy) (Rs/unit)

Y_2 = Shipping cost of product B (Stainless steel) (Rs/unit)

Z_1 = Labor cost (Lakh Rs)

Q_1 = Sales (Lakh Rs)

Q_2 = Profit (Lakh Rs)

Statistical data set of the company is given below:

Table 4.1: Statistical data of supplier and manufacturer

DMUs	X1	X2	X3	Y1	Y2	Z1	Q1	Q2
DMU1	12	44	3	35	18	8	85	140
DMU2	q	35	5	45	20	10	90	125
DMU3	14	46	3	28	18	7	105	160
DMU4	8	46	6	42	28	12	110	130
DMU5	9	32	4	38	30	12	105	155
DMU6	11	38	5	38	25	9	85	135
DMU7	12	45	3	44	20	14	115	125
DMU8	14	45	2	32	15	12	110	150

X1, X2, X3 are the input variables and Y1, Y2 are the output variables for the supplier model and these YI, Y2 along with Z1 became input variables and Q1 and Q2 are the output variables for the producer model respectively.

After the DEA computation of both the models, we will find out the projected values of various input and output variables which tells about the inefficient DMU and later we will determine the efficiency of models and average efficiencies of all the DMUs and on the basis of average efficiency scores, most efficient DMU will be determined.

4.4.2: Case 1: Supplier Model

Step1: Select the CCR model (CCR- O) in the DEA Solver software.

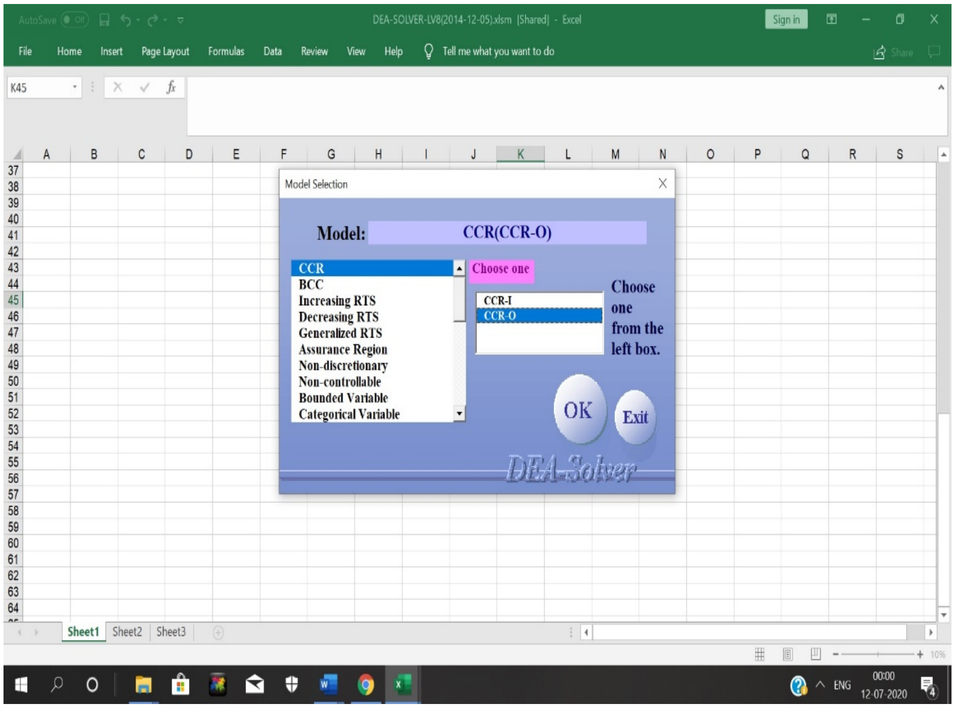


Figure 4.6: Screenshot showing selection of CCR (CCR-O) model

Step2: Import the data of supplier given in table4.2 in the software.

Table 4.2: Statistical data of supplier

Suppliers	**Input**			**Output**	
	X1	**X2**	**X3**	**Y1**	**Y2**
Supplier 1	12	44	3	35	18
Supplier 2	9	35	5	45	20
Supplier 3	14	46	3	28	18
Supplier 4	8	46	6	42	28
Supplier 5	9	32	4	38	30
Supplier 6	11	38	5	38	25
Supplier 7	12	45	3	44	20
Supplier 8	14	45	2	32	15

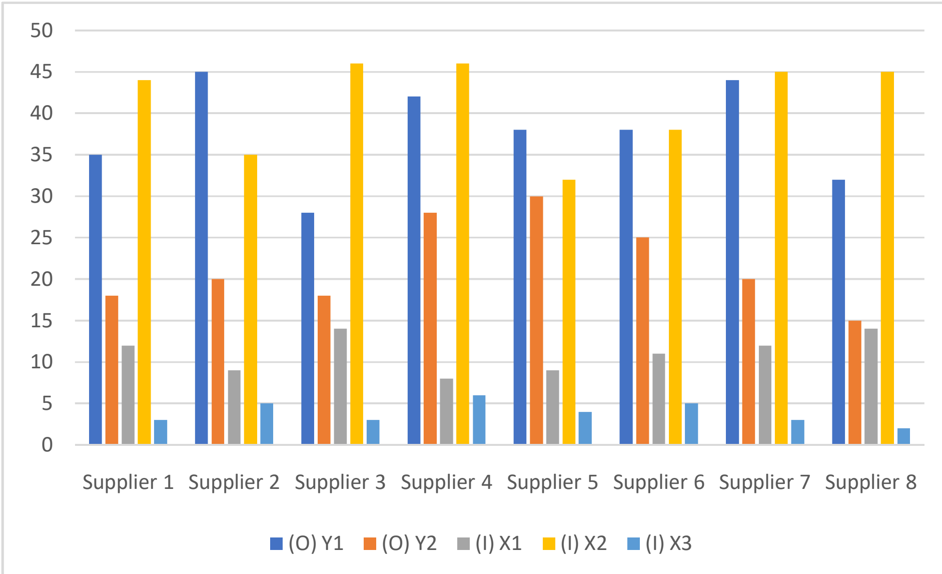


Figure 4.7: Graph showing the statistical data of supplier

Step3: Select the location for saving DEA computation data and the run the model to obtain the results.

