Chapter 6

Risk Management Framework: Supplier Selection Model Incorporating Risks and Costs into Global Sourcing Decisions

6.1 Introduction

In this chapter, as a sequel to development of Bayesian network model based risk assessment index of Indian automobile industry based on risk sources in sourcing/ supply network and a force field analysis of the risk drivers, i.e. enablers and barriers arrived at through survey based structured research through EFA, a risk management framework has been developed in form of a cost model that incorporates the minor cost factors that are often ignored while making major/ strategic sourcing decisions factoring in the identified associated risks. Several subjective factors have been quantified in order to calculate the costs. The data envelopment analysis (DEA) approach has been used to calculate the weighted sums of inputs and outputs and hence the efficiency rate. All the developed constructs of SSRM have been put together to form a normative decision making framework, wherein based on the rate, the beneficial supplier is chosen. It has been established that a well developed approach and strategy for offshoring greatly affects the total cost of outsourcing. This chapter contains five sections that are as follows. In this introductory section we present the extracts of relevant literature comprising strategic sourcing continuum, cost models and global supply network risks. In the next section, i.e. Section 2, we explain the research methodology in detail used in development of the DEA based supplier selection model factoring in both the costs and risks. In Section 3, we test our proposed model using a case study. Next section, i.e. Section 5 presents analysis of the model developed followed by the conclusion of the proposed method in the last section, i.e. Section 5.

With changing times today, businesses are expanding globally, having more than one markets to satisfy as their most prominent growth strategy. With increasing competitiveness, comes the responsibility to satisfy customers with quality, at the same time to maximize profits (Kogut and Kulatilaka, 1994; Attren and Attren, 2018). Hence, global sourcing, or commonly, the make or buy decision comes into play that results in demand and supply points spreading to more than one country. This environment allows companies to choose the optimum manufacturing and selling point(s), which could depend on the desired costs, quality and many other factors. Costs can be

reduced by achieving cheaper raw material costs, or better labour costs etc., in a country different than the selling market. Hence, it becomes important to study how these costs can be minimized to provide the companies with maximum profit.

Forward-thinking companies are making their value chains more elastic and flexible. With the decline of the vertically integrated business model, sourcing is evolving into a strategic process for organizing and fine-tuning the value chain (Cho and Kang, 2001; Nassimbeni, 2006; Negi et al., 2018). Souring is used just another name of procurement. This is the area that has huge potentials for cost reductions. Anderson and Katz (1998) provided a procurement maturity model that acts as a pathway to companies for cost reduction and revenue enhancement through strategic sourcing. Strategic sourcing is the core activity of purchase and supply management. Strategic sourcing can be defined as "satisfying business needs from markets through proactive and planned analysis of supply markets" (Skinner, 1964; Ferdows, 1997). Purchases of outside goods and services are increasing in almost all industries. Initially companies used to make some critical items within factory, but over the last decade there is increased reliance on supply markets. With these trends, sourcing is migrating from tactical to strategic domain and this has implications on how businesses are translating into highly lucrative opportunities for cost reduction and profit enhancement.

There seems to be a wide agreement on the factors that trigger sourcing decisions, with the primary factor being reductions in the purchase price of goods (Monczka and Trent, 1991; Cho and Kang, 2001; Nassimbeni, 2006; Rehmaan et al., 2018). However, firms do not only want to save cost by sourcing parts and components from outside suppliers, but often also enter into such relationships to obtain access to new technologies or higher quality products, or to establish a foothold in new markets (Monczka and Giunipero, 1984; Monczka and Trent, 1991; Cho and Kang, 2001; Nassimbeni, 2006).

The transaction cost theory is the foundation for many of the sourcing theories that concern cost perspective. The transaction cost originates from Coase (1937) but nowadays when talking about transaction cost many people refers to Williamson (1975). Some companies have even outsourced so much of their production that they have lost their ability to develop new products (Tisdale, 1994). Many companies, however, seem to have only have a vague understanding about the risks and benefits of outsourcing, except from a general idea that it will reduce cost, gain access to other companies' competence and allow them to focus on their core competencies (Smith et al.,

1998; Kahkanen and Lintukagnas, 2018). It is of great importance that companies are aware of both advantages and disadvantages about sourcing, since the results of the decision are dependent on the employees and their skills. A questionnaire about sourcing decisions (Brannemo, 2005) indicates that companies consider sourcing decisions as complex and companies tend to have a lack of models supporting the sourcing decision process. Despite the advantages of outsourcing, companies do not have understanding of its potential risks, while making decisions (Vining and Goberman, 2017). Thus, the need for a model supporting sourcing decisions is important. Sourcing decisions aim at establishing and managing supply networks by evaluating characteristics, factors, or criteria like supplier quality consciousness, cost potential, reliability of delivery, innovativeness, and geographical location (Mangan, et al., 2016). Different authors make use of different terms for these characteristics, factors, considerations, and criteria: Smeltzer et al. (2003) call them outsourcing risk issues, Minkyun, et al. (2015) call them operational and tactical considerations and MacCarthy and Attirawong (2003) call them outsourcing risk factors. Levy, (1995) summarizes sourcing characteristics into location-specific factors and relational factors. Location-specific factors determine the optimal location for each activity in the supply network considered in isolation from the rest. Relational factors address the relationship between the activity being sourced and other activities within the value chain. Holweg et al., (2011) defined three basic elements in global sourcing decisions: static, dynamic and hidden costs. Global sourcing decisions are scrutinized due to increased level of geo-political risks (Cheng and Cheu, 2018). Baker et al. (2016) highlight that innovation in policy uncertainty triggers decline in outsourcing and other offshore investments.

On the other hand, businesses need to incur additional costs like setting up a new business infrastructure consisting warehouses, distribution centers and production plants (Matos, 2017). Additionally, businesses need to develop new processes for planning and controlling the flow and storage of raw materials, in-process inventory, finished goods, and related information from point of origin to destination. As a result, these processes can lead to increased additional costs (Buckley, 2018).

Other than the costs, risks also come into action (Negi et al., 2018). Businesses expose themselves to uncontrollable risk factors, like price fluctuations at the manufacturing point, political, disaster and natural risks, the exchange rates, and also the huge transportation costs,

along with the taxes and duties (Zsidisin, et al., 2004, Manuj and Mentzer, 2008a; 2008b). Qualitatively too, efforts would be required to ensure an efficient working at the supplier's side to meet the company's standards.

There are very few models that capture all types of costs in sourcing decisions. Some of the papers highlighted risk factors in decisions and have provided mitigation plans for risks involved in sourcing. Companies struggle to find a true cost of sourcing decision (Zeng and Rossetti, 2003; Black, 2017). A decision framework can be developed for strategic sourcing decisions by combining cost factors and risks factors. The objective of this research paper is to combine the costs and risks factors in global sourcing decisions. In next two sub-sections a brief overview of costs and risks involved in sourcing decisions have been provided.

