Chapter 3
Research Methodology
This chapter 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. In this chapter, the concept behind various proposed integrated models such as Efficiency Ranking Method using DEA and TOPSIS (ERM-DT), Efficiency Ranking Method using SFA and TOPSIS (ERM-ST) and Efficiency Ranking Method using SFA and SDEA (ERM-SSD) is explained in brief. In the end, various statistical tools and computer softwares used for the analysis purpose are explained in detail.

3.1 Introduction

The assessment of the performance of business organization is important due to ever increasing stringent market conditions, growing competition and dynamic nature of the business environment. Business managers are always in the search of potential areas in order to improve their operational competitiveness through product development, innovation, marketing and human resource management techniques. Managers have recognized the need of innovative strategies and competitive realities which demand new measurement systems. During the past few years, academics and practitioners have demonstrated 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).

To remain in the competition and to upgrade the performance continuously, it is necessary to make comparisons with peers. These comparisons may evaluate progress in achieving given goals or targets, assess trends in performance over time, or weigh the performance of one organization against another (Poister, 2003). In today’s stringent market, the Decision Maker (DM) faces enormous challenges in sustaining the business growth. As a result, the decision maker has to evaluate several business alternatives, using multiple criteria before making the final decision in a limited time at his/her disposal. In such a scenario, Multi-Criteria Decision Making (MCDM) tools play an important role in making this process lucid and transparent. 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.

3.2 Objectives of the Study
Based on the above discussion, one may argue that there is a need to evaluate and analyze the performance of organization/s based on multiple performance indicators which will take into account multifaceted objectives of the business and will be comprehensive in nature. Towards this end, following are the aims and objectives for the proposed 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.

3.3 Scope of the Study
One of the objectives of the study is to identify lacunas in the present performance evaluation procedure used by the Indian corporate organization and to develop performance evaluation model/s to satisfy the requirement of the industry.
There are various performance evaluation and benchmarking tools which are used for multi-criteria decision making purpose such as Analytical Hierarchy Process (AHP), Elimination and Choice Expressing Reality (ELECTRE), Multi-Attribute Utility Theory, etc. In this study, four different performance evaluation tools namely; Data Envelopment Analysis (DEA), Super efficiency DEA (SDEA), Technique of Order Preference by Similarity to Ideal Solution (TOPSIS) and Stochastic Frontier Analysis (SFA) are studied in depth for their merits, demerits and applicability in various businesses in the chapter on Literature review. These techniques have been 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 come up with three different efficiency ranking methods namely; Efficiency Ranking Method using DEA and TOPSIS (ERM-DT), Efficiency Ranking Method using SFA and TOPSIS (ERM-ST) and Efficiency Ranking Method using SFA and SDEA (ERM-SSD).

3.4 Research Design

The primary objective of the study is to look for possibilities and develop a model/s by combining various tools that will evaluate and analyze a multi-dimensional performance of any corporate organization. For this purpose, following research design is adopted.

3.4.1 Pilot Study

The primary objective of this study was to study and understand the management practices and various performance evaluation systems that are prevalent in Indian corporate organizations. For this purpose, a random sample of three hundred organizations from manufacturing and service sector were selected from Confederation of Indian Industry (CII) data base. Further, the questionnaire (attached in Appendices) was designed in consultation with the guide and industry experts to get the required information from the Indian corporates. Though the organizations were selected randomly, the data was collected 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 5 parameters namely; accuracy, sustainability, applicability, ease of output and suitability for decision making.

Out of the sample of three hundred organizations, response was obtained from hundred and one companies.

*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 hypothesis were tested using non-parametric Mann-Whitney test which is explained in detail in Chapter 2.

3.4.2 *Literature Review*

Total of 243 research papers/articles and few books are reviewed in this study. This review is presented in three different sections. Each section introduces MCDM tool studied followed by the review of literature. In the first section, review of literature of applications of DEA and SDEA is presented. In Section two, literature review of applications of TOPSIS is presented and in Section three, review of literature of applications of SFA is presented.

3.4.3 *Main 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 come up with three 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).

3.4.4. Data

After the development of the proposed models, these models are validated using three different data sets namely;

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

Hypothetical Data

In order to apply the proposed models, data have been generated randomly using excel software. For tools like CRS-DEA and SDEA, in the literature, researchers have come up with the thumb rule to decide on the number of DMUs to be considered in the sample. According to this rule, the desired number of DMUs to be selected in the sample is approximately 2.5 to 3 times the total number of input and output variables (Andersen and Petersen, 1993; Shang and Sueyoshi, 1995; Seiford and Zhu, 1999; Zhu, 2001; Saen, 2008). This number ensures better discrimination power for these tools. Hence, in this research, we have considered a sample of 12 DMUs for the case of 2 input and 2 output variables and a sample of 18 DMUs for the case of 3 input and 3 output variables. 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 (www.rbi.org.in). 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 (www.iba.org.in)

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 (from [www.moneycontrol.com](http://www.moneycontrol.com)) for following parameters are considered for the analysis.

