International Journal of Human Capital in Urban Management
(IJHCUM)

Homepage: http://www.ijhcum.net/

ORIGINAL RESEARCH PAPER

Application of Data Envelopment Analysis to assess the efficiency using income aspect in the local government

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ARTICLE INFO

Article History:
Received 11 December 2021
Revised 29 February 2022
Accepted 26 March 2022

Keywords:
BCC-O model
Cash income
Data Envelopment Analysis
The Municipality of Tehran
Performance assessment
Sustainable income

ABSTRACT

BACKGROUND AND OBJECTIVES: Given the tremendous progress of today's societies and the expectations of the people from public institutions that are increasing day by day, having complex organizations is inevitable. As a non-parametric border method, data envelopment analysis approach has been presented as a relative assessment tool to evaluate performance assessment of The Municipality of Tehran with 22 districts. This paper aims to assess all 22 districts of Tehran in terms of cash and sustainable income.

METHODS: In this paper, BCC output-oriented model has been opted to employ DEA for the performance assessment of Tehran Municipality in 2020. In order to formulate optimal programs, especially in the income programs of the regions, it is necessary to consider the specific conditions and characteristics of each region. Therefore, while cash and sustainable incomes have been selected as the model's output, number of building permits, number of inhabitants, number of housing deals, and the price of the residential unit have been considered as inputs of BCC-O model.

FINDINGS: BCC-O approach was implemented to classify 22 districts of The Municipality of Tehran. The findings revealed that 50 percent of districts namely 1, 6, 9, 12, 16, 17, 18, 19, 20, 21, 22 operated efficiently. Also, it was determined that there has not been a proportional analogy between cash and sustainable income in comparison with input indices. For such areas an alternative program is proposed using the method.

CONCLUSION: Due to the continuous increase of population of Iran and consequently the increase of citizens' requests and the lack of resources and facilities in Tehran Municipality on the other hand, it is necessary to formulate and implement the annual plans of the regions with higher accuracy. Given that at present the annual plan of cash and stable income of regions are based on past years performance ignoring specific conditions of each region, so it is possible to evaluate a more real and precise value of income plan through DEA model with considering the conditions of each district. Decision-makers of inefficient districts can modify the approved plans of cash income and sustainable income base on the optimal value of the proposed data envelopment analysis model. Based on BCC-O model, guidelines are provided for transferring inefficient districts from the current state to the efficient ones. These values can be the basis for compiling the revenue plan for next year in districts of The Municipality of Tehran.

DOI: 10.22034/IJHCUM.2022.03.0*

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
32	4	3

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Note: Discussion period for this manuscript open until October 1, 2022 on IJHCUM website at the "Show Article.

INTRODUCTION

As a public, independent, and non-governmental institution with a governmental nature and local function, the municipality is responsible for managing the city and serving the people and tourists, and as one of the main elements of urban management, it tries to manage the city by fulfilling its duties as well as possible and provides more satisfaction and welfare for the citizens. The scope and variety of tasks in the municipality are extensive, so if the municipal organization can evaluate the municipalities of the districts using opportune indicators at appropriate intervals, it will undoubtedly provide the groundwork for success, continuous development, and interest groups' satisfaction. In order to achieve a favorable evaluation, considering the organizational structure and extensive tasks of the municipality, an appropriate assessment method is needed that can provide the necessary feedback on the progress towards the set goals, staff and citizen satisfaction, identify areas for attention, and creation of information for decision-makers. Many organizations try to implement pure concepts in their business, but there is a large gap between the current and desired situations for many of them. To reduce this gap, the organization can achieve a realistic view of its performance by conducting an effective evaluation and plans for performance improvement opportunities. Performance appraisal (PA) refers to the methods and processes used by organizations to assess the level of performance of their employees and subdivisions to provide them with feedback. Having appropriate performance measures in place facilitates the communication of a well-defined structure for moving towards achieving an organization's goals (Neely, 2004). Developed by Charnes *et al.* (1978) based on the earlier work of Farrell (1957), Data Envelopment Analysis (DEA) is a famous technique to assess the performance of similar Decision-Making Units (DMUs). It is a non-parametric method based on linear programming that estimates the relative efficiency of DMUs using multiple inputs and outputs. Kohl *et al.* (2019) applied the DEA in healthcare with a focus on hospitals. They concluded that a further contribution of their research was its function as a roadmap to important methodological literature and publications, which provide crucial information on the setup of the DEA studies. Thus, this paper should be of assistance to researchers planning to apply DEA in a hospital setting by providing information on (a) possible pitfalls when setting up a DEA analysis, and (b) possible ways to apply the DEA analysis in practice. Finally, they discuss what could be done to advance DEA from a scientific tool to an instrument that is actually utilized by managers and policy-makers. Yang *et al.* (2020) concluded that the foremost broadly utilized strategy for the valuation of the overall performance of a set of identical DMUs that use analogous sources to yield related outputs is DEA. However, the witnessed values of the symmetry or asymmetry of different types of information in real-world applications are sometimes inaccurate, ambiguous, inadequate, and inconsistent, so overlooking these conditions may lead to erroneous decision-making. They utilized the DEA for measuring performance of 13 hospitals of Tehran University of Medical Sciences of Iran. The results exhibited the usefulness of the suggested approach and point out that the model has practical outcomes for decision-makers. Taboada and Han (2020) applied a combination of the DEA Exploratory Data Analytics (EDA) to assess the efficiency and sustainability of urban rail transit for London. The paper delt with the efficiency and sustainability of Urban Rail Transit (URT) using EDA and DEA. The first stage of the proposed methodology was EDA with already available indicators and suggested indicators to directly characterize the efficiency and sustainability of this transport mode. The second stage was assessing the efficiency of URT with two original models, based on a thorough selection of input and output variables, which is one of the key contributions of EDA to this methodology. The first model compared URT against other urban transport modes, applicable to route personalization, and the second scored the efficiency of URT lines. They claimed that the main outcome of their research was the proposed methodology, which has been experimentally validated using open data from the transport for London Urban Rail Transit Network and additional sources. Mocholi-Arce *et al.* (2022) used DEA to do performance assessment of the Chilean water sector. Their study applied a two-stage network structure model to evaluate water service providers cost and operational performance embracing service quality variables. An empirical analysis of the Chilean water and wastewater industries over the 2010–2018 period was presented. Moreover, in the second stage