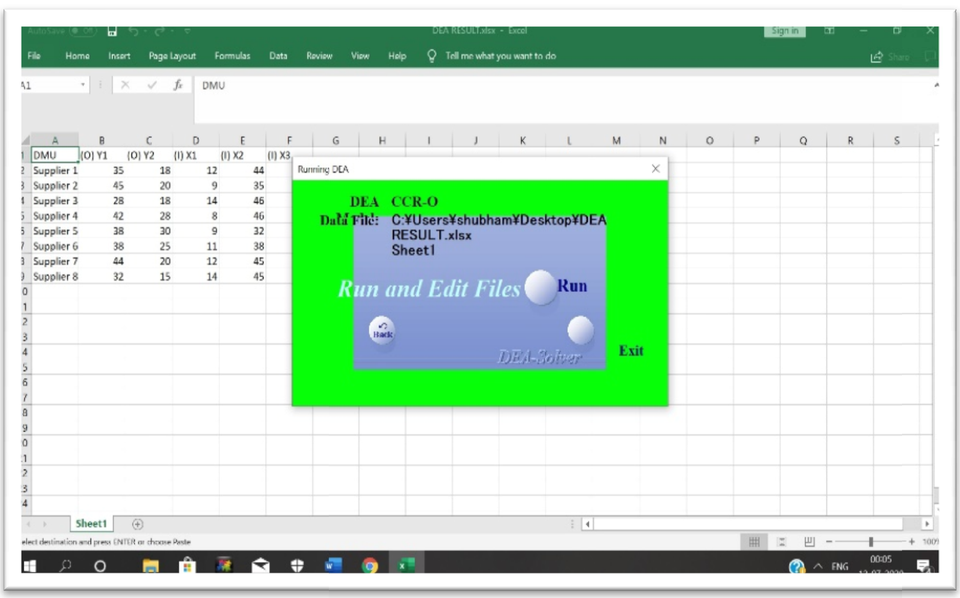
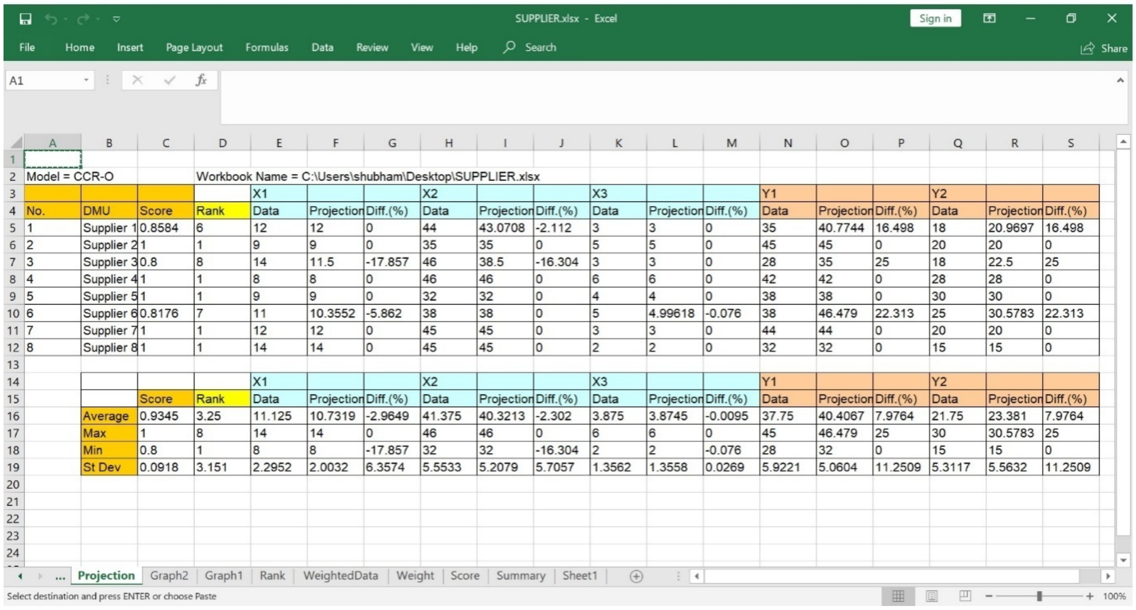


Figure 4.8: Screenshot showing the allocating the location for DEA computation

Step4: Exit the model to obtain the results.



Model = CCR-O   Workbook Name = C:\Users\shubham\Desktop\SUPPLIER.xlsx

				X1			X2			X3			Y1			Y2		
No.	DMU	Score	Rank	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)
1	Supplier 1	0.8584	6	12	12	0	44	43.0708	-2.112	3	3	0	35	40.7744	16.498	18	20.9697	16.498
2	Supplier 2	1	1	9	9	0	35	35	0	5	5	0	45	45	0	20	20	0
3	Supplier 3	0.8	8	14	11.5	-17.857	46	38.5	-16.304	3	3	0	28	35	25	18	22.5	25
4	Supplier 4	1	1	8	8	0	46	46	0	6	6	0	42	42	0	28	28	0
5	Supplier 5	1	1	9	9	0	32	32	0	4	4	0	38	38	0	30	30	0
6	Supplier 6	0.8176	7	11	10.3552	-5.862	38	38	0	5	4.99618	-0.076	38	46.479	22.313	25	30.5783	22.313
7	Supplier 7	1	1	12	12	0	45	45	0	3	3	0	44	44	0	20	20	0
8	Supplier 8	1	1	14	14	0	45	45	0	2	2	0	32	32	0	15	15	0

			X1			X2			X3			Y1			Y2		
	Score	Rank	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)
Average	0.9345	3.25	11.125	10.7319	-2.9649	41.375	40.3213	-2.302	3.875	3.8745	-0.0095	37.75	40.4067	7.9764	21.75	23.381	7.9764
Max	1	8	14	14	0	46	46	0	6	6	0	45	46.479	25	30	30.5783	25
Min	0.8	1	8	8	-17.857	32	32	-16.304	2	2	-0.076	28	32	0	15	15	0
St Dev	0.0918	3.151	2.2952	2.0032	6.3574	5.5533	5.2079	5.7057	1.3562	1.3558	0.0269	5.9221	5.0604	11.2509	5.3117	5.5632	11.2509

