Chapter 5

Measurement of Flexibility and its Benchmarking using Data Envelopment Analysis in Supply Chains

The previous chapter presents a method to determine flexibility performance measure of a supply chain using modified Fuzzy Analytic Hierarchical Process and the usage of the suggested measurement framework is demonstrated using representative data. This chapter demonstrates application of Data Envelopment Analysis (DEA) to facilitate measurement and benchmarking of SC flexibility. DEA helps in finding relative efficiencies of similar SCs, bench marking and evaluate areas of possible improvements. This chapter is broadly organised into a discussion on DEA for performance measurement and demonstration of using DEA for benchmarking flexibility in SC.

5.0 INTRODUCTION

A method to determine flexibility performance measure of a SC using modified Fuzzy Analytic Hierarchical Process (FAHP) is presented at Chapter 4. A comparative analysis of some widely-cited PMS for SC flexibility has also been undertaken in the previous chapter (Chapter 4). This chapter presents a methodology for bench marking of flexibility capabilities in SC using Data Envelopment Analysis (DEA).

The key elements in SC performance measurement, according to Beamon (1999), are measurement of: (i). Resources, (ii). Output and (iii). Flexibility. Resource measures concentrate on efficiencies, are related to costs and targets effective utilization of resources. Output measures emphasize on customer responsiveness and aims at providing high level of customer service. Flexibility measures how well the system reacts to uncertainty and its ability to respond to a changing environment. ‘Resources’ measures and ‘Output’ measures have been widely used in SCPMS models. However, ‘Flexibility’ has been limited in its application to SCPMS. In an uncertain environment, SCs must be able to respond to change. Flexibility measures the ability of the SC to adapt to volume and schedule variations from other partners of the SC (Stevenson & Spring, 2007).

Data envelopment analysis (DEA) is a nonparametric method in operations research and economics for the estimation of relative efficiencies of similar units and used for their benchmarking. DEA 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. This chapter demonstrates use of DEA to facilitate effective measurement and benchmarking of SC flexibility. Methods of calculating flexibility attributes, a discussion on DEA for performance measurement and demonstration of using DEA for benchmarking flexibility in SC forms the structure of this chapter.

5.1 Measuring Flexibility Attributes

The degree to which the SC can respond to random fluctuations in the demand pattern provides a measure of its flexibility. Beamon (1999) discussed two types of flexibility–Range flexibility and Response flexibility. 'Range flexibility' measures the extent the operation can be varied. 'Response flexibility' measures the ease (in terms of cost, time, or both) with which the operation can be varied. The SC need to adapt adequately to the uncertain environment by incorporating range flexibility and response flexibility in its design (Beamon, 1999b). Beamon (1999) identified four types of SC flexibility and suggested quantitative ways to measure them; they are discussed in the following paragraphs.

5.1.1 Volume flexibility (Fv)

Volume flexibility is the ability to change the output level of products produced. The volume flexibility measure, Fv, measures the proportion of demand that can be met by the SC system within range of volumes that are profitable. In this approach, it is assumed that demand volume (D) is a random variable which follows a normal distribution and that there is a minimum and maximum profitable output volume during any period. With sufficient data regarding demand volumes, over a period, the volume flexibility (Fv) is calculated as under:

$$F_V = P\left(\frac{O_{\min} - \overline{D}}{S_D} \leq D \leq \frac{O_{\max} - \overline{D}}{S_D}\right) \tag{5.1}$$

$$Fv = \emptyset\left(\frac{O_{min} - \overline{D}}{S_D}\right) - \emptyset\left(\frac{O_{max} - \overline{D}}{S_D}\right) \tag{5.2}$$

Where:

P = Probability of meeting the demand between O_{min} and O_{max} based on normal probability distribution.

ϕ = Standard normal distribution table value that represent area to the left of the Z score.

O_{min} & O_{max} = The minimum and maximum profitable output volume during the period.

