Relationship between performance measures of Indian water supply services and their determinants

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Abstract

In recent times, water-supply services in India are increasingly striving to improveoperational efficiencies. This necessitates performances of water-supply operations to be analyzed for possible improvements. Performances are measured in terms of specific attributes of individual utilities, and therefore determining factors underlying various measures of efficiency assume significant importance. This Paper employs use of Regression-analysis to determine nature of relationship between the input and output variables for performance evaluation carried out using Data envelopment analysis applied to 20 urban centers in India. The paper details the importance of these indicator determinants on performance-measures with reference to policy implications and outcomes.

Keywords:water-supply services, operationalefficiencies, performancesof water-supply operations, regression analysis, Data Envelopment analysis, indicator,policy implications

1   Introduction

India possesses 18% of the world's population but just 4% of its water resources. India's finite and fragile water resources are stressed and depleting, while sectoral demands for waterare growing rapidly. At its Independence in 1947, India's population was less than 400 million, with per capita water availability being over 5,000 cubic meters per year. With the population having grown to over a billion now, the per capita water availability has fallen to barely 1,545 cubic meters per year (Census,2011). Despite these constraints, it is to India's credit that the provision of safe drinking water has taken great strides. India has contributed more than any country to those gaining access to improved drinking water sources in the world, 46% of the population has gained access to improved drinking water since 1990 and has met the Millennium Development Goal for water (WHO/ UNICEF, 2015). These numbers are

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commendable but when the data is looked at in more detail, it is clear that there in inequity in its access. This is a key issue that has been highlighted in the 12th Five year plan by the Planning Commission of India (Planning Commission 2012). Significant environmental problems have also emerged due to economic development fuelled by burgeoning agriculture and industrial production and has resulted in declining per capita water availability due to deteriorating raw water qualities.Efficient usage of water across sectors has thus emerged as a major issue in the modern times (National Water Policy, 2012).The rising consumption will further aggravate water scarcity as population, food production, industrialization and living standards continue to rise over the next two decades. This scenario wherein the water availability has been shrinking, even when the demand has been growing, warrants the induction of efficiencies in usage water as a precious limited resource. For this reason, efficiencies also need to be established in the delivery and operation of water supplies that constitute the lifeline of urban development.

The solution to water supply problems in India has traditionally been related to capacity addition or to quality improvement, rather than improvements in the service efficiencies of the existing services. Ideally, efficient operation of existing water supply schemes is a theoretical first step in any move to make the schemes operate in a viable fashion. Increased emphasis on performance improvements can bring benefits of large internal savings which may be beneficially deployed for greater expansion and coverage of services especially to the poor, and for furthering service quality improvements. Hence it becomes imperative to measure efficiencies, and to identify those operational variables that play the most significant role in the determination of efficiencies.

This paper explores the inefficiencies prevalent in the 20 urban areas of Indian water supply utilities and presents an evaluation of the potential of efficiency improvements that are possible in urban utilities. It further uses Regression analysis to identify those operational variables that play the most significant role in the determination of efficiencies.

2   Review of relevant studies

Many studies have been carried out to measure performances of water utilities in developed and developing countries. Water utilities use different inputs such as capital, labor and energy to deliver water to residents. These utilities use different levels of inputs and outputs, and a utility appears to be inefficient if it uses more resources to produce matchingoutput than the 'best practice' utility does.

2.1 Efficiency analysis in the water supply sector

Since the 1970s the performance evaluation of water utilities has been carried out mainly through several key performance indicators (KPI) (e.g. scorecards, Tynan and Kingdom, (2002); Yepes and Dianderas, (1996) or through overall performance scores which synthesize in a single value the trend of a group of measures (e.g. financial ratios, Guerrini*et al.*, (2011), non-parametric methods like DEA, Thanassoulis, (2000), and parametric methods like regression analysis, Corton, (2003).