of analysis, they analyzed the impact of a set of exogenous variables on the performance of water companies. Results revealed that the Chilean water companies had notable room to reduce costs and improve operational performance. Moreover, it was found that the public water provider performed better than fully private and concessionary water providers. Shao *et al.* (2019) evaluated the eco-efficiency of China's industrial sectors between 2007 and 2015 by using the Directional Distance Function (DDF) of network DEA, which contains a two-stage structure that divides industrial processes into three linked subprocesses, i.e., the production, wastewater and waste gas treatment processes. They expressed because the industrial process always results in pollutant emissions, pollution treatment has become necessary for the sustainable development of industry. Their results showed that the eco-efficiency of the mining industry was the lowest due to a decline in its performance during the waste gas treatment process, while due to the excellent performance during the production wastewater treatment process, the eco-efficiencies of the electricity, gas production and supply industries were the highest. Kalinichenko *et al.* (2022) performed a research for exploring the potential of Data Envelopment Analysis for enhancing pay-for-performance program design in primary health care. In recent years, implementation of pay-for-performance (P4P) programs in health care has become a worldwide initiative. However, most P4P programs incorporate systems of Performance Indicators (PI) without accounting for trade-offs between indicators. Their article had two objectives: (1) developing a DEA methodology for performance assessment of primary care providers; and (2) propose an innovative methodology for P4P contracting based on the DEA assessment results. They claimed that the applicability and advantages of the proposed methodology were illustrated with data from Portugal, but it can easily be adapted to different sets of PIs or domains, making it relevant for performance assessment and for P4P reward setting in other contexts and countries. The application of DEA and Malmquist index by Luo *et al.* (2019) to evaluate the efficiency of green technology innovation in strategic emerging industries. They stated that green technology innovation is the main driving force for sustainable development of China's strategic emerging industries. Improving the efficiency of green technology innovation is an effective way to achieve this developmental goal. The correct approach to measuring the efficiency of green technology innovation is a hot issue. The empirical results showed that changes in trends of technology innovation efficiency of strategic emerging industries are increasing, due mainly to technological progress and promotion of technology efficiency. Qi *et al.* (2022) used performance evaluation using DEA for construction safety from a hybrid perspective of cross-sectional and longitudinal in three regions of Jiangsu, Zhejiang and Shanghai from 2003 to 2019. They stated that rapid expansion of urbanization in developing countries such as China brings explosive growth of the construction industry. It is necessary to evaluate construction performance in terms of safety, in order for sustainable development maintaining the speed of construction production without compromising safety performance. It was found that these regions don't maintain the state of fully BCC-efficient after achieving the optimal ratio between inputs and outputs in construction safety management. In consideration of the severity of undesirable outcomes, the construction industry performs better in the avoidance of workplace fatalities than in the prevention of non-fatal accidents. Distinct patterns of input indicators and output indicators during the period can give impetus to pooling their experience for cross reference among Jiangsu, Zhejiang and Shanghai. Additionally, practical experience of these regions can be referred to by other developing countries, in order for the balance between construction safety performance and industrial development in the aspects of added-value of the construction industry, completed-area of building construction, and total number of employees in construction companies. Zhu *et al.* (2018) used the DEA for analyzing the green Total Factor Productivity (TFP) of China's mining and quarrying industry for the period of 1991-2014 with regard to technology, scale, and management. According to them, China's mining and quarrying industry is characterized by high pollution, high energy consumption, and high emissions. Improving this sector's green TFP is of great importance for furthering the sustainable development of China's economy. Technological progress was the most important contributor, and the decline in scale efficiency and management efficiency were two inhibitors. Fortunately, in recent years,

management efficiency has gradually improved and become a new impetus for green TFP growth. Second, the characteristics of the green TFPs in the sub-industries vary considerably. During the sample period, the green TFPs of the Mining and Processing of Ferrous Metal Ores (MPFMO), the Mining and Processing of Non-Ferrous Metal Ores (MPNFMO), and the Mining and Processing of Non-metal Ores (MPNO) grew rapidly and became the benchmarks, whereas those of the Mining and Washing of Coal (MWC) and the Extraction of Petroleum and Natural Gas (EPNG) remained very low. Third, the returns to scale of the sub-industries also varied. EPNG, MPNFMO, MPNO were in the stage of increasing returns to scale or constant returns to scale during the entire period, whereas MWC and MPFMO have recently entered the stage of decreasing returns to scale. The results showed an increase in the green TFP by 71.7%. Technological progress was the most important contributor, and the decline in scale efficiency and management efficiency were two inhibitors. Rashidi and Cullinane (2019) utilized the DEA to derive an efficiency score reflecting the degree to which Sustainable Operational Logistics Performance (SOLP) is achieved within each sample nation. DEA was applied to derive an efficiency score reflecting the degree to which SOLP was achieved within each sample nation. A comparison between the national rankings achieved under the LPI and SOLP evaluation regimes revealed that there is a statistically insignificant monotonic correlation between them. While one country may be a top performer with respect to one of the evaluation approaches, it does not emerge as such under the other. However, the results of the analysis suggest that logistics industries of the United States, the Netherlands, Norway and Australia were found to be top performers under both approaches, while that of Greece, Korea, Italy and Portugal were found to be poor performers under both. The paper concluded that the SOLP approach provides useful information that supplements that provided by the LPI, but that it better facilitates performance improvements within a nation's logistics industry by helping to identify the sources of inefficiency and the nations which possess benchmark performing logistics sectors. Mostafavi and Sadra Abarghouei (2018) conducted a research to assess the efficiency of districts of The Municipality of Tehran by using DEA model. The number of input and output of their model were 4 and 7, respectively. Results showed that the districts 9, 10, 13, 16, 17, 21 and 22 were categorized as efficient one. Benito *et al.* (2019) used DEA methodology to examine the efficiency of small Spanish municipalities' drinking water supply services. The results reveal a negative and considerable impact of population density and citizens' level of income on the efficiency of drinking water delivery. When the provision of water is managed directly by the local government, it is more efficient. Onbaşıoğlu (2021) investigated empirically the efficiency, technical efficiency, productivity, and the determinants factor of implementing sustainable development policy of the five major municipalities in North Cyprus by conducting DEA and Tobit analyses during the period from 2004 to 2018 quarterly. The empirical results showed that the size of the economically active population of a city, lower expenditures, and grants result in a higher efficiency, whereas the independent revenue sources (grants) and the per capita expenditures of North Cypriot municipalities had a negative effect on the efficiency. The employment rate in the municipalities had a considerable negative effect on the efficiency score. The results of Tobit analysis also showed that population had a positive impact which may increase the technical efficiency. Modiri *et al.* (2014) assessed efficiency of urban life quality in the districts of Tehran using DEA as an effective way for efficiency measuring. They claimed that utilized method can help urban planning for perceive and priority of urban issues and finding a solution for removing these problems. Cooper *et al.* (2011) indicated that the advantages of DEA, which lead to its widespread use, include empirical orientation and the absence of the need for prior assumptions inherent in other approaches, such as statistical regression analysis. Furthermore, they reported that studies of benchmarking practices using DEA have shown inefficiencies in some of the most profitable firms, and it has, therefore, been found to provide a better method for establishing benchmarks than using profitability as a criterion. Zayyari *et al.* (2010) stated that facing a lack of resources and facilities is the main reason of measuring efficiency to manage and dedicate resources to achieve the maximum level of services or productions. They claimed that DEA can be considered as one of the most effective approaches to measure efficiency. Therefore, they applied DEA