Figure 4.9: Screenshot showing projection values of various variables

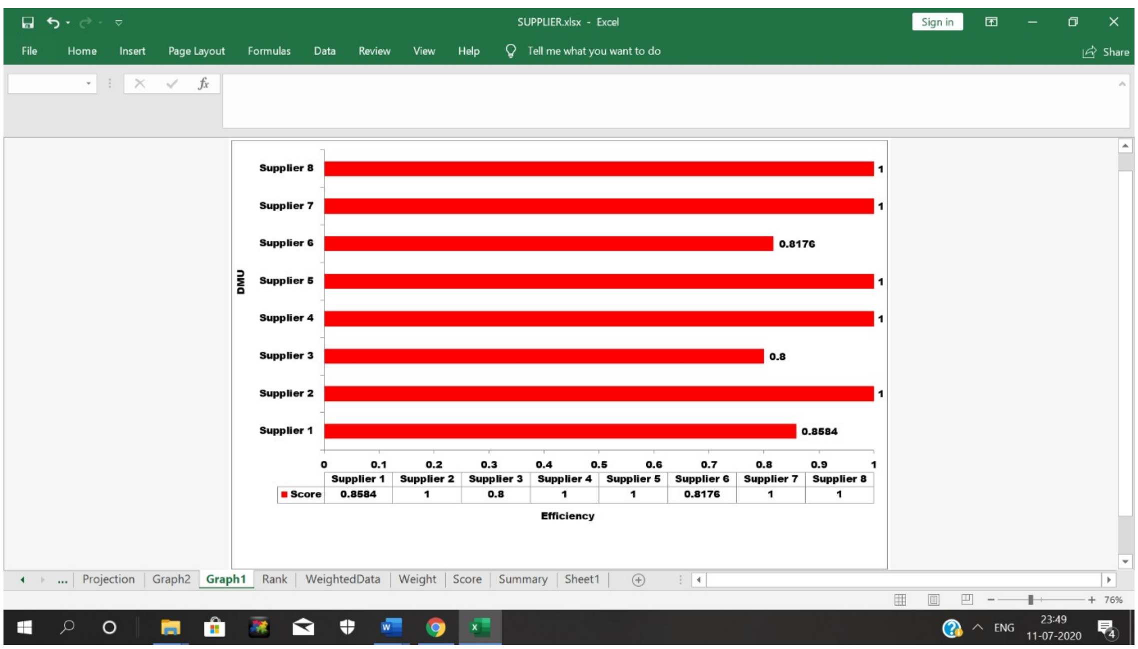


Figure 4.10: Screenshot showing the efficiency of various DMU

4.4.2: Case 2: Producer Model

Step1: Select the CCR model (CCR- O) in the DEA Solver software.

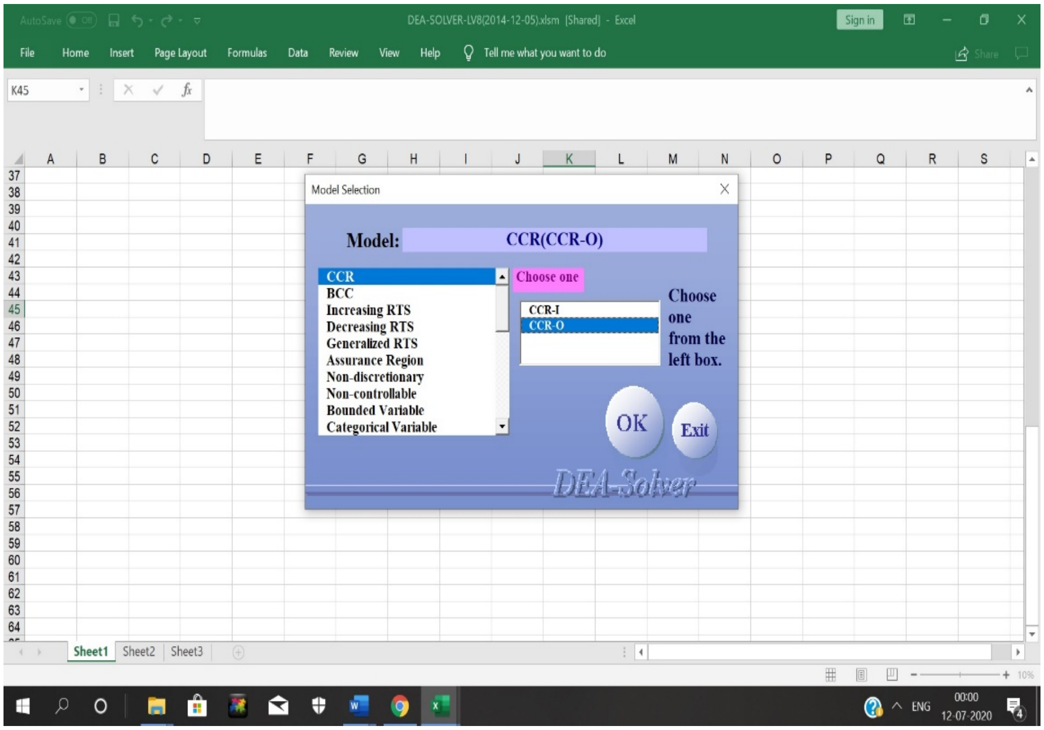


Figure 4.11: Screenshot showing selection of CCR (CCR-O) model

Step2: Import the data of producer given in table 4.3 in the software.

