Multi-dimensional Modeling for
Performance Evaluation of Indian Corporate Organizations

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ABSTRACT

To sustain and excel in this competitive environment, business managers need to continually improve their operational performance. Hence, there is a need for a comprehensive multidimensional performance measurement system which is robust, dynamic and efficient to evaluate the current status of the business. In the present study, four performance evaluation (Multi-Criteria Decision Making (MCDM)) tools namely Data Envelopment Analysis (DEA), Super Efficiency DEA (SDEA), Technique for Order of Preference with Similarity to Ideal Solution (TOPSIS) and Stochastic Frontier Analysis (SFA) have been studied. Further, an attempt has been made to look for possible integration of these tools so as to propose different integrated models which are suitable for different business scenarios. The proposed models are Efficiency Ranking Method using DEA and TOPSIS called ERM-DT, Efficiency Ranking Method using SFA and TOPSIS called ERM-ST and Efficiency Ranking Method using SFA and SDEA called ERM-SSD.

The proposed models are applied to a set of hypothetical data which is randomly generated to gauge the suitability and applicability. Further, each model is applied to the real data set obtained from Indian PSU Banks (representing the service sector) and from Indian Cement companies (representing the manufacturing sector). Each of the proposed models is compared with the conventional model for its performance using Spearman’s rank test and Mean Squared Deviation (MSD) method. Finally, all the proposed models are being compared for their performance in terms of ranks assigned by each of them to every alternative/DMU under study.

1. MOTIVATION

The assessment of the performance of business organization is given unprecedented publicity for reasons related to stringent market conditions, growing competition and dynamic nature of the business environment. Business managers are under constant pressure to improve their operations competitiveness. For several years, business managers in a broad range of industries have been reworking on the methodology to measure the performance of their businesses. Over the years, academics and practitioners have begun to demonstrate that accrued-based performance measures are best obsolete and more often harmful (Donald Curtis, 1987). Moreover, they are static and are computed at the end of a financial period. Many practitioners believe that income-based financial figures are better at measuring the consequences of
yesterday’s decision than they are at indicating tomorrow’s performance (Eccles, 1991). Measuring and evaluating the present status of an organization, considering various dimensions including the financial, operational, economical, and supply chain that are tangible and intangible is a challenge. For this reason, there is a need for a comprehensive performance measurement system.

2. PILOT STUDY
The primary objective of this study was to understand and study the management practices and various performance evaluation systems that are prevalent in Indian corporate organizations. For this purpose, a pilot study of more than hundred corporate organizations representing both service and the manufacturing sector was undertaken. Further, the questionnaire was designed to get the required information from the Indian corporates. Responses were obtained from the experts. These experts were identified on the basis of their job profile. They were among the higher management group in the organization in the strategic role either the operational head or higher authority in the corporate office having decision making power and who were responsible for monitoring the overall performance of their business unit.

Questions were asked related to following key areas.

- Criteria used for performance evaluation
- Techniques used for this purpose
- Comparison of performance with peers
- Rating of present performance evaluation system on the basis of five parameters like accuracy, sustainability, applicability, ease of output and suitability for decision making.

Respondents were asked to rate their present performance evaluation system on the five point Likert scale with five being excellent and one being very poor.

Hypotheses Testing for Pilot Study
In order to study the overall rating of the performance evaluation system used by Indian corporate organizations on the basis of five different parameters namely: accuracy, sustainability, applicability, ease of output and suitability, five different hypotheses were tested which are listed below:
Hypothesis 1: Average accuracy ratings are equal across both the categories (manufacturing and services).

Hypothesis 2: Average sustainability ratings are equal across both the categories.

Hypothesis 3: Average applicability ratings are equal across both the categories.

Hypothesis 4: Average ease of output ratings are equal across both the categories.

Hypothesis 5: Average suitability for decision making ratings are equal across both the categories.