Thanassoulis, (2000), in his studygave an introduction to the basic DEA, models for assessing efficiency under constant and variable returns to scale. It gives an account of the use of DEA to estimate potential cost savings at water companies in England

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and Wales in 1994. Romano &Guerrini, (2011), reviewed 43 Italian water utility companies and using data envelopment analysis assessed their cost efficiencies and concluded that the ownership structure, size and geological location had an impact on the performance of water utilities. Cruz et al (2012) assessed the performance of water utilities in Portugal and Italy using global indicators on a sample of 88 water utilities for the year 2007. The study also identified the impact of the ownership structure on efficiency. In one of the rare studies in Asia, Marques et.al (2014) analyzed Japanese water utilities for many factors affecting efficiency, governance, monthly water charge, water losses, production etc. The study also extended literature by studying the impact of various exogenous variables on the efficiency of water utilities. In a study of Peruvian water utilities, Lin (2005)finds a high correlation of utilities between models with accounted-for water as qualityvariable. Corton(2003) illustrates the applicability of the framework of benchmarking for developingeconomies. Author gives a regression model for operating cost by using region variable as a dummy variable. Corton and Berg (2009) provided a comprehensive efficiency analysis in six countries in the central American region. In addition to key sector performance indicators, the analysis considers several benchmarking methodologies to assess technical and cost efficiency.

2.2 Inputs and Outputs specific to the Indian water supply services

In India, a few attempts have been made to measure efficiencies of water supplying municipalities. Gupta et. al (2006)was the first to estimate technical efficiency of 27 urban water utilities in India considering water produced as a function of revenue expenditure and production capacity. Singh et al., (2010), evolved suitable sustainability based benchmarking framework to assess aggregate efficiency of 18 Indian urban water utilities using data envelopment analysis (DEA). The study made use of six models with different combinations of input and output variables. The input parameters used in the analysis include Total expenditure, Percentage of water treated, Unaccounted for water, electricity expenditure, Number of staff; water produced, Total number of connections, Length of distribution network and total revenue receipts as output parameters. The performance analysis of water utilities suggested the need for greater attention towards service adequacy, service reliability and business viability parameters. The analysis on aggregate technical efficiency and scale efficiency suggested scope for improvement in technology and operational scale and hence cost savings.
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Vishwakama & Kulshrestha (2013) evolved a framework for evaluating the relative efficiencies of water supply sector and applied DEA to 20 urban centers in the state of Madhya Pradesh, India. They employed three models with common output variables, number of connections, length of distribution network and average daily clear water production while staff per 1000 connections, Unaccounted for water (UFW) and operating expenditure are used in different combinations as inputs.The overall results indicated that the water supply services were quite inefficient compared to the best practices. The results also showed that significant savings are possible if best practices were adopted with respect to operating expenditure, number of staffs and non-revenue water. Again Vishwakarma et.al (2016) evaluated cost efficiencies of 18 water supply utilities in India. The results indicate large relative inefficiencies and a

scope of savings of 24.5% of average current operating and maintenance costs even with existing levels of resource inputs.

This paper presents an evaluation of the potential of efficiency improvement in water supply utilities in urban centers of India. The objective of this paper is to investigate the efficiency for the Indian urban water supply services. The study seeks to answer the following specific issues:

    A. What are the DEA inputs and outputs that mainly affect the utility performances for urban water supply services in India?
    B. What is the relationship between the outputs and inputs, and the order of importance in which outputs explain the input variables?
    C. What is the quantum of inefficiencies in water supply operations for sample urban cities in India?
    D. What is the extent of savings possible if inefficiencies are mitigated?
    E. What are the best practices in India with regard to operations of water supply services?
    F. What impact does the size of utility impose on the service efficiencies? Is there a case for restructuring the large utilities?
    G. What are the determinants that influence utility efficiency measures?

3. Methodology

DEA involves creation of a non-parametric frontier from the observed set of data. The performance of each utility is evaluated relative to the best frontier by solving the linear programming problems. The comparative efficiency of several homogeneous utilities is measured by aggregating the multiple performance indicators into a single framework for identifying the best practice.