This research studies the need and benefits of incorporating these costs into sourcing decisions, and also, prepares a method for the same, with a case application. The literature section studies in detail what exactly is strategic sourcing and how global supply networks can be optimized with the use of strategic sourcing. It also studies the difference between landed cost models and TCO models, implications of both, and what difference the application of each makes, in the case study. This study examines how theory needs to be practically applied to the businesses for better results. In this research, a global supplier selection model is proposed based on the combined costs and risks factors. This study however takes more of an ideal case; real situations might have a bit modified application of the same.

6.1.1 Strategic Sourcing: Concept and Models

This section provides a detailed overview of strategic sourcing and how it leads to development of a cost model. With the progressive decline of the vertically integrated business model, sourcing has turned out to be a fine way to mitigate the risks of costs. The cost reductions that can occur as a result of a good strategy are noteworthy. Chiang et al. (2012) and Sharma, (2016) aptly summarizes the contextual review of Strategic Sourcing and its impact on supply chain agility. Smeltzer et al. (2003) defined strategic sourcing as a comprehensive process of acquiring inputs, and managing supplier relations, by achieving the organization's long-term objectives. Narasimhan and Das (1999) view strategic sourcing as the use of supplier capabilities in the process of design and manufacturing to achieve strategic objectives. Sislian and Satir (2000) defined it as a framework that can assist managers in the process of making

buying decisions, considering competitive advantage as a primary factor. Anderson and Katz (1998) defined strategic sourcing as a procurement framework with total cost of ownership helping firms add value and improve their competitive positions.

The sourcing model theory has evolved from 'make versus buy decision' to 'vested outsourcing' and has been refined into a 'Seven Sourcing Business Model' which look at sourcing as a continuum. The concept, evolution and description of strategic sourcing models have been covered in detail in Section 2.2.2 of Chapter 2.

Young et al. (2009) commented that landed cost models are not adequate to capture all cost in off shoring and illustrated important criteria like price, quality, flexibility, delivery reliability etc. Carr and Ittner (1992) investigated total cost of ownership (TCO) and attempted to develop conceptual models that embraced all relevant costs beginning with the identification of demand and ending with the ultimate disposition of a spent asset. Ellram (1993, 2000) classified cost activities into pre-transaction, transaction, and post-transaction phases, whereby the estimate of future costs and an entire range of administrative overhead costs would not be overlooked.

On the other hand, TCO provides a better inspection opportunity for determining the total cost caused by supplier activities on a buyer's organization (Hallikas et al., 2004). The TCO approach is a structured methodology for determining the true cost of acquisition of a product, considering all the costs related to purchasing and using the product (Bacchetti et al., 2017). TCO considers the buyer's entire value chain and mainly evaluates the supplier performance by taking into account all the costs caused by a supplier (Degraeve, Labro, and Roodhooft, 2000). These costs are not limited to the purchasing price but also include cost elements such as: quality, transportation, maintenance, and administration (Ellram, 1995; Degraeve et al., 2000). As opposed to an initial-price perspective that mainly accepts short term approach, TCO allows for a long-term perspective selecting different buying situations (Ferrin and Plank, 2002). TCO is a more exhaustive methodology covering all visible and hidden costs in souring decisions. Dogan and Aydin (2011) have illustrated TCO factors in global supplier selection problem.

Ellram and Siferd (1998) suggested six categories: quality, management, delivery, service, communications, and price. However, this categorization examines only those purchasing activities that contribute directly to total cost of ownership (TCO). Dogan and Aydin (2011) suggested six categories of TCO, viz. 1 Downtime cost Planned and unplanned downtime costs, out-of-service costs, maintenance costs; 2 Logistics cost Freight, packaging, customer service, handling, tariffs warehousing, duties, import fees, outbound costs; 3 Operation cost Assembly and manufacturing,

labour, long-term operations, and equipment; 4 Quality related cost Durability, replacement, field failure, customer downtime, calibration cost, rework, scrap, customer returns, rejection costs; 5 Administrative cost Administration of post-purchase agreements, supplier selection and evaluation, partnering and team costs; 6 Transaction cost Procurement, ordering, and transactional activity costs. (Degraeve et al., 2000) have provided four major categories; 1 Landed cost: cost of materials/services, transportation costs, customs, insurance, storage, etc; 2 Life cycle costs, such as administration, handling and quality; 3 Additional in-house costs, such as R&D and supplier management; 4 Any regulatory costs involved: tariffs, quotas or government regulations. Ferrin and Plank (2005) identified twelve TCO cost drivers, namely Operation, Quality related, Logistics, Technological advantage, Supplier reliability and capability, Maintenance, Inventory cost, Life cycle, Initial price, Customer related, Opportunity cost and Miscellaneous costs. Anderson and Katz (1998) provided four factors of TCO, these factors include: Supplier economics and other supply network costs; Buyer's cost of acquiring and managing product and services; Quality, inventory and reliability; and value of product/ service to customers. Following table 1 describes the various models used in strategic sourcing.

Table 6.1: Various Models used in Strategic Sourcing

Model	**Description**
Transactional-Based	
Basic Provider	Includes a wide range of market options, but a set price or products and services where, little differentiation is involved.
Approved Provider	Includes purchase of goods and services from pre-qualified suppliers, leading to competitive costs among suppliers for pre-approval.
Relation-Based	
Preferred Provider Model	An approved provider becomes a preferred one by offering unique differentiators, like value added benefits and services.
Performance Based-Managed Services	Seeks supplier accountability for achieving cost reduction/ performance targets.
Vested Business	Goes beyond sourcing, organization and supplier share an economic interest in each other's success.

Investment-Based	
Shared Services	An internal organization is formed based on the outsourcing arrangement, to centralize all the operations.
Equity Partnership	Includes a legal binding entity, ranging from buying a supplier to creating a subsidiary to forming an equity sharing joint venture. Used when a company wants to avoid outsourcing.

Sharma (2016) has aptly studied, how over the years sourcing has changed its notion from a corporate function to a core activity with the use of right strategy and business minds. These days, decisions regarding offshoring and reshoring of manufacturing facilities and processes are of strategic importance for companies (Presley et al., 2016). Recent shifts point strategic sourcing toward a more comprehensive dominant logic, one that integrates goods with services and aligns strategic sourcing processes with organizational performance goals. 5S practice is reflective of strategic gains along cost, quality, and time trajectories associated with its orientation (Eltantawy et al., 2014). Holweg et al. (2011) defined three basic set of elements in global sourcing decisions viz static, dynamic and hidden costs.

Bhutta and Huq (2002) breaks the costs under TCO into four categories, namely: 1 Manufacturing: raw material, labour etc.; 2 Quality: quality inspection, rework etc.; 3 Technology: designing, engineering etc.; and 4 After-sales service costs.

Cavinato (1992) put forward the following cost model to incorporate the various costs that need to be incurred as a part of TCO.

Table 6.2: Cavinato's Cost Model

S. No.	**Cost Factor**	**Description**
1	Traditional Basic Input Costs	Primary price of the product/material.
2	Direct Transaction Costs	Costs of detecting, transmitting the need for, and processing the material flow in order to acquire the goods.
3	Supply Relational Costs	Costs of creating and maintaining a relationship with supplier.
4	Landed Costs	Includes factors like procurement and transportation of raw material, inventory costs, warehouse costs, etc.

