Performance Benchmarking of Kandahar Water Supply Systems using Data Envelopment Analysis (DEA)

Mohammad Aslam Haziq, Abdul Rahman Mosameem, Esmatullah Muslim, Rahmatullah Dost and Nazir Ahmad Qani

Abstract—Two Water Supply Systems (WSSs) have been operating and providing drinking water services to two discrete districts, namely, Second Ayno Maina (AM-WSS), District 10, owned and managed by a private sector: AFCO Corporation, and Central Kandahar (CK-WSS), Share-Naw, District 2, owned and managed by government entity: Department of Kandahar Water Supply and Sewerage, for four and ten years respectively. Both the WSSs use groundwater as source of drinking water, and due to overpopulation and urbanization, they tend to expand their services and improve their performances, despite the fact that the primary step to do so is the performance assessment of the existing systems, lacking at the moment and needs a careful consideration. Therefore, the research study is aimed at assisting the responsible authorities of the performances being carried by their existing systems and satisfaction level of their customers against the services provided, along with their international comparisons, with similar-sized associated water supply schemes. Two sets of primary data were collected, including service-provider-driven and customer-driven, from relevant authorities and districts respectively. More specifically, for consumer-driven data collection, 66 and 75 questionnaires were distributed to the consumers of (AM-WSS) and (CK-WSS) respectively. Both the data set was classified as the input and output performance indicators (PIs), and was analyzed using SPSS, DEAP and Ms. Excel softwares, in compliance with Data Envelopment Analysis (DEA) methodology. The findings showed that (AM-WSS) had a relative technical efficiency, te of 1 (100 %), whereas CK-WSS had a te of 0.545. As a result, CK-WSS was the only System considered and recommended for amendments. Furthermore, the analysis of the findings showed that CK-WSS needed to focus on decreasing the staff size and total expenditure by 45 % to comply with optimization. The team recommends to train their personnel and reduce the number by 45 %, and additionally recommends to collect, keep and register all the necessary data of the schemes in an organized manner for future demands, plans, rehabilitation, performance, and improvements of the corresponding components of their systems.

Index Terms—Water Supply Systems (WSSs), Data Envelopment Analysis (DEA), Overpopulation and Urbanization, Performance Indicators.

I. INTRODUCTION

Researches on operating and maintaining water supply systems (WSSs) have long traditions in human history. According to WHO 2012, access to safe drinking water in sufficient quantity and at affordable cost is the right of every human being, irrespective of the location and the size of the community. Recent theoretical developments revealed that in 2010, almost 85 % of the global population (6.74 billion people) had access to piped water supply systems through house connections [1]. With respect to that, alone in USA the span of the water distribution pipes reached to almost 1 billion miles [2] and included an estimated 154,000 finished water storage facilities [7], [8]. Like all other infrastructure systems, the water sector also faces a number of global challenges in the 21st century, including population growth, uncertain climate changes, socio-environmental issues, limited water resources, industrialization, urbanization and economic crisis [17].

It is one of the prime objectives of any water utility to operate and maintain a WSS at its maximum possible efficiency at a viable cost [10]. A common strategy to achieve this goal would essentially require not just infrastructure expansion, but more importantly to adopt rational and optimum maintenance, rehabilitation and renewal (MRR) strategies to improve efficiency levels [10], [31].

The first step towards a sustainable WSS is to evaluate the performance of a given WSS, which further provides the basis for detailed investigations (detailed condition assessment and MRR strategies) [10], [40], [43]. The performance of a WSS can be assessed by selecting suitable performance indicators (PIs) [12], [6], [9], [26], [7], [8], [30], [24], [4]. Several benchmarking techniques are available and are being used throughout the world, from simple ratio analysis to complex mathematical and statistical modelling [31].

Among them DEA, Data Envelopment Analysis is the most widely used [31], [44] and a relatively new (First used by Charnes et al. 1978) technique that is adopted by many researchers worldwide. The general concept of performance benchmarking of a WSS using DEA is to compare its performance with other similar utilities in terms of suitable PIs. Haider et al (2013) carried out a state-of-the-art review literature on systems of PIs, and then based on their review,
proposed a suitable system of PIs for small and medium WSSs (SM-WSSs).

This research initially discusses major challenges and problems prevalent in the WSSs of Kandahar City, and then establishes the need for benchmarking. The research further explores various methods of benchmarking and reviews DEA in particular. It then illustrates the application of this technique regarding the two WSSs in Kandahar City, namely; Kandahar Ayno Maina Water Supply System (AM-WSS) and Central Kandahar Water Supply System (CK-WSS), and analyzes the results with respect to their performance levels and improvement opportunities.