CRS, VRS Models and Technical Efficiencies

Let us assume that data is accessible for M outputs and N inputs for each of I firms. For the ith firm they can be represented by the column vectors x_i and q_i respectively. N×I input matrix, X, and M×I output matrix, Q depicts the data for all of the I firms. The optimum weights can be obtained by solving mathematical programming equations:

$$max_{u,v}(\frac{u^{'}q_i}{v^{'}x_i})$$

Subject to $\quad \frac{u^{'}q_j}{v^{'}x_j} \leq 1, \qquad j = 1,2,3....,I$

$$u,v \geq 0$$

This involves finding the values for u and v, such that the efficiency measures for the ith firm is maximised and subjected to the constraints that all the efficiency measures are less than or equal to 1 *(Coelli et al, 1998).*

Using the duality in linear programming, the equivalent envelopment form can be derived as:

$$min_{\theta,\lambda}\theta,$$

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$$\text{Subjected to,} \qquad -q_i + Q\lambda \geq \mathbf{0}$$

$$\theta x_i - X\lambda \geq \mathbf{0},$$

$$\lambda \geq 0$$

where, θ is a scalar and λ is I×1 vector of constants.

The value of θ obtained gives the efficiency score for i^{th} firm. Linear programming problem should be solved I times, i.e, ones for each firm. $\theta \leq 1$, indicates that the firm is technically efficient, with the value 1 indicating a point on the frontier *(Coelli et al, 1998).*

Constant Returns to Scale LP problems can be easily modified to account for Variable Returns to Scale by adding the convexity constraint I1'λ=1,

$$min_{\theta,\lambda}\theta,$$

$$\text{Subjected to,} \qquad -q_i + Q\lambda \geq \mathbf{0}$$

$$\theta x_i - X\lambda \geq \mathbf{0},$$

$$I\mathbf{1}'\lambda = \mathbf{1}$$

$$\lambda \geq 0$$

whereI1 is an I×1 vector of ones'.

The convexity constraint, $I\mathbf{1}'\lambda,$ ensures that an inefficient firm is benchmarked against firms of similar size and not as in CRS model, where a firm is benchmarked against all firms irrespective of their size *(Coelli et al, 1998).*

Efficiency scores in the presence of multiple input and output factors can be defined as:

$$Efficiency = \frac{weighted\,sum\,of\,outputs}{weighted\,sum\,of\,inputs}$$

In the sample, for each individual utility the linear program is solved. This creates a frontier using the information about the most efficient utilities and the efficiency of the rest of the utilities relative to this is measured. DEA attempts to estimate the efficient frontier by adopting piece-wise linear approximation. Efficiency scores are approximated by measuring how far a utility is from the frontier.

4.   Data, Results and Discussions

4.1 Data
The data used in this exercise is taken from Indian government organization, Central Public Health and Environmental Engineering Organization (CPHEEO).

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CPHEEOProvides information for water utilities based on 2005 data. A Simple model for the analysis is framed based on the availability of data. The input and output variables of the model are as follows

Input Variables	Output Variables
Operating Expenditure (OPEX)(Rs. Millions)	Quantity of water supplied (MLD)
Unaccounted for water (UFW)((%)	Length of distribution network (Km)

Table 1 shows the descriptive statistics of variables used. Mean quantity of water supply for sample urban cities is 63MLD, while range of maximum and minimum water supplied are 682 MLD and 1.00MLD respectively. The water losses in some sample cities areas high as 36% of total water produced reflecting poor efficiencies in distribution networks.

