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DATA ENVELOPMENT ANALYSIS FOR ASSESSING EFFICIENCY IN PUBLIC UTILITIES WITH A FOCUS ON WATER AND SEWERAGE SERVICES

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ABSTRACT

This article aims to demonstrate that the Data Envelopment Analysis method can be employed to evaluate the operational efficiency of public utility enterprises under state ownership or local government jurisdiction, such as cities and municipalities. These enterprises are tasked with delivering high-quality public services to citizens at affordable prices. Achieving this goal necessitates efficient management and judicious use of public resources. The research evaluated the efficiency of public water utility enterprises in the Federation of Bosnia and Herzegovina using the Data Envelopment Analysis method. Three indicators were used as inputs in the model: asset value, number of employees, and total expenses. The output indicator was total revenue, which reflects the number of users under relatively uniform service tariffs. The findings reveal that 92.31% of these public utilities exhibit technical efficiency levels above 90%. Additionally, 53.85% demonstrate 100% technical efficiency in input utilisation. The results highlight enterprises that inefficiently use assets incur above-average costs or employ more workers than necessary. The study concludes that the Data Envelopment Analysis model effectively identifies state-owned public utility enterprises that consume above-average resources to deliver the same scope and quality of services.

KEY WORDS

data envelopment analysis, resource efficiency measurement, public utility companies, public water supply and sanitation companies

CLASSIFICATION

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INTRODUCTION

Public utility companies are public organisations that provide services for the public good in the field of communal services, such as water supply, sewage, waste management, public lighting, etc. Local governments or the state often own them, and their goals usually include providing public services efficiently and affordably. Hence, efficiency is imperative in their operations. Efficiency is defined as the ratio of results achieved to resources used to achieve those results. In other words, efficiency refers to the ability to perform a task with as few resources as possible while achieving desired results. Efficiency in business means that resources, such as time, money, labour, etc., are used in the best possible way to achieve desired results.

Public utility enterprises are frequently criticised for their inefficiency, lack of transparency, insufficient accountability of management for inefficient governance, lack of oversight from founders, and political interference in their operations. This is particularly evident in countries undergoing transition, such as Bosnia and Herzegovina. The issue is especially pronounced in public utility enterprises responsible for water supply and sanitation. Due to the outdated water supply network, lack of infrastructure maintenance and numerous illegal connections, the loss in the water supply network in FBiH is estimated at over 59%, and in some cases reaches a value of 70% [1]. The percentage of lost water is high compared to the fact that water losses worldwide are reported to be a maximum of 15% and up to 7% in some EU countries.

According to Transparency International’s research [2], most companies with majority state capital are characterised by significant political influence in the appointment of management and supervisory boards and similar methods of company management. This negatively affects their business operations because management and supervisory boards appointed in this way completely shift all responsibility for poor performance onto the relevant ministries and governments. Additionally, although the law defines the obligation of the audit committee to submit a report at each annual meeting, these reports are usually superficial and lack significant consideration of risk studies that detail risky areas and contracts concluded between public enterprises and related parties. Another limiting factor for the efficiency of public enterprises is the high risk of corruption [3].

This article aims to demonstrate that the Data Envelopment Analysis (DEA) method can be employed to evaluate the operational efficiency of public utility enterprises under state ownership or local government jurisdiction, such as cities and municipalities. Efficiency testing of public water utility enterprises from the Federation of Bosnia and Herzegovina (FBiH) was conducted using the DEA method. Three indicators were employed as model inputs: the value of assets, the number of employees, and the total expenses of the company. The total revenue indicator was utilised as the output, as it reflects the number of users under conditions of relatively uniform service tariffs. The research results indicate that the DEA model is an effective means of detecting public utility enterprises under state ownership that consume an above-average quantity of resources for the same scope and quality of services provided. It is recommended to use the scaled efficiency measure, representing the ratio of the Banker-Charnes-Cooper (BCC) model to the Charnes-Cooper-Rhodes (CCR) model. The findings suggest that DEA analysis can also serve as a valuable tool in the planning and control of resource consumption within public utility enterprises.

