MEASUREMENT OF FLEXIBILITY AND ITS BENCHMARKING USING DATA ENVELOPMENT ANALYSIS IN SUPPLY CHAINS

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***Abstract**: Supply Chain Flexibility is becoming a key strategic issue for Supply Chain (SC) performance. Performance Measurement Systems (PMS) for Flexibility is critical for its monitoring, control and improvement. A comparative analysis of some widely cited PMS for SC flexibility have been undertaken and it indicates that the flexibility measurement methodology proposed by Beamon (1999) is a suitable framework for SC Flexibility measurement. However there are limitations in this framework when they are used for benchmarking similar SC. Data Envelopment Analysis (DEA) helps in finding relative efficiencies of similar SCs, bench marking and evaluate areas of possible improvements. This paper demonstrates use of DEA with SC Flexibility measurement to facilitate effective measurement and benchmarking of SC flexibility.*

Keywords: Data Envelopment Analysis (DEA), Flexibility Measurement, Flexibility in Supply Chain, Performance Measurement System (PMS), Supply Chain Management (SCM).

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1. Introduction

Managing Supply Chain (SC) operations is critical to any organization's ability to compete effectively in today's global and dynamic environment. Good Supply Chain Management (SCM) practices results in a variety of advantages such as increased customer value, increased profitability, reduced cycle times, less inventory levels (William et al., 2007) and increased flexibility (Hoek et al., 2001). Flexibility is increasingly mentioned as one of the major challenges to the business world, given volatile markets and increasingly varying performance requirements (Li et al., 2009). Companies are becoming increasingly aware that for competing in continuously changing environment, it is necessary to monitor, understand and control their flexibility capabilities.

Literature survey indicates that interest on performance measurement of SCs has notably increased in the last two decades (Taticchi et al., 2010). Various performance metrics are in place for measuring effectiveness of SC. Different perspectives of Supply Chain Performance Measures (SCPM) are available in literature. Flexibility and agility in SC have been considered as one of the performance parameters in many studies; however detailed study focusing on measurement of flexibility in SC is limited (Li et al., 2009). The measurement of flexibility in large, complex systems, such as supply chain systems, has rarely been addressed. There have been attempts to create a framework for agile supply chain and its measurement (Hoenk et al, 2001) and development of an instrument to measure supply chain agility (Li et al., 2009). Beamon (1999) has proposed a framework for measurement of flexibility in SC and identified performance measures for flexibility in SC. The present research is examining the Performance Measurement aspects of flexibility in SC and suggesting a methodology for bench marking of Flexibility capabilities in SC using Data Envelopment Analysis (DEA).

This paper is organized into the following sections: (i) Performance Measurement in SC; (ii) Measurement of Flexibility in SC; (iii) DEA for Performance Measurement and Benchmarking; (iv) Demonstration of using DEA for benchmarking flexibility in SC.

2. PERFORMANCE MEASUREMENT IN SC

Supply Chains (SC) are increasingly depending on Performance Measurement Systems (PMS) as a means to align their processes and resources with strategy and to achieve their organization objectives (Neely, 2005). Literature review indicates that a number of frameworks and models for performance measurement have been developed since 1980s. Tangen (2004) suggests that a major objective of such PMSs is to encourage proactive rather than reactive management. Gunasekaran et al. (2001) adds that performance measures can facilitate a greater understanding of the Supply Chain (SC) and improve its overall performance therefore achieving organisational objectives.

Much progress has been made since last two decades in establishing PMSs which include a portfolio of measures aimed to balance the more traditional, single focus view on profitability (Taticchi et al., 2010). Andy Neely (2005) defined PMS as a balanced and dynamic system that enables support of decision-making processes by gathering, elaborating and analyzing information. Bititci et al. (1997) defines SCPM as the reporting process that gives feedback to employees on the outcome of actions. Tangen (2004) proposed that performance should be defined as the efficiency and effectiveness of action.

Effective SCPM has been associated with a variety of advantages including increased customer value, increased profitability, reduced cycle times and average inventory levels and even better product design (William et al., 2007). The objective of SCPM therefore has to facilitate and enhance the efficiency and effectiveness of SCM. The main goal of SCPM models and frameworks is to support management by helping them to measure business performance, analyze and improve business operational efficiency through better decision-making processes (Tangen, 2005). An effective, integrated and balanced SCPM can engage the organisation's performance measurement system as a vehicle for organisational change. It also provides insight to reveal the effectiveness of strategies and to identify potential opportunities. It makes an indispensable contribution to decision making in SCM, particularly in re-designing business goals and strategies, and re-engineering processes (Charan et al., 2008).