S. No.	Cost Factor	Description
5	Quality Costs	Costs of warranties,.customer service and goodwill/
6	Operations/ Logistics Costs	Includes receiving and make-ready costs, space and production costs etc.
7	Indirect Financial Costs	Payment terms to the supplier.
8	Tactical Input Factors	This factor recognizes the high cost, effort, and time needed to develop a supplier relationship one gives the impression of being in the business for the long run.
9	Intermediate Customer Factors	Customer service and the quality of information, transportation, and inventory links are included here.
10	Strategic Business Factors	Costs of critical success factors embedded in the design of physical product or services that act as a benchmark of the company.

6.1.2 Global Supply Network Risks

This section discusses the theoretical foundations associated with global supply networks, strategic sourcing, the costs incurred throughout the network and the factors included in those costs. As likely as it is, Global supply networks are more vulnerable to risks than local businesses attributing to the distance between the supplier and the customer. Hence, this gives a reason to study and assess the risk factors and possibly quantify them (Babu and More, 2017).

Stadtler, (2015) appropriately discussed the concept of supply network management to include to movement and storage of raw materials, finished goods and in the process, the inventory, labour, inter-linked networks and cost management. As clear as it is, from the point of procurement of raw material to the delivery of finished goods at consumer end-point, with each node in the supply chain, there are a variety of risk factors that lead to uncertainty in cost estimations. The need to assess the risks and challenges faced by global supply networks today is well described by (Prater et al., 2001, Rao and Goldsby, 2009 and Mangan et al., 2016).

One of the major factors that contribute to the risk in such supply networks is the geographical location of a particular supplier and the factors that determine it. Broadly defined, some of these factors might include wages, production costs, political, economic, environmental stability and also the growth rate of the supplier's country (Cheng and Cheu, 2018). Political activities like terrorist attacks, government change etc, can play a great role in the credibility of a

particular location, as discussed by Jüttner et al. (2010). Gomes et al. (2015) elaborated on the foundations of the economic pillar of supply network building model for cost analysis. Another major factor that comes into play is the sustainability factor that incorporates environmental and social aspects. This integration, called as the triple-bottom-line (TBL) dimensions of organizational sustainability (Elkington, 1998, 2004), has continuously gained relevance for managerial decision making in general and for supply network management (Carter and Rogers, 2008).

This distance can create problems more complex than it might seem (Henrick and Scheile, 2016). On the face of it, increased transportation costs are the most obvious one (Sindi and Roe, 2017). Going deeper, factors like increase in demand and lead time, need of minimum inventory levels and difficulty in communication emerge (Chuang, 2001).

A risk analysis framework can be used to study each supplier. This framework would evaluate the costs between local supplier and international supplier and also between low cost and long term suppliers. The categories of supplier specific risks can be broadly classified as: political, natural disasters, financial stability of supplier, economic, security and terrorism, logistics, supplier relationships, and reliability risks (Palaniswami et al., 2009). Under highly uncertain conditions, the initial benefit of lower cost budget can be well exceeded by risks associated with global suppliers (Kirilmaz and Eral, 2017). In this research following categories of risk factors have been adopted for the development of model.

Table 6.3: Risks of Strategic Sourcing

Major Risk Factor	**Sub Risk Factor**
Business Risk	Demand Risk
	Credit Risk
Economic Risk	Economic Stability
	Country Risk
	Exchange rate risk
External Risk	Price risk
	Regulatory Risk
	Supply Disruption

6.2 Research Methodology

For this research we carry out the selection of the vendor to whom the manufacturing could be outsourced with optimum profit in two major steps, each with some sub-steps. In the first step, we use the science of rejection, instead of selection. We try to shortlist vendors from the available options by allotting them points based on their performance, in the defined categories, by employing analytical hierarchy process (AHP) as explained in section 3.1. In the second step, we use a more mathematical approach, i.e. DEA model, to select the perfect option by comparing the efficiency rates of the shortlisted vendors based on both the cost and risk inputs and revenues generated as output. The schematic diagram is given in Fig. 1 below and the details of both steps are given in next two sub-sections, i.e. 3.1 and 3.2.

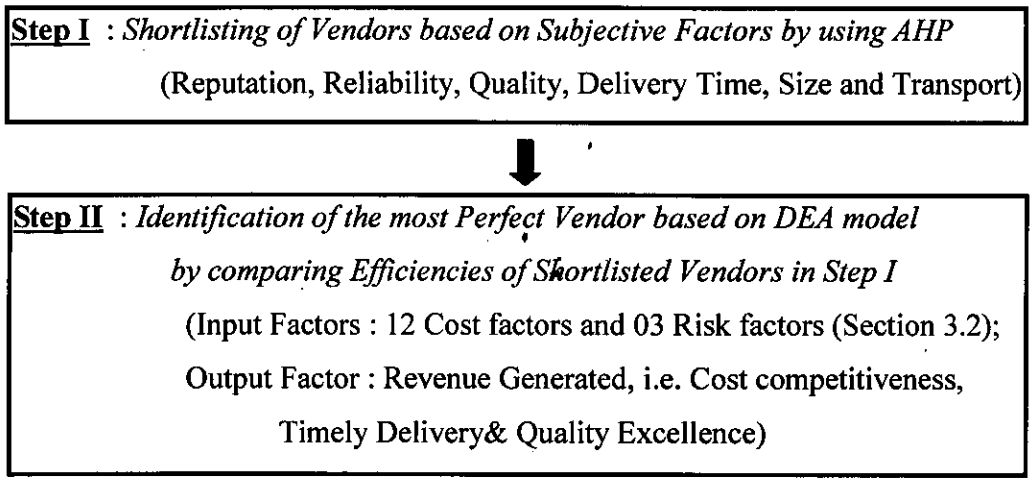


Fig.6.1: Schematic Diagram of Research Methodology:Vendor Selection Framework

6.2.1 Step 1: Short listing of Vendors based on Subjective Factors

In the first step amongst the various options available (say 50 Nos), we shortlist the vendors based on the following identified six subjective factors:

- **Reputation**: This would mean the current reputation of a particular vendor in the market, based on it past performance, its brand value etc.
- **Reliability**: How responsible or trustworthy in case of emergency situations and product quality the vendor is, would count for its reliability.
- **Quality**: This would include the quality of end product delivered, in bulk and also small quantities; this could be assessed to an extent by customer feedback from past records.

- **Delivery Time**: This is another important factor to meet the customer demand on time. A deal loses its value, if not met on time.
- **Size**: This refers to the maximum and minimum size of delivery that a particular vendor can provide at a time. It is significant, as it determines the flexibility of the vendor.
- **Transport**: It is important for a vendor to be flexible with both modes of transport that is, by air and by water, as the optimum cost of transport requires both in some proportion.