The above stated hypotheses were tested using non-parametric Mann Whitney test U test at 5% level of significance. All the hypotheses (except hypothesis 5) were accepted suggesting the fact that the average ratings of the current performance measurement system given by both service and manufacturing industry are the same on the basis of accuracy, sustainability, applicability and ease of the output. Hypothesis 5 was rejected showing some difference in the average rating given by both the industries on the basis of suitability of the current performance evaluation system. But, the average performance ratings of all five parameters were found to be between 3.22 and 3.54 out of 5, which were well under 4. The present work therefore prompts applicability of performance evaluation schemes across all sectors, especially manufacturing and services.

3. LITERATURE REVIEW

A review of literature of various applications of performance evaluation techniques such as Data Envelopment Analysis (DEA), Super Efficiency DEA (SDEA), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and Stochastic Frontier Analysis (SFA) in variety of fields of business was undertaken. Findings of this exercise, paved the way towards the development of the proposed methodologies in the areas specified. This comprehensive survey of the literature in the areas of application of DEA, SDEA, TOPSIS and SFA was carried out in order to establish their credentials for the proposed use of their integrated approaches. The literature review established the research gaps and the scope of research with respect to the use of these established techniques in an integrated approach so as to make the best use of their individual strengths.
Literature review of papers on DEA and SDEA

DEA is a non-parametric benchmarking tool originally developed by Farrell (1957) and further extended by Charnes, Cooper and Rhodes (1978), which measures the relative efficiency of a set of firms that use a variety of identical inputs to produce a variety of identical outputs. The individual unit in this set of firms is referred to as Decision Making Unit (DMU). This is an independent unit which uses multiple inputs to produce multiple outputs. The performance of DMU is measured in DEA using the concept of efficiency or productivity, which is defined as the ratio of total outputs to total inputs. The best performing unit in the set of DMUs is assigned a score of 100 percent or 1 and the remaining DMUs get a score ranging between 0 and 100 percent or equivalently between 0 and 1 relative to the score of best performing DMU. SDEA is an extension of DEA which is developed by Andersen and Petersen (1993) with the aim to enhance the discrimination power of DEA.

In the first phase of the literature review, number of applications of DEA and SDEA are studied in detail. Out of variety of applications of DEA, a select few articles are discussed in the literature review chapter, which could be of wide interest to the researchers and practitioners. Articles are classified according to the identified themes, and on the basis of area of applications. The themes considered here are selection, ownership, target setting, managerial implications, optimization, allocation, ranking, efficiency, benchmarking and performance evaluation. Papers are further classified on the basis of the area of application. Chosen areas of application are: education, finance, healthcare, hospitality, agriculture, energy etc. A summary of key observations in each of the themes is also presented. It is hoped that this work will provide a ready reference on DEA and act as an informative summary kit for the researchers and practitioners for their future work.

Literature review of papers on TOPSIS

In the second phase of the literature review, different applications of TOPSIS are studied. Technique of Order Preference by Similarity to Ideal Solution (TOPSIS), since its invention, has been a tool at the hands of decision makers and researchers; and it is one of the most widely used multiple criteria decision-making tools (MCDM). TOPSIS was first proposed by Hwang and Yoon (1981). The technique is a multi-criteria decision making tool having four components namely; goal, objectives, criteria and alternatives. TOPSIS is based on a principle which selects...
an alternative which is close to the positive ideal solution and as far from the negative-ideal solution as possible. The ideal solution is formed as a composite of the best performance values exhibited (in the decision matrix) by any alternative for each attribute. The negative-ideal solution is the composite of the worst performance values.

Many outstanding works based on TOPSIS have been published in the literature. They include applications of TOPSIS in different fields such as selecting a best alternative, performance evaluation, ranking of the alternatives, planning, optimization, decision making etc. In this study, different applications have been classified into six themes such as selection, evaluation, ranking, decision-making, optimization and allocation. These articles are further classified based on areas of applications like personal, engineering, technology, social etc.