The article structure is as follows. After the introduction, a review of previous research on the possibilities of using the DEA model to detect inefficiencies in public utility enterprises is provided. The research methodology is explained, with a clarification of the DEA techniques used, followed by the presentation and explanation of the research results. Finally, conclusions and recommendations for future research are provided.

EFFICIENCY OF PUBLIC UTILITY ENTERPRISES

A range of studies have explored the issue of efficiency in public utility companies. Krajewski & Thompson [4] and Courville [5] both highlight the potential for inefficiency in these companies, with Krajewski and Thompson specifically noting the trade-offs between employment costs and service. Public utilities are often criticised for their low efficiency in providing their services, which can lead to low service quality, low profitability, and high costs for users [6-9]. Nagasawa [10] highlights the struggle of local public enterprises to balance public interest and efficiency, which can lead to potential cost inefficiencies. Miranti [11] reveals significant inefficiency among regional public utility water companies, with positive technological adjustment not translating into efficiency improvements. Article [12] suggests that public monopolies may have greater incentives for cost-reducing investment, but this may not always translate to improved efficiency. Molinos-Senante & Maziotis [13] Have demonstrated that in England and Wales, public waste management utilities are more efficient than public water utilities. They also showed that, on average, a water company can increase its technical efficiency by operating in more densely populated areas and by investing in technology to reduce bursts in water mains. In a study conducted by Molinos-Senante & Maziotis [14], the results indicated that the water industry demonstrated high levels of cost efficiency. Based on average results, it appeared that the public water companies performed slightly better than private ones, with full private water companies being more efficient than concessionary. However, the analysis of the trend in companies' efficiency revealed that full private water companies' efficiency increased over the years 2010-2018, whereas the opposite was true for public water companies. It has also been found that environmental variables might have a higher impact on public water company costs and inefficiency than private ones.

Several studies have found no significant difference in efficiency between public and private utilities. Cullmann et al. [15] and Hall & Lobina [16] both found no systematic difference in efficiency, with Cullmann attributing this to changes in the energy sector and Hall highlighting the need for balanced policies. Lambert, Dichev, & Raffiee [17] even found that publicly-owned water utilities were more efficient overall. Souza, Faria & Moreira [18] also found no significant difference in efficiency between Brazilian public and private water utilities. Atkinson & Halvorsen [19] further complicates the picture, suggesting that both types of firms are equally cost-efficient.

A range of methods have been proposed to measure cost inefficiency in public companies. Merewitz [20] suggests using statistical cost functions to compare observed costs with those of efficient properties. Liu [21] introduces a dual approach that considers both technical and allocative inefficiency, using the duality between production and cost functions. Kumbhakar [22] uses a translog cost function to incorporate technical and allocative inefficiencies and develops a maximum likelihood method to measure these costs. Farsi and Filippini [23, 24] focused on the application of panel data models to measure cost efficiency in electricity distribution and multi-utility companies in Switzerland. They found that these models were effective in predicting inefficiency and that considering unobserved firm-specific effects led to lower inefficiency estimates. Kumbhakar [25] applied a panel data model to estimate cost efficiency in electricity production by investor-owned utilities in Texas, finding evidence for both permanent and residual cost inefficiencies.

Many studies have explored the use of data envelope analysis to analyse resource inefficiency. Finkler & Wirtschafter [26] applied DEA to medical care decision-making, identifying cost-effectiveness frontiers. Friesner, Mittelhammer & Rosenman [27] developed a Bayesian approach to infer industry inefficiency from DEA estimates, accounting for mismeasurement. Banker, Chang & Natarajan [28] addressed the use of aggregate cost or revenue data in DEA evaluation, identifying significant allocative inefficiency in the public accounting industry.

Husain, Abdullah & Kuman [29] analysed the efficiency of transportation in Malaysia using the DEA model. Serano-Cinca, Fuertes-Callen & Mar-Molinero [30] employed the DEA model to measure the efficiency of internet companies. Zi [31] presented an integrated model utilizing DEA and rough set to assess government efficiency. Lannier & Porcher [32] used a data envelopment analysis and a stochastic frontier analysis (SFA) to assess the relative technical efficiency of decision-making units in the French water supply sector.