Table 4.3: Statistical data of producer

Producers	**Input**			**Output**	
	Y1	**Y2**	**Z1**	**Q1**	**Q2**
Producer 1	35	18	8	85	140
Producer 2	45	20	10	90	125
Producer 3	28	18	7	105	160
Producer 4	42	28	12	110	130
Producer 5	38	30	12	105	155
Producer 6	38	25	9	85	135
Producer 7	44	20	14	115	125
Producer 8	32	15	12	110	150

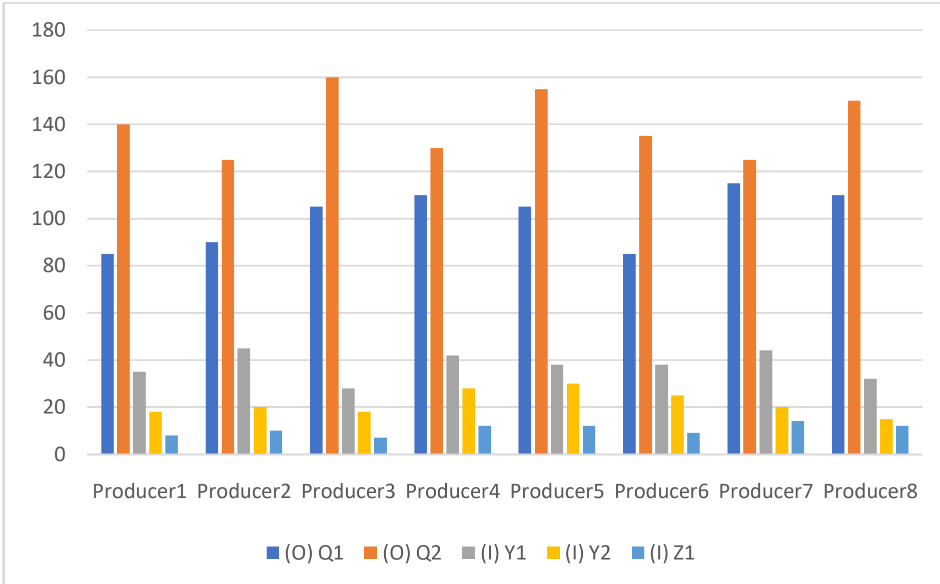


Figure 4.12: Graph showing the statistical data of producer

Step3: Select the location for saving DEA computation data and the run the model to obtain the results.

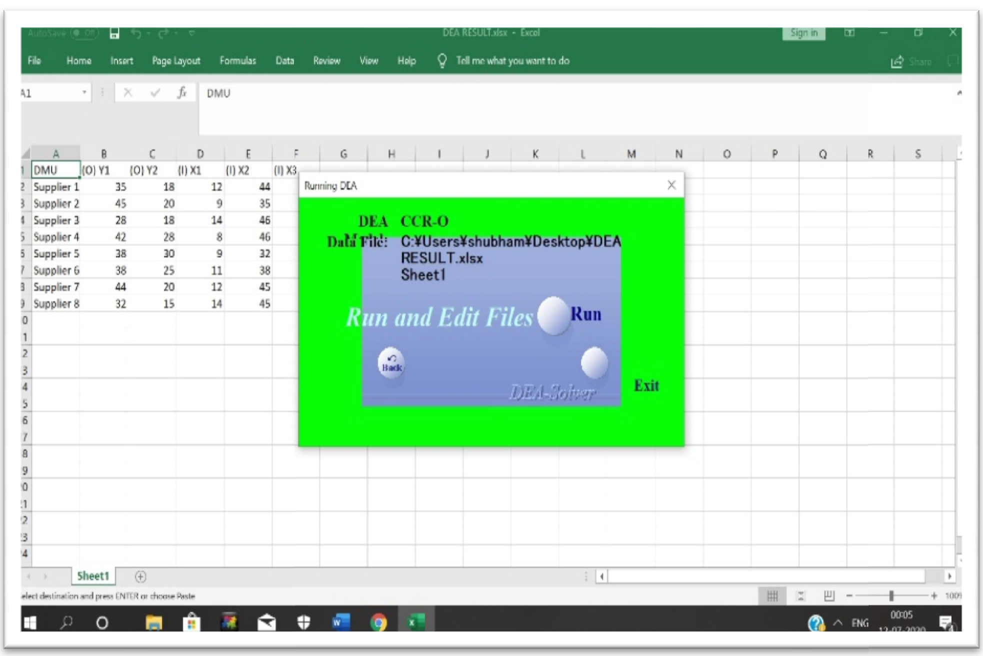
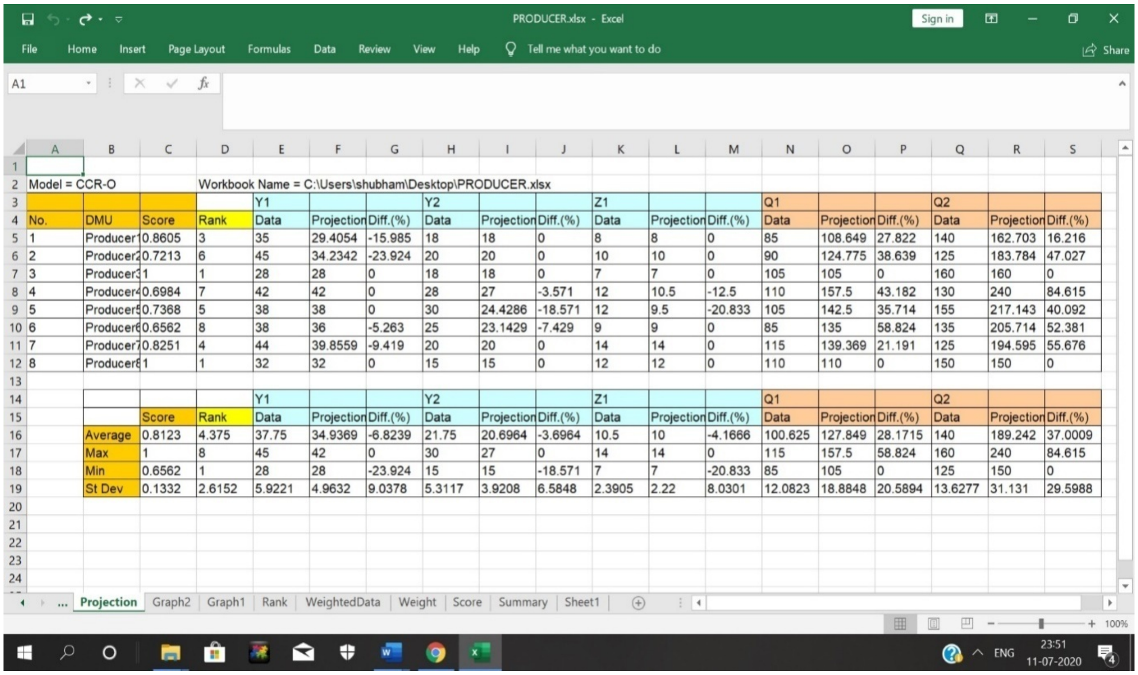


Figure 4.13: Screenshot showing the allocating the location for DEA computation

Step4: Exit the model to obtain the results.