Subsequently, weights, i.e., $x_1, x_2, \ldots, x_6$, are allotted to each of these factors based on inter-se priority of these factors by employing AHP. Brief description of the AHP is given below:

- In AHP, various attributes are compared using pair-wise comparison matrix. Pair-wise comparison matrix is a better method for eliciting human decision.
- Fill up the upper triangular matrix. To fill the lower triangular matrix, we use the reciprocal values of the upper diagonal. If a_{ij} is the element of row i and column j of the matrix, then the lower diagonal is filled using the formula: $a_{ji} = 1/a_{ij}$.
- Having prepared a comparison matrix, now compute priority vector, which is the normalized Eigen vector of the matrix. Sum each column of the pair-wise comparison matrix. Then we divide each element of the matrix with the sum of its column, we have normalized relative weight. The sum of each column is 1.
- The normalized principal Eigen vector can be obtained by averaging across the rows.
- To check the consistency of pair-wise comparison matrix, λ_{max} is computed by multiplying priority vector with pair-wise comparison matrix. Then we take the sum of resultant matrix. Consistency index is computed using $CI = (\lambda_{max}-n)/(n-1)$.
- Consistency ratio (CR) is used to compare consistency of different size matrices. For each n (size of the matrix), the value of RI is given. The CR is then calculated by using the formula CR= CI / RI. The value of CR for a consistent matrix should be less than 0.10.

Then we assign the vendors points for the above-mentioned six categories, i.e. $u_1, u_2, \ldots, u_6$. Suppose we have 50 vendors in 50 different locations to choose from, say, $v_1, v_2, v_3, \ldots\ldots, v_{50}$, then the composite score of each vendor is calculated as:

$$V_i = \sum x_j u_k$$

Where i = 1,2,….,50

j = 1,2,….,6

k = 1,2,…,6

Based on the composite score, we can shortlist the appropriate number of units, (i.e. vendors, say @ 10%, i.e. around five to six) to further evaluate the best suitable one by adopting the DEA model as explained in the next step, i.e. 3.2.

6.2.2 Step 2: DEA Framework and Approach

The data envelopment analysis (DEA) framework had become increasingly important over the years to make purchasing decisions, owing to its ease of use. The main limitation of this method is that the weights are arbitrarily set for various supplier performance attributes used in the weighted scoring methods (Narasimhan et al., 2001). Thus, the allotment of these weights defines the final ranking, which may be difficult to be specified objectively. In this research, DEA is used to develop a framework to select the optimum supplier based on some input and output factors.

The DEA is used to evaluate vendors in materials and supply management in absence of weights for the criteria. The DEA method is thus based on categories, "input", "output" and "efficiency". The basic method was applied by Charnes et al. (1978) to determine the efficiency of decision making units. Martos (1964) examined this problem as a special case of linear programming models.

In supplier selection literature, many of multi criteria decision making (MCDM) and optimization tools have been used. Talluri et al. (2006) used chance constrained DEA model for vendor evaluation. Although, many types of methodologies have been used, but in case of global sourcing, incorporation of the risk and costs factors got less attention. In this research we have tried to combine the TCO factors with risk factors in global supply network.

For the DEA approach, we evaluate the shortlisted productive units, say 'n' number of units are evaluated. Each unit requires some input factors to produce the desired output factors. In this case, we consider the output factor to be revenue generated (cost competitiveness, timely delivery, and quality excellence). The input factors include the following 15 factors (i.e 12 cost and 03 risk factors):

- **Manufacturing Cost**: As the name suggests, it includes the cost of designing, planning, processing and development of product.

- **Warehouse Cost:** This includes mostly maintenance costs of the warehouse.
- **Operations Cost:** This includes labour costs, equipment assembly costs etc.
- **Quality Cost:** This includes replacement, returned product, warranty costs.
- **Logistics Cost:** This includes packaging, handling, duties and tariffs etc.
- **Transportation Cost:** This includes the cost of transportation of manufactured goods from the start point to end point.
- **Inventory Cost:** This includes the cost of holding a particular inventory in safe stock.
- **Administration Cost:** Includes managing the vendor, documentation and team costs.
- **Transaction Cost:** Includes the transaction and ordering costs.
- **Training Cost:** This includes the setup cost of the deal and making the vendor familiar with how the company works.
- **Communication Cost:** This includes the costs incurred to maintain relations with the vendor.
- Miscellaneous Costs.
- Business risk.
- Economic risk.
- External risk.

Let's assign the input factors by variables as $x_1, x_2, \ldots\ldots x_{15}$.

Let's assign the output factors by variables as y_1 in this case.

Let us formulate the DEA model, assuming the efficiency of the 0^{th} Vendor, i.e E_0, to be:

$u.y_0/v.x_0 \rightarrow max$

such that

$$u.y_j/v.x_j \leq 1; \quad (1)$$

$$j = 0,1,2,\ldots\ldots p. \quad (2)$$

$$u \geq 0, \; v \geq 0. \quad (3)$$

This is the basic DEA model. These equations can be converted into a linear programming model. Thus we define the efficiency rate as, $E = u.y_j/v.x_j$ where our objective function is to maximise E. We calculate the relative efficiencies of each of the units and find the most efficient choice. This can be done using softwares like, DEAP, Excel Solver etc.

6.3 Case Application

We have applied the DEA method to select the optimum vendor for the Indian automobile firm to outsource manufacturing of the goods. This firm generally outsources to Asian counties, with a budget of 200 million INR. Looking at the company's needs, we take the total revenue generated to be 400 million INR.

As the first step, we shortlist the vendors initially based on the six identified subjective factors as described in the Section 6.2.1 and out of the 50 options, only five vendors have been shortlisted. Relative priority of the subjective risk factors is determined by using the AHP. The pair wise comparison matrix of the factors as relevant to the industry is given at Table 4 below. The value of CR is less than 0.10, so in general the decision maker is consistent in decision making.

Table 6.4: Pair wise Comparison Matrix

	Quality	**Delivery Time**	**Reliability**	**Size**	**Reputation**	**Transport**	**Priority Vector**
Quality	1	3	6	5	9	5	0.645
Delivery Time	1/3	1	4	4	8	2	0.323
Reliability	1/6	1/4	1	3	6	1/3	0.189
Size	1/5	1/4	1/3	1	6	1/2	0.118
Reputation	1/9	1/8	1/6	1/6	1	1/6	0.046
Transport	1/5	1/2	3	2	6	1	0.153

CI = (λmax -n) / n- 1; (6.0184 - 6) / 6-1; 0.0036

CR = CI / RI ; 0.0036 /1.24 = 0.0029

Value of CR is less than 0.10, so in general decision maker is consistent in decision making.

Once, we get the priority vector for vendor selection criteria, then we multiply these weights to the vendor rating on the above listed criteria's that gives the weighted score for full set of suppliers. The full set of suppliers considered was 50 and during Step I and five vendors were shortlisted for the company.