This study is divided into five sections, including the general introduction, problem statement, scope and limitations and objectives of the research. Section 2 discusses the previous studies, and certain case studies are explored for the benchmarking purposes that further review the literature on benchmarking and DEA in water sector. Section 3 presents the methodology for the research. Section 4 covers the analysis of DEA results for the two WSSs in Kandahar City. Finally, section 5 provides conclusions and recommendations.

The poor performance of public water supply systems often stems from inefficiencies and mispricing [7], [19], [18]. Those inefficiencies need to be measured systematically to decide upon suitable remedial actions, and benchmarking is a robust measurement tool for achieving this purpose [45], [46].

To the best of our knowledge, no methodical efforts have yet been made to measure and benchmark the efficiencies of Kandahar WSSs. Even though the existing performance evaluation conducted by the Department of Kandahar Water Supply Sector (DKWSS) providing an initial rough assessment, it does not sufficiently address some key and fundamental questions, such as which WSS operates more efficiently, what lessons can be learnt from one another to optimize their performance, in light of internationally best practices and best performing WS-schemes under similar conditions, by comparing a number of key performance indicators (PIs), including personnel trainings, billing accuracy, etc.

Although several internationally recognized benchmarking initiatives have already been undertaken by many countries across the globe [10], Kandahar’s drinking water sector has hardly witnessed any benchmarking study. This research, therefore, intends to fill this gap and adopts a suitable and applicable benchmarking framework for sustainability-based performance assessment. In the present study, we measured relative efficiencies for the two water supply systems located in Kandahar City in order to benchmark them against the best performing WSS located in India, under similar conditions, in accordance with the sustainability criteria of Service Sufficiency and Resources Conservation.

The main objectives of the paper are to (1) assess the performance of the two WSSs in terms of efficiency, in accordance with the performance indicators (PIs) proposed by [10] for small and medium sized water supply systems (SM-WSSs). Consequently, based on assessment thereof, to (2) adopt a systematic approach to benchmark these two WSSs in regard to some other similar characterized WSSs internationally.

II. LITERATURE REVIEW

Performance is the degree to which infrastructure provides the services to meet the community expectations and is a measure of effectiveness, reliability and cost [23]. The performance of a WSS depends on efficient and reliable operations of all the functional components including water resources, physical assets, personnel, operational activities and environmental and financial activities [10]. For a WSS to be benchmarked as efficiently and effectively as possible, an efficient and reliable correlation between all the ancillary and functional components is required. A single malfunction in any of the functional components can cause the entire WSS to failure. Subsequently, the cost incurring for the corrective measures of such failures is expected to be much more than the cost which would have been incurred for the planned preventive measures [10]. Water Supply Systems (WSSs), therefore, to operate with maximum possible efficiency and minimum cost, justify the need for the performance assessment or performance benchmarking.

A. Terminologies

The Canadian Water and Waste Association (CWWA, 2009) briefly defined some of the terms as follows,

1) Performance Indicators (PIs) – A performance indicator (PI) is a parameter or value derived from other parameters, which provides information about the achievements of an activity, a process or an organization with a significant extension beyond that directly associated with the calculated value of the parameter itself. For example, indicators, such as the average number of liters of water supplied per person per day are typically expressed as commensurate or non-commensurate ratios between the variables.

2) Variables - Performance indicators involve the measurement of data variables generated by analysis of the service performed. The selected variables should be easy to understand; accurately measurable with available equipment, staff, and funds; easily reproducible or comparable; should refer to the geographical area and reference time of the study area; and be relevant to the indicator to be developed. These are basically the baseline data required to determine the associated value of a PI, e.g., number of service connections, population served, total water main length, and annual costs.

3) Benchmark - This is a numerical point of reference generally for the past or present. For example, in 2008, the average supply of water to residential customers was 350 Liter per capita per day (LPCD). The benchmark values established for the future should be considered as targets.

4) Target - A target in reference is a determined value for the PI, which is to be achieved over time through the conduct of a program. For example, a target for average water supply would be to reduce average demand to 300 Liter per capita per day (LPCD) by 2012. The International Water Supply Association (IWSA) selected the topic “Performance Indicators” for one of its world congresses during the early 90s, but the
concept could not attract much interest. However, 3 to 4 years later this concept was highlighted by a number of senior members of water utilities. A good PI system is one that contains PIs which are fewer in number, clearly defined, non-overlapping, useful for global application (i.e., wider applicability), easily understandable, refer to a certain time period (i.e., preferably one year), address a well-defined geographical area, and represent all the relevant aspects of water utility performance [28].