approach for assessing efficiency of Iran's provinces efficiency from view point of development. Their results showed that ten provinces had equal efficiency and opted as the superior ones from perspective of maximum developing along with the minimum level of facilities. Olejniczak (2019) investigate the relationship between Poland municipalities' income potential and the relative efficiency of their expanses by employing the DEA CCR-O model. It can be concluded that there is a link between the level of own revenues per capita and efficiency. Soko and Zoric (2018) measure the municipal efficiency in Bosnia and Herzegovina by implementing DEA with Variable Return Scale (VRS) and Constant Return Scale (CRS). Sixteen percent of municipalities were found efficient under the VRS assumption with an average efficiency score of 0.7115. The average municipal efficiency under the CRS assumption was 0.7458 and only 11% of them were efficient by using this model. The findings reveal a positive and significant impact of the number of residents on municipal efficiency. Lo Storto (2016) aimed at measuring the cost efficiency of 108 Italian major municipalities. The results reveal that Scale inefficiencies were found in some of the municipalities and there was a trade-off between expenditure efficiency and effectiveness. Miri *et al.* (2014) present an investigation to assess the performance of 22 districts of The Municipality of Tehran. The study employed DEA to evaluate the relative efficiency of decision-making units. The proposed model used fixed assets, employee expenses, and total income as input, and green space development, resumption and waste, development of cultural spaces as well as of passages and highways are assumed as the output of the model. The findings reveal that 9 districts were operating efficiently and 14 districts were inefficient. Lo Storto (2013) applied the DEA model for assessing expenditure efficiency of 103 Italian major municipalities. The percentage of efficient municipalities in the CCR and BCC models were 58% and 64% of the sample. Saranga and Moser (2010) claimed that increasing global competitiveness is forcing companies to cut costs and develop operational excellence. They stated that it is necessary to structure, develop and manage organizational activities in line with organizational objectives to achieve proper function. However, a challenge in respect of business units designated as support functions is establishing their direct value added to overall corporate financial performance. This is cited as a key objective of senior management, and therefore a crucial focus in developing a performance management system for such units. To utilize performance measurement to establish business units as value-adding, it is necessary to go beyond merely measuring performance to analyze the performance in such a way it can demonstrate the function adds value. In this respect, Neely (2004) has identified a key challenge in managing through measurement as being to shift the focus to the targets. The results indicated that where managers are faced with large amounts of raw performance data, they tend to concentrate on justifying individual figures, as opposed to learning from the current situation and applying it to identify how the targets can be achieved. He proposed that managers need to be educated in how to present the data in such a way as to promote such discussion. The DEA has been successfully applied in various sectors like banking (Thanassoulis, 1999), supplier selection (Levary, 2008; Nourbakhsh *et al.*, 2013), industrial (Fan *et al.*, 2017), logistics (Xu *et al.*, 2009), healthcare (Jacobs, 2001; Khani *et al.*, 2012; Ghotbuee *et al.*, 2012), operational research (Ruiz and Sirvent, 2022), university assessment (Loganathan and Subrahmanya, 2022), manufacturing (Wahab *et al.*, 2008), education (Bessent *et al.*, 1982). The aforementioned studies reveal that the DEA-method has extensive and significant utilization in efficiency assessment of executive units. Various indices could be implemented to perform the efficiency assessment using the DEA. Th literature shows no similar research of using DEA approach to evaluate performance assessment based on financial indices. The main motivation of present study is application of the DEA approach to assess the efficiency of 22 districts of The Municipality of Tehran based on two indices i.e. cash income and sustainable income in 2020. Utterly, efficient and inefficient districts are determined and comments are presented to change and improvement. The current study has been carried out in Tehran in 2021.

MATERIALS AND METHODS

The Municipality of Tehran: Tehran City, the capital of Iran, is located at 51° 17′to 51' 33′ east longitude and 35° 36′ to 35° 44′ north latitude. The city of Tehran is the largest and most populous city with a population

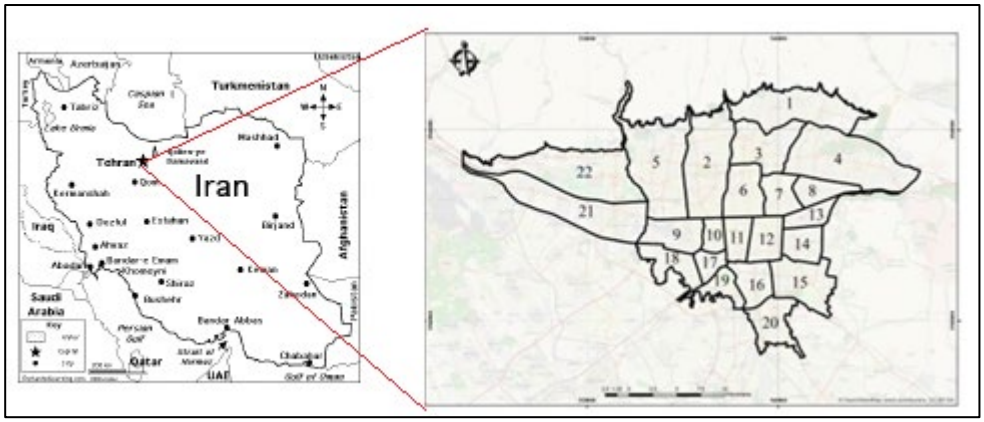

Fig. 1: The map of Tehran along with 22 districts

of about 8.6 million people, according to the 2016 population and housing census, and is the most densely populated center in the country with an area of 615 km^2. Tehran is divided to 22 districts that has shown in Fig. 1. The largest and the smallest districts of Tehran are 4 and 17 with an area of 62 and 9 km^2, respectively. The highest and lowest populations with 917,000 and 174,000 are in the Districts 4 and 9, respectively.