$\overline{D}$ = Mean of the demand volume

S_D = Standard deviation of demand volume $\overline{D}$ and S_D are calculated using the formulas:

$$\overline{D} = \frac{\sum_{t=1}^{T} d_t}{T} \tag{5.3}$$

$$S_D^2 = \frac{\sum_{t=1}^{T} (d_t - \overline{d})^2}{T-1} \tag{5.4}$$

Where d_t is the demand during period t, and T is the number of periods considered.

$F_V \in (0,1)$ and F_v represents the long-run proportion of demand that can be met by the supply chain system.

5.1.2 Delivery flexibility (F_D)

Delivery flexibility (F_D) is the ability to change planned delivery dates. This ability allows the SC to accommodate rush orders and special orders. Delivery flexibility is measured as the percentage of slack time by which the delivery time can be reduced.

$$\text{The total slack time for all jobs j} = \sum_{j=1}^{J} \left(L_j - t^*\right) \tag{5.5}$$

$$\text{Minimum delivery time for all jobs j} = \sum_{j=1}^{J} \left(E_j - t^*\right) \tag{5.6}$$

$$F_D = \frac{\sum_{J=1}^{j}\left(\left(L_j - t*\right) - \left(E_j - t*\right)\right)}{\sum_{J=1}^{j}\left(L_j - t*\right)} \quad (5.7)$$

Where:

L_j – Latest time period during which the delivery can be made for job j

E_j – Earliest time period during which the delivery can be made for job j

j - 1, . . . to J jobs in the system

t* - Current time period (Modal value of time taken to complete the job)

5.1.3 Mix flexibility (Fm)

Mix flexibility (Fm) is the ability to change the variety of products produced. Mix flexibility measures either the range of different product types that may be produced during a particular time period, or the response time between product mix changes. The time required to produce a new product mix gives the product mix flexibility (Fm).

$$F_m = T_{ij} \quad (5.8)$$

Where T_{ij} is the change over time required from product mix i to product mix j, with $T_{ij} \geq 0$ for any i and j.

5.1.4 New product flexibility (Fn)

New product flexibility is the ability to introduce and produce new products which also includes the modification of existing products. It is measured as either the time or cost required to add new products to existing production operations.

$$Fn = T \quad (5.9)$$

where T is the time required to add new products, with $T \geq 0$.

5.2 DEA for Performance Measurement

DEA is a performance measurement technique developed by Charnes, Cooper, & Rhodes (1978) and is used for determining the relative efficiency of a set of comparable business called Decision Making Units (DMU). It has been applied to a wide range of problems in the fields of management, economics and business operations (Cook & Seiford, 2008). In DEA, efficiency is defined as:

$$Efficiency = \frac{Weighted\ sum\ of\ outputs}{Weighted\ sum\ of\ inputs} \tag{5.10}$$

The weights attached to each input and output is not, however, specified a priori. Instead they are computed to show each unit under comparison in its most favorable light (George & Rangaraj, 2008). The envelope, or frontier, becomes the surface linking all units whose relative efficiency cannot be exceeded. By definition units on that (Eq. 5.10) surface are then assigned 100 percent efficiency. The best possible efficiency for other units in the sample then brings them as close as possible to the envelope. The efficiency score computed by DEA is a numerical value that describes a system's relative efficiency in terms of inputs and outputs (Talluri, 2000; Yang, Wu, Liang, Bi, & Wu, 2011).

If there are 'n' DMUs, each with 'm' inputs and 's' outputs, the relative efficiency score of a test DMU 'p' is obtained by solving the following model (Talluri, 2000).

$$Max\left(\frac{\sum_{k=1}^{s} v_k\, y_{kp}}{\sum_{j=1}^{m} u_j x_{jp}}\right) \tag{5.11}$$

S.t.

$$\left(\frac{\sum_{k=1}^{s} v_k\, y_{ki}}{\sum_{j=1}^{m} u_j x_{ji}}\right) \le 1 \quad \forall i \tag{5.12}$$

$$v_k, u_j \ge 0 \quad \forall j, k$$

Where: k = 1 to s; j= 1 to m; I = 1 to n

y_{ki} = Amount of output ‘k’ produced by DMU ‘i’

x_{ji} = Amount of input ‘j’ used by DMU ‘i’

v_k = Weight given to output ‘k’

u_j = Weight given to input ‘j’