B. A Brief Summary of the Performance Indicators Systems

The PIs are grouped in different categories by various agencies [26], [4], [30], [42], [24], [16], [8] as mentioned before. Different agencies have used different terminologies as per their specific organizational setups and operational requirements. For example, [28] included a water interruption indicator in the operational category, whereas the same indicator was grouped into the customer relations category by [8]. Moreover, various indicators are associated with economic performance of a WSS and are interrelated (e.g., finance, economic, and pricing). Some of the agencies like [26] have included indicators of pricing and finance in separate categories, whereas others have grouped them into the same category of economic and finance [7], [4]. Generally, in the case of SM-WSSs, because of relatively smaller financial expenditures than for L WSSs (for which various categories have been developed), the most relevant financial PIs can be collected into one category.

From comparison of different categories through the literature, it is observed that most PIs are related to finance, customer service, and operation of a WSS. Importance given to these PIs indicates that these are the most important categories and also have strong interaction between each other.

C. Performance Benchmarking of Water Utilities - A Brief Summary of Some Case Studies

Small- and medium-sized water supply systems often face problems with availability of the data required to calculate the PIs [29]. Mostly, WSSs in developing countries face similar problems irrespective of the size of WSS. In the following sections, some case studies of performance assessment PA of WSSs in developing countries are described to identify the basic PIs used by the water regulatory agencies with very limited data. Outcomes of the application of these selected indicators are described briefly as well.

(1) South Asia- Bangladesh, India, Indonesia, Nepal and Pakistan.

According to [47], the urban water sector in South Asia continues to be plagued with severe deficiencies with regard to availability, quality, and equity of services. Although access to infrastructure is increasing according to official records, access to reliable, sustainable, and affordable water and sanitation services remains poor. In most urban areas piped water is available for only a few hours in a day. Many cities do not even recover their operation and maintenance costs from user charges and survive on large amounts of government support.

To promote sustainable performance improvement in the urban water sector across South Asia, [47] is supporting the development of performance measurement and benchmarking programs in India, Pakistan and Bangladesh [47].

Bangladesh is one of the most densely populated countries in the world with over 146 million residents [47]. According to the Government of Bangladesh, the urban utilities in Bangladesh are not performing well owing to lack of effective management. Under the Bangladesh benchmarking and performance improvement for water utilities project facilitated by Water and Sanitation Program - South Asia (WSP-SA), the concept of performance benchmarking was introduced in June 2005 for 11 utilities of all sizes (i.e., serving a population ranging from 21,000 to 10,000,000). The Government of Bangladesh took the initiative to introduce benchmarking and performance improvement programing tools (i.e., IB-Net) along with other stakeholders [3], [5], [11].

A similar study conducted by [45] to present a yardstick efficiency comparison of 269 Indonesian municipal water utilities (MWUs), showed that 39 percent of the total sample was facing serious problems. The data collected and gathered from different sources was analyzed using the latest technique DEA, and the performance indicators selected for this performance benchmarking were proposed by the systems mentioned earlier in this report. Number of staff per 1,000 connections, Ratio of OM to 1,000 connections (IDR million) and Ratio of OH cost to revenue are considered as the input measures. Accounted for water, Coverage areas of service, Production efficiency, operating hours, Billing effectiveness, return on equity, Ratio of revenue to operating costs, Cash ratio and Solvability are considered as the output measures for this study.

Singh et al. (2014) also conducted a study on 12 MWUs in Northern India using the same technique as mentioned in this research DEA using the DEAP software. Total expenditure (Rs. Million) and Staff size are selected as the input measures, Water supplied (MLD) and Number of connections are selected as the output measures for the study. The study was conducted for the purpose of presenting a yardstick efficiency comparison for the 12 MWUs, and the results of the study showed that almost 4 of the WSSs were 100 % relative efficiency and were selected as the benchmark for the other WSSs. The study also showed that some of the WSSs need to bring certain potential reductions in their inputs to meet their specified goals.

In a similar study conducted by WB, the performance of over 30 urban water utilities across Bangladesh, India, and Pakistan under WSP-SA was compared to evaluate the effectiveness of the program [41]. Almost all of the utilities in these countries are providing intermittent supply with an average duration of 5 h per day [32], [34]. As a result of the benchmarking process in Rajkot, India, a 48% increase in billing and 31% increase in collection were achieved in a 3-year period between 2006 and 2009. Moreover, 20,000 unauthorized connections have also been regulated in the same time frame [41]. It can be observed in Table 9 that the benchmarking process is currently focusing on meeting water demands and revenue collection to meet the financial and operational requirements in these South Asian countries. It is expected that with time, water quality, personnel,
environmental, and water resource indicators will also be included in the benchmarking process.

2. Australian Countries

The urban water utility sector in Australia has not always been the focus of government policy [33], [37], [39]. The first landmark document, 'A Water Resource Policy', dates from 1994 and was produced by the Council of Australian Governments (COAG). Its main emphasis was bringing water prices to a cost recovery level in order to enhance allocative and dynamic efficiency [25]. The performance assessment was conducted using DEA and Stochastic Frontier Analysis methods for data analysis by considering the Water resources/environments (Water sourced Water supplied) as performance indicator categories.

