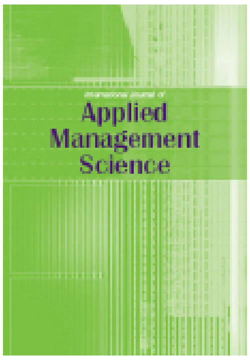


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# Municipal water supplies efficiencies in Gaza Strip: a data envelopment analysis approach

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# Municipal water supplies efficiencies in Gaza Strip: a data envelopment analysis approach

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**Abstract:** This paper reports the findings of a research carried out to evaluate the efficiency of municipal water supply systems using Data Envelopment Analysis (DEA). Input and output variables needed for DEA were identified using literature review and questionnaires. Input variables considered in this paper include Number of Connections (NC), Length of Water Network (LWN), Number of Employees (NE) and Maintenance and Operation Costs (MOC), while Total Revenues (TR) and Number of People Served (NPS) were used as output variables. Values of these variables were obtained for the existing 25 municipalities for the years of 2015, 2016 and 2017 and the averages of these variables were calculated and used in the model. The paper uses Charnes, Cooper and Rhodes (CCR) model and Banker, Chames and Cooper (BCC) model. Results indicate that length of water network and maintenance and operation costs were the major sources of inefficiencies.

**Keywords:** efficiency; data envelopment analysis; water services; municipalities.

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## 1 Background

Gaza Strip is a coastal strip of land along the Mediterranean Sea. It is about 41 kilometres long, and 6–12 kilometres wide, with a total area of 360 square kilometres. Annual rainfall is between 150 and 350 mm. Groundwater is the only significant source of water in Gaza Strip. In Gaza, the water crisis is a function of population growth, an agriculturally intensive economy, a fragile water ecosystem, and a highly inequitable distribution of resources.

For its freshwater supply, Gaza relies almost entirely on groundwater drawn from its aquifer, which is often only a few meters from the surface. Since it is near the Mediterranean, it is vulnerable saltwater intrusion, and contamination from agricultural and industrial activities.

Water sector is managed by municipalities and village councils individually with supporting role from Coastal Municipalities Water Utilities (CMWU), UN Relief Works Agency (UNRWA), and Ministry of Local Government (MOLG), where each municipality or village council has its own water policy, water tariff, operating and maintenance systems. The monitoring of water and waste water operations of service providers in Gaza Strip is carried out by Water Sector Regulatory Council (WSRC), which is an official regulatory council for water sector in Palestine. The WSRC aims to ensure that the services are effective, sustainable, and are provided at affordable prices through monitoring water operation processes related to production, transport, and distribution of water.

The responsibility of water supply is clearly and consistently assigned, across the 25 municipalities in Gaza Strip, to the Water and Sanitation Departments. The percentage of population who receive their water services from municipal service providers reaches 74% of the Gaza strip population (WSRC, 2018). Water quality is the biggest obstacle to municipal service providers according to reports of the Palestinian Water Authority as well as UN reports, as more than 96% of the water that the population is supplied with through a variety of service providers is not potable (Efron et al., 2018). Network water supplied through municipal providers or the CMWU is chlorinated but not suitable for drinking and is mainly used for cleaning and gardening. Moreover, institutional arrangements in Gaza Strip are weak, resulting from a lack of investment, from the exigencies of the occupation and lack of support by the local population. Therefore, it is of vital importance to find applicable solutions for coping with such serious issues for water sector, particularly solutions that target municipal water service providers in Gaza strip. This could be achieved through conducting an overall performance assessment for water operations aspects to identify how to improve the current performance of each of these municipal water service providers considering technical, managerial and economical aspects. However, and due to the large number of factors and indicators characterising water service operations, it is hard for decision makers to make informed decisions and thus the need for identifying a tool that could handle such a case.