The fractional program shown as above at (Eq. 5.11 and 5.12) can be converted to a linear program for ease of solving as an LPP. The linear formulation of the DEA problem is given as follows (Talluri, 2000):

$$\begin{aligned} & Max\left(\sum_{k=1}^{s} v_k\, y_{kp}\right) \\ & s.t.\ \sum_{j=1}^{m} u_j\, x_{jp} = 1 \\ & \qquad \left(\sum_{k=1}^{s} v_k\, y_{ki} - \sum_{j=1}^{m} u_j\, x_{ji}\right) \le 0 \quad \forall i \\ & \qquad v_k, u_j \ge 0 \quad \forall j, k \end{aligned} \tag{5.13}$$

The above problem is run ‘n’ times (one run per DMU) to calculate the relative efficiency scores of the DMUs. A DMU is considered to be efficient, if it obtains a score of 1 and a score of less than 1 implies that it is inefficient. Each DMU selects input and output weights that maximize its efficiency score. Therefore, the ‘v_k’ and ‘u_k’ values gives output and input weight ages corresponding to max relative efficiency possible for the DMU considered.

5.3 Benchmarking with DEA

For every inefficient DMU, DEA identifies a set of corresponding efficient units that can be utilized as benchmarks for improvement. The benchmarks can be obtained from the dual of the DEA LPP formulation given above at (5.13).

Min E

Subjected to:

$$\sum_{i=1}^{n} \lambda_i y_{ki} \geq y_{kp} \quad \forall j$$

$$\sum_{i=1}^{n} \lambda_i x_{ki} \leq E.x_{kp} \quad \forall k \tag{5.13}$$

$$\lambda \geq 0 \quad \forall i$$

Where:

E = Efficiency score, and λ_i = Dual variable

These dual variables (λ_i) can be used to construct an efficient Hypothetical Composite Unit (HCU). HCU can be used to measure excess use of inputs and potential increase in outputs.

There are two basic DEA orientation models; viz. input reduction, and output augmentation. The former, also known as input-oriented model emphasizes how to use minimum input resources to achieve a given level of output. The latter, known as output-oriented model, focuses on using a given level of input to achieve the maximum possible output (Cook & Seiford, 2008; Hillier, 2011; Talluri, 2000).

DEA is receiving increasing importance as a tool for evaluating and improving the performance of manufacturing and service operations. It has been extensively applied in performance evaluation and benchmarking (Cook & Seiford, 2008; Pinder & Price, 2005; Seydel, 2006; Yang et al., 2011). DEA approach has the following benefits which make it suitable for bench marking in SC:

1. DEA deals with individual cases (Madu & Kuei, 1998).
2. It can produce a single measure for each company (Madu & Kuei, 1998).
3. It places no restriction on the functional form of the input-output relationship (Hillier, 2011).
4. It is able to handle disproportionate multiple inputs and outputs (George & Rangaraj, 2008).
5. It does not require the decision maker to decide on any priory arbitrary weights (George & Rangaraj, 2008).

6. It focuses on revealed best-practice frontiers rather than on central tendency properties of empirical data (Madu & Kuei, 1998).

7. It can provide an indication of the levels of improvement needed before an inefficient company could be considered efficient (Talluri, 2000).

5.4 Demonstration of Using DEA for Benchmarking Flexibility in SC

A simplified and generic approach to SCPMS has been adopted to demonstrate using of DEA for bench marking Flexibility. The SC model considered is shown in Figure 5.1 which contains four echelons. The four echelons–supply, manufacturing, distribution and consumers comprise of numerous facilities. DEA methodology considers relationship between multiple inputs with multiple outputs.