D. Data Envelopment Analysis (DEA) and its importance in performance benchmarking

Data Envelopment Analysis (DEA) is a relatively new approach for evaluating the performance of a set of peer entities called Decision Making Units (DMUs) which convert multiple inputs into multiple outputs [12]. The definition of a DMU is generic and flexible. Recent years have seen a great variety of applications of DEA for use in evaluating the performances of many different kinds of entities, engaged in many different activities in many different contexts in many different countries (Table I). One reason is that DEA has opened up possibilities for use in cases which have been resistant to other approaches because of the complex (often unknown) nature of the relations between the multiple inputs and multiple outputs involved in many of these activities (which are often reported in non-measurable units) [13].

### TABLE I: INTERNATIONAL RESEARCHES ON WATER UTILITIES PERFORMANCE BENCHMARKING BASED ON DEA

<table>
<thead>
<tr>
<th>Publication</th>
<th>Year</th>
<th>Dataset</th>
<th>Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norman and Stoker (1991)</td>
<td>1991</td>
<td>England and Wales, 28 water-only companies</td>
<td>DEA</td>
</tr>
<tr>
<td>Thanassoulis (2000)</td>
<td>2000</td>
<td>England and Wales, 10 water and sewerage companies</td>
<td>DEA</td>
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<td>Anwandter and Oznava (2002)</td>
<td>2002</td>
<td>Mexico, 110 water utilities</td>
<td>DEA</td>
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<tr>
<td>Thanassoulis (2002)</td>
<td>2002</td>
<td>England and Wales, 10 water and sewerage companies</td>
<td>DEA</td>
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<tr>
<td>Tupper and Resende (2004)</td>
<td>2004</td>
<td>Brazil, 20 water and sewerage companies</td>
<td>DEA</td>
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<td>Picazo-Tadeo et al. (2008)</td>
<td>2008</td>
<td>Spain, 40 water utilities</td>
<td>DEA</td>
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<tr>
<td>Guder et al. (2009)</td>
<td>2009</td>
<td>Germany, 373 water utilities</td>
<td>DEA</td>
</tr>
<tr>
<td>Renzetti and Dupont (2009)</td>
<td>2009</td>
<td>Canada, 64 water utilities</td>
<td>DEA</td>
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<tr>
<td>Singh et al. (2011)</td>
<td>2011</td>
<td>North India, 35 urban water utilities</td>
<td>DEA</td>
</tr>
<tr>
<td>Zschille (2015)</td>
<td>2015</td>
<td>Germany, 364 water utilities</td>
<td>DEA</td>
</tr>
<tr>
<td>Molinos-Senante et al. (2016)</td>
<td>2016</td>
<td>Chile, 25 largest water utilities</td>
<td>DEA</td>
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</table>

E. Size-based Classification of Water Supply Systems

The WSSs are categorized on the basis of their sizes to efficiently perform their organizational, financial, human resources, and operation and management (O&M) activities. The criterion of system size classification varies around the world [16] (Table II). In most parts of the world, including Central and North America, the utilities are commonly classified as small, medium, and large based on the volume of supplied water, number of connections, and population served [14].

In New Zealand’s and South Africa’s water research councils, the basis of size classification is the number of connections [20], [22]. According to the Irish Environmental Protection Agency, the small system is the one that serves less than 5000 people [16]. British Columbia, Canada, has a tiered classification for small water systems (WSs) based on the number of connections, ranging from 1 connection for a restaurant or resort to more than 20 000 connections [35], [36].

<table>
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<tr>
<th>Syste</th>
<th>USEPA</th>
<th>USEPA</th>
<th>World Bank</th>
<th>New Zealand</th>
<th>SA-WRC</th>
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<td>Large</td>
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<tr>
<td>Medium</td>
<td>3300 – 50000</td>
<td>3300 – 10000</td>
<td>125000-500000</td>
<td>2500-10000</td>
<td>10000</td>
<td>50000</td>
</tr>
<tr>
<td>Small</td>
<td>&lt; 3300</td>
<td>&lt; 3300</td>
<td>&lt; 125000</td>
<td>&lt; 500</td>
<td>&lt; 10000</td>
<td>10000</td>
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III. METHODOLOGY

The methodology section basically consists of three main subsections, including the Study area, Data collection and Data Analysis

A. Study Area

The research area consists of two main districts, the only districts having WSSs, located in Kandahar City of Afghanistan (Fig. 1) including the Second Ayno Maina Township, district 10, which is a relatively new and modernly designed township compared to the First Ayno Maina and other places of the city, and Share-Naw, district 2, was previously called old-city of the City, for its primitive historical background.