Extensive research has been done to identify effective scientific tools and models to cope with such a variety of input and output factors for water services systems. Among these tools, the most popular is Data Envelopment Analysis (DEA) which is considered a powerful nonparametric approach that provides a single measure of technical efficiency when dealing with multiple inputs and multiple outputs. The focus of DEA is on the individual observations rather than on the average. Furthermore, DEA-approach has proved especially valuable in cases where correct weighing of inputs and outputs is unknown or cannot be derived (Charnes et al., 1985). The literature available indicates a moderate use of such an approach for service providers in various countries. Further, literature indicates the possibility of incorporating many evaluation criteria to each service provider such as: number of customers, operating expenditure, network status, volume delivered, manpower, revenue, etc.

In this study, the performance efficiency has been measured and analysed for water services administered by municipalities in Gaza Strip using the input-oriented DEA model. The method was chosen due to its capability of incorporating technical, managerial and economical aspects as criteria for evaluation to produce a measure of efficiency for each municipality. The purpose of analysis is identifying the efficient providers and establishing benchmarks that can be used to measure progress in the management of water resources for each of the inefficient providers. The study also computed the potential improvements needed for inefficient municipalities to become efficient through identifying benchmarks so that inefficient municipalities learn from those best practicing ones.

This paper organised as follows: A brief literature review is given in Section 2. Section 3 introduces the methodology. While, application is given in Section 3, Section 4 covers the results and analysis.

## 2 Literature review

DEA has been used to tackle water resource management problems in countries like, Japan, Ghana, Mexico, and USA.

Aida et al. (1998) used DEA to evaluate the water systems in 108 cities in the Kanagawa Prefecture region in Japan. Their inputs included the number of employees, operating expenses before depreciation, and equipment, population, and the length of pipes. Their outputs included water billed and operating costs. They demonstrated that DEA can be useful in evaluating the efficiency of the water sectors in industrialised countries.

Byrnes et al. (1986) used DEA to assess the relative efficiency of private versus public ownership in water utilities. The findings indicate that there is not much difference in the technical efficiency scores between private and public firms.

Kirkpatrick et al. (2006) also addressed the issue of ownership and its effect on performance of the sector. The study examined the effects of privatisation on the performance of the sector using data from African water utilities. Both the Stochastic Frontier Analysis (SFA) and DEA techniques were used for the analysis. A summary of input and output variables used in previous studies is given in Table 1.

**Table 1** Examples of variables used in water service studies using DEA

| *Author (s)* | *Inputs* | *Outputs* |
|---|---|---|
| Byrnes et al. (1986) | 1 Ground water (gal)<br>2 Surface water (gal)<br>3 Purchased water (gal)<br>4 Part time labour (cost)<br>5 Full time labour (cost)<br>6 Length of pipe line (mile)<br>7 Storage capacity (gal) | 1 Volume of water delivered (gal) |
| Woodbury and Dollery (2004) | 1 Management costs<br>2 Maintenance and operation costs<br>3 Energy and chemical costs<br>4 Capital replacement costs | 1 Number of people served<br>2 Annual water consumption ($m^3$)<br>3 Water quality index<br>4 Water service index |
| Garcia-Valiñas and Muñiz (2007) | 1 Operational costs<br>2 Density of rainfall | 1 Water delivered<br>2 Length of mains<br>3 Population supplied (number of inhabitants) |
| Mugisha (2007) | 1 Pipe network length<br>2 Operating expenses (including depreciation)<br>3 Staff (labour) | 1 Water billed/water delivered (%)<br>2 Number of connections |
| Alsharif et al. (2008) | 1 Water losses (NIS)<br>2 Water and energy (NIS)<br>3 Maintenance (NIS)<br>4 Salary of workers (NIS) | 1 Total revenue (NIS) |