*Literature review of papers on SFA*

Stochastic Frontier Analysis (SFA), an econometric model based on the concept of stochastic production frontier since its invention, has been used quite often by decision makers and researchers. Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) almost at the same time proposed this model. It facilitates the estimation of the maximum possible production given a set of inputs or the minimum possible cost of a set of outputs. SFA defines a stochastic frontier with a probability distribution. The production function specification of SFA can be either Cobb-Douglas (linear logs of output and input) or quadratic (in input) or normalized quadratic or a Translog function where the Translog function is the generalization of the Cobb-Douglas function.

In the literature review, various articles are studied with a view to understand the spread of the SFA applications in different fields. For the convenience, these applications have been classified into different themes. Different themes considered are agriculture, finance, energy etc. Papers are further classified on the basis of the area of application such as social, political and personal.

4. **OBJECTIVES OF THE STUDY**

Following aims and objectives were identified from the literature review and pilot study:

- To look for possibilities and develop model/s that will suit different requirements for evaluating a multi-dimensional performance of a business unit.
• To develop a framework using two or more MCDM tools to benchmark the best performance of a business unit as compared to the best and the worst in the similar business vertical.

• To develop a framework using two or more MCDM tools to benchmark the average performance of a business unit as compared to the best and the worst in the similar business vertical which will account for random error.

• To develop a framework using two or more MCDM tools to benchmark the average performance of a business unit as compared to only the best in the similar business vertical which will account for random error.

• To evaluate and analyze the performance of any corporate organization using the proposed model/s.

• To carry a comparative analysis of the different performance evaluation models proposed.

• To conduct an evaluation of the proposed models and gauge its competence ability.

5. THEME OF THE STUDY

Based on the pilot study and the literature review done thereafter four MCDM tools namely DEA, SDEA, SFA and TOPSIS are considered for further study. These techniques are chosen on the basis of their suitability, applicability and flexibility for the proposed integrated approaches. While studying applications of these techniques, it is observed that these techniques have been used in both the manufacturing as well as service sector of the industry globally. Each of these techniques has its own merits and demerits. Hence, in this study, an attempt is made to integrate two or more of these techniques and to propose different efficiency ranking methods which are given below;

1. Efficiency Ranking Method using DEA and TOPSIS (ERM-DT),
2. Efficiency Ranking Method using SFA and TOPSIS (ERM-ST) and
3. Efficiency Ranking Method using SFA and SDEA (ERM-SSD).
After the development of the proposed models, these models are validated using three different data sets namely;

a. Hypothetical data
b. Secondary data from service sector and
c. Secondary data from manufacturing sector

_Hypothetical Data_
In order to apply the proposed models, data have been generated randomly using excel software. A sample of twelve DMUs for the case of two input and two output variables and a sample of eighteen DMUs for the case of three input and three output variables is considered. Depending upon the number of inputs and outputs, data are generated randomly on requisite number of DMUs.

_Secondary Data- Service sector_
As a primary objective of the study is to design and develop a multi-dimensional performance evaluation system for Indian corporate organization/s, which will cater to the different needs of the business, the proposed models are further substantiated by data from banking sector.

_Data from PSU Banks_
Data from twenty-six PSU banks operating in India and listed on the NSE are considered for the validation purpose. These twenty-six Public Sector Banks (PSBs) control more than ninety percent of all deposits, assets and credits of the Indian banking sector. The parameters on which data are collected are as follows:

- Net Profit
- Total Income
- Operating Expenses
- Total Assets
- Total Business and
- Number of Employees

Data are obtained for the financial year 2012-13 from official website of Indian Bank Association.
Data from a Nationalized Bank operating in India

Data from a premier nationalized bank operating in India which has the largest network of branches in any public sector bank in the state of Maharashtra has been considered for the validation purpose. The parameters on which data are collected are as follows:

- Total Business
- Total Income
- Operating Expenses and
- Number of Employees

The selection of the parameters was done in consultation with the banks’ management. Data were collected directly from the Head Office of the bank.