Table 1. Descriptive Statistics

Variable	Mean	Standard Deviation	Maximum	Minimum
O & M Expenditure (Rs Millions)	66.3	221.5	1005	0.6
Unaccounted for water (%)	12	9	36	1
Quantity of water supplied (MLD)	63	150	682	1
Surface water (%)	86	21.4	100	44
Length of Distribution network (Km)	206	434	1936	6
Staff per 1000 connections	12.2	10	47	2
Connections metered (%)	4	4	15	0

Source: CPHEEO (2005)

4.2 Efficiency estimatesand potential savings

Table 2 gives the estimates of Technical efficiency under constant returns to scale, Variable returns to scale and scale efficiency. In the sample cities it is found that Nellore and Hyderabad are not only operating at the frontier but also are operating at optimum scales. The water utilities of cities Warangal, Vijaywada and Hindpur are technically efficient but are not operating at optimum levels. 15 utilities out of 20 are operating under Increasing returns to scale (IRS), implying that these utilities give proportionately increasing returns for outputs for a corresponding increase in the input level, thus indicating that as the size of these municipalities increases in future, they would tend to become more efficient. Some of these municipalities (3 out of 20) had decreasing RTS, demanding descaling of the size of their operations. On the other side, 9 utilities had efficiency scores less than 50% under CRS. On an average, the sample utilities are delivering about 54% of their potential if they would have been operating at optimum scale. The decomposition of Technical efficiency shows that about 21% of inefficiency is due to scale inefficiency and another 32% is pure technical inefficiency.The results presented in Table 2provides an exhaustive decomposition of potential savings in the water supply sector over all the sample utilities. Potential Savings were estimated using the prospective level of operations as per VRS efficiency scores in accordance with the approbation of Sawkins&Accam, 1994). Table 2.also demonstrates the necessity for induction of efficiency in the urban water supply services in India.It is theoretically possible to save nearly Rs. 5.39 Million in the short run, and this constitutes as much as 31.75% of the OPEX incurred presently. it is

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possible to theoretically save 19% of the total quantum of water currently being wasted as UFW, in the short run.

Table 2: Various measures of Technical Efficiency

S.No	City	CRS	VRS	Scale	Potential Saving	
					OPEX (Rs. Millions)	UFW (%)
1	Anantapur	0.40	0.73	0.55	2.50	1.09
2	Chittoor	0.31	0.33	0.94	8.41	16.56
3	Cuddapah	0.28	0.30	0.93	10.27	12.49
4	Eluru	0.64	0.66	0.97	3.08	2.65
5	Guntur	0.34	0.42	0.81	34.25	14.61
6	Hindpur	0.89	1.00	0.89	0.00	0.00
7	Kakinada	0.70	0.74	0.95	4.14	0.78
8	Kurnool	0.23	0.48	0.48	3.91	3.66
9	Nandyal	0.33	0.72	0.46	2.09	1.13
10	Nellore	1.00	1.00	1.00	0.00	0.00
11	Ongole	0.51	0.65	0.78	2.70	2.08
12	Qutubullapur	0.36	0.37	0.97	13.03	12.59
13	Rajamundry	0.42	0.47	0.89	10.86	4.81
14	Tenali	0.29	1.00	0.29	0.00	0.00
15	Tirupati	0.46	0.48	0.96	8.17	8.91
16	Vijaywada	0.82	1.00	0.82	0.00	0.00
17	Warangal	0.98	1.00	0.98	0.00	0.00
18	Anakapalle	0.59	0.82	0.72	0.30	2.33
19	Gudur	0.21	0.50	0.42	4.12	2.98
20	Hyderabad	1.00	1.00	1.00	0.00	0.00
	Mean	**0.54**	**0.68**	**0.79**	**5.39** **31.75%**	**19.10%**

4.3 Returns to Scale Estimates

Table 3 reveals the operating scale of sample water utilities. The Scale efficiency results indicate that only 2 utilities are operating under optimum scale (Constant Returns to scale or CRS). Remaining utilities are either operating under increasing (IRS) or decreasing returns to scale (DRS). About 85% of sample utilities are operating under IRS and all the remaining water utilities are operating under DRS. Generally the utilities that are operating under IRS are relatively small cities. It is interesting to note that these utilities do not follow marginal cost pricing and hence full cost is not recovered. These results have implication for urban domestic water pricing.