Model = CCR-O   Workbook Name = C:\Users\shubham\Desktop\PRODUCER.xlsx

				Y1			Y2			Z1			Q1			Q2		
No.	DMU	Score	Rank	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)
1	Producer1	0.8605	3	35	29.4054	-15.985	18	18	0	8	8	0	85	108.649	27.822	140	162.703	16.216
2	Producer2	0.7213	6	45	34.2342	-23.924	20	20	0	10	10	0	90	124.775	38.639	125	183.784	47.027
3	Producer3	1	1	28	28	0	18	18	0	7	7	0	105	105	0	160	160	0
4	Producer4	0.6984	7	42	42	0	28	27	-3.571	12	10.5	-12.5	110	157.5	43.182	130	240	84.615
5	Producer5	0.7368	5	38	38	0	30	24.4286	-18.571	12	9.5	-20.833	105	142.5	35.714	155	217.143	40.092
6	Producer6	0.6562	8	38	36	-5.263	25	23.1429	-7.429	9	9	0	85	135	58.824	135	205.714	52.381
7	Producer7	0.8251	4	44	39.8559	-9.419	20	20	0	14	14	0	115	139.369	21.191	125	194.595	55.676
8	Producer8	1	1	32	32	0	15	15	0	12	12	0	110	110	0	150	150	0

			Y1			Y2			Z1			Q1			Q2		
	Score	Rank	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)
Average	0.8123	4.375	37.75	34.9369	-6.8239	21.75	20.6964	-3.6964	10.5	10	-4.1666	100.625	127.849	28.1715	140	189.242	37.0009
Max	1	8	45	42	0	30	27	0	14	14	0	115	157.5	58.824	160	240	84.615
Min	0.6562	1	28	28	-23.924	15	15	-18.571	7	7	-20.833	85	105	0	125	150	0
St Dev	0.1332	2.6152	5.9221	4.9632	9.0378	5.3117	3.9208	6.5848	2.3905	2.22	8.0301	12.0823	18.8848	20.5894	13.6277	31.131	29.5988

Figure 4.14: Screenshot showing projection values of various variables

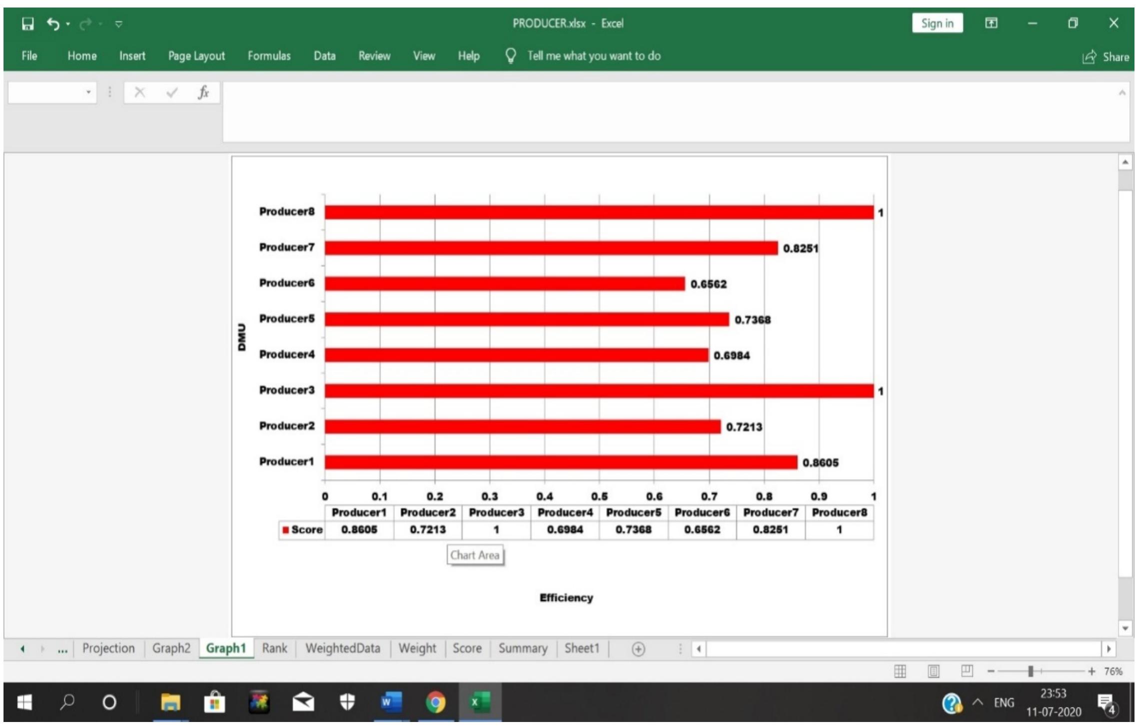


Figure 4.15: Screenshot showing the efficiency of various DMU

4.5: Result and Discussion

4.5.1: Analysis of Supplier Model

4.5.1.1: Projection values of supplier model

Table 4.4: Projection values of variables obtain by DEA model

Suppliers	**Input**			**Output**	
	X1	**X2**	**X3**	**Y1**	**Y2**
Supplier 1	12	43.0708	3	40.7744	20.9697
Supplier 2	9	35	5	45	20
Supplier 3	11.5	38.5	3	35	22.5
Supplier 4	8	46	6	42	28
Supplier 5	9	32	4	38	30
Supplier 6	10.3552	38	4.9962	46.479	30.5783
Supplier 7	12	45	3	44	20
Supplier 8	14	45	2	32	15

