Chapter 8
Conclusions
This chapter summarizes the work presented in the thesis and suggests the scope for future work.

8.1 Introduction

The proposed model called ERM-DT is an integration of two MCDM tools namely; DEA and TOPSIS. Through this approach, an attempt has been made to address the issue of ‘unique ranking’ in conventional DEA. The proposed model recommends the best alternative/DMU from the set of alternatives/DMUs that is closest from the ideal solution and at the same time is farthest from the non-ideal solution.

The integrated model called ERM-ST is an integration of two MCDM tools namely; SFA and TOPSIS. The proposed model ERM-ST can handle a case with multiple outputs and multiple inputs without a need to develop an aggregate measure of outputs. Through integration of SFA with TOPSIS, a method is proposed to benchmark average performance of a DMU with the best and the worst performing alternative/DMU in the sample under study.

The proposed model ERM-SSD is an integration of two MCDM tools namely; SFA and SDEA. It acknowledges stochastic nature of data and recommends the best alternative/DMU whose average performance is compared with the best alternative/DMU in the sample under study.

Various models proposed share some common features which are discussed below:

1. All the proposed models are benchmarking tools which benchmark the performance of an individual DMU against the best and the worst (in case of ERM-DT and ERM-ST) or against the best (in case of ERM-SSD) performance of the DMU in the sample of DMUs.
2. Each model measures the relative performance of a DMU in terms of its technical efficiency which can be further ranked.
3. Each model provides tie-breaking method while ranking these DMUs.
4. Each model can consider financial as well as non-financial parameters as input or output variables.

The characteristics of each of the proposed models and its applicability in different business environment are presented herewith.
8.2 Characteristics of Proposed Models

In this study, three efficiency ranking methods have been proposed. These ranking methods are based on different algorithms depending on various integrating tools used for integration. As a result, each one of the proposed methods possesses different characteristics which are explained below:

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

This proposed model ERM-DT is an integration of two MCDM tools namely; DEA and TOPSIS which are non-parametric in nature. Both DEA and TOPSIS have their own advantages and disadvantages which are discussed in Chapter 4 in detail. The new model/s because of integration is able to overcome some of the limitations of each of the integrating tools (in this case DEA and TOPSIS). Some of the advantages are described below:

1. The proposed model ERM-DT is based on two stages. In the first stage, Farrell’s definition is used to compute efficiency of a DMU which is nothing but the ratio of output to input. As a result, efficiency for each DMU in the sample gets computed directly without assigning different weights (rather in this case weights are equal) to different output and input variables. This assignment of unbiased weights avoids or overcomes one of the limitations of conventional DEA of overrating some of the DMUs.

2. The proposed model is also able to overcome another major limitation of DEA which is its poor discrimination power. ERM-DT assigns unique ranks to individual DMU in the sample thus providing a tie-breaking procedure.

3. Another limitation of DEA is that it is gives best results if applied to a group of DMUs which operate in a homogeneous environment. In this study, we have shown that the proposed model can be applied to a set of DMUs who may operate in less homogeneous environment. This is validated by applying the proposed model to 26 PSU Banks and a group of 15 Cement companies operating in India.

4. It is a well-known fact in the literature of DMU that the discrimination power of DEA improves as the number of DMUs becomes larger as compared to the total number of input and output variables. Towards this end, in the literature it is suggested that the total number of DMUs should be at least 2.5 times to 3 times the total number of input and
output variables. Through our proposed model we have shown that for different cases (sample of 12 DMUs for the case of 2 input and 2 output variables, sample of 18 DMUs for the case of 3 input and 3 output variables) ERM-DT provides unique ranking method. On comparing these results with that of DEA, we observe that DEA fails to assign unique ranks even after maintaining the desired ratio.

5. SDEA is an improved version of DEA which was developed by Andersen and Petersen (1993) with the sole aim of improving the discrimination power of conventional DEA. While comparing results of ERM-DT with that of SDEA, we observe that there is significant amount of correlation/agreement between the ranks assigned by ERM-DT and SDEA. However, ranks assigned to different DMUs are not identical. This may be attributed to the fact that the basic algorithms that are used while developing these 2 models are quite different. SDEA benchmarks the performance of an individual DMU with the best among the sample of DMUs. While ERM-DT benchmarks the performance of a DMU obtained in the first stage against the best and the worst performance in the second stage using TOPSIS.

6. In SDEA, because of the inherent characteristic of the algorithm used, at times efficiency score assigned to efficient DMU can go well above 1. So, in case of SDEA there is no upper bound to the efficiency score assigned to efficient DMUs. Whereas, in the proposed approach, efficiency scores are always between 0 and 1 irrespective of the status of individual DMU (efficient or inefficient).