Data envelopment analysis

DEA is an applied mathematical state of the art programming method for measuring the relative efficiency of similar matched units that has been developed by Charnes *et al.* (1978) based on Farrel (1957) method with several input and output indicators. This approach is utilized to assess DMU's performance. DMU is a unit of an organization that is managed by an administrator provided that has a systematic process. In DEA literature, system's input elements and system's output elements are substituted with 'input' and 'output' phrases based on economic science. DEA suppose that DMUs apply similar inputs for similar outputs but with different value levels. It'll be simple and clear the expression of input-output ratios if output function is available and determined. But in many cases, the function is undetermined and inaccessible and it is more complex and even impossible to present. DEA is based on optimization process using linear programming that its function and parameters are undetermined. Therefore, DEA is categorized as non-parametric approach. There are two common models to apply DEA approach for performance assessment: (1) CCR model (2) BCC model (Azar and Gholamrezaei, 2006).

CCR model

Developed by Charnes *et al.* (1978), so-called CCR, CCR is the first and a linear programming model of DEA that seeks to maximize the relative efficiency score of the unit pth by selecting a set of weights for all inputs and outputs. However, the score of each unit must be less than or equal to one. According to CCR model, efficiency is defined as the ratio of the weighted sum of outputs to inputs Eq. 1 (Egilmez, 2013):

$$EF_j = \frac{u_1 y_{1j} + u_2 y_{2j} + \ldots + u_n y_{nj}}{v_1 x_{1j} + v_2 x_{2j} + \ldots + v_{mj} x_{mj}} = \frac{\sum_{r=1}^{n} u_r y_{rj}}{\sum_{s=1}^{m} v_s y_{sj}} \quad (1)$$

where x and y, respectively represent input and output, v and u are vectors inputs and outputs, respectively. While s and r are the output and input counts, j demonstrates the jth DMU. The first limitation is the denominator of Eq. 1. To overcome this problem, it is possible to solve CCR model in the form of linear programming. The second limitation ensures that under the selected set of weights, the efficiency score of any decision unit does not exceed one. The linear form is Eq. 2:

CCR'_D-I

$$MAX\ w_p = \sum_{r=1}^{s} u_r y_{rp} \quad (2)$$

Subjected to

$$\sum_{i=1}^{k} v_i x_{ip} = 1 \quad (2\text{-}1)$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{k} v_i x_{ij} \le 0 \quad j=1,2,\ldots,n \quad (2\text{-}2)$$

$$u_r \ge 0 \quad r=1,2,\ldots,s \quad (2\text{-}3)$$

$$v_i \ge 0 \quad i=1,2,\ldots,k \quad (2\text{-}4)$$

In this model w_p is relative efficiency of pth DMU_p. The presented model by Eq. 2 should be performed for each decision-making unit to determine the efficiency of each units. Based on the experiments, if the number of units doesn't differ much from the total number of inputs and outputs, after solving, most units will be in the efficient border. In fact, the model would be unrealistic. Dual model is used to avoid this problem. Dual form of Eq. 2 is as Eq. 3:

CCR'_p-I

$$MIN\ z_p = \theta \quad (3)$$

Subjected to

$$\sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{rp} \quad r=1,2,\ldots,s \quad (3\text{-}1)$$

$$\theta x_{ip} - \sum_{j=1}^{n} \lambda_j x_{ij} \ge 0 \quad i=1,2,\ldots,k \quad (3\text{-}2)$$

$$\lambda_j \ge 0 \quad j=1,2,\ldots,n \quad (3\text{-}3)$$

θ is sign free. The pth DMU is efficient if and only if limitations of Eqs. (3-1) and (3-2) are required in model Eq. 3. To determine the efficiency of a DMU using an objective function approach via a linear programming, Eq.3 is developed as Eq. 4:

CCR_p-I

$$MIN\ z_p = \theta - \sum_{r=1}^{s} s_r^+ - \sum_{i=1}^{k} s_i^- \quad (4)$$

Subjected to

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{rp} \quad r=1,2,\ldots,s \quad (4\text{-}1)$$

$$\theta x_{ip} - \sum_{j=1}^{n} \lambda_j x_{ij} - \bar{s}_i = 0 \quad i=1,2,\ldots,k \quad i=1,2,\ldots,k$$

$$\lambda_j \ge 0 \quad j=1,2,\ldots,n \quad (4\text{-}2)$$

$$s_r^+ \ge 0 \quad r=1,2,\ldots,s \quad (4\text{-}3)$$

$$s_i^- \ge 0 \quad i=1,2,\ldots,k \quad (4\text{-}4)$$

Where θ is sign free, λ_j, s_r^+ and s_i^- are dual variables. To ensure that no weight is assigned a zero number and all inputs and outputs include in solution, Eq. 2 is justified using ε of value 0.001 or 0.0001 as Eq. 5:

CCR'_D-I

$$MAX\ w_p = \sum_{r=1}^{s} u_r y_{rp} \quad (5)$$

Subjected to

$$\sum_{i=1}^{k} v_i x_{ip} = 1 \quad (5\text{-}1)$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{k} v_i x_{ij} \le 0 \quad j=1,2,\ldots,n \quad (5\text{-}2)$$

$$u_r \ge \varepsilon \quad r=1,2,\ldots,s \quad (5\text{-}3)$$

$$v_i \ge \varepsilon \quad i=1,2,\ldots,k \quad (5\text{-}4)$$

Introduced by Eq. 5 is CCR input-oriented approach. This model tries to approach an ineffective DMU to effective border by keeping the amount of inputs constant and increasing the output proportionally. Output-oriented model is another one that uses outputs as the basis. Keeping the outputs constant and reducing the inputs is the basis of this method. In these two models (input and output oriented), it is assumed that production has constant return to scale.