Five vendors were shortlisted for the company, on which the DEA used performed. We got the cost ranges and risk ranges of the five vendors for the mentioned input category. From that we took a median as the input factor cost. We then calculated the efficiency rate of each of them as we

had the input factors and the output factors. The expression in the denominator for the efficiency rate expression remained the same for all the vendors, as revenue generated by the company was same in this case, when experienced over a specific time period. Following table shows the cost ranges and risk ranges for the input factors. The input range was provided by the managers of these five vendors. They provided the ranges based on the data of last five years.

The DEA model analysis was then performed in accordance with the details given in the Section 6.2.2 above on the five shortlisted vendors. We obtained from respective managers the cost ranges and risk ranges of the five vendors for the 15 input categories (enumerated in Section 6.2.2, i.e. 12 cost factors and 03 risk factors), as shown in the Table 6.5. We then calculated the mean of all the input factors, as shown in the Table 6.7. The output factors ranges and median data are as given in Tables 6.6 and 6.8 respectively. The managers provided the data of last five years. The efficiency rate of each vendor has been then calculated based on the DEA model by employing the mean of input factors and the median of output factors. The expression in the denominator for the efficiency rate expression remained the same for all the vendors, as revenue generated by the company was same in this case, when experienced over a specific time period.

Table 6.5: Cost Ranges and Risk Ranges for the Input Factors

S. No.	Factor	Cost Range (million INR)				
		V1	V2	V3	V4	V5
1	Manufacturing Cost	23-25	20-23	25-27	24-29	25-27
2	Warehouse Cost	9-12	10-14	13-17	11-14	14-18
3	Operations Cost	12-16	15-19	11-14	14-18	13-16
4	Quality Cost	5-8	6-8	4-7	6-9	7-10
5	Logistics Cost	8-11	9-13	9-12	10-13	7-10
6	Transportation Cost	15-18	17-20	12-14	13-17	14-17
7	Inventory Cost	6-8	6-9	4-7	7-10	5-8
8	Administration Cost	3-6	5-7	4-5	2-5	4-7
9	Transaction Cost	5-7	4-5	2-5	4-7	3-6

S. No.	Factor	Cost Range (million INR)				
		V1	V2	V3	V4	V5
10	Training Cost	2-4	3-5	1-3	2-5	4-6
11	Communication Cost	3-5	2-6	1-4	2-5	3-6
12	Miscellaneous	5-8	5-8	5-8	5-8	5-8
13	Business Risk	2-4	2-3	3-4	1-2	2-3
14	Economic Risk	2-3	2-3	2-4	2-4	1-2
15	External Risk	1-2	2-3	2-3	2-4	3-4

Table 6.6: Cost Range of Output Factors

S. No.	Output Factor	Input Range				
		V1	V2	V3	V4	V5
1	Cost Competitiveness	23-25	20-23	25-27	24-29	25-27
2	Timely Delivery	9-12	10-14	13-17	11-14	14-18
3	Quality Excellence	12-16	15-19	11-14	14-18	13-16

Table 6.7: Mean of Input Factors

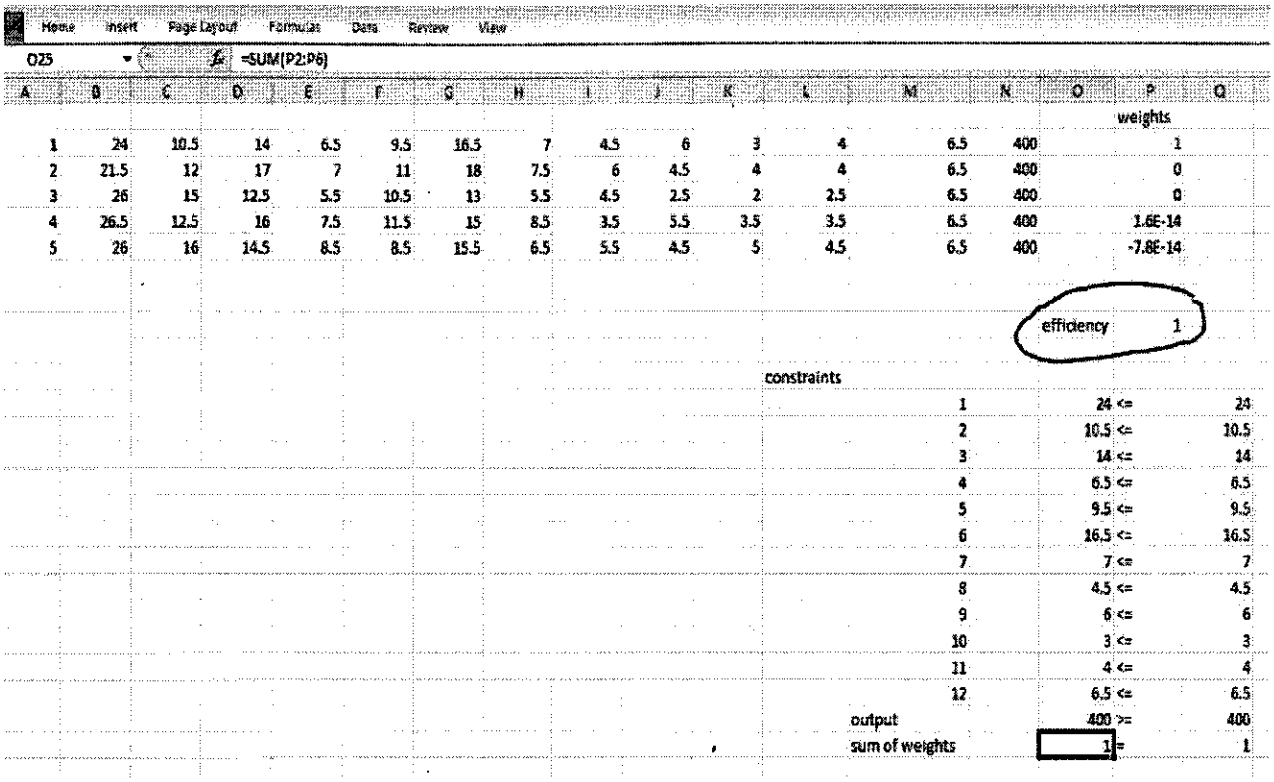
S. No.	Factor	Mean Value to be Taken (million INR)				
		V1	V2	V3	V4	V5
1	Manufacturing Cost	24	21.5	26	26.5	26
2	Warehouse Cost	10.5	12	15	12.5	16
3	Operations Cost	14	17	12.5	16	14.5
4	Quality Cost	6.5	7	5.5	7.5	8.5
5	Logistics Cost	9.5	11	10.5	11.5	8.5
6	Transportation Cost	16.5	18	13	15	15.5

S. No.	Factor	Mean Value to be Taken (million INR)				
		V1	V2	V3	V4	V5
7	Inventory Cost	7	7.5	5.5	8.5	6.5
8	Administration Cost	4.5	6	4.5	3.5	5.5
9	Transaction Cost	6	4.5	3.5	5.5	4.5
10	Training Cost	3	4	2	3.5	5
11	Communication Cost	4	4	2.5	3.5	4.5
12	Miscellaneous	6.5	6.5	6.5	6.5	6.5
13	Business Risk	3	2.5	3.5	1.5	2.5
14	Economic Risk	2.5	2.5	3	3	1.5
15	External Risk	1.5	2.5	2.5	3	3.5