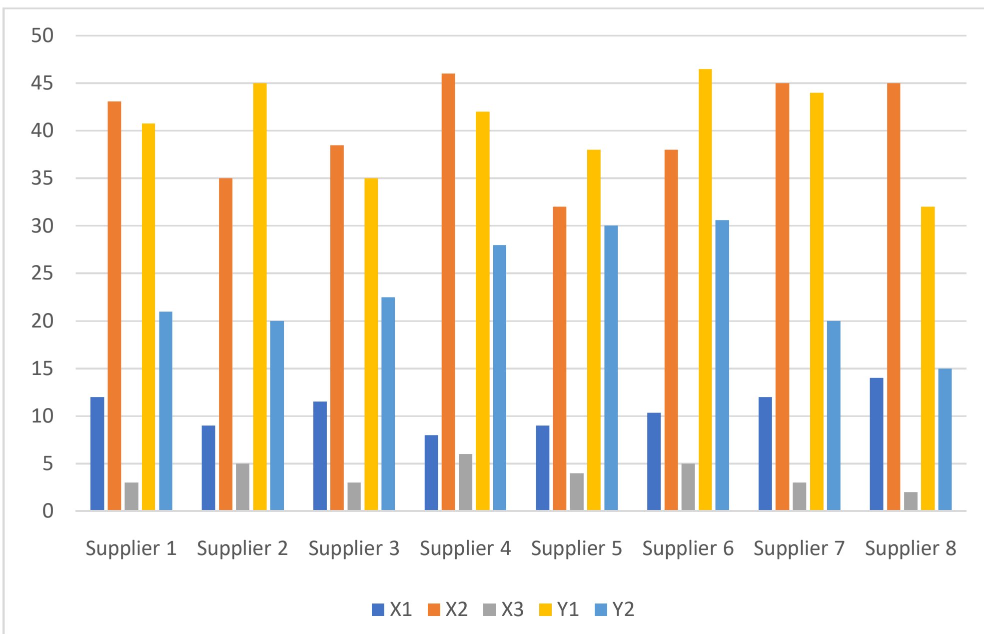


Figure 4.16: Graph showing the projected values of supplier model

For output variable Y1, there is a projection percentage difference of 16.498% for supplier 1, 25% for supplier 3 and 22.313% for supplier 6 respectively.

For output variable Y2, there is a projection percentage difference of 16.498% for supplier 1, 25% for supplier 3 and 22.313% for supplier 6 respectively.

Minimum the difference more efficient the DMU.

4.5.1.2: Efficiency values of supplier model

Table 4.5: Efficiency of Supplier model obtain by DEA model

DMU No.	DMU Name	Efficiency
1	Supplier 1	0.8584
2	Supplier 2	1.0000
3	Supplier 3	0.8000
4	Supplier 4	1.0000
5	Supplier 5	1.0000
6	Supplier 6	0.8176
7	Supplier 7	1.0000
8	Supplier 8	1.0000

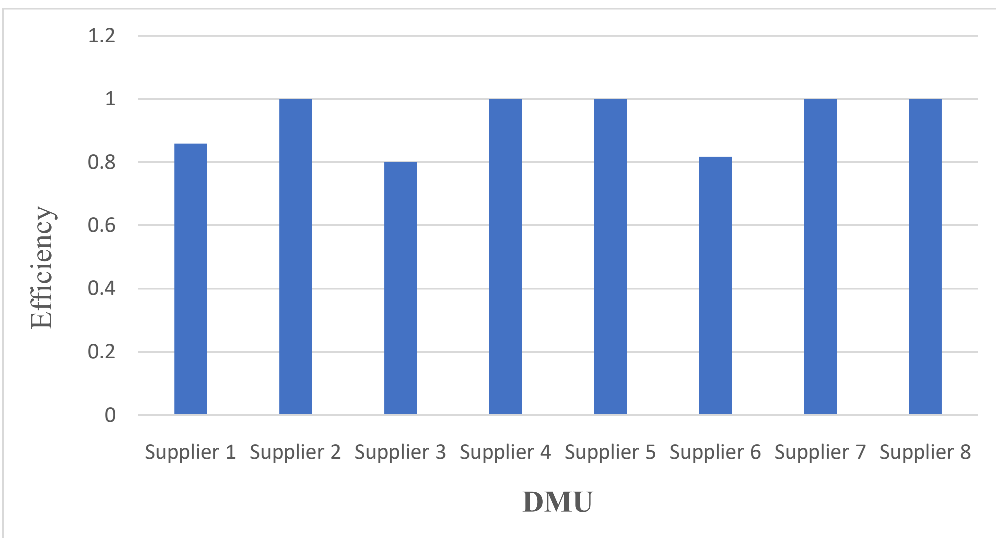


Figure 4.17: Graph showing efficiency of supplier model obtain by DEA model

Among all the suppliers, the supplier 2, supplier 4, supplier 5, supplier 7 and supplier 8 has the best efficiency score of **1**and thus these are the most efficient DMUs among all. Remaining DMUs i.e. supplier 1, supplier 3 and supplier 6 are the inefficient DMUs and the supplier 3 is the worst DMU with efficiency score of **0.8**. The supplier 1, supplier 3 and supplier 6 can become efficient by working on their output slacks accordingly.

Therefore, for the efficient supply chain of company, any one supplier can be selected from the supplier 2, supplier 4, supplier 5, supplier 7 and supplier 8.