Secondary Data-Manufacturing sector

In order to validate these proposed models using data from manufacturing sector, data from fifteen cement companies listed on NSE are considered in the sample. Data for the financial year 2012-13 are considered. The sample of fifteen companies is selected based on the fact that these fifteen companies together cover more than ninety percent of the market capitalization in the cement sector.

Data for following parameters are considered for the analysis.

- Net sales
- Net profit
- Assets
- Employee cost

6. METHODOLOGY OF THE PROPOSED MODELS

The proposed methodologies are explained in brief as follows:

Efficiency Ranking Model using DEA and TOPSIS (ERM-DT)

The stepwise proposed Efficiency Ranking Model using DEA and TOPSIS (ERM-DT) is explained below. In the first stage, efficiency of DMUs or different decision alternatives are measured using CRS-DEA model (Charnes et al. 1978), based on Farrell (1957) and in the
second stage, TOPSIS model (proposed by Hwang and Yoon, 1981) is applied to find the best alternative by ranking these alternatives. The procedure is outlined as follows:

**Step 0: Initialization:**
Identify ‘n’ DMUs to be evaluated with ‘k’ inputs and ‘l’ outputs.

**Step 1:**
Identify and compute ‘l x k’ ratios of output to input (with single output in the numerator and single input in the denominator) as given by expression 4.4, on the basis of which each DMU is to be evaluated. Let this number be ‘m’.

**Step 2:**
Consider these ratios as the criterion value for each alternative. Out of the ‘m’ dimension some may be benefit (more the better) and some may be cost (less the better) criteria. This forms the decision matrix. The individual member of this decision matrix is denoted by $x_{ij}$ where $i=1,...,n$ (DMUs) and $j =1,...,m$ (Criterion).

Next, normalize these scores $x_{ij}$ using the following equation:

$$\frac{x_{ij}}{x^*_{ij}} \quad \text{where} \quad x^*_{ij} = \max\{x_{ij}\}; i = 1,...,n$$

Designate these scores by $v_{ij}$

The weights in the proposed approach are considered to be equal for all the criteria.

**Step 3:**
Determine the ideal solution $A^*$ as a set of maximum values $v^*_j$ with respect to each criterion $j$ and negative ideal solution $A^-$ as a set of minimum values $v^-_j$ with respect to each criterion $j$ these values are given by

$$A^* = \{v^*_1, v^*_2, v^*_3,..., v^*_m\}$$

$$A^- = \{v^-_1, v^-_2, v^-_3,..., v^-_m\}$$

Where, $v^*_j = \{\max (v_{ij})\}$ if $j$ is benefit criterion (for desirable output)

$= \{\min (v_{ij})\}$ if $j$ is cost criterion (for undesirable output)

$v^-_j = \{\max (v_{ij})\}$ if $j$ is cost criterion (for undesirable output)

$= \{\min (v_{ij})\}$ if $j$ is benefit criterion (for desirable output)
Step 4:
Calculate the separation measures $S_i^*$ and $S_i^-$ for each alternative (DMU) where $S_i^*$ represents separation measure from the ideal solution and $S_i^-$ represents the separation measure from the negative ideal solution.

Where,

$$S_i^* = \sqrt{\sum_{j=1}^{m} (v_j^* - v_{ij})^2}$$

$\forall i = 1,2 \ldots, n$

$$S_i^- = \sqrt{\sum_{j=1}^{m} (v_j^- - v_{ij})^2}$$

$\forall i = 1,2 \ldots, n$

Step 5:
Calculate the relative closeness to the ideal solution $C_i^*$, where

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*}$$

where, $0 < C_i^* < 1$

Step 6:
Rank the DMUs in the descending order of $C_i^*$.

Efficiency Ranking Model using SFA and TOPSIS (ERM-ST)

The ten step procedure is explained as follows:

Step 1:
Identify ‘$n$’ DMUs or alternatives to be evaluated with ‘$k$’ inputs and ‘$l$’ outputs.

