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Benchmarking the Performance of State-Owned Power Distribution Utilities

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Abstract

One of the greatest challenges faced by developing nations today is to operate and manage their power industries in efficient and economical way. This study focuses on one aspect of economic performance, namely the efficiency with which electricity is generated. A non-parametric technique, Data Envelopment Analysis (DEA) is used to compare the performance of State Owned Power Distribution Utilities (SOPDU) with those other in similar stage of development. Technical efficiency of electric utility is the critical element for its competitiveness in the Power Market and very relevant in the Indian Power sector presently. This Study is aimed to measure the efficiencies of 16 SOPDU for the year 2011-12 by applying DEA models with single input and two outputs. The result of this model shows that SOPDU are generally inefficient in expenditure frontier and there is an urgent need for intro inspection. This will help for SOPDU. The result shows that the total average of overall, technical and scale efficiencies are 32.7%, 71.6% and 51% respectively. This efficiency measurement assists the utilities by identifying their shortcomings, setting targets and trying to reach the set targets.

Power is recognized as a basic need of the modern human being. 'Electricity for all by 2012' program was a great initiative towards the electricity generation through State Owned Power Distribution Utilities. Ensuring the quality of the product/service is the next most important consumer right (Painuly, 2020). Having standardized, reliable power is of utmost importance for the electricity consumer (Tyagi et al, 2020). Reform of power distribution is today widely viewed as fundamental for improving commercial performance and financial viability of the power sector in India (Vishwakarma and Tyagi, 2017). Few States worked on PPP model and took private sector help in CSR fund utilization (Tyagi, 2012) For example by promoting ICT usage (Tyagi and Chawla, 2017; Tyagi et al., 2021). To improve the commercial performance of their state utilities, unbundling state entities, creating more independent regulatory

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systems, and putting in place measures to control losses and theft. However, in respect of electricity consumer's interest, the progress has been very slow and slower than many originally hoped. Only few State Owned Power Utilities (SOPUs)/ Distribution Companies (Discoms) in the country are working towards protecting their consumer interest. (Kohli, 2011)

Power Sector is highly capital intensive sector and has attracted attention of researchers from worldwide due to technical and managerial problems related to generation, transmission and distribution. However power sector reforms had been initiated in most of the countries since last two decades. The recent years for the power sector in India have been a witness for growing concerns over the financial health of Distribution Utilities. It was observed that a settlement of past dues alone would not solve the basic problem faced by the SEBs; it is essential that the problem of current un-viability of this sector is addressed on priority, otherwise dues/losses would mount further. The "Study on Specific Aspects of the Power Sector for Impact on State Finances" for "The Thirteenth Finance Commission, Government of India" shows the projected Net Losses for the next four years based on the prevailing tariffs. As per these studies, the cumulative Net Loss of the States in 2010-11 is projected at Rs.68,643 Cr and further projections for 2014-15 at Rs.116,089 Cr. Assuming constant nominal tariff (2008) and without considering subsidy. Further, assuming increase in tariff @ 3% each year based on the past trend and subsidy received assumed at 65% of subsidy booked based on data for 2008-09, the profitability status of state utilities is projected to come down to a cumulative net – loss of Rs.49,213 Cr. by the year 2014-15. Further, as per **"**Performance of State Power Utilities**"** published by PFC (Power Finance Corporation), the aggregate losses of all the utilities on subsidy received basis are estimated to be of the order of Rs.44,469 Cr for year 2009-10. Urgent and immediate action for sustainable distribution sector is therefore necessary.

Benchmarking

Benchmarking is a process that develops performance indices for specific entities and compares them to industry norms for the purpose of measuring entity performance, and identifying areas needing improvement. This benchmarking process can reveal potential areas where a particular DISCOM's performance is lacking and point to directions for further detailed examination to identify any underlying contributing causes or mitigating factors to the performance gap. Having a clear assessment of its strengths and weaknesses, a DISCOM can formulate a better corporate strategy to improve its competitive position in the marketplace. Benchmarking of distribution utilities is often a complicated exercise as it employs multiple inputs and outputs. The benchmarking method can be broadly classified into two groups:

- The *average method* (simple comparisons, ordinary least square (OLS), Total factor productivity (TFP) indices) and *Frontier methods* (Corrected ordinary least squares (COLS), stochastic frontier analysis (SFA), Data Envelopment Analysis (DEA)).

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While the **average method** compares the target utility to some of average performance, the **frontier methods** compare the target utility to the most efficient comparable utilities. The frontier methods are regarded as more scientific and precise as compared to the average methods. The frontier methods create an efficiency frontier from a sample of utilities, which is then used as the benchmark against which performance of the subject utility is measured.

