SYNOPSIS

Increased energy consumption (especially of electricity) is inevitable with higher GDP growth particularly in economics like India which have embarked on a high economic growth. Economic growth world over is driven by energy, whether in the form of finite resources such as coal, oil and gas or in renewable forms. Apart from oil, coal is another important fossil fuel on which our energy economy demands. Coal accounts for 50% of total commercial energy supplied in India. The rising demand for coal and the inability of the domestic coal production to meet the demand is a challenging task to improve the productivity and reducing cost through technological upgradation.

Coal industry is one of the major public sector units in India. In India Coal India Ltd. (CIL) and Singareni Collieries Company Ltd. (SCCL) are the two major coal producing industries to meet the required energy demand. Past record of this sector does not shows a very encouraging picture in terms of return on investment, productivity improvement and performance improvement. At present the economic policy of Indian Government and the industrial policy are under revolutionary change. Emphasis is being given to the efficient utilization of the existing resources, optimal allocation of funds and dealing with the control measures on meeting the targeted production with higher productivity at minimal expenditure.

To improve the productivity and performances, it is necessary to go for technology optimization i.e. mechanization, semi-mechanization. Due to high labour cost and high investment cost on machinery, it is necessary to optimize both man and machine at optimum level. In this context, it becomes essential for management to select most suitable method for measuring performances and productivity of various units which is very close to actual performance.

Singareni Collieries Company Limited (SCCL) is the only coal mining company in south India. Bulk of coal production in India is from government - owned mines managed by Coal India Limited (CIL) and
Singareni Collieries Company Limited (SCCL). SCCL is a public sector mining organization is the largest producer of coal in India after coal India Limited (CIL) with manpower of 77,000 and catering the energy needs of southern part of India. The company is now operating 42 Underground (UG) mines and 15 Open Cast (OC) mines.

Productivity improvement and cost control have become key objectives of SCCL coal mines in recent years. As a result many research works have carried out on productivity improvement in coal mines. Operation Research techniques like Linear Programming (LP), Non Linear Programming (NLP), Data Envelopment Analysis (DEA), Fuzzy systems, Stochastic Data Envelopment Analysis (SDEA) and Bench marking etc are very popular tools in productive improvement which can aggregate the input and output components in such situations for obtaining an overall performance measure to improve productivity.

**Objectives of the Thesis**

- Selected various coal mines in SCCL and calculated relative efficiency of mines by using Data Envelopment Analysis (DEA) which helps to rank them based on their efficiency score.
- The efficiency score has been calculated based on two approaches of DEA Viz., Constant Return to Scale (CRS) and Variable Return to Scale (VRS) and comparison is made between them for ranking of the coal mines.
- The comparison is made between Input-oriented CRS and Output-oriented CRS, Input-oriented VRS and Output-oriented VRS, Input-oriented CRS and Input-oriented VRS, Output-oriented CRS and Output-oriented VRS.
- Benchmarking and ranking of coal mines based on efficiency scores using advanced DEA models like, Increasing Returns to Scale (IRS), Decreasing Returns to Scale (DRS), Cross Efficiency (CE), Scale Efficiency (SE), Super-Efficiency and Additive model.
• The inefficient coal mines can pursue continuing improvement strategies by adjusting the slack and target values.

• Discussed and analyzed improvement areas of inefficient coal mines and recommended for improving productivity of coal mines by reducing various cost inputs.

Methodology

Data Envelopment Analysis (DEA):

Data Envelopment Analysis (DEA) is a relatively new “data oriented” approach for evaluating the performance of a set of peer entities called Decision Making Units (DMUs) which convert multiple inputs into multiple outputs. DEA is a multi-factor productivity analysis model for measuring the relative efficiency of a homogenous set of coal mines (DMU’s).

For every inefficient coal mine, DEA identifies a set of corresponding efficient coal mines that can be utilized as benchmarks for improvement of performance and productivity. DEA developed based on two scale of assumptions viz., Constant Return to Scale (CRS) model and Variable Return to Scale (VRS) model. Comparison is made between CRS and VRS models.

Benchmarking of coal mines using advanced DEA models:

The output increases by that same proportional change of inputs then there are constant returns to scale (CRS), sometimes referred to simply as returns to scale. If output increases by less than that proportional change, there are Decreasing Returns to Scale (DRS). If output increases by more than that proportion, there is Increasing Returns to Scale (IRS). Cross Efficiency (CE) in DEA allows for effective discrimination between niche performers and good overall performers. Cross efficiency score of a DMU represents how well the unit is performing with respect to the optimal weights of another DMU.
In DEA, Scale Efficiency (SE) is routinely calculated. This measure may, however, tell us very little about whether a production unit is over- or undersized. Super-efficiency data envelopment analysis (DEA) model is obtained when a decision making unit (DMU) under evaluation is excluded from the reference set. Super-Efficiency model is obtained when a decision making unit (DMU) under evaluation is excluded from the reference set. In basic models of DEA, we distinguish between input-oriented and output-oriented models. In this model, we combine both orientations in a single model, called Additive model.

Organization of the Thesis

The present thesis consists of six chapters and the brief summary of each chapter is as follows:

Chapter 1: Introduction to Coal Mining Industry

This chapter gives a brief overview on Global, Indian and Singareni Collieries Company Limited (SCCL) coal industry scenario with focus on coal production, consumption and explains the technical terms necessary to understand the coal mining industry. It covers tools used for coal mining and various types of coals which affects its productivity improvement and price.

Chapter 2: Literature Review

It presents the review of literature on various concepts of productivity. A brief overview of various productivity improvement techniques in coal mines. This chapter provides review on Data Envelopment Analysis (DEA) techniques and applications.
Chapter 3: Concept of Data Envelopment Analysis (DEA)  
Methods and Materials  

This chapter provides the discussion on various DEA models available and their methodologies and applications.

The DEA models includes Constant Returns to Scale (CCR), Variable Returns to Scale (VSR), Increasing Returns to Scale (IRS), Decreasing Returns to Scale (DRS), Cross Efficiency (CE), Scale Efficiency (SE), Super-Efficiency, Stochastic Data Envelopment Analysis (SDEA) and Additive model. In this chapter also discussed weight restrictions in DEA, Applications of DEA in coal mines and extensions of DEA.

Chapter 4: Evaluation of DMUs Using DEA in coal mines  

This chapter provides to evaluate the performance of the Coal mines to establish the bench marking of Under Ground (UG) and Open Cast (OC) mines using Input-oriented and Output-oriented CRS model. Identified the best mines in each category is used as bench mark for improvement productivity of corresponding inefficient coal mines. Calculated virtual efficient inputs or output and target production of mines for improvement by reducing slacks and reducing inputs.

Chapter-5 Benchmarking Of OC Mines Using DEA Models and Methodologies.  

In this chapter carried Benchmarking of 15 Open Cast Mines for improving productivity (Output) using the Variable Return to Scale (VRS) Model (Input-oriented and Output-oriented) and comparison made between the two basic CRS and VRS models. The Correlation is calculated using the Spearman’s rank correlation coefficient and suggested improvements for non-efficient mines. The analysis carried using TORA and DEA Software’s.

The analysis also carried out of OC Mines using some of the advanced DEA Models are Increasing Returns Scale (IRS), Decreasing Returns Scale (IRS), Cross Efficiency (CE), Scale Efficiency (SE) and Additive Model.
Chapter 6 Conclusions and Scope for Future Work

This chapter presents the conclusions of the present research work. The significant contributions of the research are highlighted and the scope for future work is discussed.