B. Data Collection

There are two sets of primary data collected, namely, service-provider-driven and consumer-driven, which can be explained as follows:

Fig. 1. Study area framework and clear vision of the two sub-areas selected for this Research.

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The first set of primary data was collected through questionnaires filled in by service providers, being in charge of water supply services to community, under their respected area of jurisdiction, in Kandahar City. The questionnaire was comprehensive and contained in-depth site specific questions about the performance of the WSSs, including: established and started date of the system, service coverage area, adequacy of daily supply, total number of personnel, staff training status, availability of professional staff for monitoring, operation and maintenance of water supply systems, entailing water quality, pressure management, leakage control, and billing mechanism and metering aspects.

The second set of primary data was filled in by consumers for which a separated questionnaire was designed, inquiring the consumers’ perceptions regarding different aspects of the WSSs, particularly water quality supplied, including taste, odor and color; adequacy of pressure in the tap water, sufficient quantity of water availability, the degree of satisfaction of services provided, encompassing personnel and other basic services.

C. Sampling

The city of Kandahar has a total of 1,252,786 pop. with average of ten persons per household and average pop. density of 23 persons per kilometer-square as per Central Statistics Organization of Islamic Republic of Afghanistan [42], [38]. Of total population, roughly 5,000 (0.4 %), 20,000 (1.6 %) live in Second Ayno Maina and Share-Naw respectively. The remaining number of people 1,227,786 (98 %) live in other districts of the city, using private water wells as source of water consumption and do not fall within the scope of the study. The data was collected in the concerned districts on 3 May 2018, namely, Second Ayno Maina and Share-Naw. In the study, the Slovin’s formula was used for sampling purposes, adopted from [15] with a minimum of 10 % error, obtaining 98 and 100 number of samples from each region respectively, however, in practice, due to various reasons, including availability of resources and time constraints, the questionnaires are only distributed to 66 and 75 participants/households respectively.

\[ n = \frac{N}{1+Ne^2} \]  

Where, \( n \) is the sample size, \( N \) is the total population and \( e \) is the confidential interval or the limited error. Simple random sampling was employed to choose the households in order to have an equal chance of distribution and selection.

D. Performance Indicators from the Collected Data

There were primarily two steps taken to extract site-specific Performance Indicator (PIs).

The first step included was to disseminate, collect the already established questionnaires aimed at involved people, encompassing both the service provider and service receiver to have their perception and necessary input as per goals and objectives of the research, and, subsequently, to extract essential PIs from service-provider-driven collected data accordingly.

The second step involved was the analysis phase of the extracted PIs, in conjunction with consumer-driven collected data and their level of satisfaction, using comparatively advanced software, such as, DEAP v.2, SPSS and etc., which will be described in-depth in section 4.7 accordingly.

However, the suitable extracted PIs through service-provider-driven collected data can be elucidated as follows:

1) Total expenditure (Millions/year).
   This PI was selected by [21] to extract the information about the total expenditure specified to the O & M of the selected WSS.

2) Staff size (Persons).
   Mamata et al. (2013) selected the staff size factor for the intention to know how much care is taken for the rehabilitation and maintenance of the WSS.

3) Supplied Water (MLD).
   This PI was selected for the intention to know if the service is sufficient.

4) Total No. of Connections (Number).
   The total number of connections shows the serviceability and sustainability criteria, describing the number of connected houses to the WSS for services

E. Data Analysis

Having collected the data, consumer-driven, from 66 households living in second Ayno Maina and 75 households living in Share-Naw, the second step was to analyze the data by sufficient tools and through internationally recognized procedure.

A SPSS v. 16 was used as a means of analyzing different statistical parameters, including frequency, percentage, mean and standard deviation, for a number of reasons, mainly relevant to consumers, including: socio-economic aspects of consumers, education level of consumers, purpose of tap water, satisfaction level of consumers on water quality (color, taste, etc.), water availability, adequacy of pressure at the consumer tap, staff’s behavior and interactions with consumers, and complaints about overall performance and serviceability of WSSs.

On the other hand, DEAP v.2 software was used for technical efficiency and analysis of benchmarking, as a result of collection of data and selection of appropriate PIs with classified input and output variables. Moreover, the relative efficiencies, targeted inputs and/or outputs, potential reduction in each of the inputs and/or outputs in percentage are the results of DEAP v.2, a highly recognized software globally.

Lastly, the processes of finding the relative efficiency of any Decision-Making Unit (DMU) among other peers is known as Data Envelopment Analysis (DEA).

IV. RESULTS AND DISCUSSION

This section initially discusses the results obtained from the questionnaires, and how they affect the relative efficiency of each WSS. However, the second part of this section draws conclusions from the results and discusses the outcomes of each conclusion.