**Table 1** Examples of variables used in water service studies using DEA (continued)

| *Author (s)* | *Inputs* | *Outputs* |
|---|---|---|
| Renzetti and Dupont (2009) | 1 Materials and energy (\$/year)<br>2 Labour (\$/year)<br>3 Distribution Length (km) | 1 Total water quantity ($m^3$/year) |
| Munisamy (2009) | 1 Operating expenditure<br>2 Network length<br>3 Volume of non-revenue water | 1 Volume delivered<br>2 Number of connections<br>3 Service area ($km^2$) |
| Carvalho and Marques (2011) | 1 Staff cost<br>2 Other operation and maintenance expenses<br>3 Capital expenses | 1 Volume of water billed<br>2 Number of customers |
| Romano and Guerrini (2011) | 1 Cost of material<br>2 Cost of labour<br>3 Cost of services<br>4 Cost of leases | 1 Population served<br>2 Water delivered |
| Gupta et al. (2012) | 1 Revenue expenditure (rupees/year)<br>2 Water production capacity (litre/day) | 1 Total amount of water supplied (litre/day) |
| Mahmoudi et al. (2012) | 1 Total cost (Rial)<br>2 Capital cost (Rial) | 1 Volume of water consume ($m^3$)<br>2 Number of customers<br>3 Income (Rial) |
| Mbuvi et al. (2012) | 1 Number of employees<br>2 Network length (m) | 1 Population served<br>2 Water sold ($m^3$/year) |
| Guerrini et al. (2013) | 1 The sum of amortisation, depreciation, and interest paid<br>2 Staff costs<br>3 Other operating costs<br>4 The length of the mains | 1 Population served<br>2 Total revenues |
| Ghasemi et al. (2014) | 1 Operating costs (Rial)<br>2 Manpower costs (Rial)<br>3 Water Infrastructure (Rial)<br>4 Number of Subscribers | 1 Volume of water sold ($m^3$)<br>2 Length of distribution network (km)<br>3 Volume of water loss ($m^3$)<br>4 Improvement and development of network (Rial)<br>5 Wash network (km) |

The findings of literature review indicate an obvious usage frequency of certain inputs and outputs. For example, the length of water carrier lines or networks, number of labour/staff and maintenance/operations expenditures have been the most frequently used factor as input in many models. On the other hand, some inputs have not been used that much. These include: materials, chemicals and rainfall data. Further, water revenues and customers served were ones of the most frequently used factors considered as outputs of DEA models used in calculating water providers' efficiencies.

## 3 Methodology

Data Envelopment Analysis (DEA) is a "data oriented" approach for evaluating the performance of a set of peer entities called Decision Making Units (DMUs). DEA can have fixed or Constant Return to Scale (CRS) and Variable Return to Scale (BCC). In CRS, the outputs and inputs have a linear relationship. In other words, CRS means that if inputs are increased or decreased, outputs will be increased and decreased by the same proportions and also is known as the CCR (Charnes, Cooper and Rhodes) model. The CCR input oriented model attempts to minimise the inputs usage to produce given output levels for each DMU. This model is effective to use under an ideal condition to operate DMUs at optimal size. Since such a matter is only theoretically achieved, a model called the BCC model (Banker, Charnes, Cooper) was developed to overcome the imperfect conditions using the concept of variable returns to scale analysis.

### *3.1 CCR model*

Assuming that there are *n* DMUs: DMU1, DMU2,…, DMU*n*, with *k* inputs: $x_1, x_2, \ldots, x_k$ and *m* outputs: $y_1, y_2, \ldots, y_m$, the CCR model can be formulated as follows:

$$\text{Min}\,\theta = \sum_{i=1}^{k} v_i x_{ij} \tag{1}$$

Subject to:

$$\sum_{r=1}^{m} u_r y_{rj} = 1 \tag{2}$$

$$\sum_{i=1}^{k} v_i x_{ij} - \sum_{r=1}^{m} u_r y_{rj} \geq 0 \quad j = 1, \ldots, n \tag{3}$$

$u_r, v_i \geq 0$, where $u_r, v_i$ are the weights of output *r* and input *i*. $\theta$ is the radial (input reducing) measure of technical efficiency.