4.5.2: Analysis of Producer Model

4.5.2.1: Projection values of Producer model

Table 4.6: Projection values of variables obtain by DEA model

Producers	INPUT			OUTPUT	
	Y1	Y2	Z1	Q1	Q2
Producer 1	29.4054	18	8	108.649	162.703
Producer 2	34.2342	20	10	124.775	183.784
Producer 3	28	18	7	105	160
Producer 4	42	27	10.5	157.5	240
Producer 5	38	24.4286	9.5	142.5	217.143
Producer 6	36	23.1429	9	135	205.714
Producer 7	39.8559	20	14	139.369	194.595
Producer 8	32	15	12	110	150

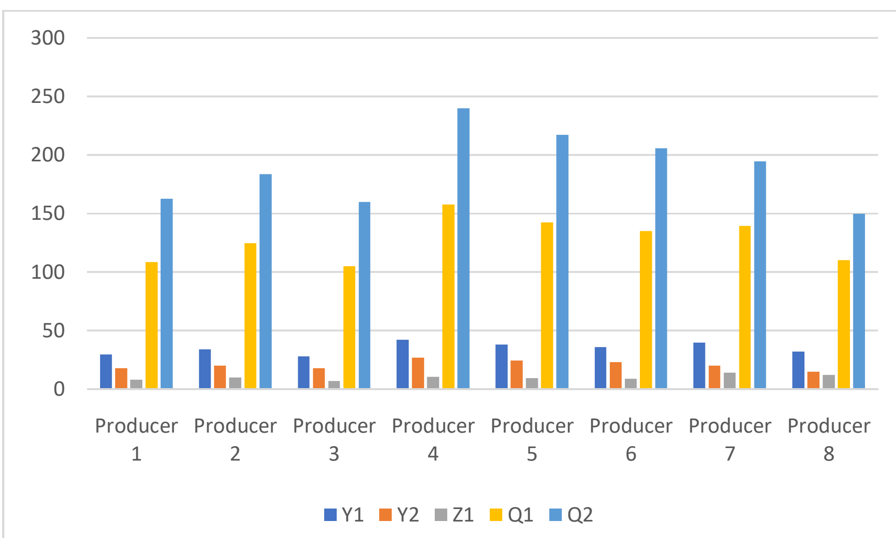


Figure 4.18: Graph showing the projected values of producer model

For output variable Q1, there is a projection percentage difference of 27.822% for producer 1, 38.639% for producer 2, 43.182% for producer 4, 35.714% for producer 5, 58.824% for producer6 and 21.191% for producer 7 respectively.

For output variable Q2, there is a projection percentage difference of 16.216% for producer 1, 47.027% for producer 2, 84.615% for producer 4, 40.092% for producer 5, 52.381% for producer6 and 55.676% for producer 7 respectively.

Minimum the difference more efficient the DMU.

4.5.2.2: Efficiency values of Producer model

Table 4.7: Efficiency of Producer model obtain by DEA model

DMU No.	DMU Name	Efficiency
1	Producer 1	0.8605
2	Producer 2	0.7213
3	Producer 3	1.0000
4	Producer 4	0.6984
5	Producer 5	0.7368
6	Producer 6	0.6562
7	Producer 7	0.8251
8	Producer 8	1.0000

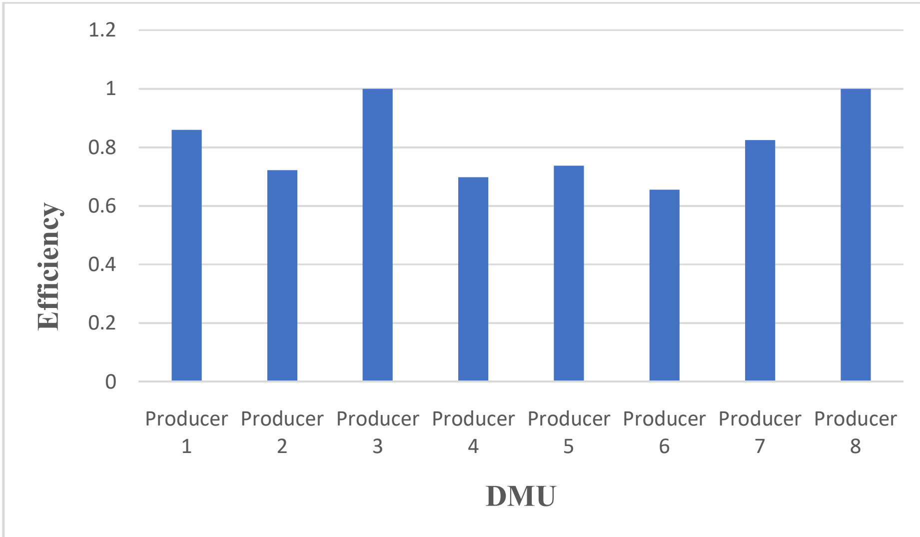


Figure 4.19: Graph showing efficiency of Producer model obtain by DEA model

Among all the producer, producer 3 and producer 8 has the best efficiency score of **1**and thus these are the most efficient DMUs among all. Remaining DMUs i.e. producer 1, producer 2, producer 4.

Producer 5, producer 6 and producer 7 are the inefficient DMUs and the producer 6 is the worst DMU with efficiency score of **0.6562**. The producer 1, producer 2, producer 4, producer 5, producer 6 and producer 7 can become efficient by working on their output slacks accordingly.

Therefore, for the efficient supply chain of company, any one producer can be selected from the producer 3 and producer 8.

4.5.3. Comparison of Models

The efficiency of the DMU has the direct impact on the effectiveness and reliability of the supply chain of any organization. More the efficiency of DMU, more effective and efficient will be the supply chain. Thus, for finding the finding out the most efficient DMU, we have to compare the efficiency of both producer and supplier model and also find out the average efficiency of all DMUs.

Table 4.8: Comparison of efficiencies of models

DMU	Supplier Efficiency	Producer Efficiency	Average efficiency
1	0.8584	0.8605	0.8594
2	1.0000	0.7213	0.8606

3	0.8000	1.0000	0.9000
4	1.0000	0.6984	0.8492
5	1.0000	0.7368	0.8684
6	0.8176	0.6562	0.8281
7	1.0000	0.8251	0.9125
8	1.0000	1.0000	1.0000

Figure 4.20: Graph showing the comparison of efficiencies of DMUs

From the table 4.6 and figure 4.18, it can be seen very clearly that among all the suppliers, the supplier 2, supplier 4, supplier 5, supplier 7 and supplier 8 has the best efficiency score of 1and thus these are the most efficient DMUs among all. Remaining DMUs i.e. supplier 1, supplier 3 and supplier 6 are the inefficient DMUs and the supplier 3 is the worst DMU with efficiency score of 0.8. Therefore, for the efficient supply chain of company, any one supplier can be selected from the supplier 2, supplier 4, supplier 5, supplier 7 and supplier 8.