Numerous studies have applied the DEA model in analysing efficiency in various sectors, including logistics companies [33], Islamic banks [34], commercial banks [35], hotel sector [36], construction companies [37], healthcare sector [38], and so forth.

Scientific research indicates that the DEA model can effectively assess the efficiency of input utilisation or outcome achievement across various sectors. However, there is a notable lack of research regarding the potential application of the DEA model in determining the efficiency of resource utilisation in public utility enterprises.

METHODOLOGY

ANALYTICAL APPROACH

The DEA method will be used to measure the efficiency of public utility companies in terms of water supply and sewage in FBiH. DEA analysis is a nonparametric linear programming technique used to evaluate the relative efficiency of decision-making units (DMUs) that have the same inputs and outputs but differ in the level of resources they have and the level of activity within the transformation process [39] Each DMU uses one or more inputs to produce one or more outputs. Data on selected inputs and outputs are included for all analysed DMUs in a linear program that represents the selected DEA model. DEA is a method for determining the best DMU among different and comparable DMUs.

Unlike parametric methods that estimate the performance of an entity in relation to average performance, DEA is a method that calculates the maximum performance measures for each unit included in the analysis, assigning optimal weights to each indicator. More efficient units are those that provide a higher output for a given amount of input. Inputs and outputs should be selected to cover all resources and all relevant activities or outcomes for a particular efficiency analysis. Among them, those that best represent the process being evaluated and provide a true picture of overall performance should be identified. In addition, the relationship between the number of input and output variables and the number of DMUs analysed should be considered to make the analysis results as close to reality as possible. Apart from the choice of the model, this is almost the only element of subjectivity in DEA. If the goal is to minimise inputs while achieving (at least) a given level of output, an input-oriented model is used. In contrast, an output-oriented model is chosen to maximise output while using (at most) a given amount of input.

The DEA models used in our research are the CCR and BCC models. The main difference between the models lies in the assumed transformation of inputs into outputs. The CCR model is the most commonly used and well-known DEA model, which is based on the assumption of constant returns. The CCR model for input oriented DMUs can be mathematically represented as:

$$\min_{\theta,\lambda} \quad \theta, \tag{1}$$

subject to

$$\theta x_o \geq X\lambda,\, Y\lambda \geq y_o \text{ and } \lambda \geq 0.$$

The optimal solution to this program-characterizing a technology with constant returns to scale, CCR, is denoted by θ^*_{CCR}. The constraints reguire the observation $(\theta^*_{CCR}x_0, y_0)$ to belong to P_{CCR}, while the objective seeks the minimum θ_{CCR} that reduces the input vector x_0 radially to $\theta_{CCR}x_0$ while remaining in P_{CCR}. Those observations associated λ multipliers are greater than zero define the enveloping hyperplane. A feasible solution signalling radial efficiency is $\theta^*_{CCR} = 1$. Therefore if $\theta^*_{CCR} < 1$ the observation is radially inefficient and ($\lambda X, \lambda Y$) outperforms (x_0, y_0).

The measurement of technical efficiency assuming variable returns to scale (VRS), as introduced by Banker [40] – known as BCC model considers the following production possibility set

$$\text{PVRS}=\{(x,y)|x \quad X\lambda, y \quad Y\lambda, e\lambda = 1, \lambda \quad 0\}. \tag{2}$$

Therefore, the only difference with the CCR model is the adjunction of the condition $\sum_{j=1}^{n} \lambda_j = 1$.

The drawbacks of DEA are its sensitivity to data errors and the fact that it evaluates relatively (comparing each entity only with the best one in the observed set) rather than absolutely. The basic DEA model cannot perform analysis with negative numbers, and it is desirable to have strictly positive data (without zero values). This is defined as the model's 'positivity requirement. '

DATA

The research includes 13 public utility companies for water supply and sewage in the Federation of Bosnia and Herzegovina (FBiH), covering the entire population of these companies in FBiH.