A. Results and Findings of the Research

The results obtained from the primary and secondary data showed that one of the WSS’s efficiency was relatively lower than the other. Using DEAP software, it was proved that certain potential reductions are needed to make both
WSSs equally relatively efficient (Fig. 2, 3 and 4).

Table IV shows relative efficiencies of the two WSSs in accordance with the selected PIs. The Water supplied (MLD) and No. of connections (numbers) are considered to be the inputs, whereas the Staff size (persons) and total expenditure (Millions/year) are considered as the outputs for the performance benchmarking purposes.

The second phase consisted of the process of benchmarking these two WSSs with other worldwide accepted and standardized Water utilities, for the purpose of performance benchmarking in accordance with the PIs selected for achieving the objectives of the research.

Table IV also shows the technical efficiencies of the 14 Water utilities calculated with the help of DEAP software, and as well as the Target inputs in percentage for each Water utility to be relatively efficient with the other selected peers.

To achieve maximum efficiencies with minimum cost, the software used here also demonstrated to certain potential reductions in each of the Water utilities for both inputs. Table III shows additional information about the 14 Water utilities accordingly.

Table IV shows a brief summary of the relative efficiencies and all relevant information about the performance indicators and the potential reductions in percentage, as well as the target inputs for the both inputs indicators, total expenditure (Millions/year) and the staff size (persons).

The results in Table III clearly indicates that 6 out of the 14 WSSs have equal technical and scale efficiencies (te = se), and the rest (8 DMUs) of the WSSs have higher scale efficiencies than the others (se > te).

The results also show that AM-WSS is one of the perfectly efficient utilities, along with the other 4 Indian Water utilities with a relative efficiency of 1 (te=1).

A comparison of the te (technical efficiencies) and se (scale efficiencies) can be seen in Fig. 4 for further information.

B. General Efficiency Analysis

This section covers the results of efficiency analysis in terms of te scores, se scores, benchmark DMUs and input and output slacks. For each DMU, ranking position, number of DMUs under different efficiency ranges and potential reductions in each DMU.

It is evident from Table IV, that te scores for the 14 WSSs range from 0.415 to 1 (100%) with its average mean value as 0.748. Se scores for the 14 WSSs range from 0.666 to 1 (100%) with its average mean value of 0.897 (Table IV and Fig. 4), which means that the se or scale efficiencies are stronger than the te or technical efficiencies. From this analysis, it can be drawn that the Municipal and Water Sector Authorities may focus on strengthening their technology and improvements rather than the operational efficiencies.

From Fig. 4, it is clear that for 6 out the 14 DMUs, te=se, and for the rest of the DMUs, se > te (Table IV and Fig. 4), DMUs with se > te need to focus on the focus on productivity and technology improvement. These measures would enhance the operational efficiency of the DMUs.

DMUs with te=se, means the WSSs is either improved at both operational and technological aspects or may need to focus on taking certain remedial measures for both operational and technological aspects. For example, renewing the infrastructure may increase efficiency in terms of te, whereas training personnel and employing them in the technical areas may enhance se.
TABLE III: DEA RESULTS: SCALE EFFICIENCIES, RANKING, PEERS AND SLACKS FOR 14 DMUs

<table>
<thead>
<tr>
<th>No.</th>
<th>DMUs</th>
<th>te* (%)</th>
<th>se** (%)</th>
<th>Ranking</th>
<th>Output slack-1</th>
<th>Output slack-2</th>
<th>Input slack-1</th>
<th>Input slack-2</th>
<th>Peers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Amravati</td>
<td>0.58</td>
<td>0.75</td>
<td>5</td>
<td>25.05</td>
<td>0</td>
<td>14.99</td>
<td>0</td>
<td>2</td>
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<td>Aurangabad</td>
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<td>1</td>
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<td>Bhusawal</td>
<td>0.85</td>
<td>0.99</td>
<td>2</td>
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<td>0.58</td>
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<td>0</td>
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<td>0</td>
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</table>

* Technical efficiency, ** Scale efficiency

TABLE IV: DEA RESULTS: RELATIVE EFFICIENCIES OF THE 14 WSSS ALONG WITH THEIR TARGET INPUTS AND THEIR POTENTIAL REDUCTIONS IN EACH WSS.