The producer 3 and producer 8 has the best efficiency score of 1and thus these are the most efficient DMUs among all. Remaining DMUs i.e. producer 1, producer 2, producer 4, producer 5, producer 6 and producer 7 are the inefficient DMUs and the producer 6 is the worst DMU with efficiency score of 0.6562. Therefore, for the efficient supply chain of company, any one producer can be selected from the producer 3 and producer 8.

But for finding out the most efficient DMU, we must consider the average efficiencies of the DMUs. The average efficiency of DMU 8 is 1 and therefore it is the most efficient DMU among all 8 DMUs and the average efficiency of DMU 6 is 0.8281which is minimum among all the DMUs and therefore DMU 6 is the worst DMU among all DMUs.

4.6: Conclusion

The work of a supply chain management is to construct a network (which start from raw material and end to the customer) which minimize the input cost and maximize the quality and profit. For this, all the supply chain in the system must be effective, reliable and efficient. In the present work, two stage supply chain problem of a gear manufacturing company has been considered as a real-world case study. There are total 8 DMUs which are suitable for the producers but the best choice for any supply chain will directly increase the profit of the company, so only one must be chosen which constructs a best supply chain network. Two CCR DEA models (supplier model and producer model) has been constructed using DEA Solver software. With the help of these models, efficiencies of both models has been determined and on the basis of average efficiencies score of all the 8 DMUs, it is concluded that the DMU 8 is the most efficient among all the DMUs and implementing this DMU will make the whole supply chain effective and efficient.

CHAPTER 5

Conclusion and Future Scope

5.1 Introduction

The objective of this study is to develop a model which could maximize the efficiency of the supply chain network. A thorough literature review has been done in the field of Supply Chain Management and Data Envelopment Analysis (DEA). Through this literature review various critical success factors or enablers which plays an important role in effective implementation of the supply chain network are found. Then a relationship among these critical success factors was found using Data Envelopment Analysis (DEA) approach. This technique is used to prepare a model which can help in effective issues in supply chain. Finally, a model was prepared using DEA approach to determine the most efficient supply chain network.

5.2 Summary of work done

- An extensive literature survey has been done in the field of supply chain management and data envelopment analysis and various researchers have given profound contribution in this field.
- SWOT analysis of a gear manufacturing company is conducted to determine the strength, weakness, opportunities and threats to the company.
- Then a mathematical model has been developed using DEA approach for effective supply chain network.

- One problem on “Supply Chain Management of Supplier and Manufacturer” is taken from a gear manufacturing company.
- Finally, the CCA based DEA model has been constructed for the evaluation of the problem. Its helps in determining the most efficient DMU among all the DMUs and construct the most efficient supply chain network.
- It helps for chosen the most effective and efficient supply chain network among 8 decision making unit and construct the most efficient supply chain network.
- Applied data envelopment analysis technique on the supplier, result shows the efficiency of each supplier, supplier 2, supplier 4, supplier 5, supplier 7 and supplier 8 have a highest efficiency which signifies that these suppliers will attain maximum profit at minimum cost.
- Furthermore, data envelopment analysis technique on the manufacturer, result shows the efficiency of each producer, producer 3 and producer 8 have a highest efficiency which signifies that producer 3 and producer 8 attained maximum profit at minimum cost.

- Overall efficiency of DMU 8 has the maximum value 1. DMU 8 is the most efficient among all the DMUs and implementing this DMU will make the whole supply chain effective and efficient.

5.3 Learning from the study

- Got good exposure of the current supply chain problems in the industry and got good opportunity to work on this problem.
- Received good insight of latest trends and technologies available to achieve most efficient network in the supply chain through extensive literature review.
- Gathered a lot of knowledge about the critical success factors for effective data envelopment analysis in implementing in the supply chain.
- Learning of a technique Data Envelopment Analysis (DEA) and the development of a model using this technique.
- Learning of a statistical software called Microsoft Excel which can be used for various experimental calculation.
- Received good insight of latest research in the field of Data Envelopment Analysis system management and its application in the field of supply chain management.

- Learned how to solve the various data envelopment analysis problems in the field of supply chain using DEA-Solver software.

5.4 Limitations

- The change in the opinion of supply chain partners in one go is very difficult to execute even with the detailed list of results and discussions.
- The implementation of proposed model may be proven costly as the entire structure of supply chain should be modified.
- In this work, DEA framework has been developed with eightDMUs for the implementation of SCM in the industry.
- In this work, data envelopment analysis technique is used to find out the most efficient supply chain network.

5.5 Scope of future work

- To enhance DEA model's capabilities in supplier evaluation, we can combine goal programming, dynamic programming, and DEA, simultaneously.

- To forecast trend of efficiency of DMUs, we can combine DEA-DA and goal programming.

- Three further research directions can be drawn from the research Environmental efficiency analysis of China's regional industry: a data envelopment analysis (DEA) based approach. Firstly, Malmquist index can be introduced in dynamic analysis of region development. Secondly, it will be interesting issues to think how to account for uncertain undesirable outputs in models for future research. Thirdly, some suitable methods can be proposed to select data for environmental efficiency analysis of China's regional industry under the big data environment.

5.6 Concluding remarks

The objective of this research was to develop a most efficient supply chain network and find out the efficiency of all DMUs which are very useful in the supply chain of an industry. These variables assume importance because on the basis of these variable the company decide the suppliers and manufacturing system because it affect the cost and quality of the finished product. Through careful examinations of the results obtained from

DEA-Solver software, among the eight DMUs, we have to choose only one which make supply chain network best. The work of a supply chain management is to construct a network (which start from raw material and end to the customer) which minimize the input cost and maximize the quality and profit. In this research, there are total 8 DMUs which are suitable for the manufacturer but the best choice for any supply chain will directly increase the profit of the company, so only one DMU has to be chosen which construct a best supply chain network**.** The present work is only suitable for choosing the best supply chain network and find out the all DMUs efficiency. So, it may be a challenge for the future research scholars to explore some new and different types of areas on which DEA technique will apply and that will be beneficial for the future data envelopment analysis system.

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