BCC model

This model adds $\sum_{j=1}^{n} \lambda_j = 1$ convexity constraint to the initial linear programming of CCR. There, return to scale could be constant, decreasing or increasing. Adding this constraint leads to insert a new variable (u) into dual model of BCC. The initial linear programming and dual of BCC are as Eq. 6:

BCC_D-I

$$MAX\ w_p = \sum_{r=1}^{s} u_r y_{rp} + u_o \quad (6)$$

Subjected to

$$\sum_{i=1}^{k} v_i x_{ip} = 1 \quad (6\text{-}1)$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{k} v_i x_{ij} + u_o \le 0 \qquad j=1,2,\ldots,n \qquad (6\text{-}2)$$

$$u_r \ge \varepsilon \qquad r=1,2,\ldots,s \qquad (6\text{-}3)$$

$$v_i \ge \varepsilon \qquad i=1,2,\ldots,k \qquad (6\text{-}4)$$

u_o is sign free (6-5)

BCC_p-I

$$MIN\ z_p = \theta - \sum_{r=1}^{s} s_r^+ - \sum_{i=1}^{k} s_i^- \qquad (7)$$

Subjected to

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{rp} \qquad r=1,2,\ldots,s \qquad (7\text{-}1)$$

$$\theta x_{ip} - \sum_{j=1}^{n} \lambda_j x_{ij} - \bar{s}_i = 0 \qquad i=1,2,\ldots,k \qquad (7\text{-}2)$$

$$\sum_{j=1}^{n} \lambda_j = 1 \qquad (7\text{-}3)$$

$$\lambda_j \ge 0 \qquad j=1,2,\ldots,n \qquad (7\text{-}4)$$

$$s_r^+ \ge 0 \qquad r=1,2,\ldots,s \qquad (7\text{-}5)$$

$$s_i^- \ge 0 \qquad i=1,2,\ldots,k \qquad (7\text{-}6)$$

Output-oriented of BCC model can be developed with adding $\sum_{j=1}^{n} \lambda_j = 1$ constraint to the initial linear programming of CCR output-oriented. In this paper, BCC output-oriented model has been implemented to survey districts performance of The Municipality of Tehran.

Indices of performance assessment

Sustainable income definition

According to the comprehensive plan of sustainable incomes and other financial resources of The Municipality of Tehran, sustainable incomes are those municipal incomes owning to the following characteristics:

1. Persistence: It is stable and doesn't undergo extreme fluctuations at least in the short run.
2. Flexibility: the income base increases over time and expands along with expanding expenditures to avoid financial constraints and to define the necessary implementation planning to achieve it.
3. Desirability: Earning money from that source promotes the justice-oriented approach and doesn't damage the environmental, physical, social, and economic structures (Hajilou *et al.*, 2017)

Survey design and data collection

The Municipality of Tehran sources include seven major revenue groups and its credit is provided in both cash and non-cash forms. The main groups are (1) Public incomes, (2) Income of private tolls, (3) Service fees and earnings of profit institutions, (4) Income from the funds and property of the municipality, (5) Government grants and affiliated organizations, (6) Grants and gifts and assets, (7) other sources. According to the approved budget report of The Municipality of Tehran Information and Communication Technology Organization (TMICTO), the share of incomes from public tolls is 86 percent of total income, of which 36 percent is related to sub-codes of tolls on building permits, tolls on balconies and overhangs, and renovation tolls (Tehran Municipality Information and Communication Technology Organization-TMICTO, 2020). These sub-codes make up a significant portion of cash and sustainable income.

Analytical framework

Determining Input and Output variables: In the present study, two indicators of cash and sustainable income are selected as the model outputs. Also, along with the above description, four variables are considered as the inputs of the model (1) number of building permits, (2) number of inhabitants, (3) number of housing deals, and (4) the price of the residential unit. Fig. 2 shows the structure of the model with its inputs and outputs along with unit of measurement. The following constraint has been considered in this model (Bowlin, 1998):

(Number of inputs + outputs)
× 3 ≤ number of decision-making units (8)

Decision-making units are considered as a system in DEA that transfer inputs to output. Obviously, a superior and more efficient system produces more output with fewer inputs. DEA models aim to maximize efficiency by providing a systematic approach to decision-making units (Zayyari *et al.*, 2010).