<table>
<thead>
<tr>
<th>No.</th>
<th>Water Supply Utility</th>
<th>Water Supplied (MLD)</th>
<th>No. of Connections (*1000)</th>
<th>Total Expenditure (Millions/Year)</th>
<th>Staff Size (*10)</th>
<th>Technical Efficiency, te (%)</th>
<th>Input targets 1 (Total Expenditure)</th>
<th>Input targets 2 (Staff Size *10)</th>
<th>Potential Reductions (%) for Input 1</th>
<th>Potential Reductions (%) for Input 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Amravati</td>
<td>60</td>
<td>38.84</td>
<td>68.1</td>
<td>26.2</td>
<td>0.58</td>
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<td>15.2</td>
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<td>71.00</td>
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<tr>
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<td>Bhusawal</td>
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<td>16.4</td>
<td>11.2</td>
<td>0.85</td>
<td>13.95</td>
<td>9.5</td>
<td>14.94</td>
<td>15.18</td>
</tr>
<tr>
<td>5</td>
<td>Dhule</td>
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<td>23.62</td>
<td>46</td>
<td>10.8</td>
<td>0.71</td>
<td>26.74</td>
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<td>85.2</td>
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<td>23.7</td>
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<td>18.18</td>
<td>12.3</td>
<td>43.36</td>
<td>43.32</td>
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<td>Nashik</td>
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<td>82.28</td>
<td>194.1</td>
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<tr>
<td>10</td>
<td>Solapur</td>
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<td>62.6</td>
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<tr>
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<td>4.5</td>
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<td>7</td>
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<td>5.5</td>
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<td>8.65</td>
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<td>1</td>
<td>10</td>
<td>4</td>
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</tr>
</tbody>
</table>

For the outputs, out of all the DMUs, 3 DMUs have slack for net per capita supply, while 3 of the DMUs have slack for the total number of connections. For the inputs, out of all the DMUs, 4 DMUs have slack for total expenditure, whereas only 1 DMU has slack for both the inputs total expenditure and staff size.

Thus, there is a scope for decreasing the Total expenditure by 33 percent for all the DMUs, with the highest potential reduction for Yavatmal being more than 50 percent in contrast to the lowest DMU, being 15 percent which is the DMU of Chandrapur.

Form Table IV, it is also seen that a scope for decreasing the Staff size by more than 33 percent for all the Water utilities may affect efficiencies in the positive direction. The highest potential reduction in Staff size is for Yavatmal about more than 50 percent in contrast to Chandrapur with the lowest potential reduction of more than 15 percent in the Staff size factor. This percentage may attract the focus of Municipal and Water Sector Authorities to take remedial measures for increasing the relative efficiencies of the above DMUs.

C. Analysis of the Two DMUs Operating in Kandahar City

In this study, our main focus was in two DMUs AM-WSS and CK-WSS out of the 14 DMUs, as the 12 DMUs are illustrated and benchmarked by Singh et al. (2014).

Fig. 4 shows the results for the 2 DMUs located and operating in Kandahar City and are under consideration in this study.

The technical efficiency (te) for AM-WSS is 1, which is perfectly efficient and has a relative efficiency of 100% from the DEA analysis, and this score is equally high and appreciable in terms of scale efficiency as well, which can be extracted in the conclusion that it is efficiently operating very well in terms of both technology (i.e., Pumping stations, Mains and Sub-mains, Water storage facility and Tanks etc.) and as well operational aspects (i.e., Trained personnel, appreciable and sustainable supply of water to the consumers, etc.).

The potential reductions for both inputs are 0 calculated by the DEAP. The potential reductions clearly show that this Water utility needs not to bring any changes in the input variables since the outputs are suitable and can satisfy the current needs of the consumers.

For the other hand, is less than unity, which means the system is not running perfectly efficient and needs to either bring certain potential reductions in the input variables, or in contrast, strive to increase their outputs in terms of Staff size and Total expenditure. The results form DEA (Table IV) clearly show that CK-WSS to run with perfect efficiency and provide services efficiently, should reduce their staff size from 55 to 30 and train them for the operation and maintenance of the WSS. Similarly, the Total expenditure needs to be reduced form 7 Million to 3.28 Million per year for the WSS to run with maximum possible efficiency and

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minimum cost.

Form Fig. 4, it can be seen that the se for CK-WSS is greater than its te, which clearly means that this Water utility needs to focus on operational side changes more than on the technical side. Personnel training, for example, is essential for being perfectly efficient rather than renewing the whole infrastructure (Pumping stations, storage tanks, pipes etc.) of the DMU. Though the analysis shows potential for reducing staff size, average staff per 1,000 connections is well within the range of (five to ten) obtained from international average of developing countries.

D. State-wise Performance Analysis

This section carries out performance analysis for the two union territories (Northern Indian States and Kandahar City). Calculations of efficiencies and other variables (staff size, total expenditure per year, total number of connections, etc.) for each of the 14 Water utilities are based on the respective average values of variables of all the utilities belonging to the state under consideration. The analysis highlights the following facts:

1) Aurangabad, Bhusawal, Parbhani and Wardha states have the highest te scores of 1 with relative efficiencies of (100%), but Yavatmal, Solapur, Nashik, N. Waghala, Kolhapur, Dhule and Amravati have lower te scores and are relatively, 0.415, 0.566, 0.666, 0.566, 0.571, 0.712 and 0.58, respectively. These Water utilities need to focus on improving their technical efficiencies in terms of technology and infrastructure. In which the lowest one is Yavatmal.