Benchmarking Techniques

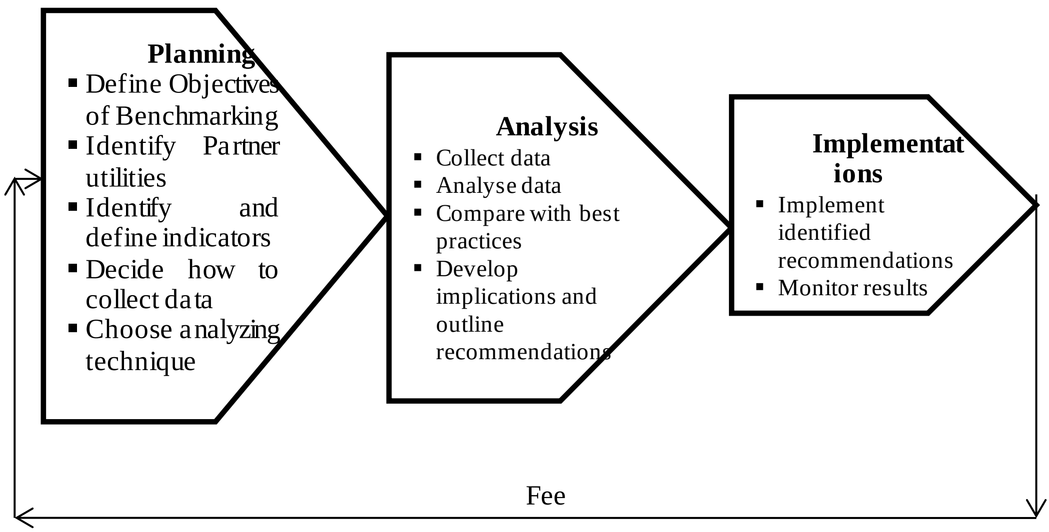

Figure 1: Benchmarking Techniques

A typical Benchmarking framework invariably constitutes 3 components (as shown in Figure 1)

- Planning
- Analysis
- Implementation

Data Envelopment Analysis

DEA occasionally called frontier analysis was first place ahead by Charnes, Cooper and Rhodes in 1978 (Pillai, 2000). It is a performance measurement technique which, can be used for evaluating the relative efficiency of decision-making units (DMU's)[1] in organizations. The most basic DEA model is CCR based on Charnes, Cooper & Rhodes (1978) which have constant returns to scale; however there are also DEA models which address varying returns to scale known as BCC based on Banker, Charnes and Cooper (1984) (T. Coelli, D.S.P. Rao and G.E. Battese).

Inputs in DEA are defined as inputs resources utilized by the DMUs or conditions affecting the performance of DMUs, while outputs are the benefits generated as a result of the operation of the DMUs. By using the selected input and output variables, DEA software finds for the points with the lowest input value for any given output, connecting those points to form the efficiency frontier. The utility which is not on the frontier is considered to be inefficient. A numerical coefficient is given to each firm, defining its relative efficiency. This method can easily accommodate a multiplicity of inputs and outputs. This method is also useful because returns to scale is taken into consideration in calculating efficiency, thus allowing for the concept of increasing or decreasing efficiency based on size and output levels.

Review of Literature

(Nexant, 2004) say that Benchmarking is a process that develops performance indices for specific entities and compares them to industry norms for the purpose of measuring entity performance, and identifying areas needing improvement (Garg and Gupta, 2020, Gupta 2016 Gupta et al 2013). This benchmarking process can reveal potential areas where a particular DISCOM's performance is lacking and point to directions for further detailed examination to identify any underlying contributing causes or mitigating factors to the performance gap. Having a clear assessment of its strengths and weaknesses, a DISCOM can formulate a better corporate strategy to improve its competitive position in the marketplace.

(Thakur T, Singh P) say that Benchmarking studies in the area of distribution sector is relatively new phenomena and few studies have been reported mostly in developed countries. Till date no detailed study has been carried out for Indian electric Utilities. Recently, Prayas has done primary study for six private distribution utilities. Prayas in its occasional report compares six private distribution utilities of India on five aspects, namely, T & D losses, Receivables, manpower, distribution investments, and distribution cost on the basis of easily available public data. They also identify important

[1] DMU is a distinct unit within an organization that has flexibility with respect to some of the decisions it makes, but not necessarily completes freedom with respect to these decisions. Banks, police stations, hospitals, tax offices, prisons, defense bases (army, navy, and air force), schools and university departments, are examples of such units to which DEA has been applied.

aspects that should be covered in-depth performance review of private distribution utilities.

(James T and Pollitt M, 2000) says that The main feature of many power sector reforms is the market-orientation of their approaches to achieve the efficiency objective by using the discipline of the product and capital markets to achieve internal efficiency through the price mechanism, competition, and privatization (Gupta and Gupta, 2012; Gupta and Sharma, 2012; Gupta and Verma, 2008). These reforms generally involve introduction of competition into electricity generation, design of organised power markets, and unbundling of the electricity generation, transmission, distribution, and supply (or retailing) activities. Other power sector reforms have also involved ownership transfers and privatization of the existing assets.

(Filippini M, 2005) say that as competition is introduced into electricity generation, incentive regulation of distribution utilities has become more common. Most of the regulation schemes used in practice are based on benchmarking that is, measuring a company's efficiency against a reference performance. In benchmarking applications the regulator is generally interested in obtaining a measure of firms' efficiency in order to reward (or punish) companies accordingly. The reliability of efficiency scores is therefore crucial for an effective implementation of the incentive mechanism.