Step 2:
Define various combinations by considering single output and multiple inputs. Apply stochastic frontier analysis with error component model to compute efficiency. The efficiencies thus computed will be for various output combinations. For instance, for two inputs and two outputs case, there will be six combinations, three each for every output. In case, if the efficiency values obtained for a particular combination are similar, then one may ignore that combination from
further analysis as it will not have any impact on the performance measure. The various combinations so obtained are called dimensions.

**Step 3:**
For the efficiencies obtained in step 2, construct the correlation coefficient matrix $R = [r_{ij}]$ where $r_{ij}$ denotes correlation coefficient between the technical efficiencies obtained for the $i^{th}$ and the $j^{th}$ dimension. Indicate a correlation between the dimensions of the magnitude greater than or equal to 0.85 as ‘1’ and correlations coefficient lower than 0.85 as ‘0’. This is done to identify if there is good correlation between the dimensions under consideration. It is proposed that the decision maker may choose a different value, indicating good correlation between the dimensions.

**Step 4:**
Apply Binary Ordering Algorithm (BOA), to get the block structure so that the criteria are dependent of each other within the block and are independent of each other between the blocks. BOA eliminates dependent criteria and selects independent criteria thus reducing the bias or duplication in decision making.

**Step 5:**
Select the dimension from each block that has maximum number of other dimension dependent on it. In case of a tie, pick up the criterion randomly. This will form a set ‘C’ of criteria which will be considered as the final set on the basis of which the set of DMUs will be evaluated. Let there be ‘m’ such criteria in the set ‘C’.

For each of these ‘m’ criteria, select efficiency scores ($e$) obtained using SFA model for all DMUs and form matrix ‘E’ where, $E = [e_{ik}]; i = 1, ..., n$ (DMUs) and $k = 1, ..., m$ (selected criteria).

**Step 6:**
From the decision matrix ‘E’, construct a normalized decision matrix $P = [p_{lk}]$. Normalize scores are obtained using following expression.

$$p_{lk} = \frac{e_{ik}}{\sqrt{\sum e_{ik}^2}} \text{ for } i = 1, ..., n; k = 1, ..., m$$

Get a weighted score $v_{lk}$ where $v_{lk} = w_k * p_{lk}$ by multiplying each entry of the normalized decision matrix by its associated weight (in the present case under consideration, weights for all the criteria are assumed to be equal hence the weight assigned is $1/m$, where ‘m’ is the number of
selected criteria. Alternatively, this step may be skipped altogether to arrive at same results. However, if a Decision Maker (DM) wishes to select another weight, construct a weighted normalized decision matrix ‘V’. Denote individual member of this decision matrix by \( v_{ik} \): where \( i=1, ..., n \) (DMUs) and \( k=1, ..., m \) (selected criteria).

**Step 7:**
Identify the maximum and minimum values for each criterion. Determine the ideal solution \( A^* \) (set of maximum values \( v_k^* \) with respect to each criterion) and negative ideal solution \( A^- \) (set of minimum values \( v_i^- \) with respect to each criterion) given by

\[
A^* = \{v_1^*, v_2^*, v_3^*... v_m^*\}
\]

\[
A^- = \{v_1^-, v_2^-, v_3^-... v_m^-\}
\]

Where, \( v_k^* = \{\text{max} \ (v_{ik})\} \) if \( k \) is benefit criterion

\( = \{\text{min} \ (v_{ik})\} \) if \( k \) is cost criterion

\( v_k^- = \{\text{max} \ (v_{ik})\} \) if \( k \) is cost criterion

\( = \{\text{min} \ (v_{ik})\} \) if \( k \) is benefit criterion

**Step 8:**
Calculate the separation measures \( S_i^* \) and \( S_i^- \) for each alternative (DMU) where \( S_i^* \) represents separation measure from the ideal solution and \( S_i^- \) represents the separation measure from the negative ideal solution.

