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# EVALUATION OF EFFECTIVENESS OF MUNICIPALITIES IN BLACK SEA REGION WITH DATA ENVELOPMENT ANALYSIS*

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## Abstract

This study aims to measure to what extent 18 municipalities in the Black Sea Region are effective compared to each other. The Data Envelopment Analysis (DEA) method was employed to measure the effectiveness of municipalities in comparison to each other. To calculate effectiveness values, the input-oriented CCR and BCC models from DEA models, as well as the input-oriented dual CCR models for ineffective municipalities were established based on the CCR model results. In the present study, input variables were determined as goods and services procurement expenses, personnel expenses, and capital expenses, while output variables were determined as enterprise and property revenues, tax revenues, and other revenues. The LINDO 6.1 software program was used in the solution of the models. According to the solutions of CCR and BCC models, the municipalities of Bartın, Bayburt, Bolu, Çorum, Düzce, Karabük, Kastamonu, Ordu, Rize, Samsun, Sinop, Tokat, and Trabzon are fully effective, while Amasya, Artvin, Giresun, Gümüshane, and Zonguldak are not. According to the solutions of dual CCR models, the municipalities of Bartın, Bolu, Çorum, Düzce, Karabük, Ordu, Samsun, Sinop, Tokat, and Trabzon are fully effective, while Amasya, Artvin, Bayburt, Giresun, Gümüşhane, Kastamonu, Rize, and Zonguldak are not. Moreover, the dual CCR model results suggested new input values for the ineffective municipalities to achieve effectiveness.

***Keywords***: Data Envelopment Analysis, Effectiveness Measurement, Local Governments, Municipality
***JEL Classification***: C44, C67, D57

# KARADENİZ BÖLGESİ'NDEKİ BELEDİYELERİN ETKİNLİKLERİNİN VERİ ZARFLAMA ANALİZİ İLE DEĞERLENDİRİLMESİ

## Öz

Bu çalışma, Karadeniz Bölgesi'ndeki 18 belediyenin birbirlerine kıyasla ne derece etkin olduklarını ölçmeyi amaçlamaktadır. Belediyelerin birbirine kıyasla etkinliklerini ölçmek için Veri Zarflama Analizi (VZA) yöntemi kullanılmıştır. Etkinlik değerlerini hesaplamak için VZA modellerinden girdi yönelimli CCR ve BCC modelleri, CCR modellerinin çözümü sonucunda etkin olmayan belediyeler için girdi yönelimli dual CCR modelleri kurulmuştur. Çalışmada girdi değişkenleri; mal ve hizmet alım giderleri, personel giderleri, sermaye giderleri, çıktı değişkenleri ise teşebbüs ve mülkiyet gelirleri, vergi gelirleri, diğer gelirler olarak belirlenmiştir. Modellerin çözümünde LINDO 6.1 programı kullanılmıştır. CCR ve BCC modellerinin çözümlerine göre; Bartın, Bayburt, Bolu, Çorum, Düzce, Karabük, Kastamonu, Ordu, Rize, Samsun, Sinop, Tokat ve Trabzon belediyeleri tam etkin, Amasya, Artvin, Giresun, Gümüşhane ve Zonguldak belediyeleri tam etkin değildir. Dual CCR modellerinin çözümlerine göre; Bartın, Bolu, Çorum, Düzce, Karabük, Ordu, Samsun, Sinop, Tokat ve Trabzon belediyeleri tam etkin, Amasya, Artvin, Bayburt, Giresun, Gümüşhane, Kastamonu, Rize ve Zonguldak belediyeleri tam etkin değildir. Ayrıca dual CCR modellerinin çözümlerinden, etkin olmayan belediyelerin etkin olması için yeni girdi değerleri bulunmuştur.

***Anahtar Kelimeler***: Veri Zarflama Analizi, Etkinlik Ölçümü, Yerel Yönetimler, Belediyeler
***JEL Sınıflandırması***: C44, C67, D57

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## 1. INTRODUCTION

Population growth, unemployment, problems arising from geographical and natural conditions, difficulties in accessing public services such as education and health, and the inability to provide sufficient services to citizens are factors accelerating the migration of people from rural areas to large cities. Due to these reasons, the increase in urban populations increases the responsibilities of municipalities within local governments. Municipalities need adequate financial resources to fully deliver their services to the public. Strong financial structures of municipalities ensure that they can provide their services to the public in the most efficient manner without interruptions.