(Jain S, Thakur T, Shandilya A, 2010) say that DEA has been applied for both production and cost data. By using the selected input and output variables, DEA software finds for the points with the lowest input value for any given output, connecting those points to form the efficiency frontier. The utility which is not on the frontier is considered to be inefficient. A numerical coefficient is given to each firm, defining its relative efficiency. This method can easily accommodate a multiplicity of inputs and outputs. This method is also useful because returns to scale is taken into consideration in calculating efficiency, thus allowing for the concept of increasing or decreasing efficiency based on size and output levels. The most important job in this efficiency analysis is the right selection of inputs and outputs.

Filippini M, Farsi M, Aurelio Fetz, 2005) says that the non-parametric approaches such as Data Envelopment Analysis (DEA) use linear programming to determine a company's efficiency frontier, which is assumed to be deterministic. The primary advantages of the non-parametric approaches are as follows: a) no specific functional form is imposed; b) are generally easier to estimate and can be implemented on small datasets; c) are transparent methods and easily understandable. The main drawbacks: a) any departure from the frontier is measured as inefficiency, i.e., the method does not allow for stochastic factors, measurement errors and unobserved heterogeneity; b) as more variables are included in the model, the number of firms on the frontier increases;

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c) statistical inference requires elaborate and sensitive re-sampling methods like bootstrap techniques. DEA method is the most commonly used approach in practice.

(Kuah C.T., Wong K.Y., Behrouzi F, 2010) say that despite its simplicity, CCR has some limitations. First, an inefficient DMU and its benchmarking DMUs may not be similar in their operations. The reason is due to the composite DMU does not exist in reality. To surmount this problem, performance-based clustering methods have been used by researchers to cluster similar DMUs into groups. The efficient DMUs in a cluster are utilized to benchmark other inefficient DMUs in a particular cluster. The second limitation of CCR model is that it assumes constant return to scale (CRS), which may not be true for some applications. To address this issue, researchers have implemented variable return to scale (VRS) into the original DEA model. The basic VRS model is known as BCC (Banker, Charnes, Cooper) model.

(Nexant, 2004) proposes development of performance metrics in five categories of DISCOM operations: (1) operational performance, (2) customer service, (3) metering, billing and revenue collection, (4) operational cost control, and (5) financial performance and competitiveness. On the basis of international practice and input from experts in the region, the study team assembled a list of over 100 potential measures. This list was subsequently reduced to 30 metrics to manage the scope of a pilot project and to take into account the difficulties of collecting reliable data.

(DSM) Demand-side management is used to describe the actions of a utility, beyond the customer's meter, with the objective of altering the end-use of electricity - whether it be to increase demand, decrease it, shift it between high and low peak periods, or manage it when there are intermittent load demands - in the overall interests of reducing utility costs. In other words DSM is the implementation of those measures that help the customers to use electricity more efficiency and it doing so reduce the customers to use the utility costs.

(Sirse, 2012) Demand Response is an effort to create additional capacity during the peak hours, by involving voluntary load curtailment by consumers during peak hours or when requested by the distribution companies. The load curtailment can be achieved through implementing load reduction by Energy Efficiency or by load shifting measures.

Research Methodology

Problem Statement: Though the government has taken several initiatives to strengthen the power sector under Electricity Act, 2003, these have achieved limited success. The major factors responsible for low performance of power distribution sector in India:

- Absence of a strong penalty system for non-compliance by discoms
- Higher amount of financial losses. During the year 2011-12, the financial losses of discoms (without subsidies) were around Rs 55 billion.
- Poor financial health of discoms due to the rising cost of power because of high cost of fuel, interest payment, delays in implementation of generation and transmission projects, high ATC losses and expensive short term power purchases.
- Delays in generation and transmission projects due to land acquisition issues, the lack of clear resettlement and rehabilitation and environment policy frameworks increased the cost of power procurement for discoms
- The current tariffs have failed to accommodate the higher cost components due to delay in revision, inappropriate accounting methods for calculating tariffs and delays in subsidy disbursement by the state governments
- Higher gaps in the actual cost of power and revenue realised.
- Presence of cross subsidies. To avoid high commercial losses, discoms prefer cross-subsidisation by large industrial consumers instead of eliminating these cross-subsidies gradually.
- Commercial losses due to low metering efficiency, theft and pilferages

Motivation/Need for Research

To bring the change and improve the efficiency of the sector what is required is introduction of competition within the organizational set up. To bring the competitive culture within the organization what is required is performance ranking of its different functional units. To rate the performance we need to find the parameters which will help us to gauge the performance.

“Benchmarking performance of State Owned Power Distribution Utilities (SOPDU) using Data Envelopment Analysis” is the research work that deals with process and techniques adopted for “benchmarking” of SOPDU to reveal potential areas where a particular distribution utilities performance is lacking and point to directions for further detailed examination to identify any underlying contributing causes or mitigating factors to the performance gap.