Where,

\[
S_i^* = \sqrt{\sum_{k=1}^{m} (v_k^* - v_{ik})^2}
\]

\( \forall \ i=1,2,...,n \)

\[
S_i^- = \sqrt{\sum_{k=1}^{m} (v_k^- - v_{ik})^2}
\]

\( \forall \ i=1,2,...,n \)

**Step 9:**
Calculate the relative closeness to the ideal solution \( Z_i^* \), where,
\[ z_i^* = \frac{s_i^-}{s_i^- + s_i^+} \text{ where, } 0 < c_i^* < 1 \]

**Step 10:**

Rank the DMUs in the descending order of \( Z_i^* \).

**Efficiency Ranking Model using SFA and SDEA (ERM-SSD)**

The five step procedure is explained as follows:

**Step 1:**

Identify ‘n’ DMUs or alternatives to be evaluated with ‘\( k \)’ inputs and ‘\( l \)’ outputs.

**Step 2:**

Define various combinations/dimensions using each output and all inputs. Apply stochastic production function with error component model of SFA to compute technical efficiency of each DMU. The efficiencies thus computed will be for ‘\( l \)’ output dimensions. For instance, for two inputs and two outputs there will be two such dimensions, one for each output.

**Step 3:**

Use efficiency scores obtained in Step 2 as Input Criteria (IC) and output as dummy variable with constant value (say 1) (Dummy Output Criterion, DOC). Apply Super Efficiency DEA with input orientation (SDEA-I) model to find efficiency score for each DMU/alternative. This efficiency score is designated as (SSD-I)i, Where i= 1, 2, 3…n. SDEA with input orientation will help in minimizing inputs (resources, cost etc.) for the given level of outputs.

**Step 4:**

Use efficiency scores obtained in Step 2 as Output Criteria (OC) and dummy variable with constant value (say 1) as input (Dummy input Criterion (DIC). Apply Super Efficiency DEA with output orientation (SDEA-O) model to find efficiency score for each DMU/alternative. This efficiency score is designated as (SSD-O)i, Where i= 1, 2, 3…,n. SDEA with output orientation will help in maximizing outputs (revenue, profit, efficiency etc.) for the given level of inputs.
Step 5:

Combine SSD-O and SSD-I values obtained in step 3 and 4 using arithmetic mean to get a combined efficiency score (for each DMU). This efficiency score is called SSD score. Use these SSD efficiency scores to rank the DMUs/alternatives in ascending order of magnitude. In this case, arithmetic mean is used to combine two score; SSD-O and SSD-I so as to give equal weightage to both the scores.

7. HYPOTHESES BUILDING

In order to understand the ranking scheme of proposed models, the ranks assigned by the proposed models to the individual DMUs are compared with those assigned by the conventional performance evaluation model. Following are the hypotheses framed on the basis models proposed.

Hypothesis 1
H0: There is no association/correlation between the ranks of individual DMUs obtained by ERM-DT and CRS-DEA.
H1: There is association/correlation between the ranks of individual DMUs obtained by ERM-DT and CRS-DEA.

Hypothesis 2
H0: There is no association/correlation between the ranks of individual DMUs obtained by ERM-DT and SDEA.
H1: There is association/correlation between the ranks of individual DMUs obtained by ERM-DT and SDEA.

Hypothesis 3
H0: There is no association/correlation between the ranks of individual DMUs obtained by ERM-ST and TOPSIS.
H1: There is association/correlation between the ranks of individual DMUs obtained by ERM-ST and TOPSIS.
Hypothesis 4
H0: There is no association/correlation between the ranks of individual DMUs obtained by ERM-ST and SDEA.
H1: There is association/correlation between the ranks of individual DMUs obtained by ERM-ST and SDEA.

Hypothesis 5
H0: There is no association/correlation between the ranks of individual DMUs obtained by ERM-SSD and CRS-DEA.
H1: There is association/correlation between the ranks of individual DMUs obtained by ERM-SSD and CRS-DEA.

Hypothesis 6
H0: There is no association/correlation between the ranks of individual DMUs obtained by ERM-SSD and SDEA.
H1: There is association/correlation between the ranks of individual DMUs obtained by ERM-SSD and SDEA.