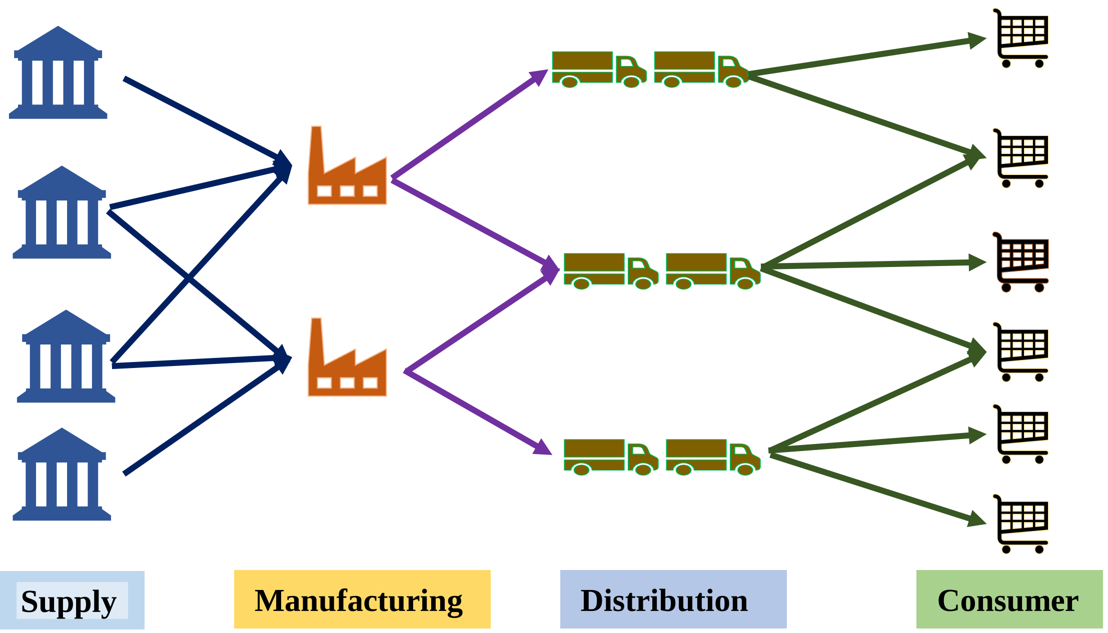

Figure 5.1 The Supply Chain Model Considered

5.4.1 Performance measures considered

The present study considers the 'Resources' consumed in the SC as the input parameters and the 'Flexibility' measures as the outputs. Resource parameters and Flexibility parameters as proposed by Beamon (1999) are summarized at Table 5.1.

DEA is effective when organizations operating under similar conditions are compared. SCs with similar processes and features can only be compared to establish benchmarking. In the current case, four input parameters (Total cost, Distribution costs, Manufacturing cost and Inventory) and two output parameters (Volume flexibility and Delivery flexibility) are considered

The flexibility parameters Volume flexibility (F_V) and Delivery flexibility (F_D) are calculated based on the procedure suggested by Beamon (1999) and as explained at section 5.2 of this chapter.

Table 5.1 List of Input and Output Parameters

INPUT: RESOURCES		OUTPUT: FLEXIBILITY	
INPUT PARAMETER	**EXPLANATION**	**OUTPUT PARAMETER**	**EXPLANATION**
Total cost	Total cost of resources used. Measure of capital	Volume flexibility	The ability to change the output level of products produced.
Distribution costs	Total cost of distribution, including transportation and handling costs	Delivery flexibility	The ability to change planned delivery dates.
Manufacturing cost	Total cost of manufacturing, including labor, maintenance, and re-work costs	Mix flexibility	The ability to change the variety of products produced.
Inventory	Costs associated with held inventory	New product flexibility	The ability to introduce and produce new products (this includes the modification of existing products).

5.4.2 Data set

Data set for six SCs under considerations (DMUs) are given at Table 5.2. The input data is obtained from financial documents (annual reports) of six participating companies. Capital costs and the inventory costs are taken from the cash flow statement. The manufacturing costs and inventory costs are inferred from the profit and loss account. Volume flexibility and delivery flexibility are calculated based on equations Eq. 5.2 and Eq. 5.7 as explained in sections 5.1.1 and section 5.1.2 respectively.