The most widely cited Supply Chain Performance Measurement Systems (SCPMS) are the SMART (1988), the performance measurement matrix (1989), the Balanced Scorecard (1992), the integrated dynamic PMS (1997) and the Performance Prism (PP)

(2001). In the Indian context, there have been many attempts to measure the performance at the organizational level, but very few attempts have been made to measure the performance at inter-organizational level and measure flexibility at SC level.

3. MEASUREMENT OF FLEXIBILITY IN SC

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, supply chains 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. Beamon (1999) discussed two types of flexibility: (i) Range flexibility and (ii) 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.

Literature indicates several advantages of flexible supply chains (Beamon, 1999; Hoek et al., 2001 and Li et al. 2009). Significant of them are enumerated as under:

- Reductions in the number of backorders.
- Reductions in the number of lost sales.
- Reductions in the number of late orders.
- Increased customer satisfaction.
- Ability to respond to and accommodate demand variations, such as seasonality.
- Ability to respond to and accommodate periods of poor manufacturing performance (machine breakdowns).

- Ability to respond to and accommodate periods of poor supplier performance.
- Ability to respond to and accommodate periods of poor delivery performance.
- Ability to respond to and accommodate new products, new markets, or new competitors.

Flexibility measures are different from resource and output measures in many aspects. Slack (1983) indicates that flexibility measures potential behavior, whereas other operational objectives are actually demonstrated by the system's operating behavior (performance). Therefore, flexibility does not have to be demonstrated by the system in order to exist. Beamon (1999) identified four types of SC flexibility; they are:

- **Volume flexibility**. It 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 supply chain system within range of volumes that are profitable.

- **Delivery flexibility**. It is the ability to change planned delivery dates. Delivery flexibility is measured as the percentage of slack time by which the delivery time can be reduced.

- **Mix flexibility**. It 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.

- **New product flexibility**. It 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.

Hoek et al. (2001) conducted an audit of agility in the SC and introduced agility as an emerging management concept centered on responsiveness to dynamic, turbulent markets and customer demand. Based on this audit it was established that customer sensitivity is the key element in SC agility. The other factors of SC agility constructs are Virtual integration, Process integration and Network integration.

Li et al. (2009) developed an instrument for measuring supply chain agility. They developed a 12-item instrument with six dimensions per item. The instrument has been validated through research. The proposed methodology can be used to examine the links between SC agility-related variables, SC agility, and outcomes of agility.

4. DEA FOR PERFORMANCE MEASUREMENT

DEA is a performance measurement technique developed by Charnes et al. (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. In DEA, efficiency is defined as:

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

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. The envelope, or frontier, becomes the surface linking all units whose relative efficiency cannot be exceeded. By definition units on that 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.

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).

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

S.t.

$$\left(\frac{\sum_{k=1}^{s} v_k \; y_{ki}}{\sum_{j=1}^{m} u_j x_{ji}} \right) \le 1 \qquad \forall\ i \qquad\qquad [1]$$

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

Where: k = 1 to s; j= 1to 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 [1] 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):

$$Max \left(\sum_{k=1}^{s} v_k \; y_{kp} \right)$$

$$s.t. \; \sum_{j=1}^{m} u_j \; x_{jp} = 1$$

$$\left(\sum_{k=1}^{s} v_k \; y_{ki} - \sum_{j=1}^{m} u_j \; x_{ji} \right) \le 0 \qquad \forall\, i \qquad\qquad [2]$$

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

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. So the v_k and u_k values gives output and input weight ages corresponding to max relative efficiency possible for the DMU considered.

Benchmarking in 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 [2].

Min E

Subjected to:

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

$$\sum_{i=1}^{n} \lambda_i x_{ki} \leq E.x_{kp} \quad \forall k \qquad [3]$$

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

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.

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. DEA approach has the following benefits which make it suitable for bench marking in SC:

- DEA deals with individual cases (Madu et al, 1998).
- It can produce a single measure for each company (Madu et al, 1998).
- It places no restriction on the functional form of the input-output relationship.
- Able to handle disproportionate multiple inputs and outputs (George et al. 2009)

- Does not requiring the decision maker any priory arbitrary weights(George et al. 2009).
- It focuses on revealed best-practice frontiers rather than on central tendency properties of empirical data (Madu et al, 1998).
- It can provide an indication of the levels of improvement needed before an inefficient company could be considered efficient (Talluri 2000).