Hypothesis 7
H0: There is no association/correlation between the ranks of individual DMUs obtained by ERM-DT and ERM-ST.
H1: There is association/correlation between the ranks of individual DMUs obtained by ERM-DT and ERM-ST.

Hypothesis 8
H0: There is no association/correlation between the ranks of individual DMUs obtained by ERM-DT and ERM-SSD.
H1: There is association/correlation between the ranks of individual DMUs obtained by ERM-DT and ERM-SSD.

Hypothesis 9
H0: There is no association/correlation between the ranks of individual DMUs obtained by ERM-ST and ERM-SSD.
H1: There is association/correlation between the ranks of individual DMUs obtained by ERM-ST and ERM-SSD.
8. DATA ANALYSIS AND SOFTWARE USED

Objectives of the study are to carry a comparative analysis of different performance evaluation models proposed, to conduct an evaluation of the proposed model and to gauge its competence ability. For this purpose, the proposed models are compared and evaluated for their individual performance based on the ranks assigned by each of them to the set of DMUs under study. The ranks assigned by various approaches are compared with those obtained by conventional models using Spearman’s rank test and Mean Squared Deviation (MSD).

The Spearman’s correlation coefficient is a measure of the linear association between two variables which are available in ordinal scale. That is, it measures the strength of association between two ranked variables. It is the nonparametric version of the Pearson product-moment correlation. Spearman’s rank test is used to test the strength of a relationship between ranks assigned by different criteria to the same set of units. In other words, it tests whether there is association or disassociation between the ranks obtained by two different techniques. A perfect Spearman correlation of +1 or −1 occurs when each of the variables is a perfect monotone function of the other. The test statistic for this test is given by

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}$$

Where
- $\rho$ = Spearman’s rank correlation coefficient
- $n$ = the number of items or individuals being ranked
- $x_i$ = the rank of item $i$ with respect to one variable/criterion
- $y_i$ = the rank of item $i$ with respect to a second variable/criterion
- $d_i = x_i - y_i$

The second method used to compare the ranks assigned by the proposed model and the conventional model is Mean Squared Deviation (MSD). This is calculated by first finding the mean efficiency score for each DMU using each of the models under study. Then different pairs of methods are formed and a squared deviation between the ranks obtained by two methods in the pair is obtained. And finally, a mean of these squared deviations is calculated for each pair of the method. Ideally, this mean should be closer to 0 if there is no difference between the ranks assigned by two different methods in the pair.
Different computer softwares are used in this study for evaluating proposed models. The details are given below.

- For the application of CRS-DEA, DEAP (Data Envelopment Analysis (computer) Program Version 2.1) designed by Prof. Coelli T. J. (Centre for Efficiency and Productivity Analysis (CEPA) The University of New England, Australia) is used.
- For the application of SDEA, DEA-Solver, an add-in which is available with the book by Cooper W. W, Seiford L. M. and ToneK, Data Envelopment Analysis, Springer, 2007 is used.
- For the application of SFA, FRONTIER version 4.1 developed by Prof. Coelli T. J. (Centre for Efficiency and Productivity Analysis (CEPA) The University of New England, Australia) is used.
- For the application of TOPSIS, MS-Excel has been used.

9. ANALYSIS AND FINDINGS
Post development, the proposed models are applied to different sets of data. Each model is illustrated using hypothetical data set with two outputs, two inputs and three outputs, three inputs. Further, the proposed models are validated using data of twenty six Indian PSU Banks and the data obtained from fifteen Cement companies operating in India. Further, ranks assigned by the proposed models are compared with those assigned by the conventional model using Spearman’s rank test and the MSD method.