Table 5.2 Data Set

SC (DMU)	Total cost (Rs in Crores)	Manufacturing cost (Rs in Crores)	Distribution costs (Rs in Crores)	Inventory (Rs in Crores)	Volume flexibility (In Percentage)	Delivery flexibility (In Percentage)
	Input	Input	Input	Input	Output	Output
SC-1	7.85	4.74	1.25	0.95	71	77
SC-2	6.00	4.35	1.33	0.85	74	85
SC-3	5.75	3.87	1.45	1.12	62	95
SC-4	6.55	4.02	1.33	0.95	55	85
SC-5	7.00	4.34	1.12	0.85	65	97
SC-6	7.25	5.00	1.31	0.97	66	63

5.4.3 DEA formulation

The benchmarking is done by solving the dual of the DEA given at Eq. 5.13. The dual variables (λ_i) correspond to HCU and E the efficiency measure of the DMU under consideration. HCU can be used to measure possible improvements in terms of reduction in inputs and increase in outputs of the DMU.

The mathematical formulation for the case under study is given at Appendix. The Data Envelopment Analysis Online Software (DEAOS) has been used to solve the above DEA formulation.

5.4.4 Efficiency score

DEA calculates relative efficiencies of DMUs (SC) based on the multiple input and output parameters. The efficiency Score of SCs evaluated is given at Table 5.3. The relative efficiencies indicate that SC -2, SC -3, and SC -5 are relatively efficient in terms of flexibility whereas there is scope for improvement in case of SC -1, SC -4, and SC–6.

Table 5.3 Relative Efficiency Score

SC (DMU)	Relative Efficiency
SC - 1	98.43%
SC - 2	100.00%
SC - 3	100.00%
SC - 4	90.74%
SC - 5	100.00%
SC - 6	88.31%

The weights calculated for HCUs (λ values) are given at Table 5.4.

Table 5.4 Weights Calculated

SC (DMU)	Total cost (Rs in Crores)	Manufacturing cost (Rs in Crores)	Distribution costs (Rs in Crores)	Inventory (Rs in Crores)	Volume flexibility (In Percentage)	Delivery flexibility (In Percentage)
	Input	Input	Input	Input	Output	Output
SC-1	0.000	0.055	0.592	0.000	0.014	0.000
SC-2	0.000	0.054	0.577	0.000	0.014	0.000
SC-3	0.000	0.196	0.166	0.000	0.010	0.004
SC-4	0.000	0.189	0.000	0.251	0.000	0.011
SC-5	0.000	0.061	0.656	0.000	0.015	0.000
SC-6	0.018	0.000	0.661	0.000	0.013	0.000

5.4.5 Improvements possible

Based on relative efficiencies and the weights improvements possible at each of the measurement parameter are obtained. The results are tabulated at Table 5.5. It indicates, for inefficient SCs, the ideal combination of inputs and outputs possible. For example, for SC-1, the delivery flexibility can be improved from 77% to 99.2% with total cost reduced from Rs

7.85 to 7.39 Cr; Manufacturing cost from Rs 4.74 to 4.66 Cr; Distribution costs from 0.95 to 0.91 Cr and Inventory from 0.95 to 0.91Cr. Similar improvements are possible other inefficient SCs viz. SC-4 and SC-6.

Table 5.5 Improvements Possible

SC (DMU)	Total cost (Rs in Crores)	Manufacturing cost (Rs in Crores)	Distribution costs (Rs in Crores)	Inventory (Rs in Crores)	Volume flexibility (In Percentage)	Delivery flexibility (In Percentage)
	Input	Input	Input	Input	Output	Output
SC-1	7.85 to 7.39	4.74 to 4.66	1.25 to 1.23	0.95 to 0.91	71 to 71	77 to 99.2
SC-2	6 to 6	4.35 to 4.35	1.33 to 1.33	0.85 to 0.85	74 to 74	85 to 85
SC-3	5.75 to 5.75	3.87 to 3.87	1.45 to 1.45	1.12 to 1.12	62 to 62	95 to 95
SC-4	6.55 to 5.68	4.02 to 3.64	1.33 to 1.125	0.95 to 0.86	55 to 56.28	85 to 85
SC-5	7 to 7	4.34 to 4.34	1.12 to 1.12	0.85 to 0.85	65 to 65	97 to 97
SC-6	7.25 to 6.40	5 to 4.19	1.31 to 1.15	0.97 to 0.82	66 to 66	63 to 89.38