Where $x_{ij}$ is the amount of input *i* consumed by DMU *j* and $y_{rj}$ is the amount of output *r* produced by DMU *j*.

$x_{ij} \geq 0$ and $y_{rj} \geq 0$ further assume that each DMU has at least one positive input and one positive output values.

The above gives a measure of overall efficiency of each DMU such that technical and scale efficiencies are aggregated into one value. Moreover, it assumes that all DMUs operate at optimal scale. The constraint shown in equation (3) requires that the efficiency of any DMU does not exceed one.

### *3.2 BCC model*

The model represents as follow:

$$\theta^* = \min \theta \tag{4}$$

Subject to

$$\theta x_{io} \geq \sum\nolimits_{r=1}^{n} \lambda_j x_{ij} \;\; i = 1, \ldots, m \tag{5}$$

$$y_{ro} \leq \sum\nolimits_{j=1,\neq 0}^{n} \lambda_j y_{ij} \;\; r = 1, \ldots, s \tag{6}$$

$$\sum\nolimits_{j=1,\neq 0}^{n} \lambda_j = 1 \tag{7}$$

$$\lambda_j \geq 0 \left(\forall_j\right) \tag{8}$$

where $\lambda$ is constrained to be non-negative.

Further, super efficiency for both (CCR and BCC) can be calculated through relaxing the constraint that requires that efficiency cannot exceed 1.

### *3.3 Variable selection and data collection*

The research variables were obtained and validated using literature review, questionnaires and interviews with heads of municipalities, technicians, researchers, experts, operating and maintenance units, engineering departments and financial departments. Based on the foregoing, certain inputs and outputs were refined/combined/omitted. The final list of the variables includes four input variables and two output variables and their definitions as shown in Table 2.

In Gaza Strip, the municipalities have their own wells and they buy water from private wells and distribute it to the public. In this paper, 25 municipalities covering the five governorates (DMUs) are considered as main service providers to be evaluated for their relative performance efficiencies,

**Table 2** Set of variables used in the paper and their definitions

| *Variable* | *Unit* | *Type* | *Definition* |
|---|---|---|---|
| Number of Connections (NC) | – | Input | Total number of subscriptions in area |
| Length of Water Network (LWN) | Km | Input | Length of network or main pipelines in area |
| Number of Employees (NE) | – | Input | Total number of managerial and non-managerial staff |
| Maintenance and Operation Costs (MOC) | NIS | Input | Cost of maintaining, the operations, materials, salaries, wages and other miscellaneous expenses |
| Number of People Served (NPS) | – | Output | Total number of populations in area |
| Total Revenue (TR) | NIS | Output | The value of water according to water billing, not the revenue collected |

Accordingly, the dataset values per each input and output were obtained for years 2015, 2016 and 2017 from WRSC Performance Reports for this study. These reports describe set of key performance indicators selected and used by the council including a number of technical, financial, and quality values. In this study, average values of three years are computed for each of these variables used per each DMUs. Table 3 shows average values for input and output variables.