Table 6.8: Median of Output Factors

S. No.	Output Factor	Cost Range (million INR)				
		V1	V2	V3	V4	V5
1	Cost Competitiveness	24	21.5	26	26.5	26
2	Timely Delivery	10.5	12	14.5	12.5	16
3	Quality Excellence	14	17.5	12.5	15.5	14.5

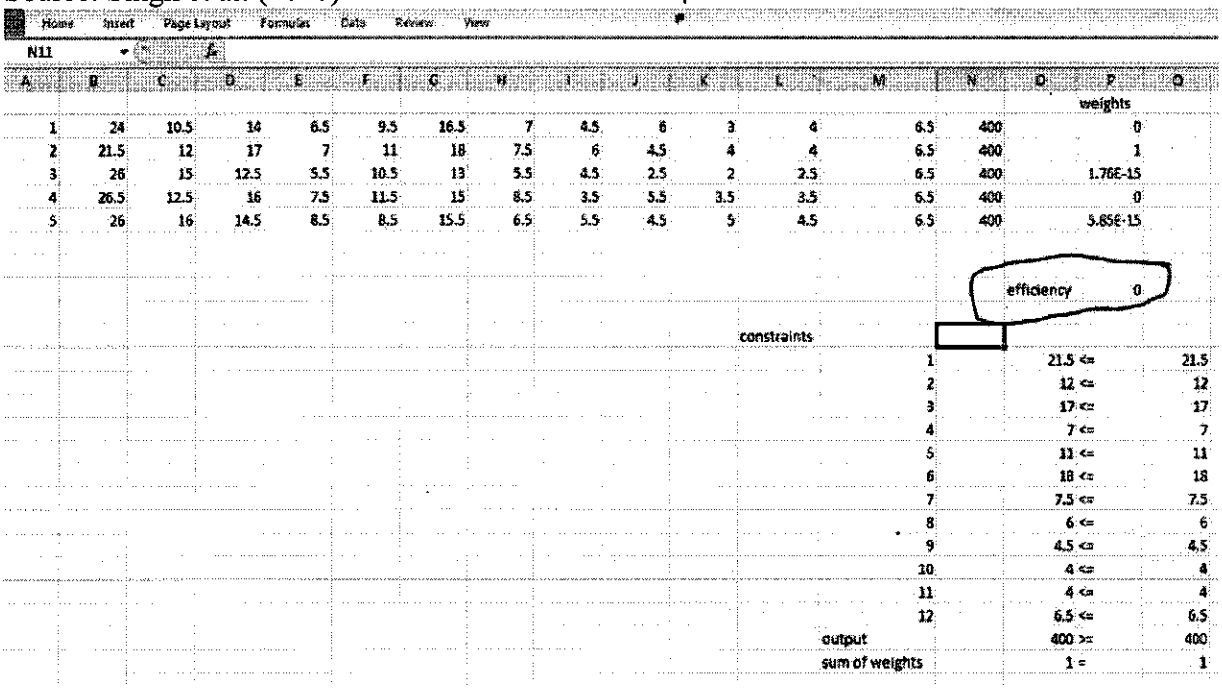
The following figures, i.e 6.2 to 6.6, show the relative efficiencies of each of the five vendors and the efficiencies have been summarised in Table 6.9.



															weights
1	24	10.5	14	6.5	9.5	16.5	7	4.5	6	3	4	6.5	400		1
2	21.5	12	17	7	11	18	7.5	6	4.5	4	4	6.5	400		0
3	26	15	12.5	5.5	10.5	13	5.5	4.5	2.5	2	2.5	6.5	400		0
4	26.5	12.5	16	7.5	11.5	15	8.5	3.5	5.5	3.5	3.5	6.5	400		1.6E-14
5	26	16	14.5	8.5	8.5	15.5	6.5	5.5	4.5	5	4.5	6.5	400		-7.8E-14

		efficiency	1
constraints			
	1	24 <=	24
	2	10.5 <=	10.5
	3	14 <=	14
	4	6.5 <=	6.5
	5	9.5 <=	9.5
	6	16.5 <=	16.5
	7	7 <=	7
	8	4.5 <=	4.5
	9	6 <=	6
	10	3 <=	3
	11	4 <=	4
	12	6.5 <=	6.5
output		400 >=	400
sum of weights		1 =	1

Fig.6.2: Efficiency of Vendor A
Source: Singh et al. (2018)

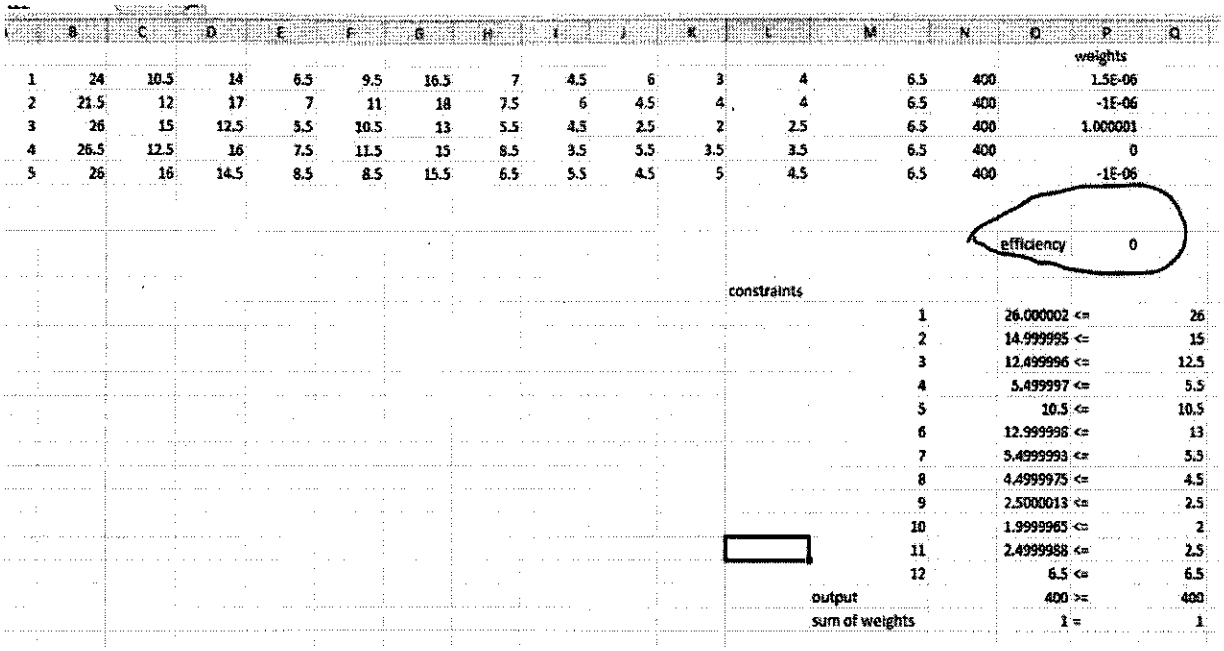


															weights
1	24	10.5	14	6.5	9.5	16.5	7	4.5	6	3	4	6.5	400		0
2	21.5	12	17	7	11	18	7.5	6	4.5	4	4	6.5	400		1
3	26	15	12.5	5.5	10.5	13	5.5	4.5	2.5	2	2.5	6.5	400		1.76E-15
4	26.5	12.5	16	7.5	11.5	15	8.5	3.5	5.5	3.5	3.5	6.5	400		0
5	26	16	14.5	8.5	8.5	15.5	6.5	5.5	4.5	5	4.5	6.5	400		5.85E-15