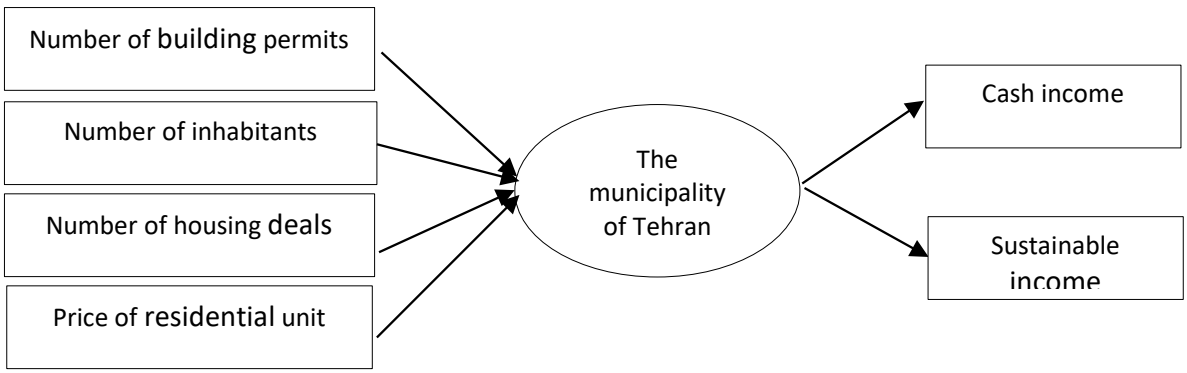

Fig. 2. Components of proposed DEA model

Table 1: Output and input data set of The Municipality of Tehran districts

District	Inputs				Outputs	
	X_1	X_2	X_3	X_4	Y_1	Y_2
	No. of building permits*	No. of inhabitants*	No. of housing deals*	price of residential unit* (Million dollar)	cash income* (Million dollar)	sustainable income* (Million dollar)
1	348	493889	4326	245.0	5999.3	778.8
2	460	692579	7162	179.1	3206.2	339.3
3	324	330004	3606	209.8	3869.8	355.5
4	643	917261	7025	122.5	2384.8	280.5
5	383	856565	12169	141.9	3227.6	255.7
6	232	250753	3029	156.7	3211.2	307.1
7	370	312002	4800	107.6	1393.6	161.0
8	387	425044	4636	106.1	683.1	136.0
9	144	174115	1748	81.4	324.8	48.1
10	236	326885	7025	76.4	338.8	71.9
11	325	308176	3750	76.9	880.2	101.9
12	231	240909	2359	64.0	1977.4	219.3
13	270	253054	2791	99.7	444.0	69.8
14	493	489101	5216	83.3	480.2	103.1
15	999	659468	4201	61.5	461.4	104.5
16	341	267678	1327	60.0	461.4	80.5
17	300	278354	1809	59.0	328.8	57.6
18	243	419249	1890	51.1	1121.4	87.4
19	261	255533	584	61.0	325.5	44.3
20	333	367600	1283	56.0	1246.2	84.8
21	307	186319	1365	80.9	638.1	123.1
22	301	175398	1202	111.1	1304.5	125.5

* Tehran Municipality Information and Communication Technology Organization

Data collection

Input and output variables of each district have been extracted for year 2020 (Table 1). Fig. 3 represents a graphical presentation of input and output variables.

RESULTS AND DISCUSSION

The efficiency of decision-making units based on BCC-O model has been shown in Fig. 4. Referring to Fig. 4, while the efficient districts are 1, 6, 9, 12, 16, 17, 18, 19, 20, 21, and 22, the rest are inefficient. As