Objective of Research

1. To identify existing key performance indicators for state owned power distribution utility
2. To identify the input and output variables affecting performance of power distribution utilities
3. To benchmark the performance of power distribution utilities of Gujarat using Data Envelopment Anaylsis
4. To provide input cost target value and cost savings for the state owned power distribution utility

Research Design

In literature for electric distribution utility, parametric and non-parametric approaches are frequently used for the benchmarking of distribution utility. In this Study non-parametric approach i.e. DEA to benchmark the performance of distribution utility has been used. In this Study the process of creating a standard/best practice against which the performance of utility can be measured has been done using parameters such as Overall Efficiency, Technical Efficiency, Scale Efficiency, Return to Scale and Input Target Value. Thus the efficiency of the benchmarked utility has been measured as to how efficiently they are able to utilize their inputs to produce the required output.

Source of Data: Quantitative research using the secondary data has been taken from standard of performance report, ARR report and Annual report published by distribution utilities on the regulatory website. Various other sources of secondary data may include Journals, Internet, Conferences, books, magazines.

Statistical tools

Analytical tool such as Data Envelopment Analysis for Benchmarking of SOPDU, OM Excelv4 has been used for forecasting some of the data to the year for study i.e. 2011-12 and SPSS for finding out the descriptive statistics of 16 SOPDU and Correlation between input and Output Variable has been used.

Key Performance Indicators (KPI) for Distribution Utility: Performance Targets provide reliable measuring tools for monitoring and regulating business activities, technical standards, cost reduction, maximum availability of plant to ensure reliable power supply of the utility and thus more effectively guide it to become a financially viable utility. Broad categories of Key Performance Indicators identified for utility distribution are:

- Operational Performance
- Operational Cost and Management

- Financial Performance
- Customer Service Quality
- Energy Efficiency and Demand Side Management (DSM)
- Workforce (Including Health and Safety)
- Sustainability

The subcategories and specific metrics under each broad category are given below in the table:

KPIs for Utility Distribution		
Key performance Indicators (KPI)	**Category**	**Measures/Metrics**
Operational Performance	Quality & Reliability of Power Delivery	SAIFI
		SAIDI
		CAIDI
		ASAI (Avg. amount of time electricity is available to customers
		Interruptions per 100km of distribution line
		Frequency of voltage fluctuation events
	Distribution Operating Expenses	ATC losses
		Total Operating Expense/Energy Delivered
		Controllable Expenses/Energy Delivered
		Substation metered & having annual energy audit
		Net fixed assets/energy delivered
		Total energy related expense/energy delivered
		Efficiency a & technology transfer
	Dispatch Efficiency	DSM (Kw reductions in peak system demand and B/C ratio)
		Demand response (kW of demand under contracts)
	Repair & Maintenance	Total outages
		Service restoration time

		Emergency response
		Annual transformers replaced/serviced
Operational Cost & Management	Distribution cost/min	
	Total labour cost/consumer	
	Customer service cost	
	O & M Expenses per unit of energy	
	Non labour maintenance expense	
Financial Performance	Return on equity	
	Cost Recovery Index	Operation recovery/cost excluding capital expenses
	Accounts receivable as a percentage of revenue from energy sales	
	Capital Structure	
	Average tariff level	
	Return on Asset	
	Debt Service Ratio	
	cost of Capital	
	Net profit as percentage of Energy Costs	AS energy costs increases the percentage profit decreases
	Debt Interest Coverage	
	Return on average rate base (%)	
Customer Service Quality	Performance Connection Service	Lead time to provide new connection
		Lead time to restore connection upon payment following disconnection
		Lead time to replace meters in case of complaint
		Connection completed within 5 days

	Performance in Complaint handling	Response time from fault complaint to service time
	Call center performance	Service level
Energy Efficiency & DSM	kWh annual reduction in total energy use	
Workforce (Including Health & Safety)	All injury/illness frequency	Physical exertion while lifting pulling, pushing etc
Sustainability	Disabling injury/illness frequency	Over exertion, pushing their limits
	Severity Rate	
	Lost time work incidents	Employee accidents results in misses work
	Non-accidents related costs	Days absent, sickness, etc
	Employee Training & Development	

To monitor performance of the utility, the framework for the use of Key Performance Indicators (KPIs) will need answering:

1. What to measure?
2. How to measure?
3. How to present the information across different utility levels for decision/action support?

Key Performance Indicators (KPIs) provides a casual analysis of problem in the network. Though the KPIs are known the Indian distribution utilities are not profitable, this is because of

- Lack of execution of follow up interventions
- Due to mismanagement of distribution utility as they get directly pass through to the end consumers.
- Missing incentive layers for efficient utility

DEA and Analysis

Data Envelopment Analysis (DEA) models

Data envelopment analysis (DEA) is a popular benchmarking method. DEA is a multi-factor productivity analysis model for measuring the relative efficiencies of a homogenous set of decision-making units (DMUs). It can be applied to analyze multiple outputs and multiple inputs without pre-assigned weights and without imposing any functional form on the relationships between variables. The technique was suggested by (Charnes A, Cooper W and Rhodes E, 1978), and is built on the idea of (J Farrell M., 1957). With time a number of models and modifications have also evolved. DEA models can be output or input oriented and can be specified as constant returns to scale (CRS) or variable returns to scale (VRS) (Jamasb Tooraj, 2004).