		efficiency	0
constraints			
	1	21.5 <=	21.5
	2	12 <=	12
	3	17 <=	17
	4	7 <=	7
	5	11 <=	11
	6	18 <=	18
	7	7.5 <=	7.5
	8	6 <=	6
	9	4.5 <=	4.5
	10	4 <=	4
	11	4 <=	4
	12	6.5 <=	6.5
output		400 >=	400
sum of weights		1 =	1

Fig.6.3: Efficiency of Vendor B

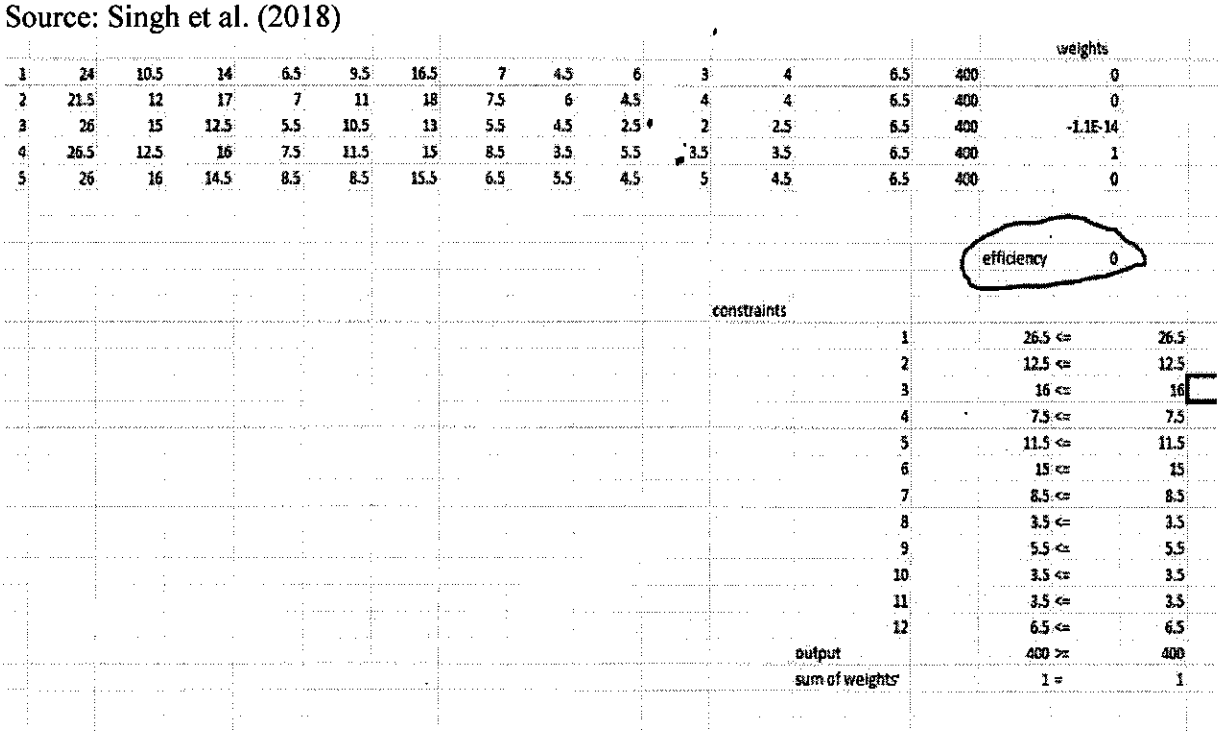
Source: Singh et al. (2018)



	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
															weights	
1	24	10.5	14	6.5	9.5	16.5	7	4.5	6	3	4		6.5	400	1.5E-06	
2	21.5	12	17	7	11	18	7.5	6	4.5	4	4		6.5	400	-1E-06	
3	26	15	12.5	5.5	10.5	13	5.5	4.5	2.5	2	2.5		6.5	400	1.000001	
4	26.5	12.5	16	7.5	11.5	15	8.5	3.5	5.5	3.5	3.5		6.5	400	0	
5	26	16	14.5	8.5	8.5	15.5	6.5	5.5	4.5	5	4.5		6.5	400	-1E-06	
														efficiency	0	
											constraints					
													1	26.000002 <=	26	
													2	14.999995 <=	15	
													3	12.499996 <=	12.5	
													4	5.499997 <=	5.5	
													5	10.5 <=	10.5	
													6	12.999998 <=	13	
													7	5.4999993 <=	5.5	
													8	4.4999975 <=	4.5	
													9	2.5000013 <=	2.5	
													10	1.9999965 <=	2	
													11	2.4999988 <=	2.5	
													12	6.5 <=	6.5	
												output		400 >=	400	
												sum of weights		1 =	1	

Fig.6.4: Efficiency of Vendor C

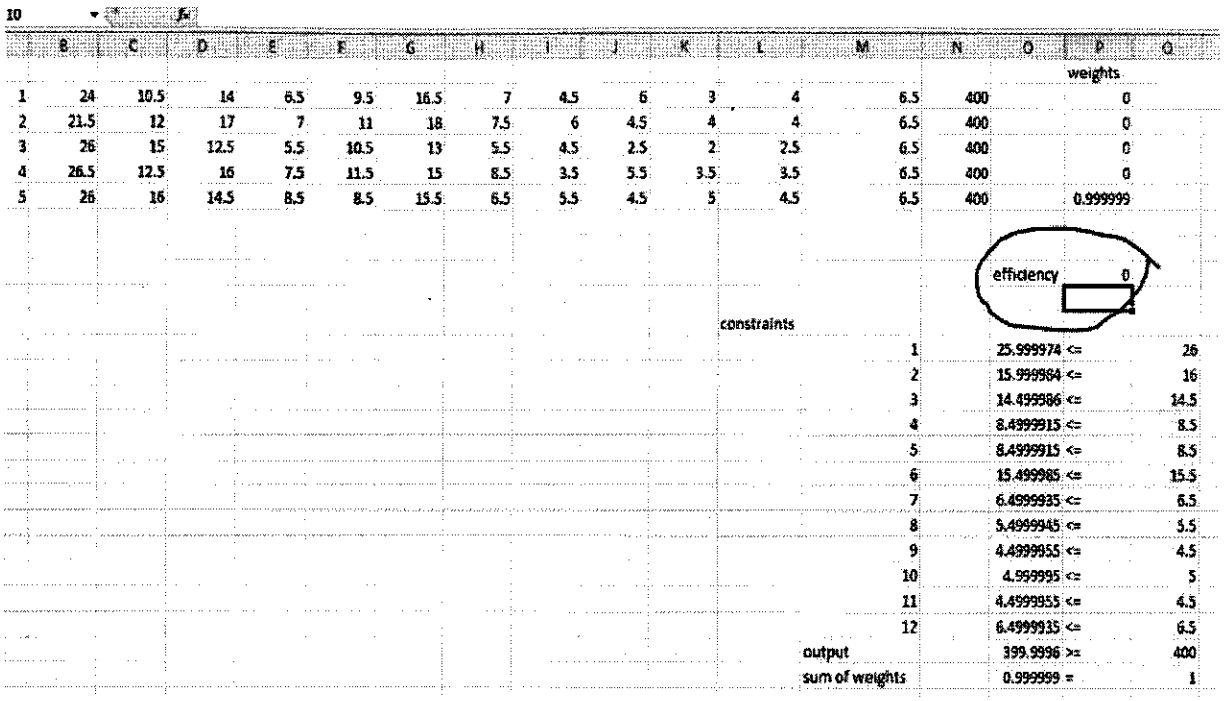
Source: Singh et al. (2018)