All data used in the analysis are publicly available on the website of the Financial Information Agency FIA [41]The model's inputs are total asset value, total expenses, and the number of employees, and the output is total revenue. We could not take business results as the output because a certain number of companies operate at a loss. Given that the price of water per m3 is relatively uniform, the revenue amount primarily depends on the number of service users.

The data used in the analysis are given in Table 1, with the following information: Name of DMU, Input 1 (total asset), Input 2 (number of employees), Input 3 (total expenses), and Output (total revenue).

RESULTS

DESCRIPTIVE STATISTICS

Table 2 gives descriptive statistics values for the observed inputs: asset value, number of employees, total expenses, and output total revenue.

The results show that there are significant variations in the value of assets, number of employees, total expenses, and achieved revenues, which primarily depend on the size of the canton or area covered by the public utility company for water supply and sewage. All input values are strongly positively correlated with output values.

SELECTION OF DEA MODEL

The CCR model assumes constant returns to scale. It is suitable when all firms operate at optimal scale. However, note that this is an ambitious assumption. If the DMUs operate under optimal conditions, they have developed in perfectly matching circumstances. The BCC model (corresponding to the BCC model) assumes variable returns to scale. This is appropriate when firms do not operate at optimal scale. This is usually the case when DMUs face imperfect competition, and different regulations.

Table 1. Inputs and outputs of the model (PUC – Public Utility Company).

No. DMU	Name of DMU	Input 1 (total assets)	Input 2 (number of employees)	Input 3 (total expenses)	Output (total revenue)
DMU1	PUC Water Supply and Sewage Ltd. Tuzla	48.647.539	206	1.5043.446	15.329.080
DMU2	PUC Water Supply and Sewage Ltd. Sarajevo	832.178.330	852	66.786.459	53.496.522
DMU3	PUC Water Supply and Sewage Zenica	4.9781.213	174	7.334.610	7.628.019
DMU4	Water Supply Ltd. Mostar	46.337.068	240	12.606.968	12.661.262
DMU5	PUC Water Supply and Sewerage Ltd. Velika Kladuša	22.755.992	52	2.579.534	2.639.697
DMU6	PUC Water Supply Ltd. Posušje	22.074.664	54	3.813.801	3.895.790
DMU7	PUC Vodokom Ltd. Kakanj	15.750.544	129	4.552.475	4.573.333
DMU8	PUC Water Supply Ltd. Cazin	15.466.197	79	4.611.439	4.377.890
DMU9	PUC Water Supply Ltd. Bihać	9.987.182	129	5.052.554	5.053.411
DMU10	PUC Water Supply and Sewerage Ltd. Sanski Most	9.558.933	40	1.806.572	1.808.285
DMU11	PUC Water Supply and Sewerage Ltd. Bugojno	5.047.379	40	1.571.368	1.135.828
DMU12	PUC Vitkom Ltd. Vitez	4.814.761	78	2.707.350	2.856.065
DMU13	PUC Vodokom Ltd. Domaljevac	2.476	1	12.610	300

Table 2. Descriptive statistics indicators for the inputs and outputs of the model

Indicator	Input 1 (total assets)	Input 2 (number of employees)	Input 3 (total exspenses)	Output (total revenue)
MEAN	83261713.69	159.54	9883014.31	8881190.92
Std. Deviation	225669774.30	219.80	17633981.07	14113974.03
Coef. of Variation	2.71	1.37	1.78	1.58
Std. Error	62589534.04	60.96	4890786.38	3914512.08
Skewness	3.57	2.98	3.25	3.04
Excess Kurtosis	12.81	9.74	11.06	9.90
Media	15750544.00	79	4552475.00	4377890.00

Comparing the two models shows the source of inefficiency. The technical efficiency of the CCR model corresponds to the global measure of DMU performance. Let us compare the efficiency results of the two DEA models (CCR and BCC) and calculate the resulting ‘scale’ efficiency. Scale efficiency is obtained as (Formula 3 and Table 3):

$$SE = \frac{\theta_{CCR}}{\theta_{BCR}}. \quad (3)$$

Different models yield significant differences among efficiency values. Since the BCC model (variable returns to scale) tightly envelopes the data because of the additional constraint eλ=1, its efficiency values are higher than those of its CCR counterparts. Table 4 presents the determination of the reasons for inefficiency for each input.