5. DEMONSTRATION OF USING DEA FOR BENCHMARKING FLEXIBILITY IN SC

SC Model

A simplified and generic approach to SCPMS has been adopted to demonstrate using of DEA for bench marking Flexibility. The supply chain model considered is shown in Figure 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.

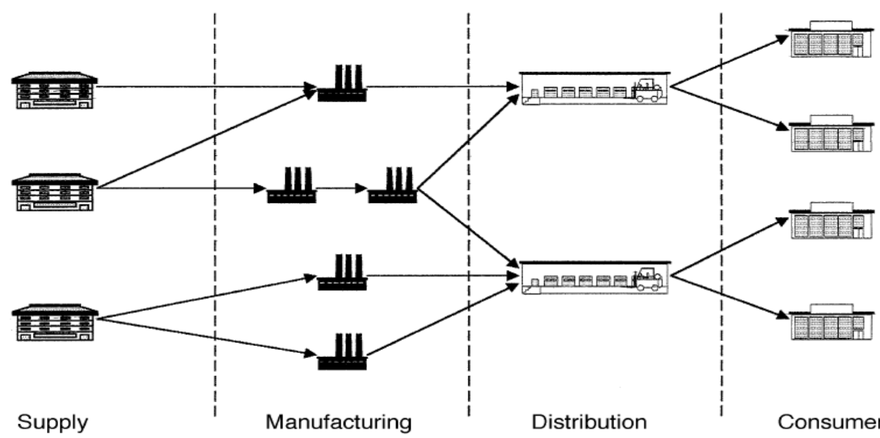

Figure 1. Supply Chain

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 1.

Table 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)

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.

$$F_v = P\left(\frac{O_{\min} - \bar{D}}{S_D} \leq D \leq \frac{O_{\max} - \bar{D}}{S_D}\right)$$

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

Where:

O_{min}, O_{max} - Minimum and maximum profitable output volume.

D - Demand volume which is a random variable with an approximate normal distribution with $\bar{D}$ as the arithmetic mean and S_D as the standard deviation.

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

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).

Data set

Data set for six SCs under considerations (DMU) are given at Table 2.

Table 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

DEA formulation

The benchmarking is done by solving the dual of the DEA given at model [3]. 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.

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 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 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 4.

Table 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

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. 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. 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

6. CONCLUSION

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). 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.

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APPENDIX

DEA FORMULATION FOR THE CASE UNDER STUDY

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 (3nd DMU), the LPP formulation:

Min E
s.t.

$7.85\ \lambda_{11} + 6.00\ \lambda_{12} + 5.75\ \lambda_{13} + 6.55\ \lambda_{14} + 7.00\ \lambda_{15} + 7.25\ \lambda_{16} \geq 5.75$ (xiii)
$4.74\ \lambda_{21} + 4.35\ \lambda_{22} + 3.87\ \lambda_{23} + 4.02\ \lambda_{24} + 4.34\ \lambda_{25} + 5.00\ \lambda_{26} \geq 3.87$ (xiv)
$1.25\ \lambda_{31} + 1.33\ \lambda_{32} + 1.45\ \lambda_{33} + 1.33\ \lambda_{34} + 1.12\ \lambda_{35} + 1.31\ \lambda_{36} \geq 1.45$ (xv)
$0.95\ \lambda_{41} + 0.85\ \lambda_{42} + 1.12\ \lambda_{43} + 0.95\ \lambda_{44} + 0.85\ \lambda_{45} + 0.97\ \lambda_{46} \geq 1.12$ (xvi)
$71\ \lambda_{51} + 74\ \lambda_{52} + 62\ \lambda_{53} + 55\ \lambda_{54} + 65\ \lambda_{55} + 66\ \lambda_{56} \leq 62E$ (xvii)
$77\ \lambda_{61} + 85\ \lambda_{62} + 95\ \lambda_{63} + 85\ \lambda_{64} + 97\ \lambda_{65} + 63\ \lambda_{66} \leq 95E$ (xviii)

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

Min E
s.t.