	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
															weights	
1	24	10.5	14	6.5	9.5	16.5	7	4.5	6	3	4		6.5	400	0	
2	21.5	12	17	7	11	18	7.5	6	4.5	4	4		6.5	400	0	
3	26	15	12.5	5.5	10.5	13	5.5	4.5	2.5	2	2.5		6.5	400	-1.1E-14	
4	26.5	12.5	16	7.5	11.5	15	8.5	3.5	5.5	3.5	3.5		6.5	400	1	
5	26	16	14.5	8.5	8.5	15.5	6.5	5.5	4.5	5	4.5		6.5	400	0	
														efficiency	0	
											constraints					
													1	26.5 <=	26.5	
													2	12.5 <=	12.5	
													3	16 <=	16	
													4	7.5 <=	7.5	
													5	11.5 <=	11.5	
													6	15 <=	15	
													7	8.5 <=	8.5	
													8	3.5 <=	3.5	
													9	5.5 <=	5.5	
													10	3.5 <=	3.5	
													11	3.5 <=	3.5	
													12	6.5 <=	6.5	
												output		400 >=	400	
												sum of weights		1 =	1	

Fig.6.5: Efficiency of Vendor D

Source: Singh et al. (2018)



	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
															weights	
1	24	10.5	14	6.5	9.5	16.5	7	4.5	6	3	4	6.5	400		0	
2	21.5	12	17	7	11	18	7.5	6	4.5	4	4	6.5	400		0	
3	26	15	12.5	5.5	10.5	13	5.5	4.5	2.5	2	2.5	6.5	400		0	
4	26.5	12.5	16	7.5	11.5	15	8.5	3.5	5.5	3.5	3.5	6.5	400		0	
5	26	16	14.5	8.5	8.5	15.5	6.5	5.5	4.5	5	4.5	6.5	400		0.999999	
														efficiency	0	
											constraints					
												1	25.999974	<=	26	
												2	15.999984	<=	16	
												3	14.499986	<=	14.5	
												4	8.4999915	<=	8.5	
												5	8.4999915	<=	8.5	
												6	15.499985	<=	15.5	
												7	6.4999935	<=	6.5	
												8	5.4999945	<=	5.5	
												9	4.4999955	<=	4.5	
												10	4.999995	<=	5	
												11	4.4999955	<=	4.5	
												12	6.4999935	<=	6.5	
											output		399.9996	>=	400	
											sum of weights		0.999999	=	1	

Fig.6.6: Efficiency of Vendor E

Source: Singh et al. (2018)

Table 6.9: Efficiencies Summarized

Vendor	V1	V2	V3	V4	V5
Relative Efficiency	1	0.72	0.58	0.43	0.63

From the above table, we find that Vendor 1 would be the most efficient choice as it provides the maximum efficiency rate.

6.4 Analysis and Limitations

The DEA approach has been implemented on a case company data to select the best choice of vendor to outsource certain part/ component. This study is unique in the regard that it takes into account the exhaustive set of costs that are often neglected or not considered important enough to make a difference as well as the effect of these risk factors on the true cost of doing business offshore. We can see that Vendor 1 didn't provide the lowest manufacturing, transportation or even logistics cost, which mainly cover all the aspects of a landed cost model. Still it turned out to be the better choice, when other minor costs were taken into account. If we just go by the manufacturing

costs, Vendor 2 seems to be the best choice, but DEA application shows clearly, how after incorporating all the costs, it is not the most efficient choice. In the above case it has been assumed that the miscellaneous cost required is same in each case. It has also been assumed that each vendor generates the same output, which is not necessary. It is observed that Vendor 1 infact doesn't provide a visible minimum cost in any specific category but still gives the highest ratio due to better internal risk management processes. In this case study, however, exhaustive set of risk factors have not been included as input. Risks and interaction among risks calculation is a complex process. The factors that need to be considered are mentioned in the literature review. After determining the risk factors and an approximate cost allowance for each, they can simply be included along with other costs as input factors. DEA evaluates each of them. Also, the first step of the methodology includes a descriptive analysis of a huge number of vendors that purely rests on subjective inputs of subject matter experts. Subsequently, it focusses on the DEA method conducted on five vendors for proper elaborations to arrive at the most effective vendor to be selected in the global sourcing environment.

Businesses generally take into account the visible major costs involving short term strategy for sourcing. With more and more studies on TCO models, a better strategy can result in lesser costs for the company, it emerges that a better strategy can result in lesser costs for the company and the present research contributes in developing a unique quantitative DEA based vendor selection model, wherein both comprehensive cost and risk factors inputs are considered for evaluation.

6.5. Conclusions and Recommendations for Future Research

With time progressing, global sourcing has led to more and more fragmentation and hence warranting a deeper study of the supply network involved in delivering a finished product.
The study proposes to focus on factors that are often neglected in implications of a landed cost model or even a TCO model. Other than that, TCO models are studied widely but not practically implied as much. If talking about a typical production firm, it might be sufficient to use the landed cost model, but for IT and other services related firms, TCO models give a more detailed, accurate and wholesome cost analysis.

There is also a huge variability amongst the firms regarding the level of strategy applied to sourcing decisions. From larger to smaller firms, the extents are different. The basic motivation

behind sourcing the work or production to another location is the cheaper labour or material costs, but if apt technique and strategy isn't applied, the cost of outsourcing can almost nullify the savings from labour and materials. Therefore a holistic assessment needs to be undertaken in a systematic manner to arrive at optimal decision making. Data requirements for undertaking an effective application of this model merits adequate attention, in both primary and secondary sources domains. Also, researches are generally conducted from the buying firm's point of view. However, the suppliers or middlemen parties might have different views and strategies for risk mitigation and cost reduction. Though this model has been applied for a particular industry, however it is envisaged that it can be effectively translated to a wider applications in future.