The DEA approach decomposed the Cost Efficiency (CE) into its two different components, Technical Efficiency (TE) and Allocative Efficiency (AE). **Technical Efficiency reflects the ability of a firm to maximize output from a given set of inputs whereas Allocative efficiency reflects the ability of the firm to use these inputs in optimal proportions, given their respective prices where the cost is minimum.** Technical Efficiency implies that there is no waste in using inputs to produce specific quantity of output. A firm is said to be technically efficient when it cannot increases any of output or decreases any of its input without reducing the quantities of other outputs or inputs. Combining these two measures provides a measure of cost efficiency. A firm is said to be cost efficient when it is both Allocative as well as technically efficient.

There can be two DEA models: CCR and BCC model and both of these models are applied in this analysis.

1. **CCR Model**

The CCR model was suggested by Charnes et al. (1978), and hence is named as CCR model and assumes constant returns to scale (CRS) assumption. If assuming data on K inputs and M outputs for each of N firms, then for the i-th firm these are represented by the column vectors xi and yi respectively. The $K \times N$ input matrix, X, and the $M \times N$ output matrix, Y, represent the data for all N firms. A measure of the ratio of all outputs over all inputs would be obtained for each firm, such as uyi / vxi, where u is an $M \times 1$ vector of output weights and v is a $K \times 1$ vector of input weights (Tone, W.W. Cooper and K., 1997).

2. **BCC Model**

BCC model was suggested by Banker, Charnes and Cooper (1984) investigates whether the performance of each DMU was conducted in region of increasing, constant or decreasing returns to scale in multiple outputs and multiple inputs situations. The CCR efficiency can be decomposed into the pure technical and scale efficiency components by this BCC model, thus investigating the scale effects (D. K. Jha, 2007). According to this model an inefficient firm is only “benchmarked” against firms of a similar size.

Selection of Variables

Results of the DEA models are based on the right selection of inputs and outputs and choosing a right variable is the most difficult task before using the model. For the selection of right variable there is no universally applicable rational template is available (A., Vaninsky, 2006) (Kamraj, 2008). An inherent assumption in DEA is that there is some relationship between the variables. Validation of the developed DEA model is done by examining the relationship between the Input and Output factors. These factors are included in the model only if the correlation of the selected factors (input and output) is positive i.e. between 0 to 1 (A. Charnes, 1985). The isotonicity relationships between the input and output factors is examined by using statistical analysis on the selected factors (inputs and outputs) (Roll, B. Golany and Y., 1989). To investigate the relation between two variables we use correlation statistical test.

Power purchase cost is the single largest cost component for distribution utilities (80%). From above stated KPI to measure operational performance indicator, distribution operating efficiency can be defined as the ratio of operating expense and energy delivered. The number of DMUs chosen for the study should be at least triple of the total number of input and output factors present (W.W. Cooper, 2001). DUMs were chosen based on the states with higher ratings (A+, A and B+) in “First integrated rating for state power distribution utilities” by ICRA/CARE rating agencies. The rating parameters of the study done by ICRA/CARE were: Financial performance, Audited accounts, Cross subsidy, Reform measures, Regulatory Environment, Forward looking parameters, Incentives.

Data Collection

Data is collected for 16 DMUs for states such as Gujarat, West Bengal, Tamil Nadu, Maharashtra, Karnataka and Andhra Pradesh. An overview of the key characteristics such as mean, standard deviation, maximum and minimum values is presented in Table 2 (Mithal Thakur, 2013). The correlation coefficients between the various input and output variable is listed in table 3, which shows the substantive relationship between the variables (input and output).

Data Sheet

Table 1: Data Sheet

Sr. No	Distribution State	Distribution Utility	Output Variable	Input Variable

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			Energy Sold (Mu)	**Operating Expenditure (Cr.)**	**Power Purchase Cost (Cr.)**
1	Gujarat	UGVCL	14100.88	342.72	5241.87
2		PGVCL	3487.00	524.20	6993.01
3		MGVCL	6726.00	290.87	2967.07
4		DGVCL	4587.00	221.07	5415.03
5	West Bengal	WBSEDCL	19061.78	248.51	7201.61
6	Tamil Nadu	TANGEDCO	61226.00	4495.89	17508.00
7	Maharashtra	MSEDCL	53253.77	2045.70	9009.61
8	Karnataka	BESCOM	21911.42	822.80	9002.19
9		MESCOM	3480.50	225.67	1121.11
10		HESCOM	3662.44	428.75	3024.73
11		GESCOM	5129.91	233.25	1610.55
12		CESC, Mysore	4207.51	255.86	1486.50
13	Andhra Pradesh	APCPDCL	35680.98	1733.90	11525.22
14		APEPDCL	14672.00	864.90	3386.15
15		APNPDCL	12286.00	445.13	4144.88
16		APSPDCL	18495.14	866.37	6010.04

Table 2: Descriptive Statistics of 16 SOPDU

Descriptive Statistics					
Desirable inputs and outputs	**Range**	**Min**	**Max**	**Sum**	**Mean**