**Table 3** Average values for input and output variables (Water Sector Regulatory Council (WSRC))

| *No.* | *Municipality* | *Number of connection (NC)* | *Length of water network (LWN) (km)* | *Number of employee (NE)* | *Maintenance and operation cost (MOC) (NIS)* | *Number of people served (NPS)* | *Total revenue (TR) (NIS)* |
|---|---|---|---|---|---|---|---|
| 1 | An Nuseirat | 8123 | 119 | 20 | 6,081,479 | 79,696 | 4,851,359 |
| 2 | Jabalia | 16,014 | 191 | 104 | 7,079,856 | 176,274 | 8,240,123 |
| 3 | Khan Yunis | 19,240 | 460 | 93 | 9,675,778 | 201,755 | 9,741,482 |
| 4 | Gaza | 52,080 | 672 | 128 | 42,991,788 | 600,467 | 18,944,963 |
| 5 | Rafah | 19,153 | 380 | 75 | 9,214,984 | 196,495 | 9,960,453 |
| 6 | Beit Lahiya | 7647 | 173 | 37 | 3,385,698 | 80,551 | 3,300,198 |
| 7 | Al Bureij | 3843 | 52 | 10 | 2,105,512 | 41,554 | 2,213,631 |
| 8 | Az Zawayda | 2510 | 88 | 6 | 744,749 | 19,602 | 1,355,559 |
| 9 | Al Qarara | 2284 | 122 | 13 | 1,864,900 | 23,766 | 1,187,886 |
| 10 | Al Maghazi | 2794 | 55 | 13 | 2,928,695 | 27,773 | 1,624,245 |
| 11 | Bani Suheila | 4861 | 111 | 24 | 4,918,413 | 39,749 | 4,371,376 |
| 12 | Beit Hanun | 4502 | 132 | 27 | 3,994,877 | 49,870 | 2,081,702 |
| 13 | Deiral Balah | 7504 | 175 | 43 | 4,101,092 | 78,834 | 4,559,114 |
| 14 | Abasan Al Kabira | 3745 | 69 | 14 | 4,251,039 | 24,030 | 1,936,005 |
| 15 | Az Zahra | 1131 | 18 | 5 | 487,525 | 4283 | 607,380 |
| 16 | Ash Shuka | 1527 | 82 | 11 | 903,651 | 13,288 | 550,090 |
| 17 | Al Fukhkhari | 1061 | 55 | 6 | 902,784 | 6292 | 315,724 |
| 18 | Al Musaddar | 352 | 18 | 5 | 225,424 | 2428 | 216,960 |
| 19 | Al Mughraqa | 1427 | 34 | 6 | 1,169,731 | 8970 | 480,529 |
| 20 | An Naser | 1415 | 47 | 7 | 821,669 | 7263 | 490,467 |
| 21 | Umman Naser | 537 | 10 | 6 | 407,433 | 4073 | 185,000 |
| 22 | Khuza'a | 1564 | 51 | 7 | 2,637,098 | 11,403 | 426,115 |
| 23 | Abasan Al Jadida | 1345 | 37 | 5 | 1,615,664 | 7372 | 783,163 |
| 24 | Wadi As Salqa | 492 | 39 | 4 | 358,444 | 5880 | 187,502 |
| 25 | Wadi Gaza | 381 | 21 | 5 | 880,024 | 3900 | 145,225 |

It is clear that the number of DMUs satisfies the number of inputs and outputs according to Golany and Roll (1989), who suggested that the number of DMUs should be at least twice the number of inputs and outputs. Further, it does satisfy the number given by Bowlin (1998) who mentioned that the number of DMUs should be at least three times of the number of inputs and outputs. Finally, it satisfies the relationship given by Boussofiane et al. (1991) who said that the number of DMUs should be the multiple of the number of inputs and the number of outputs. This research achieved all previous requirements as far as the number of DMUs is concerned.

DEA-Solver-Pro Professional version 5.0 (SAITECH, Inc., 2003) was used in this research to calculate the technical efficiency of each municipality based on both CCR and BCC input-oriented models. Further, potential improvements of the inefficient municipalities were also calculated.

## 4 Results and discussion

In the following, the results obtained are given and discussed for both CCR and BCC models.

### *4.1 CCR and BCC models results and analysis*

Table 4 shows the efficiency scores, reference set (benchmarks) and rank of municipalities in Gaza Strip for both input-oriented models, CCR and BCC.