7. For application of SDEA model, a special type of software called DEA-Solver is required. The proposed model can be run through Excel spreadsheet. So, the proposed model is simple in its application as compared to SDEA.

Similar to DEA, TOPSIS also has some limitations. The proposed model is able to overcome some of these limitations through integration of DEA and TOPSIS.

1. In TOPSIS, assignment of values to different alternatives/DMUs is at the discretion of the DM. In the proposed model, assignment of values to different alternatives/DMUs is done using efficiency scores obtained in the first stage. Thus, subjectivity in assigning values is completely removed.
2. In TOPSIS, alternatives/DMUs are evaluated according to the set of various criteria which could be of cost or benefit type. These criteria are assigned different weights depending upon their importance to the decision making process in the TOPSIS model. In the proposed model, this flexibility is maintained. In the model that is presented in this study, we have made an assumption of equal weight to each criterion. However, if it is required, the DM may choose different weights for different criteria.

3. In TOPSIS, criteria values measured in different units of measurement are required to be normalized in order to make evaluation possible; in the present model however, normalization is not necessary as different criteria values are nothing but efficiency scores for DMUs obtained through different combinations of input and output variables which are in the range of 0 to 1.

In this study, the proposed model is applied to various types of data sets and has given similar kind of results. This shows suitability and applicability of the proposed model to different types of data.

The proposed model ERM-DT benchmarks the performance of a DMU obtained in the first stage with the best and the worst performance of the sample of DMUs. The proposed model chooses an alternative/DMU which has the minimum distance from the best performing alternative/DMU and the maximum distance from the worst performing alternative/DMU in the sample under study.

Traditionally, a DM is looking for the best alternative in order to improve his/her business performance. Through the proposed model ERM-DT we have tried to improvise this decision making process by identifying the an alternative which is closest from the best but at the same time which is farthest from the worst alternative.

This type of multi-faceted performance evaluation system will certainly facilitate the DM to bring in more objectivity in the evaluation process of his/her business. It will help the DM to make informed decision by understanding the current status of all alternatives and choosing the best among them. This model will also provide some managerial implications. For example, in case of inefficient DMUs, management can take a decision in either merging that unit with a better performing unit or can even relook at the resource allocation pattern in general in order to
improve the performance of that unit. This new method can be used for setting realistic targets for the DMUs.

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

The proposed model ERM-ST is an integration of non-parametric tool TOPSIS and a parametric tool SFA. Through this model we have tried to overcome few limitations of both TOPSIS and SFA.

1. In the literature, it is seen that SFA as a parametric tool is generally not used when data has multiple outputs. In such cases, either revenue (adjusted for price differences) or an aggregate output function is used as an output measure to study production technology. The proposed approach ERM-ST can handle a case with multiple outputs and multiple inputs without a need to develop an aggregate measure of outputs. The proposed model ERM-ST is able to overcome this shortcoming of SFA. By integrating SFA with TOPSIS, we are able to use multiple outputs with multiple inputs in a SFA framework.

2. SFA benchmarks the performance of a DMU against the average performance of all DMUs in the sample. Through this integration of SFA with TOPSIS, we have tried to benchmark this average performance of a DMU with the best and the worst in the set of DMUs. According to statistical theory, the best and the worst performances are the extremes which affect the average performance to a great extent. So, at times it might become necessary for the DM to pick up an alternative whose average performance is closest from the best and farthest from the worst alternative. Earlier, it is shown using various data sets that there is significant negative correlation/agreement between the ranks assigned by ERM-ST and SDEA. This shows that the ranks assigned by these 2 methods are different. This methodology may provide more robust performance evaluation system for the DM.

3. SFA acknowledges stochastic nature of data and separates random noise from inefficiency. As a result, the technical efficiency obtained through SFA can 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.

4. While integrating SFA and TOPSIS, we have used the concept of BOA which helps in reducing the number of criteria used for the purpose of evaluation to a great extent and
also brings in objectivity while selecting these criteria. This will also help in avoiding the overlapping of the common criteria.

The proposed model is able to overcome some of these limitations through integration of SFA and TOPSIS.

1. In TOPSIS, assignment of values to different alternatives/DMUs is at the discretion of the DM. In the proposed model, assignment of values to different alternatives/DMUs is done using efficiency scores obtained in the first stage. Thus, subjectivity in assigning values is completely removed.