Energy Sold (Mus.)	57745.5	3480.5	61226	281968.33	17623.02
Operating Expenditure (Cr.)	4274.82	221.07	4495.89	14045.59	877.84
Power Purchase Cost (Cr.)	16386.89	1121.11	17508	95647.57	5977.97

Table 3: Correlation Coefficient among Input and Outputs

Correlations coefficients among inputs and outputs			
Desirable inputs and outputs	**Energy Sold (Mus.)**	**Operating Expenditure (Cr.)**	**Power Purchase Cost (Cr.)**
Energy Sold (Mus.)	1.000		
Operating Expenditure (Cr.)	0.709	1.000	
Power Purchase Cost (Cr.)	0.788	0.694	1.000

Analysis and Findings

BCC formulation is used to calculate technical and scale efficiency which assumes a Variable Return to Scale by taking into consideration the sizes of utilities. BCC formulation is used to ensures that similar sized utilities are benchmarked and compared with each other (Abbott, 2006) (A Pahwa, 2003). The total efficiency is then de-composed into pure technical and scale efficiency. The scale efficiency is given by the ratio of CRS efficiency (overall efficiency) to VRS efficiency (pure technical efficiency).

Benchmarking result

Benchmarking is the process of creating a standard or best practice against which the performance of utility can be measured (Chitkara, 1999). The set of efficient units are utilised as benchmarks for the improvement for every inefficient DMU. The benchmarks for inefficient utilities are shown in Table 4. For example the benchmarks for Gujarat (UGVCL) are Maharashtra (MSEDCL), Karnataka (GESCOM) and West Bengal (WSEDCL). This inefficient utility has been benchmarked or compared against these three (technical/scale) efficient utilities.

Table 4: Coefficient of Results of BCC Model

Sr. No	Distribution Utility	Overall Efficiency	Technical Efficiency	Scale Efficiency	Return to Scale	Benchmarks

1	UGVCL	0.849	0.907	0.936	Increasing	7 11 5
2	PGVCL	0.150	0.427	0.351	Increasing	9 4
3	MGVCL	0.609	0.759	0.765	Increasing	5 11 9
4	DGVCL	0.308	1.000	0.308	Increasing	4
5	WBSEDCL	1.000	1.000	1.000	Constant	5
6	TANGEDCO	0.592	1.000	0.592	Decreasing	6
7	MSEDCL	1.000	1.000	1.000	Constant	7
8	BESCOM	0.674	0.690	0.977	Increasing	7 11 5
9	MESCOM	0.567	1.000	0.567	Increasing	9
10	HESCOM	0.271	0.525	0.516	Increasing	5 9 4
11	GESCOM	0.705	1.000	0.705	Increasing	11
12	CESC, Mysore	0.568	0.898	0.633	Increasing	11 7 9
13	APCPDCL	0.671	0.674	0.996	Increasing	7 5 11
14	APEPDCL	0.733	0.855	0.857	Increasing	7 9
15	APNPDCL	0.763	0.854	0.894	Increasing	7 11 5
16	APSPDCL	0.683	0.729	0.937	Increasing	7 11 5
Mean		**0.634**	**0.835**	**0.752**		

BCC Results

Based on BCC results of Overall Efficiency, West Bengal State Electricity Distribution Company Limited (WBSEDCL) and Maharashtra State Electricity Distribution Company Limited (MSEDCL) is relatively efficient and the efficiency score is equal to 1. Except **WBSEDCL and MSEDCL** all other DMU are inefficient as their efficiency scores is below 1. Mean score of overall efficiency is 0.634 for all the DMU and majority of DMU i.e. 7 out of 16 lie below this mean score. Most of the DMU i.e. 15 out of 16 exhibit increasing return to scale. **TANGEDCO** shows decreasing return to scale, which indicates that further expansions of services may not be productive.

The major sources of inefficiency among the 14 inefficient SOPDU are revealed by BCC model which also provide possible improvement directions to promote the overall efficiency of each inefficient utility. The technical efficiency scores of 7 out of the 16 inefficient DMUs (i.e., **PGVCL, DGVCL, TANGEDCO, MESCOM, HESCOM, GESCOM and CESC Mysore**) are higher than the corresponding scale efficiency scores. The DMUs that are having the scale efficiency less than 1 are called scale inefficient. The overall inefficiencies of the **4 DMUs are primarily due to the scale inefficiencies**.