Table 4 shows that the use of CCR model results in 10 efficient municipalities and 15 inefficient ones. The inefficient municipalities have scores ranging from 53.64% to 97.63%. The average score of all municipalities is 87.08% with a standard deviation of 16.5%. Rafah and Beit Hanun municipalities were close to be efficient. Inefficient municipalities should learn the strategies, policies, and practices from their reference sets (benchmarks). It is noted that Al Bureij municipality is the most recurring reference set (12 times) which means that there are 12 municipalities that can learn from Al Bureij. Wadi As Salqa followed Al Bureij for being referenced 9 times. The other reference sets are An Nuseirat, Jabalia, Gaza, Beit Lahiya, Az Zawayda, Bani Suheila, Deiral Balah and Az Zahra. It is noted here that only 5 municipalities [1,7,8,11,13] can be used as benchmarks for all inefficient ones. It is proposed here that the most recurring benchmark municipality can be asked to reveal their best practices through workshops, videos, or brochures so that inefficient ones would follow suite and gradually increase their efficiencies until they become fully efficient.

As for the BCC model results, there are 15 efficient municipalities and 10 inefficient ones. The inefficient municipalities have efficiency scores ranging from 68.08% to 99.73%. The average BCC efficiency of all municipalities is 93.54% and the standard deviation is 11.09%. The municipality of An Naser has the least efficiency score for both CCR and BCC models of 53.64 % and 68.09% respectively.

Obviously, BCC yields scores that are higher than those obtained using CCR. These results are expected because of two reasons: First, theoretically, CCR and BCC are ratios that share the same denominator while the numerator of BCC ratio is greater than the numerator in CCR ratio. Secondly, BCC relaxes the slack variables to be greater than zero and adding lambda constraint. It is known that relaxing a constraint in any problem would result in one of two scenarios. The first is that the added constraint is redundant and therefore, it would not affect the value of the objective function. While, the second scenario is that the added constraint is binding and therefore the objective function would deteriorate. Clearly, the second scenario is the one in action in our case.

**Table 4** Efficiency, reference sets and ranks for BCC and CCR models

| *No.* | *Municipality* | *CCR* | | | *BCC* |
|---|---|---|---|---|---|
| | | *Efficiency score (%)* | *Rank* | *Reference set* | *Efficiency score (%)* |
| 1 | An Nuseirat | 100 | 1 | 1 | 100 |
| 2 | Jabalia | 100 | 1 | 2 | 100 |
| 3 | Khan Yunis | 95.63 | 13 | 2, 4, 7, 24 | 99.73 |
| 4 | Gaza | 100 | 1 | 4 | 100 |
| 5 | Rafah | 97.36 | 12 | 2, 6, 7, 8 | 100 |
| 6 | Beit Lahiya | 100 | 1 | 6 | 100 |
| 7 | Al Bureij | 100 | 1 | 7 | 100 |
| 8 | Az Zawayda | 100 | 1 | 8 | 100 |
| 9 | Al Qarara | 94.82 | 14 | 7, 24 | 94.9 |
| 10 | Al Maghazi | 94.65 | 15 | 7, 11 | 94.85 |
| 11 | Bani Suheila | 100 | 1 | 11 | 100 |
| 12 | Beit Hanun | 98.17 | 11 | 4, 7, 24 | 98.81 |
| 13 | Deiral Balah | 100 | 1 | 13 | 100 |
| 14 | Abasan Al Kabira | 69.65 | 20 | 1, 7, 11 | 75.21 |
| 15 | Az Zahra | 100 | 1 | 15 | 100 |
| 16 | Ash Shuka | 76.51 | 19 | 2, 7, 24 | 76.66 |
| 17 | Al Fukhkhari | 54.09 | 24 | 7, 24 | 70.36 |
| 18 | Al Musaddar | 86.48 | 17 | 8, 11 | 100 |
| 19 | Al Mughraqa | 58.23 | 23 | 7, 11 | 86.44 |
| 20 | An Naser | 53.64 | 25 | 8, 11, 13 | 68.09 |
| 21 | Umman Naser | 68.36 | 21 | 4, 7, 24 | 100 |
| 22 | Khuza'a | 63.65 | 22 | 4, 7, 24 | 73.53 |
| 23 | Abasan Al Jadida | 77.59 | 18 | 1, 11 | 100 |
| 24 | Wadi As Salqa | 100 | 1 | 24 | 100 |
| 25 | Wadi Gaza | 88.22 | 16 | 7, 24 | 100 |