5.5 Results and Discussion

Flexibility is a significant parameter in SCM in today’s dynamic environment. Measuring flexibility is necessary to monitor, control and improve SC effectiveness. Flexibility measures for SC have been identified through literature as Volume flexibility, Delivery flexibility, Mix flexibility and New product flexibility. Methodology for measurement of these flexibility measures has also been described.

DEA is a suitable tool for evaluating relative efficiencies of similar organization. An attempt has been made to use DEA for benchmarking flexibility in SCs. The procedure has been demonstrated with a sample case of six similar SC. The demonstration shows how DEA can be used for benchmarking and evaluating possible improvements in inefficient SCs. DEA results provide management with improvement potentials, targets and peer DMUs. Hence, DEA offers a detailed steering and controlling tool to specify possible changes in structure and resource allocation.

The limitation of the methodology is that, it can be employed only for SCs with similar processes. DEA is primarily a diagnostic tool and does not prescribe any reengineering strategies to make inefficient units efficient (Talluri, 2000; Yang et al., 2011). Such improvement strategies must be studied and implemented by managers by understanding the operations of the efficient units. Also, further study is required to validate that the sufficiency of inputs selected, appropriate for the selected outputs and establish correlations.

Annexure 5.1

DEA FORMULATION FOR FLEXIBILITY PERFORMANCE

E = Efficiency score of DMU under evaluation and

λ_{ij} = Dual variable corresponding to the efficient hypothetical composite unit (HCU).

For SC -1 (1st DMU), the LPP formulation:

Min E

s.t.

$7.85\ \lambda_{11} + 6.00\ \lambda_{12} + 5.75\ \lambda_{13} + 6.55\ \lambda_{14} + 7.00\ \lambda_{15} + 7.25\ \lambda_{16} \geq 7.85$ (i)

$4.74\ \lambda_{21} + 4.35\ \lambda_{22} + 3.87\ \lambda_{23} + 4.02\ \lambda_{24} + 4.34\ \lambda_{25} + 5.00\ \lambda_{26} \geq 4.74$ (ii)

$1.25\ \lambda_{31} + 1.33\ \lambda_{32} + 1.45\ \lambda_{33} + 1.33\ \lambda_{34} + 1.12\ \lambda_{35} + 1.31\ \lambda_{36} \geq 1.25$ (iii)

$0.95\ \lambda_{41} + 0.85\ \lambda_{42} + 1.12\ \lambda_{43} + 0.95\ \lambda_{44} + 0.85\ \lambda_{45} + 0.97\ \lambda_{46} \geq 0.95$ (iv)

$71\ \lambda_{51} + 74\ \lambda_{52} + 62\ \lambda_{53} + 55\ \lambda_{54} + 65\ \lambda_{55} + 66\ \lambda_{56} \leq 71E$ (v)

$77\ \lambda_{61} + 85\ \lambda_{62} + 95\ \lambda_{63} + 85\ \lambda_{64} + 97\ \lambda_{65} + 63\ \lambda_{66} \leq 77E$ (vi)

For SC -2 (2nd DMU), the LPP formulation:

Min E

s.t.