Table 5: Input Cost Target Value

Sr. No.	Distribution Utility	Operating Expenditure (Cr.)			Power Purchase Cost (Cr.)		
		Original Value	Target Value	% Reduction	Original Value	Target value	% Reduction
1	UGVCL	342.72	310.74	9.3%	5241.87	4752.67	9.3%
2	PGVCL	524.20	223.67	57.3%	6993.01	2983.90	57.3%
3	MGVCL	290.87	231.35	20.5%	2967.07	2359.97	20.5%
4	DGVCL	221.07	221.07	0.0%	5415.03	5415.03	0.0%
5	WBSEDCL	248.51	248.51	0.0%	7201.61	7201.61	0.0%
6	TANGEDCO	4495.89	4495.89	0.0%	17508.00	17508.00	0.0%
7	MSEDCL	2045.70	2045.70	0.0%	9009.61	9009.61	0.0%
8	BESCOM	822.80	567.37	31.0%	9002.19	6207.58	31.0%
9	MESCOM	225.67	225.67	0.0%	1121.11	1121.11	0.0%
10	HESCOM	428.75	225.30	47.5%	3024.73	1589.42	47.5%
11	GESCOM	233.25	233.25	0.0%	1610.55	1610.55	0.0%
12	CESC, Mys	255.86	229.64	10.2%	1486.50	1334.14	10.2%
13	APCPDCL	1733.90	1168.42	32.6%	11525.22	7766.45	32.6%
14	APEPDCL	864.90	634.90	26.6%	3386.15	2894.84	14.5%
15	APNPDCL	445.13	380.22	14.6%	4144.88	3540.45	14.6%
16	APSPDCL	866.37	631.23	27.1%	6010.04	4378.90	27.1%

As shown in Table 5, **DGVCL, TANGEDCO, MESCOM and GESCOM** are having the technical efficiency scores equal to 1 but their scale efficiency scores are less than 1. These 4 DMUs are technically efficient yet *scale inefficient*. DGVCL presents increasing return to scale which implies that it can possibly increase their operation scale to improve their overall efficiencies. The other **7 SOPDU (UGVCL, MGVCL, BESCOM, APCPDCL, APEPDCL, APNPDCL and APSPDCL) are inefficient mainly due to technical inefficiency**. The 7 (technically) inefficient SOPDU should improve the technical efficiency of the resource allocation and utilization to further increase their overall efficiency. For those DMU which display low value of scale efficiency, there is a possibility of restructuring. As these utilities have low value of scale efficiency and decreasing return to scale indicates that they have considerable scope for improvements in their efficiencies by resizing or downsizing their scale of operations to optimal scale defined by more productive utilities in the scale.

Input Cost Target Value

Target value for each inefficient utility for the input variable is calculated to make them efficient as shown in table 5. Input cost target values for most of the DMUs is lower than their actual values. For example in case of UGVCL, the input cost should be reduced by 9.3% to make it technically efficient. Mean technical efficiency of all the DMUs is 83.5% which means they can reduce their inputs by 16.5% without reducing their outputs.

Cost Savings

Mean technical efficiency of all the DMUs is 83.5% which means utilities could reduce their inputs by 16.5% without reducing their outputs. By cost benchmarking the DMUs the cost reduction by nearly 16% with the same output can be achieved. For example in case DMU of Gujarat (UGVCL), the operating expenditure is Rs 342.72 crores, so on an average the cost can be reduced by 9.3%, which is a huge money saving for further distribution. The COVID 19 has major implications on it (Gupta et al 2021).

Conclusion and Suggestions

The efficiency of DMUs which are State Owned Power Distribution Utilities (SOPDU) is examined in the present study. Mean overall efficiency of 16 DMUs is 63.4%. WBSEDCL and MSEDCL is having the overall efficiency score of 100% and varying degrees of inefficiencies are shown by all other DMUs. It is seen that DMUs, although operating around mean overall efficiency they fell far short of best practice. Mean technical efficiency of DMUs is found to be 83.5%. It is also seen that 4 of the 14 inefficient DMU (i.e., DGVCL, TANGEDCO, MESCOM and GESCOM) are scale inefficient and 7 DMU (UGVCL, MGVCL, BESCOM, APCPDCL, APEPDCL, APNPDCL and APSPDCL) are inefficient mainly due to technical inefficiency i.e. their efficiency scores are below 100%.

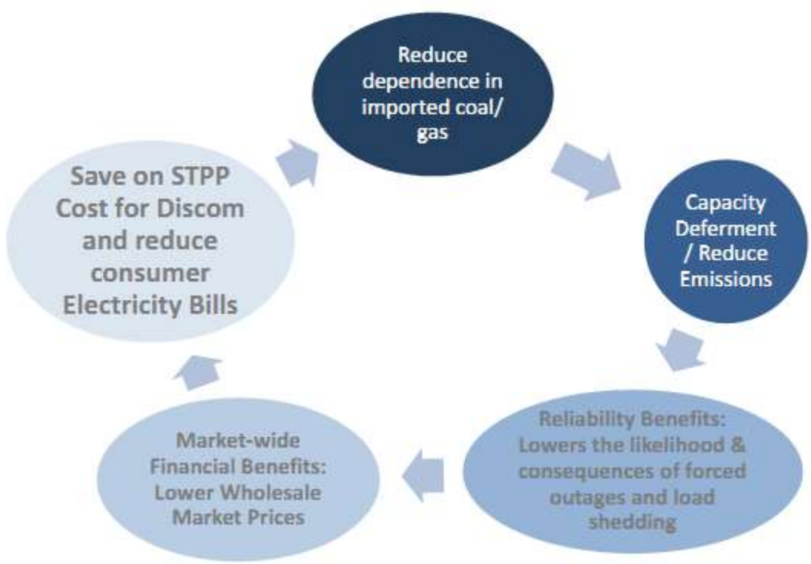
One of the reason for the lower technical score may be due to the inappropriate management practice in terms of resource utilization which may have been present in case of inefficient DMUs. Operating expenditure of most of the utilities are more than what is required to achieve efficiency of 100%. The results of the present study assist various DMUs by identifying the shortcomings, setting targets and trying to achieve the set targets.