In order to check which of the two models (CCR or BCC) better fits the application, it is not inconceivable to think of calculating the determination coefficient between municipalities size and BCC super efficiency scores. In other words, to check whether the size of the municipality is a factor in determining the efficiency. Therefore, the correlation coefficient between municipality efficiency and many other factors that could represent the municipality size could be determined. For example, if number of connections (NC) is considered to represent or (proportional to) the municipality size, the calculated correlation coefficient between municipalities size and BCC super efficiency results was found to be equal to 0.0017 which means that there is no relation between efficiency score and municipality size. Further, if the length of water network (LWN), number of employees (NE) or maintenance and operation cost (MOC) are separately used to represent the municipalities size, the determination coefficients between the municipalities size and BCC super efficiency results were 0.012, 0.0011 and 0.0079 respectively and it is still low as shown. This means that there is no relationship between efficiency score and municipalities size as represented by the number of connections, length of water network, number of employees or maintenance and operation cost. These findings imply that it is reasonable to assume that the size of the municipalities has no significant influence on the municipalities efficiency.

Therefore, and in the light of the foregoing, the results of CCR model can be adopted to be the research results. Therefore, CCR results will be used in the analysis throughout the rest of the paper.

## 4.2 Potential improvements

In this section, the potential improvements of each inefficient municipality to become efficient are given and analysed. The percentages of potential inputs' reduction of each inefficient municipality are given in Table 5.

It is clear from Table 5 that the average potential reduction of the inputs is as follows: LWN, NE, MOC and NC with average of 24%, 26%, 24% and 13% respectively from their actual values. For example, Khuza'a municipality can be fully efficient if it reduces inputs by 36% for NC, 36% for LWN, 41% NE and 73% for MOC respectively.

**Table 5** The percentages of potential inputs' improvements of each inefficient municipality

| *No.* | *Municipality* | *Number of connections (%)* | *Length of water network (%)* | *Number of employees (%)* | *Maintenance and operation cost (%)* |
|---|---|---|---|---|---|
| 1 | An Nuseirat | 0 | 0 | 0 | 0 |
| 2 | Jabalia | 0 | 0 | 0 | 0 |
| 3 | Khan Yunis | –4.374 | –47.957 | –4.374 | –4.374 |
| 4 | Gaza | 0 | 0 | 0 | 0 |
| 5 | Rafah | –2.636 | –18.573 | –2.636 | –2.636 |
| 6 | Beit Lahiya | 0 | 0 | 0 | 0 |
| 7 | Al Bureij | 0 | 0 | 0 | 0 |
| 8 | Az Zawayda | 0 | 0 | 0 | 0 |
| 9 | Al Qarara | –5.178 | –59.5 | –43.645 | –33.411 |
| 10 | Al Maghazi | –5.347 | –29.657 | –41.457 | –45.581 |
| 11 | Bani Suheila | 0 | 0 | 0 | 0 |
| 12 | Beit Hanun | –1.832 | –1.832 | –36.081 | –26.191 |
| 13 | Deiral Balah | 0 | 0 | 0 | 0 |
| 14 | Abasan Al Kabira | –30.346 | –30.346 | –30.346 | –49.462 |
| 15 | Az Zahra | 0 | 0 | 0 | 0 |
| 16 | Ash Shuka | –23.486 | –40.649 | –33.153 | –23.486 |
| 17 | Al Fukhkhari | –45.911 | –76.781 | –68.096 | –63.649 |
| 18 | Al Musaddar | –13.518 | –50.644 | –77.994 | –13.518 |
| 19 | Al Mughraqa | –41.768 | –66.771 | –63.736 | –60.849 |
| 20 | An Naser | –46.364 | –58.808 | –46.415 | –46.364 |