Table 3: Returns to Scale

Returns to Scale	Number of utilities
CRS	02
IRS	15
DRS	03

4.4 Relationship between input and output variables

To find out if any substantive relationship exists between the input and an output variable, Regression Analysis (RA) was carried on the sample data.

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It is proposed that the differences in inputs OPEX, and UFW may respectively be explained by differences in the operational environments e.g. Length of network and Water supplied. The calculations were made for the variables OPEX and UFW separately acting as the dependent variables respectively against the set of outputs acting as independent variables. In order to identify those variables of the operational environment that play the most significant role in the determination of costs, regression analyseswas carried out considering OPEX as dependent variable with the ordinary least squares method (OLS). The method was repeated for the variable UFW (acting as the dependent variable) to access if the above operating environments also explain the variations in UFW.

4.4.1 Dependent variable OPEX

To increase the validity of the proposed model, the assumption of the "isotonocity" relationship was examined amongst the input and output variables using correlations. Table 4 lists the Correlation Coefficients between the various variables. The results indicate that the variables do not violate the isotonicity assumption. The values of correlation coefficients signify that the variables are reasonably correlated: neither too less of correlation nor too high a correlation that would otherwise make it difficult to determine the unique contribution of a variable to the analysis.

Table 4. Correlation coefficients (Pearson correlation): OPEX

OPEX	OPEX	Quantity of water supplied	Length of distribution network
OPEX	1		
Quantity of water supplied	0.986	1	
Length of distribution network	0.944	0.957	1

From Table 5, representing the analysis of variance (ANOVA), the F-ratio was found to be 303.25 which is significant at $p<0.001$, indicating that there is a less than 0.1% chance that an F-ratio this large would occur by chance alone. Hence, the regression model explains the OPEX significantly well.The R^2 value of 0.972 indicates that the two independent variables could explain 97.2% of the variation in OPEX.

Table 5. ANOVA results: OPEX

	Sum of Squares	Df	Mean Square	F	R^2	Sig.
Regression	90709106	2	45354553	303.253	0.972	0.00
Residual	2542521	17	149560.1			
Total	93251627	19				

The B values depict the relationship between the OPEX and the two independent variables (predictors). As the Table 6 illustrates, it is evident that there exists a positive relationship between the predictors and the outcome, and that OPEX seems to increase as network length and the water supplied increase. In particular, Water supplied has the largest influence on the operating expenditures if the effect of other

predictor were to remain constant. It may be noted that the constant term has a rather large standard error as reflected in the corresponding t value.The t-test indicates that all predictors are making significant contribution to the model (Table 6). The t values indicate that Water Produced are particularly significant predictors of OPEX. The independent variable network length is relatively less important contributor.

Table 6. Coefficients of regression, t-test: OPEX

	Unstandardized Coefficients		t	Sig.	95% Confidence Interval for B	
	B	Std. Error			Lower Bound	Upper Bound
(Constant)	-251.566	96.840	-2.598	.018	-455.823	-377.742
Quantity of water supplied	14.591	2.053	7.106	.000	10.259	.194
Length of Network	0.005	0.708	2.007	.009	-1.488	5.892

4.4.2 Dependent variable UFW

Table 7.lists the Correlation coefficients between the various variables, and the results indicate the presence of a substantive relationship between the variables. The Table 7 also indicates that the variables do not violate the isotonicity assumption. The correlation coefficients are reasonably correlated. The results indicate the presence of a substantive relationship between the variables,In particular, strong relationship was evident between variables UFW and Water supplied.