- Net sales
- Net profit
- Assets
- Employee cost

### 3.5 Methodology of Proposed Models

In this study, three different efficiency ranking methods/models are proposed. These models have been devised for the purpose of evaluating the performance of a corporate organization and further ranking its performance on the basis of an efficiency score assigned by these models. While developing these models, each of the MCDM tools has been examined carefully for its advantages and disadvantages. The tools considered for this purpose are DEA, Super efficiency DEA (SDEA), TOPSIS and SFA. Each of these tools evaluates the performance of a DMU in different ways and assigns an efficiency score. These different methodologies have been explored further for the purpose of developing integrated approaches. Efforts are made to preserve individual strengths and overcome some of the limitations of the integrating techniques while proposing a new approach. The proposed methodologies are explained in brief as follows:

**Efficiency Ranking Method using DEA and TOPSIS (ERM-DT)**

The proposed model considers two MCDM tools namely; DEA and TOPSIS which are non-parametric in nature. Through this approach, an attempt has been made to address the issue of ‘unique ranking’ in conventional DEA. DEA is a benchmarking tool which measures the performance of a business unit with respect to the best performing unit in a group of units under evaluation. The best performing unit called an efficient unit achieves the maximum score of 1 and the less performing units called inefficient unit gets a score between 0 and 1. TOPSIS is another non-parametric tool which recommends the best alternative/DMU based on the concept of Euclidian distance. The proposed framework called Efficiency Ranking Method using DEA and TOPSIS (ERM-DT), is based on the theme of identifying the DMU, which is not only closer to the best solution (or frontier), but also away from the worst solution (or frontier).
The proposed framework, called Efficiency Ranking Model using DEA and TOPSIS (ERM-DT) enables obtain:

a) A unique ranking scheme for each of the DMU.
b) Improve discrimination power of DEA analysis.
c) Handle undesirable outputs.
d) Assign efficiency (or distance) based on the best and the worst efficiency frontier.
e) A benchmarking technique.

The proposed integrated approach using DEA and TOPSIS called ERM-DT is explained in detail in Chapter 4.

**Efficiency Ranking Method using SFA and TOPSIS (ERM-ST)**

This model works on the theme of integration of two MCDM tools namely: SFA and TOPSIS. SFA is a parametric technique that uses standard production function methodology. The model acknowledges the stochastic nature of the real time data and accounts for random error. SFA evaluates the performance of a DMU in the sample with respect to the average performance of the group of DMUs. The individual DMU is assigned an efficiency score between 0 and 1.

This proposed integrated framework ERM-ST will help the decision maker to:

a) Apply SFA framework, with multiple outputs and multiple inputs.
b) Incorporate stochastic nature of the real data and measure technical efficiency of a DMU after separating out inefficiency and random shock due to exogenous variables (if any).
c) Assign distinct efficiency scores and thus uniquely ranks to the DMUs under study.
d) Remove the subjectivity in TOPSIS in assigning values to different alternatives/DMUs.
e) Recommend the best performing unit whose average performance is compared with that of the best and the worst unit in the group.

This model is discussed in Chapter 5.

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

The third proposed approach is based on the theme of integration of two benchmarking tools namely: SFA and SDEA. SFA is a parametric tool whereas SDEA is a non-parametric tool. One of the limitations of DEA is its less discrimination power due to two conditions: a) when the sum of the number of inputs and outputs is large as compared to the total number of DMUs in the sample. b) At times, DEA assigns high efficiency to a DMU due to its very low value of single
input or very high value of output, even though that input or output is seen as relatively unimportant. Therefore, while integrating SFA with DEA a need was felt to look at advanced version of DEA called SDEA which is known for its better discrimination power. The proposed integrated model will help to

- Incorporate stochastic nature of the real data and measure technical efficiency of a DMU after separating out inefficiency and random shock due to exogenous variables (if any),
- Apply SFA with multiple outputs,
- Provide a tie-breaking procedure and
- Recommend the best alternative whose average performance is evaluated against the best DMU in the sample under study.

This model is discussed in Chapter 6.

3.6 Methodology of 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 of three different models proposed in this study namely; ERM-DT, ERM-ST and ERM-SSD.

Hypotheses for ERM-DT model

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.
Hypotheses for ERM-ST model

*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.

Hypotheses for ERM-SSD model

*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.

Hypotheses for comparing proposed models ERM-DT, ERM-ST and ERM-SSD

*Hypothesis 7*

Ho: 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*

Ho: 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**
Ho: 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.

### 3.7 Methodology for Data Analysis and Tools 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 each of these proposed models namely; ERM-DT, ERM-ST and ERM-SSD 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

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\[ d_i = x_i - y_i \]

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.

3.8 Computer Softwares used for Data Analysis

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.

3.9 Conclusions

In this chapter, the research design for the present study is discussed. The research design being described is based on aims and objectives stated earlier. The chapter also elucidates the rationale behind the proposed integrated models such as Efficiency Ranking Method using DEA and TOPSIS (ERM-DT), Efficiency Ranking Method using SFA and TOPSIS (ERM-ST) and Efficiency Ranking Method using SFA and SDEA (ERM-SSD). It further explains various data
sets used for the verification purpose, hypotheses developed for testing these models and various data analysis tool applied for statistical testing purpose. This chapter also provides a list of various computer packages/programs used at various stages of proposed models. The development and the analysis of proposed models have been explained in detail in Chapter 4, 5 and 6 respectively. The developed models are compared for their ranking methodology in Chapter 7. Conclusions are presented in Chapter 8.