2. In TOPSIS, alternatives/DMUs are evaluated according to the set of various criteria which could be of cost or benefit type. These criteria are assigned different weights depending upon their importance to the decision making process in the TOPSIS model. In the proposed model, this flexibility is maintained. In the proposed model the selected criteria are designated as dimensions. The proposed model assumes equal weight to each dimension. However, if it is required, the DM may choose different weights for different dimension.

3. In TOPSIS, criteria values measured in different units of measurement are required to be normalized in order to make evaluation possible; in the present model however, normalization is not necessary as different dimension values are nothing but efficiency scores for DMUs obtained through different combinations of input and output variables which are in the range of 0 to 1.

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

This is the third model in the series which is an integration of parametric tool SFA and a non-parametric tool SDEA.

1. While developing this model, SDEA is preferred over DEA for the specific reason that SDEA is better than DEA in discriminating efficient DMU and thus provides unique ranking scheme.

2. This proposed model also acknowledges stochastic nature of data and separates random noise from inefficiency. It benchmarks the performance of a DMU against the average performance of all DMUs in the sample in the first stage using SFA and then in the
second stage, this average performance of each DMU is further benchmarked against the performance of the best unit in the group using SDEA.

3. The score obtained by the proposed model will always have bound on both the sides as the score will always lie between 0 and 1. One of the limitations of SDEA of not having the upper bound is thus removed by this method.

4. In a business scenario, at times performance of a business unit may get affected by various exogenous variables. For example, performance of a bank-branch may get affected by number of factors (which are out of control of the DM) such as the geographical location it operates in, population in the vicinity of the branch, number of years of its existence, competitors presence in that location. The proposed model ERM-SSD will be most suited in such scenario. The developed ERM-SSD model can acknowledge the effect of such external factors.

5. Also, the proposed approach can be used for continuous monitoring of the business. For example, in case of a chain of a restaurant, the performance of the individual restaurant is likely to vary over a period of time. Moreover, the performance of an individual unit is likely to get affected by external factors like, the prevalent economic situation, competition by peers etc. Depending upon the current business performance, management may make a decision of closing some of the units, or increasing its resources to boost its performance or even merging some of the less performing units with efficient units.

8.3. Limitations and Scope for Future Study

In this study, three different efficiency ranking methods/models have been proposed for performance evaluation and ranking of DMUs. Each of these models has been validated by different sets of data. There are certain limitations to this study. However, in future, there is a scope to develop an extension to the present study based on existing limitations which are discussed below;

1. In this study, data used for analysis purpose are considered to be non-negative therefore, there exists a scope to use negative data points in future study.
2. In the proposed models, ERM-DT and ERM-ST, all the criteria/dimensions used are assumed to be of benefit type. Hence, in the future work, one may consider some criteria/dimensions which will be of cost type.

3. One of the limitations in applying DEA is that the minimum number of DMUs to be selected in the sample should be at least 2.5 to 3 times more than the total number of input and output variables for ensuring better discrimination power. As a result, the models which have been proposed in this study such as ERM-DT and ERM-SSD also carry the same assumption on requisite number of DMUs. So, in future work, one may devise altogether new algorithm to overcome this limitation of the proposed models.

4. In the proposed model, ERM-DT, DEA with input orientation and constant return to scale has been used.

5. In case of ERM-ST and ERM-SSD, equal weights have been assigned to selected criteria/dimensions for the analysis purpose. Although the proposed models have the flexibility to assign different weights to selected criteria/dimension, one may explore this possibility in future work.

6. While applying these proposed models, data from PSU banks and cement companies which represent the service sector and the manufacturing sector respectively are considered for the validation purpose. In future, one may consider different sectors for validating these models.

7. One of the advantages of DEA is its ability to identify potential areas of improvement for less performing (inefficient) DMUs. This characteristic of DEA can be used for setting targets for inefficient units. In the proposed integrated approaches, it was not possible to incorporate this characteristic of DEA because DEA was either used in the first stage or arithmetic mean of ERM-SSD-I and ERM-SSD-O was considered in the final stage in case of ERM-SSD. In future work, one may try and incorporate this characteristic of DEA in the proposed models.

8. In the proposed model ERM-ST, a threshold point of $r = 0.85$ has been selected for selecting the independent dimensions for the purpose of further analysis. In this case, there is a scope to study the sensitivity analysis by selecting different threshold points.

In a competitive business environment, DM needs efficient and multi-faceted performance evaluation system which will make the complex decision making process simple and more
effective. In this study three different performance evaluation models namely; ERM-DT, ERM-ST and ERM-SSD are proposed for measuring multi-dimensional performance of a corporate organization in different business situations. It is believed that this work will help the business decision makers and the researchers in modifying/selecting/making the best decision for improving their business performance.