Table 7. Correlation coefficients (Pearson correlation) :UFW

	UFW	Network length	Water Supplied
UFW	1.000		
Network length	.842	1.000	
Water Supplied	.964	.857	1.000

The R^2 value of 0.946 indicates that the two independent variables could explain as much as 94.6% of the variation in UFW. The ANOVA (Table 8) results indicate an F-ratio of 11.236, which is significant at $p < 0.001$

Table 8. ANOVA results: UFW

	Sum of Squares	Df	Mean Square	F	R^2	Sig.
Regression	925.401	2	462.7005	11.236	0.946	.001
Residual	700.437	17	41.202			
Total	1625.838	19				

In Table 9, the B values depict the relationship between the UFW and the two independent variables (predictors). It is evident that there exists a positive relationship between the predictors and the outcome, and that UFW seems to increase as the network length and the water supplied increase. In particular, Water supplied has the largest influence on the UFW if the effect other predictor were to remain constant.The t-test (Table 9) indicates that all independent variables are making significant contribution to the model.

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Table 9. Coefficients of regression, t-test: UFW

	Unstandardized Coefficients		t	Sig.	95% Confidence Interval for B	
	B	Std. Error			Lower Bound	Upper Bound
(Constant)	-10.056	1.683	-5.975	.000	-6.505	.136
Network length	0.024	.001	1.98	.063	.005	.001
Water Supplied	0.109	.003	3.073	.000	.03	.185

The t values indicate that Water supplied is particularly significant predictor of UFW, a fact obvious in terms of physical reality as more water will need to be supplied in order to compensate for greater losses (UFWs), as well as the fact that the larger the water supplied, the greater will be the losses in terms of volume of water lost.

4.5 Determinants of Efficiency

One other issue of concern is to determine the factors underlying the changes in the various measures of efficiency. It is expected that specific attributes of an individual utility contribute to its performance. To further aid an understanding of the results discussed above regression analysis is carried out on various measures of efficiency on utility specific variables such as staff per 1000 connections, percentage of metered connections, Source of water (Percentage of surface water). This may not be a full list of variables to explain the variation in technical efficiency across utilities,but this may help understand the systematic causes of variation in efficiency. Therefore, the relationship between efficiency indexes and their determinants are examined.

4.5.1 Percentage metering and utilities efficiency

Metering is an important instrument that helps utilities to improve their efficiency levels and reduce UFW. It makes consumers consumption conscious and utilities attentive about leaks and process water consumption information for water use efficiency (Bhattacharyya et al, 1995). Therefore, it is hypothesized that utilities with higher percentage of metered connections have high efficiency levels.

Table 10: Regression Results

Name of the variable	CRS	VRS
Staff per 1000 connections	-0.003 (-0.52)	-0.001 (-0.37)
Percentage of metered connections	0.03 (1.65)*	0.02 (1.48)*
Percentage of surface water	-0.002 (-0.854)	0.003 (0.87)

Note: *, shows the level of statistical significance at 10 %. Values in parentheses are 't-statistics'.

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The relationship between percentage of metering and various measures of efficiency are positive and statistically significant at 10% level (Table 10). It implies that metering is an important variable that helping improving the performance of water utilities.
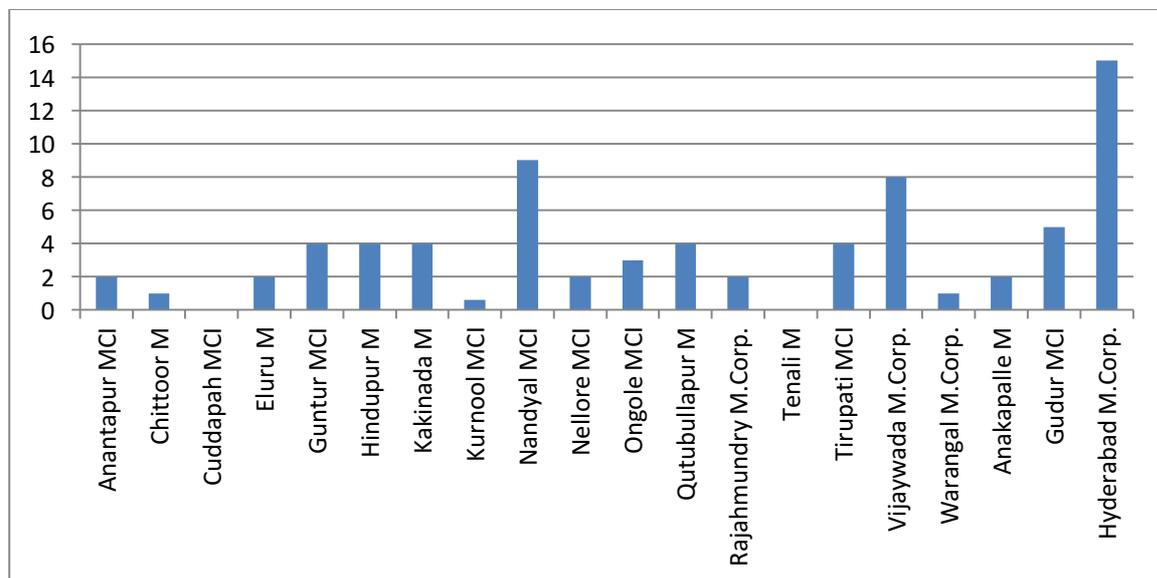