Table 3. Results of CCR and BCC models and calculation of scale efficiency.

No. DMU	Name of DMU	CCR model	BCC model	Scaleeff
DMU1	PUC Water Supply and Sewage Ltd. Tuzla	1	1	1
DMU2	PUC Water Supply and Sewage Ltd. Sarajevo	0.8438	1	0.8438
DMU3	PUC Water Supply and Sewage Zenica	0.9968	1	0.9968
DMU4	Water Supply Ltd. Mostar	0.9730	0.9824	0.9904
DMU5	PUC Water Supply and Sewerage Ltd. Velika Kladuša	0.9885	0.9897	0.9988
DMU6	PUC Water Supply Ltd. Posušje	1	1	1
DMU7	PUC Vodokom Ltd. Kakanj	0.9533	0.9647	0.9882
DMU8	PUC Water Supply Ltd. Cazin	0.9240	0.9249	0.9990
DMU9	PUC Water Supply Ltd. Bihać	0.9789	1	0.9789
DMU10	PUC Water Supply and Sewerage Ltd. Sanski Most	0.9627	0.9661	0.9965
DMU11	PUC Water Supply and Sewerage Ltd. Bugojno	0.6902	0.6957	0.9921
DMU12	PUC Vitkom Ltd. Vitez	1	1	1
DMU13	PUC Vodokom Ltd. Domaljevac	0.2043	1	0.2043

Table 4. Calculation of inefficiency ratios for DMUs (KM – the currency unit).

No. DMU	Name of DMU	Theta BCC	slackX1	slackX2
DMU1	PUC Water Supply and Sewage Ltd. Tuzla	1	0	0
DMU2	PUC Water Supply and Sewage Ltd. Sarajevo	1	0	0
DMU3	PUC Water Supply and Sewage Zenica	1	0	0
DMU4	Water Supply Ltd. Mostar	0.9824	0	46.7224
DMU5	PUC Water Supply and Sewerage Ltd. Velika Kladuša	0.9897	11902929.8464	0
DMU6	PUC Water Supply Ltd. Posušje	1	0	0
DMU7	PUC Vodokom Ltd. Kakanj	0.9647	0	21.5714
DMU8	PUC Water Supply Ltd. Cazin	0.9249	0	0
DMU9	PUC Water Supply Ltd. Bihać	1	0	0
DMU10	PUC Water Supply and Sewerage Ltd. Sanski Most	0.9661	2877007.3741	0
DMU11	PUC Water Supply and Sewerage Ltd. Bugojno	0.6957	466561.0276	0
DMU12	PUC Vitkom Ltd. Vitez	1	0	0
DMU13	PUC Vodokom Ltd. Domaljevac	1	NaN	NaN

Theta represents pure technical efficiency obtained by the VRS (BCC) model, and we can see that 7 DMUs, or 53.846%, are efficient with θ=1. The technical efficiency of 12 DMUs exceeds 90%. The lowest efficiency is observed for DMU11 (Public Utility Company Water Supply and Sewerage Ltd. Bugojno) with θ=69.57%. Regarding input and output slacks obtained without radial reductions and enlargements, it is noticeable that the first input (total asset value) is overused, with values greater than zero for three DMUs (DMU5, DMU10, and DMU11 corresponding to Public Utility Company Water Supply and Sewerage Ltd. Velika Kladuša, Public Utility Company Water Supply and Sewerage Ltd. Sanski Most, and Public Utility Company Water Supply and Sewerage Ltd. Bugojno, respectively), as well as an excessive number of employees for two DMUs (Water Supply Ltd. Mostar and Public Utility Company Vodokom Ltd. Kakanj). DMUs with high values of used assets should pay attention to the proper evaluation of balance sheet positions, primarily by correctly assessing the value of receivables and testing the recoverable value of fixed assets. The slack vectors of DMU13 have NaN values due to the inability to compare that DMU with others of a similar business range.