**Table 5** The percentages of potential inputs' improvements of each inefficient municipality (continued)

| *No.* | *Municipality* | *Number of connections (%)* | *Length of water network (%)* | *Number of employees (%)* | *Maintenance and operation cost (%)* |
|---|---|---|---|---|---|
| 21 | Umman Naser | –31.637 | –31.637 | –81.609 | –42.674 |
| 22 | Khuza'a | –36.346 | –36.346 | –40.732 | –72.834 |
| 23 | Abasan Al Jadida | –22.407 | –46.97 | –22.407 | –43.019 |
| 24 | Wadi As Salqa | 0 | 0 | 0 | 0 |
| 25 | Wadi Gaza | –11.781 | –11.781 | –59.058 | –73.681 |
| | Average | –12.9172 | –24.3301 | –26.0696 | –24.0692 |
| | Max | 0 | 0 | 0 | 0 |
| | Min | –46.364 | –76.781 | –81.609 | –73.681 |
| | St Dev | 16.4993 | 25.7279 | 28.304 | 26.5459 |

## 4.3 Super efficiency analysis

For ranking the efficient municipalities, CCR super efficiency is used because basic CCR model does not rank the efficient municipalities. In other words, the basic CCR model does not allow the calculated efficiencies to exceed 100%. Table 6 shows super efficiency scores of efficient municipalities.

**Table 6** Super efficiency scores of efficient municipalities

| *Municipalities* | *Super-efficiency score %* |
|---|---|
| An Nuseirat | 109.4 |
| Jabalia | 123.96 |
| Gaza | 112.89 |
| Beit Lahiya | 101.21 |
| Al Bureij | 126.64 |
| Az Zawayda | 160.12 |
| Bani Suheila | 148.63 |
| Deiral Balah | 102.47 |
| Az Zahra | 103.81 |
| Wadi as Salqa | 104.86 |

From Table 6, it is clear that Az Zawayda has the highest value of super efficiency. Super efficiency scores range between 100.21 and 160.12. The motive behind calculating the super efficiency is to compare those efficient municipalities and offer a reference as to what magnitude of improvement others have achieved so that those with lower super efficiencies are aware of the gap and thus work to eliminate that gap or at least reduce it.

### 4.4 Regression model

In an attempt to identify the significant inputs and thus focus on reducing them, a regression model for CCR super efficiency was built as a function of the input variables. Equation (5) shows super efficiency in terms of inputs.

$$\begin{aligned}\text{Super Efficiency (I)} = {} & 4.27\text{E-}05\,\text{NC} - 6.67\text{E-}04\,\text{LWN} - 5.38\text{E-}04\text{NE} \\ & -3.42\text{E-}08\text{MOC} + 0.9213\end{aligned} \tag{9}$$

It is clear from equation (9) that length of water network (LWN) and the number of employees (NE) have largest negative effects on super efficiency of municipalities and increasing of number of connections has a positive effect on super efficiency. Therefore, it would be advantageous to increase the number of connections and focus on decreasing the number of employees and the length of network connections. However, it is clear that decreasing the length of network connections would adversely affect increasing the number of connections. Consequently, decision makers have to strike a balance between these conflicting criteria. Other multi criteria methods could be helpful in reaching the required balance.

## 5 Conclusions

The paper used data envelopment analysis to measure the efficiency of municipalities in Gaza Strip. The paper covers 25 municipalities. Four inputs and two outputs are chosen to represent municipalities efficiency.

The use of CCR model resulted in 15 inefficient municipalities with an average of 78.74%. Length of water network and number of employees have the largest values to be reduced. Az Zawayda has the highest value of super efficiency. While Beit Lahiya has the lowest value of super efficiency score.

Finally, to help decision makers in the inefficient municipalities, regression analysis was used to expresses super efficiency as a function of inputs. This research will add a new tool to the decision makers' toolbox to effectively evaluate the performance of their municipalities and to optimally manage their resources and revise their policies, strategies and methods. Inefficient municipalities can refer to the identified benchmarks and learn from their best practices to reduce critical inputs.

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