2) Similarly, Aurangabad, Bhusawal, Chandrapur, N. Waghala, Parbhani and Wardha states have the highest se scores of 1 with relative efficiencies of (100%), except for Chandrapur and N. Waghala, with se scores of 0.992 and 0.969, respectively. But Yavatmal, Solapur, Nashik, Kolhapur, Dhule and Amravati have lower se scores and are relatively, 0.879, 0.759, 0.666, 0.683, 0.867 and 0.747 respectively. And the lowest score is of Amravati. And these DMUs need to focus on improving their operational efficiencies.

3) Aurangabad, Bhusawal, Parbhani and Wardha states are ranked as the first DMUs out of all the 14 DMUs using DEA analysis. Chandrapur is ranked as the lower te second DMU, Dhule as the third DMU, and similarly, Nashik, Aurangabad, Kolhapur, N. Waghala, Solapur and Yavatmal as the fourth, fifth, sixth, seventh, seventh and ninth DMUs, respectively.

4) AM-WSS operating in Kandahar City is ranked as the first DMU, and CK-WSS is ranked as the 13 DMU out of all the DMUs, in terms of efficiencies.

5) AK-WSS has te and se scores as relatively 1 and 1, respectively, whereas CK-WSS has te and se scores of 0.545 and 0.995, respectively. This DMU needs to focus on improving its technical efficiency rather than its operational efficiency, which is relatively higher than most of the DMUs operating in Northern India.

6) CK-WSS needs to focus on reducing the inputs staff size and total expenditure by 45 percent.

V. CONCLUSION AND RECOMMENDATIONS

A. Concluding Remarks

Two WSSs, Ayno Maina WSS (AM-WSS) and Central Kandahar WSS (CK-WSS), have been operating in Kandahar City for 4 and 10 years respectively. As a general rule, all WSSs need to operate with maximum possible efficiency and minimum cost. To achieve these goals, it is necessary to calculate its efficiency and assess the existing performance to which there was necessity in Kandahar City for the 2 WSSs.

This research was conducted on the basis of performance benchmarking with the help of the latest technique Data Envelopment Analysis (DEA) for Kandahar Water Supply sector. No previous studies have been done in the relevant field so far. The main findings of the research were calculating the relative efficiencies, and te technical efficiency, which aim to find the potential reductions in the technological aspects, and se scale efficiency, which in contrast to te aims at improving the operational efficiency, and the second main finding of the research was benchmarking these two WSSs against 12 standard WSSs operating in northern India to obtain a yardstick benchmarking for the 2 WSSs.

These efficiencies were calculated and benchmarked with reference to certain factors, Performance Indicators (PIs) in the terminology of DEA, and these PIs were classified as input and output variables and the analysis of the findings showed that AM-WSS was perfectly efficient with a relative efficiency of 100 %, whereas the other WSS was poorly efficient with a relative efficiency of 54.55%.

The analysis was performed in the latest software with accurate measurements, DEAP v.2, and showed that CK-WSS needs to focus on increasing its efficiency in terms of both technical and operational aspects. Furthermore, the analysis showed that CK-WSS to run perfectly efficiently, there is a scope in potential reduction of the input variables about 45 % in both Staff size and total expenditure per year.

The scope of the present analysis could not be widened to incorporate additional performance indicators due to limited data availability. Also, the efficiency analysis did not take into account the impact of non-controllable environment factors (such as topography, population density, water source etc.). However, there is considerable scope for further research on the subject. Urban water utilities of other cities in Afghanistan may also be included for DEA in order to draw useful lessons from the international best practices. Also the availability of data on resources and their respective prices would enable cost efficiency analysis of the utilities.

B. Recommendations

Our research was mainly limited by the lack of sufficient and exact data, we would like to recommend to focus on making a data bank for Kandahar City, particularly for second Ayno Maina and Central Kandahar, such as, population, population per square meter, net per capita rate, number of connections in Ayno Maina and Central Kandahar, metering, billing accuracy and satisfaction from services of water supply, etc.

Secondly, the results of findings showed that 15 percent people showed dissatisfaction from personnel, and DEA

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showed that a 45 percent decrease should be considered in the staff size of CK-WSS, we recommend that personnel should be trained and decreased by 45 percent.

A professional team for inspection and quality control of taste, color and odor of the supplied water should be considered for both WSSs, as the data showed that less than a quarter of the population showed dissatisfaction from the quality of the water supplied.

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We also owe a great debt of gratitude to the consumers who willingly provided us with enough and exact information which were truly essential for research.

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Abdullah Ansari

REFERENCES