Fig.1: Percentage connections metered

The maximum level of metering in the sample utilities is 15% as shown in Figure 1. In the remaining utilities the percentage of metering is less than even 10%, indicating that metering levels are dismal so that actual levels of water losses will always remain an estimate, and planning will be based on approximations.

The water delivery cost and technology is linked to the source of water (Bhattacharya et, al. 1995). Water utilities that depend on ground water sources require lumpy investments and frequent maintenances. Therefore, it is hypothesized that the utilities with higher percentage of surface water sources have high efficiency levels. The coefficient is positive for VRS efficiency and is statistically insignificant. The sign of the coefficient support the hypothesis, but it may be ambiguous as the energy prices in India are regulated. Similarly, the coefficient of staff is negative and is statistically insignificant.

4.5.2 Length of distribution network and Utility efficiency

In many cases water losses reflects the inefficiency of the management of water utilities. The relationship between Network length and UFW is positive and statistically significant (Table 9), representing those shorter networks may be easier to maintain.

5   Conclusions

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The present work attempted to evolve a framework for evaluating the efficiencies and performance of water supply utilities in the urban areas of India by using a non-parametric approach.

An assessment of the efficiencies of the water supply services indicated that there are significant inefficiencies amongst various municipalities that were investigated. The fact that water supply services exhibit marked inefficiencies implies that there is a possibility that most utilities can achieve higher levels of services with lesser inputs. This implies that these services can be improved by changing the scale of operation since most of the utilities are operating under increasing returns to scale. The results of the study also indicate that significant potential exists for effecting savings if operational expenditures and UFWs are managed prudently. Such savings are estimated to be in the range of Rs. 5.39 million annually, implying a 31.75% potential in curtailment of current operational expenses, while it is possible to save 19.10% of the water currently lost as UFW.

The regression results indicate that the variables Length of network, and Water supplied explain OPEX as well as UFW to a large degree, and that a substantive input-output relationship exists between the two. The results also indicate that the variables do not violate the isotonicity assumption. It also shows that Length of distribution network is significant determinant in reducing UFW and thus plays a major role in improving utility efficiency, particularly as shorter networks are easier to maintain. The study observes that percentage of metering is the major determinant of performance of water utilities. The data exploration also revealed that a large number of water supply utilities in India report inadequate metering (including complete absence of metering in several urban centers), leading to approximate estimations of UFWs. Under the government's declared objective to reduce the UFWs, and considering the fact that the utility efficiencies are contingent on the water loss reductions during the supplies, it may actually be pragmatic for the government to institute measures to widen the metering of water supplies. Installation of meters would also eventually eliminate the widely prevalent "underhand transactions" and would lead to establishment of a transparent regime where users pay for their consumptions, and have the incentive to reduce wastages, that currently breed inefficiencies.