OPTIMAL VALUES FOR ACHIEVING EFFICIENCY

One of the DEA's advantages is that projections can be calculated to improve efficiency. We calculated projections for each inefficient DMU without taking into account the slack vectors. The projection values are calculated as a linear combination of DMU variables from the reference set.

Table 5. Optimal values for inefficient DMUs to achieve efficiency.

DMU	Efficiency	Projection input 1	Difference, %	Projection input 2	Difference, %	Projection input 3	Difference, %
DMU4	0.9824	45519140.6	-1.76	189.0	-21.25	12384825.8	-1.76
DMU5	0.9897	10619160.3	-53.33	51.5	-1.02	2553036.6	-1.03
DMU7	0.9647	15193730.9	-3.54	102.9	-20.26	4391261.52	-3.54
DMU8	0.9249	14306900.5	-7.50	73.1	-7.50	4265669.5	-7.50
DMU10	0.9661	6358482.4	-33.48	38.6	-3.39	1745329.2	-3.39
DMU11	0.6957	3044835.9	-39.67	27.8	-30.43	1093200.7	-30.43

Therefore, DMU4 (Water Supply Ltd. Mostar) can achieve efficiency by utilising the calculated coefficients or by reducing its inputs radially in relation to theta. DMU4 would be efficient if it had the following input variable values:

- Input 1 = 0.9824 * 46337068 = 45521535.6 (reduce the value of total assets / check the accuracy of reporting balance sheet items)
- Input 2 = 0.9824 * 240 = 235.8 (reduce the number of employees from 240 to 236)
- Input 3 = 0.9824 * 12606968 = 12385085.4 (reduce total expenses by 221,883 KM)

RANKING DMUS BASED ON THE DEGREE OF EFFICIENCY

As we have previously established that there are differences in efficiency even among efficient DMUs, a super-efficiency model was used to rank them. The model enables discrimination among technical efficiencies. The super-efficiency score allows for discrimination among them by calculating individual scores that differ at observation. These scores are obtained by individual solving for each observation of any of the previous models but exclude the DMU from the reference dataset. The magnitude of the super-efficiency score determines the importance of the efficiency of each DMU in the entire dataset, Table 6.

Table 6. Ranking of DMU efficiency.

DMU	Name of DMU	Theta	Rang
DMU1	PUC Water Supply and Sewage Ltd. Tuzla	2.00	2.
DMU2	PUC Water Supply and Sewage Ltd. Sarajevo	NaN	
DMU3	PUC Water Supply and Sewage Zenica	1.01	5.
DMU4	Water Supply Ltd. Mostar	0.98	
DMU5	PUC Water Supply and Sewerage Ltd. Velika Kladuša	0.99	
DMU6	PUC Water Supply Ltd. Posušje	1.00	6.
DMU7	PUC Vodokom Ltd. Kakanj	0.96	
DMU8	PUC Water Supply Ltd. Cazin	0.92	
DMU9	PUC Water Supply Ltd. Bihać	1.25	3.
DMU10	PUC Water Supply and Sewerage Ltd. Sanski Most	0.96	
DMU11	PUC Water Supply and Sewerage Ltd. Bugojno	0.69	
DMU12	PUC Vitkom Ltd. Vitez	1.17	4.
DMU13	PUC Vodokom Ltd. Domaljevac	1944	1.

Public Utility Company Vodokom Ltd. Domaljevac, Public Utility Company Water Supply and Sewage Ltd. Tuzla, and Public Utility Company Water Supply Ltd. Bihać stand out with their efficiency, respectively.

The study has shown that the DEA method can be used to calculate the projection of inefficient public utilities by input types, and our research is consistent with the results of other studies. Unlike other studies, we propose using both DEA models, CCR and BCC, which can then be employed for a comprehensive assessment. The calculated Scale Efficiency can provide insights into the overall efficiency of these entities. Additionally, the DEA model can be used as a tool in planning and controlling the quantity of necessary resources to meet organisational goals.