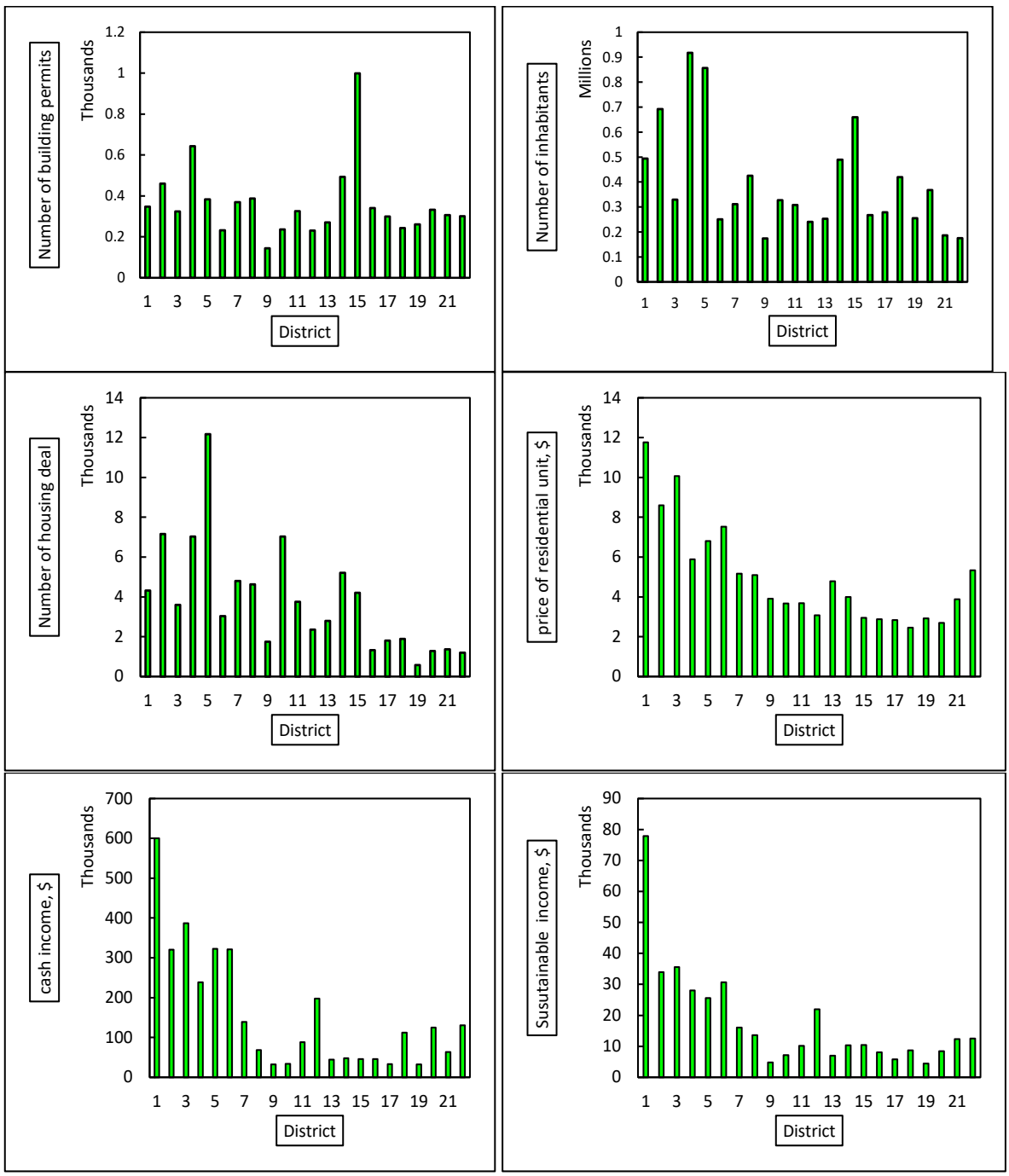

Fig. 3: A graphical representation of BCC-O's input and output

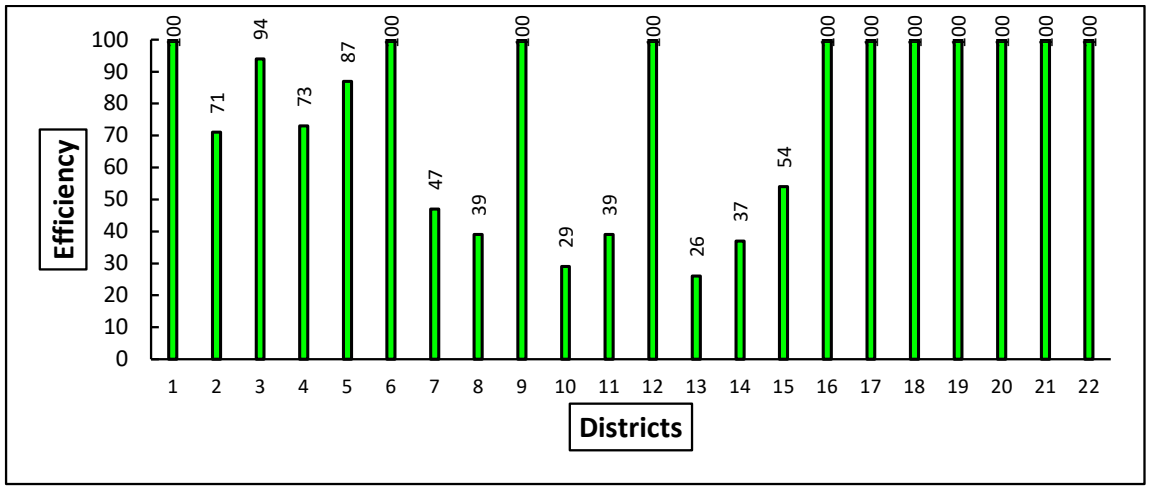

Fig. 4: Districts' efficiency

Table 2: The optimized value of sustainable income based on the BCC-O model

District	Proposed value (BCC-O model) (Million Dollar)	Approved sustainable income (Million Dollar)	Percentage change (BCC-O model to the approved value)
2	57.50	45.12	27%
3	46.10	43.90	5%
4	40.02	41.01	-2%
5	46.00	47.62	-3%
7	35.43	22.86	55%
8	34.95	13.76	154%
10	25.07	11.02	128%
11	25.90	14.02	85%
13	26.69	8.57	211%
14	27.90	14.71	90%
15	19.38	16.36	18%

Table 3: The optimized value of cash income based on the BCC-O model

District	Proposed value (BCC-O model) (Million dollar)	Approved cash income (Million dollar)	Percentage change (BCC-O model to the approved value)
2	453.38	312.72	45%
3	412.00	486.35	-15%
4	327.76	346.57	-5%
5	370.74	361.12	3%
7	294.71	144.32	104%
8	291.40	54.95	430%
10	219.02	33.56	553%
11	226.38	93.47	142%
13	251.00	30.39	726%
14	240.71	50.19	380%
15	181.29	41.33	339%

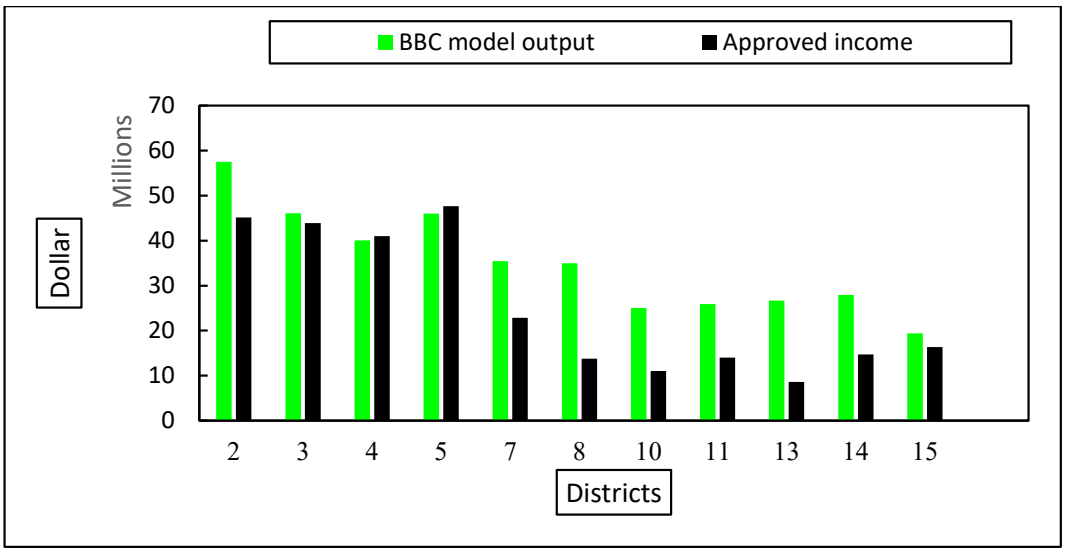

Fig. 5: The proposed value of BCC-O model vs approved sustainable income

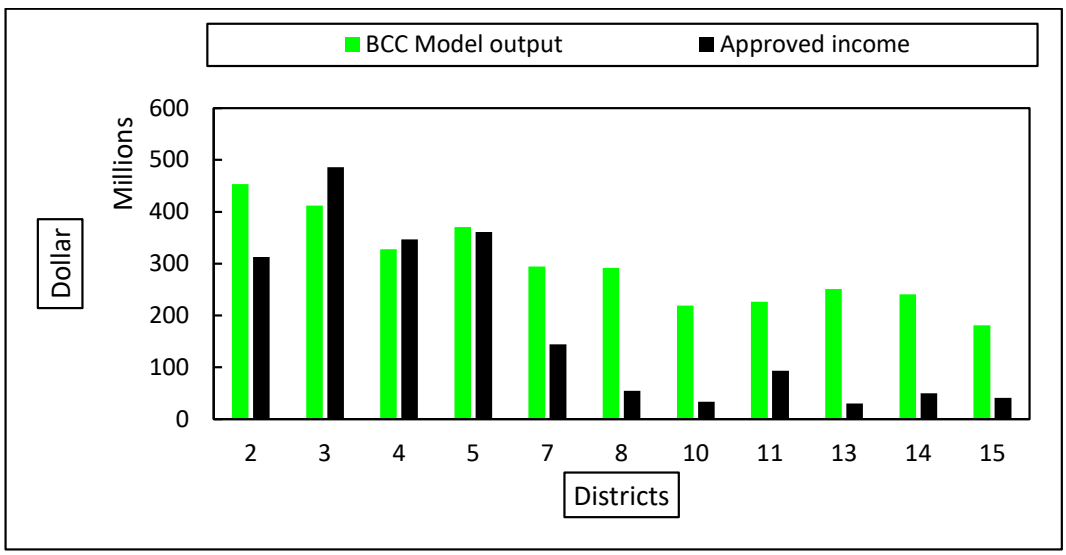

Fig. 6: The proposed value of BCC-O model vs approved cash income

it is clear, the District 13 has the lowest proficiency among inefficient ones.