$7.85\ \lambda_{11} + 6.00\ \lambda_{12} + 5.75\ \lambda_{13} + 6.55\ \lambda_{14} + 7.00\ \lambda_{15} + 7.25\ \lambda_{16} \geq 6.00$ (vii)

$4.74\ \lambda_{21} + 4.35\ \lambda_{22} + 3.87\ \lambda_{23} + 4.02\ \lambda_{24} + 4.34\ \lambda_{25} + 5.00\ \lambda_{26} \geq 4.35$ (viii)

$1.25\ \lambda_{31} + 1.33\ \lambda_{32} + 1.45\ \lambda_{33} + 1.33\ \lambda_{34} + 1.12\ \lambda_{35} + 1.31\ \lambda_{36} \geq 1.33$ (ix)

$0.95\ \lambda_{41} + 0.85\ \lambda_{42} + 1.12\ \lambda_{43} + 0.95\ \lambda_{44} + 0.85\ \lambda_{45} + 0.97\ \lambda_{46} \geq 0.85$ (x)

$71\ \lambda_{51} + 74\ \lambda_{52} + 62\ \lambda_{53} + 55\ \lambda_{54} + 65\ \lambda_{55} + 66\ \lambda_{56} \leq 74E$ (xi)

$77\ \lambda_{61} + 85\ \lambda_{62} + 95\ \lambda_{63} + 85\ \lambda_{64} + 97\ \lambda_{65} + 63\ \lambda_{66} \leq 85E$ (xii)

For SC -3 (3rd DMU), the LPP formulation:

Min E

s.t.

$$7.85\ \lambda_{11} + 6.00\ \lambda_{12} + 5.75\ \lambda_{13} + 6.55\ \lambda_{14} + 7.00\ \lambda_{15} + 7.25\ \lambda_{16} \geq 5.75 \quad \text{(xiii)}$$

$$4.74\ \lambda_{21} + 4.35\ \lambda_{22} + 3.87\ \lambda_{23} + 4.02\ \lambda_{24} + 4.34\ \lambda_{25} + 5.00\ \lambda_{26} \geq 3.87 \quad \text{(xiv)}$$

$$1.25\ \lambda_{31} + 1.33\ \lambda_{32} + 1.45\ \lambda_{33} + 1.33\ \lambda_{34} + 1.12\ \lambda_{35} + 1.31\ \lambda_{36} \geq 1.45 \quad \text{(xv)}$$

$$0.95\ \lambda_{41} + 0.85\ \lambda_{42} + 1.12\ \lambda_{43} + 0.95\ \lambda_{44} + 0.85\ \lambda_{45} + 0.97\ \lambda_{46} \geq 1.12 \quad \text{(xvi)}$$

$$71\ \lambda_{51} + 74\ \lambda_{52} + 62\ \lambda_{53} + 55\ \lambda_{54} + 65\ \lambda_{55} + 66\ \lambda_{56} \leq 62E \quad \text{(xvii)}$$

$$77\ \lambda_{61} + 85\ \lambda_{62} + 95\ \lambda_{63} + 85\ \lambda_{64} + 97\ \lambda_{65} + 63\ \lambda_{66} \leq 95E \quad \text{(xviii)}$$

For SC -4 (4th DMU), the LPP formulation:

Min E

s.t.

$$7.85\ \lambda_{11} + 6.00\ \lambda_{12} + 5.75\ \lambda_{13} + 6.55\ \lambda_{14} + 7.00\ \lambda_{15} + 7.25\ \lambda_{16} \geq 6.55 \quad \text{(xix)}$$

$$4.74\ \lambda_{21} + 4.35\ \lambda_{22} + 3.87\ \lambda_{23} + 4.02\ \lambda_{24} + 4.34\ \lambda_{25} + 5.00\ \lambda_{26} \geq 4.02 \quad \text{(xx)}$$

$$1.25\ \lambda_{31} + 1.33\ \lambda_{32} + 1.45\ \lambda_{33} + 1.33\ \lambda_{34} + 1.12\ \lambda_{35} + 1.31\ \lambda_{36} \geq 1.33 \quad \text{(xxi)}$$

$$0.95\ \lambda_{41} + 0.85\ \lambda_{42} + 1.12\ \lambda_{43} + 0.95\ \lambda_{44} + 0.85\ \lambda_{45} + 0.97\ \lambda_{46} \geq 0.95 \quad \text{(xxii)}$$

$$71\ \lambda_{51} + 74\ \lambda_{52} + 62\ \lambda_{53} + 55\ \lambda_{54} + 65\ \lambda_{55} + 66\ \lambda_{56} \leq 55E \quad \text{(xxiii)}$$

$$77\ \lambda_{61} + 85\ \lambda_{62} + 95\ \lambda_{63} + 85\ \lambda_{64} + 97\ \lambda_{65} + 63\ \lambda_{66} \leq 85E \quad \text{(xxiv)}$$