The results of the study indicate

- The reason of existence of large inefficiencies as majorities of the DMUs does not operate at the optimal levels.
- The existence of scale inefficiencies, and suggest that they have considerable scope for improvements in their efficiencies by resizing or downsizing their scale of operations to optimal scale defined by more productive utilities in the scale.
- The possibility of achieving substantial savings by adopting best practices.

A number of policy measures such as encouraging competition can be considered to improve the performance of DMUs. One the way to reduce the power purchase cost is by negotiating to reduce unit prices at the time of re-signing (TEPCO).

Cost of Power purchases constitute the single largest cost for distribution utilities it is important to establish regulatory policies. Regulators should balance interests of investor and consumer. The consumers want distribution utilities to purchase efficiently on their behalf as consumers usually don't have alternative suppliers. Distribution Utilities have interest in recovering the costs of power purchases in tariffs they charge to their consumers whereas consumers want that the distribution utilities should have a mix of both short and long term purchases at the lowest possible cost. Thus rules to incentivize distribution utilities to purchase efficiently and recover the costs of purchases must be established by the electricity regulator. A distribution utility has to purchase more power from generating companies because of the presence of various losses (Technical and Non-Technical Losses~ 30%-45%) then it would do so when the losses would have been only 10% to 20%. Designing of pass through mechanism is important to encourage DU to purchase economically. While encompassing an effective PTM (Pass Through Mechanism) electricity regulators should balance between to provide efficient incentives for expansion of power system and reasonable rates establishment as well as to provide for an expansion of the power system, regulators have the statutory obligation to set prices that allow the industry to generate enough funds.



The strategic value of DSM (Demand Side Management) measures and energy efficiency lies in their ability to improve the financial cash flow of distribution utilities (Ali 2019, 2020). Moreover, DSM and Demand Response (DR) Activity are utilised to curtail the peak electricity demand. In other words, it helps to negate spending on generation, transmission and distribution infrastructure by curtailing the peak. Thus, it can be said that funds are freed up which would otherwise be utilized to meet the peak demand. By Load Shifting the reduction of utility loads during periods of peak demand can be achieved, while at the same time building load in off-peak periods. Load shifting typically does not substantially alter total electricity sales. A typical load curve in distribution utility shows peak demand for the day at certain peak hours in the day. At that time of the day demand supply gap is largest for utility. Schemes like Gaothan feeder scheme (MSEDCL) to achieve flattening of this load curve in a judicial way, thereby reducing the cost on power purchase/lowering of wholesale market prices and reducing the penalty for unscheduled interchanges.

Operating expenditure of SOPDU can be reduced by Incentive regulation by rewarding the distribution utility with increased profits for reducing costs and improving services is the basic purpose of incentive regulation. Select the metrics, set the baseline level, choose targets for improvement and/or maintenance and apply incentives/penalties.

Revenue requirement of the utility = O&M expenses (including fuel) + Taxes + Depreciation + Rate Base * Allowed Rate of Return

Profits = Revenue- Costs

Rates are set for a future period based on an authorised rate of ROC and the expected sales. The actual earned return is different from the authorised return based on the extent to which the actual figures turn out to be different from predicted value. Incentives are more if a distribution utility increases revenues or cuts expenses which provides an incentive for the utility to increase sale or/and cut cost. O & M expenses can also be reduced by opting for outsourcing of activities in economical manner.

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Abbreviations

APCPDCL: Central Power Distribution Company of AP Limited

APEPDCL: Eastern Power Distribution Company of AP Limited

APNPDCL: Northern Power Distribution Company of AP Limited

APSPDCL: Southern Power Distribution Company of AP Limited

BCC: Banker; Charnes and Cooper Model

BESCOM: Bangalore Electricity Supply Company Limited

CCR: Charnes; Cooper and Rhodes Model

CESC: Chamundeshwari Electricity Supply Company Limited, Mysore

CRS: Constant Return to Scale

DEA: Data Envelopment Analysis

DGVCL: Dakshin Gujarat Vij Company Limited

DMU: Decision Making Unit

DU: Distribution Utility

GESCOM: Gulbarga Electricity Supply Company Limited

HESCOM: Hubli Electricity Supply Company Limited

MESCOM: Mangalore Electricity Supply Company Limited

MGVCL: Madhya Gujarat Vij Company Limited

MSEDCL: Maharashtra State Electricity Distribution Company Limited

PGVCL: Paschim Gujarat Vij Company Limited

PTM: Pass through mechanism

SOPDU: State Owned Power Distribution Utility

TANGEDCO: Tamil Nadu Generation and Distribution Corporation Limited

UGVCL: Uttar Gujarat Vij Company Limited

VRS: Variable Return to Scale

WBSEDCL: West Bengal State Electricity Distribution Company Limited