Proposed plan for inefficient districts

Tables 2 and 3 show the optimized output values using the BCC-O model for inefficient districts. A graphical representation of these tables has been presented in Figs. 5 and 6. This can be useful for decision-makers of inefficient districts to modify the approved values of cash and sustainable income according to the proposed value of BCC-O model.

The results showed that while 50 percent of districts namely 1, 6, 9, 12, 16, 17, 18, 19, 20, 21, and 22 are efficient districts, the rest are inefficient. These

districts were ranked in terms of efficiency values. The Districts 3, 5 and 4 were located at the beginning of the spectrum and the dstricts 13, 10 and 14 were placed at the end. It is clear to distinguish efficient and inefficient districts by comparing inputs and outputs of each one. Cash and sustainable income of district 1 has been achieved 9 and 6 times those of the District 8. The optimum values of cash and sustainable income were determined using BCC-O model and were compared with considered incoming plan of 2020 for the districts. The results illustrated that the cash and sustainable income have been brought up very low for the Districts 8, 12 and 13 regards to effective input indices. It can be concluded that using performance assessment is a more logical method to regulate a district revenue plan and is necessary to change the current approach of The Municipality of Tehran for regulating the revenue plan of the districts, generally with emphasis on the performance of previous years. According to Table 2, the approved sustainable income of districts has been considered very low because of their capacities and potentials except the districts 4 and 5. In particular, the districts 13, 8 and 10 have a difference of more than 100 percent between approved and proposed values. According to Table 3, the approved cash income of inefficient districts has been considered very low in 2020. For example, the actual performance of the districts 15, 8, 10 and 13 was much higher than their approved value. Input variables considered in the present study illustrate that it is necessary to increase remarkably their approved cash income for the coming years. Similar researches have been conducted by Mostafavi and Sadra-Abarghuei (2018) and Miri *et al.* (2014). Mostafavi and Sadra-Abarghuei (2018) used area, district's population, number of employees and approved budget as input variables. Cash and non-cash achieving percent, urban services and environment, traffic, prevention and crisis, cultural and social, human resources and technical and construction projects were opted as output parameters. They used CCR and BCC approaches to determine efficient and inefficient districts. The results showed that the districts 9, 10, 13, 16, 17, 21 and 22 were known as efficient ones using CCR model. Based on the BCC model, the districts 1, 4, 5 and 8 were added to the above-mentioned districts. Miri *et al.* (2014) used number of total assets, human resources expenses and total income as the input variables for their BCC input-oriented model. Four output parameters were green space development, resumption and waste, development of cultural spaces and improvement of passages and highways. They claimed that while 9 districts (i.e. the districts 1, 2, 4, 5, 13, 15, 19 and 21) were efficient, the others were found inefficient ones. The average efficiency of these 14 inefficient units was equal to 0.93. The most significant distinct among the present paper with two above-mentioned ones are type and number of inputs and outputs. However, the more confidence can be seen between the results of Mostafavi and Sadra-Abarghuei (2018) and the present study. Based on these researches, the districts 1, 9, 16, 17, 21 and 22 have been introduces as efficient ones.

CONCLUSION

Present study aimed to evaluate the efficiency of 22 districts of The Municipality of Tehran in terms of cash income and sustainable income using DEA. In fact, the purpose of ranking the 22 districts of Tehran City is identifying efficient and inefficient ones in order to improve the current situation and transfer towards higher efficiency in creating cash income and sustainable income. While number of building permits, number of inhabitants, and number of housing deals and price of residential unit opted as four input variables, cash income and sustainable income were selected as output variables. The BCC-O model has been implemented to utilize the DEA model for classifying the 22 districts of The Municipality of Tehran. The results illustrated that utilization of the DEA approach to determine efficiency model for planning could be prioritized for inefficient districts to decline the gap between districts. Hence, the capacities and limitations of each district is basic of districts planning and it will be possible to achieve social justice and development using the results of the DEA model.

SUGGESTIONS

The following recommendations are suggested for future researches:

- Due to the problems and shortcomings in the planning pattern in The Municipality of Tehran, it will be beneficial to use DEA to assess the efficiency of different urban areas including waste management, transportation developing

and assessment of organization and companies. Comparison of temporal assessment of efficiency can be considered too;
- Using residential parcel information as input parameter for implementation of DEA approach;
- Formulation of green space per capita program of districts using DEA method
- Prediction of distressed area renovation;
- Assessment of citizens' satisfaction using DEA approach.

AUTHOR CONTRIBUTIONS

A. Jafari Shahrestani, E. Sangi and H. Mazaherian performed the literature review, extracting indices and gathering information. S. Mavaghar poor performed the calculation. E. Sangi and H. Mazaherian prepared the review of the paper. E. Sangi and A. Jafari Shahrestani prepared the results and explanations of the paper.

ACKNOWLEDGMENTS

The authors would like to appreciate the Municipality of Tehran for the data support.

CONFLICT OF INTEREST

The authors have no conflict of interest to be declared concerning this review paper. Also, the authors have checked all the ethical affairs comprising duplicates, misconduct, data making, informed consent, and plagiarism.

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PUBLISHER'S NOTE

ABBREVIATIONS (NOMENCLATURE)

BCC	Banker, Charnes, Cooper
BCC-O	The output-oriented BCC model
CCR	Charnes, Cooper, Rhodes
CCR-O	The output-oriented CCR model
CRS	Constant Return to Scale
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
VRS	Variable Return to Scale
u_r	Output weights
v_i	Input weights
x_{ij}	positive inputs of the DMU_j
y_{rj}	positive outputs of the DMU_j

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HOW TO CITE THIS ARTICLE

Jafari Shahrestani, A.; Sangi, E.; Mazaherian, H.; Movaghar Hoor, S. (2022). Application of Data Envelopment Analysis to assess the efficiency using income aspect in the local government. Int. J. Hum. Capital Urban Manage., 7(3): -16.

DOI: 10.22034/IJHCUM.2022.03.0*

url: http://