10. CONCLUSIONS
The characteristics of the proposed models are as follows:

The *ERM-DT model*: This proposed model benchmarks the performance of a DMU obtained (using DEA) with the best and the worst performance (using TOPSIS). The model ranks DMUs based on minimum distance from the best performing alternative/DMU and the maximum distance from the worst performing alternative/DMU. Traditionally, a decision maker looks for the best alternative in order to improve his/her business performance. This approach also proposes a tie breaking procedure, thus enabling better decision making.
The ERM-ST model: The proposed model benchmarks the average performance of a DMU (obtained using SFA) with the performance of the best and the worst DMUs (obtained using TOPSIS). It is seen that SFA is generally not used when data consists multiple outputs. The proposed approach ERM-ST can handle such a case with multiple outputs and multiple inputs without a need to develop an aggregate measure of outputs. While measuring a technical efficiency of a DMU, SFA acknowledges stochastic nature of data and separates random noise from inefficiency and hence, the technical efficiency obtained through SFA can said be more precise. Thus, the proposed model can be of great relevance to a practical situation which generally deals with the data that has random fluctuations.

The ERM-SSD model: The proposed model recommends the best alternative whose average performance (using SFA) is evaluated against the best DMU (using SDEA). It incorporates stochastic nature of the data and measures technical efficiency of a DMU after separating out inefficiency and random shock due to exogenous variables (if any). Major advantage of this model is its applicability with multiple outputs and multiple inputs in an SFA framework. Further, this model can be applied when the data contains exogenous variables. For example, performance of a bank-branch may get affected by number of factors that are out of control of the decision maker such as the geographical location it operates in, population in the vicinity of the branch, number of years of its existence, competitors presence etc. The proposed model ERM-SSD will be most suited in such scenario.
11. SCHEME OF CHAPTERIZATION

The research thesis has the following scheme of chapterization.

Chapter one introduces the concept of Performance evaluation of an organization and its importance in the context of globalization of business environment. It also proposes the research problem for the multi-dimensional performance evaluation of an Indian corporate organization. In the end, it provides an overview of the thesis and its Chapter-wise coverage.

Chapter two begins by explaining the motivation behind this research work and its application in the real world through the pilot study conducted of Indian corporate organizations. Findings of the pilot study further define research gaps which are stated next. Further, a review of the literature of applications of four different MCDM tools such as Data Envelopment Analysis (DEA), Super Efficiency DEA (SDEA), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and Stochastic Frontier Analysis (SFA) is presented.

Chapter Three discusses the research methodology. It states the objectives and scope of the study and discusses the research design adopted in this study. The research design includes data used for the purpose of the study together with hypotheses and proposed models. Various sources of data including hypothetical and secondary have been explained in detail in this section.

Chapter four explains the need to develop the ERM-DT. The proposed model is illustrated with a hypothetical data set and is later applied to the data obtained from PSU banks. The ranks obtained by the proposed model are compared with the conventional models using two different techniques namely; Spearman’s rank test and Mean Squared Deviation (MSD) for their significance.

Chapter five describes need to develop the model ERM-ST. Here the model proposed is illustrated with a hypothetical data set and is then applied the data obtained from PSU banks. The ranks obtained by the proposed model are compared with the conventional models using Spearman’s rank test and MSD for their significance.

Chapter six proposes ERM-SSD. It illustrates the model with a hypothetical data set and is then applied the data obtained from PSU banks. The ranks obtained by the proposed model are
compared with the conventional models using two different techniques namely; Spearman’s rank test and Mean Squared Deviation (MSD) for their significance.

Chapter seven compares the models proposed in this study. For this purpose, all the proposed models are applied to a common hypothetical data set and then to the data from banking sector and from the cement sector. The proposed models are compared using Spearman’s rank test and MSD for the agreement or disagreement between the ranks assigned by these approaches.

Chapter eight is the final chapter of the thesis. The chapter summarizes the major findings of the work and their salient features. It draws important conclusions of the methodologies so derived and their applicability in the business world for the purpose of decision making. It further discusses the managerial implications of the new methodology so developed for its advantages and disadvantages. This chapter also discusses the limitations of the proposed methodology. The possible extension of the current study and further scope of the study are explored. The overview of the Thesis is presented in Figure 1.
Selected References


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