For SC - 5 (5th DMU), the LPP formulation:

Min E

s.t.

$$7.85\ \lambda_{11} + 6.00\ \lambda_{12} + 5.75\ \lambda_{13} + 6.55\ \lambda_{14} + 7.00\ \lambda_{15} + 7.25\ \lambda_{16} \geq 7 \quad \text{(xxv)}$$

$$4.74\ \lambda_{21} + 4.35\ \lambda_{22} + 3.87\ \lambda_{23} + 4.02\ \lambda_{24} + 4.34\ \lambda_{25} + 5.00\ \lambda_{26} \geq 4.34 \quad \text{(xxvi)}$$

$$1.25\ \lambda_{31} + 1.33\ \lambda_{32} + 1.45\ \lambda_{33} + 1.33\ \lambda_{34} + 1.12\ \lambda_{35} + 1.31\ \lambda_{36} \geq 1.12 \quad \text{(xxvii)}$$

$$0.95\ \lambda_{41} + 0.85\ \lambda_{42} + 1.12\ \lambda_{43} + 0.95\ \lambda_{44} + 0.85\ \lambda_{45} + 0.97\ \lambda_{46} \geq 0.85 \quad \text{(xxviii)}$$

$$71\ \lambda_{51} + 74\ \lambda_{52} + 62\ \lambda_{53} + 55\ \lambda_{54} + 65\ \lambda_{55} + 66\ \lambda_{56} \leq 65E \quad \text{(xxix)}$$

$$77\ \lambda_{61} + 85\ \lambda_{62} + 95\ \lambda_{63} + 85\ \lambda_{64} + 97\ \lambda_{65} + 63\ \lambda_{66} \leq 97E \quad \text{(xxx)}$$

For SC - 6 (6th DMU), the LPP formulation:

Min E

s.t.

$$7.85\,\lambda_{11} + 6.00\,\lambda_{12} + 5.75\,\lambda_{13} + 6.55\,\lambda_{14} + 7.00\,\lambda_{15} + 7.25\,\lambda_{16} \geq 7.25 \quad \text{(xxxi)}$$

$$4.74\,\lambda_{21} + 4.35\,\lambda_{22} + 3.87\,\lambda_{23} + 4.02\,\lambda_{24} + 4.34\,\lambda_{25} + 5.00\,\lambda_{26} \geq 5.00 \quad \text{(xxxii)}$$

$$1.25\,\lambda_{31} + 1.33\,\lambda_{32} + 1.45\,\lambda_{33} + 1.33\,\lambda_{34} + 1.12\,\lambda_{35} + 1.31\,\lambda_{36} \geq 1.31 \quad \text{(xxxiii)}$$

$$0.95\,\lambda_{41} + 0.85\,\lambda_{42} + 1.12\,\lambda_{43} + 0.95\,\lambda_{44} + 0.85\,\lambda_{45} + 0.97\,\lambda_{46} \geq 0.97 \quad \text{(xxxiv)}$$

$$71\,\lambda_{51} + 74\,\lambda_{52} + 62\,\lambda_{53} + 55\,\lambda_{54} + 65\,\lambda_{55} + 66\,\lambda_{56} \leq 66E \quad \text{(xxxv)}$$

$$77\,\lambda_{61} + 85\,\lambda_{62} + 95\,\lambda_{63} + 85\,\lambda_{64} + 97\,\lambda_{65} + 63\,\lambda_{66} \leq 63E \quad \text{(xxxvi)}$$