The research results show that out of 13 observed public utilities for water supply and sewage systems in FBiH, 7 (53.85%) are efficient in using assets, workforce, and total expenditures. In terms of efficiency ranking, these seven utilities are Public Utility Company Vodokom Ltd. Domaljevac, Public Utility Company Water Supply and Sewage Ltd. Tuzla, Public Utility Company Water Supply Ltd. Bihać, Public Utility Company Vitkom Ltd. Vitez, Public Utility Company Water Supply and Sewage Ltd. Zenica, Public Utility Company Water Supply Ltd. Posušje, and Cantonal Public Utility Company Water Supply and Sewage Ltd. Sarajevo, respectively. The least efficient is Public Utility Company Water Supply and Sewage Ltd. Bugojno, with a technical efficiency of 69.75%. Three utilities: Public Utility Company Water Supply and Sewage Ltd. Velika Kladuša, Public Utility Company Water Supply and Sewage Ltd. Sanski Most, and Public Utility Company Water Supply and Sewage Ltd. Bugojno, respectively, have a higher value of assets used to provide water supply and sewage services than others. The assets are not efficiently used, meaning that they have a high value of assets. This problem may have been contributed to by inadequate accounting valuation of balance sheet items (the value of fixed assets and receivables from customers). This could have led to an overestimated value of business assets that contain impairment losses. Two utilities, Water Supply Ltd. Mostar and Public Utility Company Vodokom Ltd. Kakanj, have a noticeable excess of employees compared to the optimum. The study has shown that the DEA method can be used to calculate the projection of inefficient utilities by input types.

In general, many public utilities for water supply and sewage systems in Bosnia and Herzegovina face challenges such as ageing infrastructure, inadequate funding, and limited capacity to modernise and improve their operations. These challenges can impact the efficiency of the utilities, making it difficult for them to provide reliable and cost-effective services to their customers. The efficiency of operations in public utilities for water supply and sewage systems in Bosnia and Herzegovina may vary depending on several factors, including the level of investment in infrastructure, technology, business volume, the availability of qualified personnel, capacity for growth, and the regulatory environment. However, there have been some efforts in recent years to improve the efficiency of public utilities for water supply and sewage systems in Bosnia and Herzegovina. For example, the introduction of cost-reflective tariffs, which set the price of water and sewage services based on the actual cost of providing these services, can help to improve the efficiency of these utilities. Additionally, investment in modern technology and equipment, reduction of water waste, and improvements to water and sewage treatment processes can help to increase efficiency and reduce costs. Based on all the above, a recommendation for future research is to measure the efficiency of public utilities for water supply and sewage systems in FBiH, comparing them with utilities of the same activity from some of the more developed EU countries.

CONCLUSION

The study aimed to demonstrate that the Data Envelopment Analysis (DEA) method can be used to evaluate the operational efficiency of public utility enterprises under state ownership or local government jurisdiction. Efficient management of public resources is crucial, and the DEA model served as a tool for identifying enterprises that consume above-average quantities of resources and detecting potential inefficiencies in resource allocation.

The research results show that out of 13 observed public utilities for water supply and sewage systems in FBiH, 7 (53.85%) are efficient in using assets, workforce, and total expenditures. The least efficient is Public Utility Company Water Supply and Sewage Ltd. Bugojno, with a technical efficiency of 69.75%. Three utilities have a higher value of assets used to provide water supply and sewage services than others. The research results indicate that the DEA model is an effective means of detecting public utility enterprises under state ownership that consume an above-average quantity of resources for the same scope and quality of services provided. It is recommended to use the scaled efficiency measure, representing the ratio of the Banker-Charnes-Cooper (BCC) model to the Charnes-Cooper-Rhodes (CCR) model. The findings suggest that DEA analysis can also serve as a valuable tool in the planning and control of resource consumption within public utility enterprises.

A recommendation for future research is to measure the efficiency of public utilities for water supply and sewage systems in FBiH and compare them with utilities of the same activity from some of the more developed EU countries. This would overcome the main limitation of the research, which is the essence of the DEA model itself, which calculates efficiency only among units within the sample.

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