References

Bhattacharyya, A., T. R. Harris, R. Narayanan, & K Raffiee. (1995) Technical Efficiency of Rural Water Utilities, Journal of Agriculture and Resource Economics, 20(2), 373-391.

Census of India. (2011) Office of the Registrar General, India, Government of India, New Delhi

Coelli, T. J., Prasada, Rao, D.S., Christopher, J. O'Donnell & George, E. Battese. (1998) An Introduction to Efficiency and Productivity Analysis, Second edition, USA

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Corton, M. (2003).Benchmarking in the Latin American water sector: the case of Peru.*Utilities Policy, 11(3)*, 133-142

Corton, M. & Berg, S.V. (2009).Benchmarking Central American water utilities.*Utilities Policy, 17(3/4)*, 267-275.

CPHEEO.(2005) Status of Water Supply, Sanitation and Solid Waste Management in urban Areas. Research study series No. 88, Central Public Health and Environmental Engineering Organization, Ministry of Urban Development, Government of India, New Delhi, India.

Cruz, D., Ferraira, N., Marques, R., Romano, G., & Andrea, G. (2012) Measuring the efficiency of water utilities: a Cross national comparision between Portugal and Italy". Water Policy,149(5) ,841-852 , ISSN 1366-7017.

Guerrini, A., Romano, G. &Campedelli, B. (2011) Factors affecting the performance of water utility companies.*International Journal of Public Sector Management, 24(6), 543-566*.

Gupta, S., S.Kumar, and G. K. Sarangi. (2006) Measuring the Performance of Water Service Providers in Urban India**:** Implications for Managing Water Utilities, NIUA WP 06-08, New Delhi: National Institute of Urban Affairs.

Lin, C.(2005) Service Quality and Prospects for Benchmarking: Evidence from the PeruWater Sector. Utilities Policy 13(3), 230-239.

Marques, R.,Berg, S. & Yane S. (2014) Non Parametric benchmarking of Japanese Water utilities: Institutional and environmental factors affecting efficiency. Journal of water Research Planning and Management 140(5), 562-571.

National Water Policy .(2012). Ministry of Water Resources, Government of India

Planning Commission. (2012) Report of the steering committee on water resources and sanitation for Twelfth five year plan (2012-2017), Government Of India, New Delhi, India.

Romano, Giulia and Guerrini, Andrea. (2011) Measuring and Comparing the Efficiency of Water Utility Companies: A Data Envelopment Analysis Approach, *Utility Policies*, Vol. 19, pp. 202-209.

Singh, R. Mamata,Upadhyay, V., Mittal, K. Atul.(2010) Addressing Sustainability in Benchmarking Framework for Indian Urban Water Utilities, Journal of Infrastructure Systems,16,81-92.

Thanassoulis, E. (2000). The use of data envelopment analysis in the regulation of UK water utilities: water distribution. *European Journal of Operational Research, 126(2)*, 436-453.

Tynan, N. & Kingdom, B. (2002).*A water scorecard: setting performance targets for water utilities*. Private Sector and Infrastructure Network, note no. 242. The World Bank Group, Washington, DC, USA

Vishwakarma Amit, KulshresthaMukul, Sai AmulyaNyathikala, and KulshreshthaMudit. (2016). Cost Efficiency Benchmarking of Urban Water Supply Utilities - The Case of an Indian State Water and Environment Journal, 30,77-87.

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World Water Congress
International Water Resources Association (IWRA)
Cancun, Quintana Roo, Mexico. 29 May- 3 June, 2017

Vishwakarma Amit and Kulshrestha Mukul.(2013) Efficiency evaluation of urban water supply services in an Indian state. Water policy, 15 , 134-152

WHO and UNICEF.(2015) 25 years progress on sanitation and drinking water -2015 update and MDGassesment, World Health Organization and United Nations Children's Fund

Yepes, G. &Dianderas, A. (1996).*Water and Wastewater Utilities: Indicators*. The World Bank, Washington, DC.

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