$7.85\ \lambda_{11} + 6.00\ \lambda_{12} + 5.75\ \lambda_{13} + 6.55\ \lambda_{14} + 7.00\ \lambda_{15} + 7.25\ \lambda_{16} \geq 6.55$ (xix)
$4.74\ \lambda_{21} + 4.35\ \lambda_{22} + 3.87\ \lambda_{23} + 4.02\ \lambda_{24} + 4.34\ \lambda_{25} + 5.00\ \lambda_{26} \geq 4.02$ (xx)
$1.25\ \lambda_{31} + 1.33\ \lambda_{32} + 1.45\ \lambda_{33} + 1.33\ \lambda_{34} + 1.12\ \lambda_{35} + 1.31\ \lambda_{36} \geq 1.33$ (xxi)
$0.95\ \lambda_{41} + 0.85\ \lambda_{42} + 1.12\ \lambda_{43} + 0.95\ \lambda_{44} + 0.85\ \lambda_{45} + 0.97\ \lambda_{46} \geq 0.95$ (xxii)
$71\ \lambda_{51} + 74\ \lambda_{52} + 62\ \lambda_{53} + 55\ \lambda_{54} + 65\ \lambda_{55} + 66\ \lambda_{56} \leq 55E$ (xxiii)
$77\ \lambda_{61} + 85\ \lambda_{62} + 95\ \lambda_{63} + 85\ \lambda_{64} + 97\ \lambda_{65} + 63\ \lambda_{66} \leq 85E$ (xxiv)

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

Min E
s.t.
$7.85\ \lambda_{11} + 6.00\ \lambda_{12} + 5.75\ \lambda_{13} + 6.55\ \lambda_{14} + 7.00\ \lambda_{15} + 7.25\ \lambda_{16} \geq 7$ (xxv)
$4.74\ \lambda_{21} + 4.35\ \lambda_{22} + 3.87\ \lambda_{23} + 4.02\ \lambda_{24} + 4.34\ \lambda_{25} + 5.00\ \lambda_{26} \geq 4.34$ (xxvi)
$1.25\ \lambda_{31} + 1.33\ \lambda_{32} + 1.45\ \lambda_{33} + 1.33\ \lambda_{34} + 1.12\ \lambda_{35} + 1.31\ \lambda_{36} \geq 1.12$ (xxvii)
$0.95\ \lambda_{41} + 0.85\ \lambda_{42} + 1.12\ \lambda_{43} + 0.95\ \lambda_{44} + 0.85\ \lambda_{45} + 0.97\ \lambda_{46} \geq 0.85$ (xxviii)
$71\ \lambda_{51} + 74\ \lambda_{52} + 62\ \lambda_{53} + 55\ \lambda_{54} + 65\ \lambda_{55} + 66\ \lambda_{56} \leq 65E$ (xxix)
$77\ \lambda_{61} + 85\ \lambda_{62} + 95\ \lambda_{63} + 85\ \lambda_{64} + 97\ \lambda_{65} + 63\ \lambda_{66} \leq 97E$ (xxx)

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

Min E
s.t.
$7.85\ \lambda_{11} + 6.00\ \lambda_{12} + 5.75\ \lambda_{13} + 6.55\ \lambda_{14} + 7.00\ \lambda_{15} + 7.25\ \lambda_{16} \geq 7.25$ (xxxi)
$4.74\ \lambda_{21} + 4.35\ \lambda_{22} + 3.87\ \lambda_{23} + 4.02\ \lambda_{24} + 4.34\ \lambda_{25} + 5.00\ \lambda_{26} \geq 5.00$ (xxxii)
$1.25\ \lambda_{31} + 1.33\ \lambda_{32} + 1.45\ \lambda_{33} + 1.33\ \lambda_{34} + 1.12\ \lambda_{35} + 1.31\ \lambda_{36} \geq 1.31$ (xxxiii)
$0.95\ \lambda_{41} + 0.85\ \lambda_{42} + 1.12\ \lambda_{43} + 0.95\ \lambda_{44} + 0.85\ \lambda_{45} + 0.97\ \lambda_{46} \geq 0.97$ (xxxiv)
$71\ \lambda_{51} + 74\ \lambda_{52} + 62\ \lambda_{53} + 55\ \lambda_{54} + 65\ \lambda_{55} + 66\ \lambda_{56} \leq 66E$ (xxxv)
$77\ \lambda_{61} + 85\ \lambda_{62} + 95\ \lambda_{63} + 85\ \lambda_{64} + 97\ \lambda_{65} + 63\ \lambda_{66} \leq 63E$ (xxxvi)