The organizational units known as local governments were defined as institutions that acted as a bridge, connecting central administration, particularly in European countries like England and Italy during the 1700s and 1800s (Doğan, 2006:65). Local governments are organizations that share the geography of a specific land area and benefit from the management features of decision-making units appointed by themselves for issues concerning only the citizens residing there, with their own unique income items and budgets. Moreover, local governments play an active role and are of great importance as they are the closest units to the public in the application of public authority (Poyraz, 2017: 137; Yılmaz and Telsaç, 2021:239). Municipalities are structures that meet certain needs of citizens living within their boundaries. The political and economic activities of each country may vary. In Türkiye, municipalities refer to local government units with their own economic budgets and a management scheme determined by the public (Demir, 2019:4).

Investigating how effectively municipalities can use their resources in response to increasing populations and making a plan for this has almost become a necessity. Even legally, municipalities with populations of 50,000 and above are required to perform performance measurements and act within a strategic plan. Accordingly, municipalities conduct performance measurements both on their initiative and as required by the laws enacted. All these factors are influenced by the public's desire for quality service, the increasing pressure of public scrutiny, and performance analysis (Ertaş and Atalay, 2016:76).

This present study aims to measure the effectiveness of municipalities in the Black Sea Region relative to each other and determine how efficiently municipalities perform their services. In the study, 18 municipal decision-making units (DMUs) in the Black Sea Region, 3 input variables (goods and services procurement expenses, personnel expenses, capital expenses), and 3 output variables (enterprise and property revenues, tax revenues, other revenues) were determined. The Data Envelopment Analysis (DEA) method was utilized in determining the relative effectiveness of municipalities regarding the input and output variables for 2019. In this context, input-oriented CCR and input-oriented BCC models were established, and for municipalities that were not effective in the CCR models, input-oriented dual CCR models were established. The models were solved separately using the LINDO 6.1 program. Considering the results of the input-oriented CCR, BCC, and dual CCR models, fully effective and non-fully effective municipalities were found. Additionally, new input values were calculated for non-fully effective municipalities to become effective as a result of the solution of the dual CCR models. Thus, non-fully effective municipalities will become effective by making reductions in input values at the determined rates, thereby using their expense items more accurately. This situation will contribute to the municipalities and thus to the national economy.

This study consists of five sections: introduction, literature review, method, findings, and conclusion and evaluation. In the introduction section, information is given about local governments, the subject examined here, and the application conducted. The second section includes DEA studies related to municipalities in the literature. The third section addresses the DEA method and includes the DEA application for municipalities in the Black Sea Region. The fourth section presents the findings obtained from the DEA application. The fifth section includes the evaluation of the application results and suggestions for future studies.

## 2. LITERATURE REVIEW

Both national and international literature contains studies using the Data Envelopment Analysis (DEA) in measuring the effectiveness of municipalities, as presented below.

De Borger et al. (1994) utilized the DEA method to address efficiency differences in the management of 589 municipalities in Belgium. The study presented the results, obtained using 3 input and 5 output variables, in graphical form.

De Borger and Kerstens (1996) studied the cost and pricing policies of municipalities in Belgium, focusing particularly on private and public transportation services. The study employed five measurement methods, including parametric and non-parametric DEA. Efficiency scores of municipalities were determined, and information on pricing was provided.

Prieto and Zofio (2001) examined the ability of local governments in Spain to effectively deliver their services. This study, conducted on 209 municipalities in the Castile-Leon region of Spain, evaluated responsibilities such as water and sewage services, cleaning services, road and lighting services, and cultural services using the DEA method. The efficiency scores obtained from the DEA results provided managers with insights and recommendations on the effective use of resources.

Çağlar (2003) analyzed the effectiveness of provincial central municipalities (including metropolitan areas) in Türkiye using the DEA method. The study employed 4 different models and presented information in 3 separate sections. In the third section, the effectiveness and results of the provincial central and metropolitan municipalities were evaluated.

Tupper and Resende (2004) used the DEA method to determine the effectiveness of water and sewage service providers in Brazil for the years 1996-2000. The efficiency values obtained were observed to be below optimal performance.

Woodbury and Dollery (2004) measured the effectiveness of municipal water services in Australian cities utilizing the DEA approach. Considering the obtained efficiency values, the best-performing municipalities were identified and recommendations were provided to other municipalities.

Sousa and Stosić (2005) examined the technical efficiency of 4,796 municipalities in Brazil using the DEA method. Based on the efficiency values, recommendations were made on how municipalities could reduce excessive expenditures to increase efficiency.

Kaplan et al. (2006) assessed the effectiveness of metropolitan municipalities in Türkiye for the years 2002-2004 using the DEA method. The study provided recommendations on how municipalities could become fully effective. In total, the effectiveness of 10 municipalities was found to be 100% in 2002, 11 municipalities in 2003, and 9 municipalities in 2004 among the 16 metropolitan municipalities.

Balaguer-Coll et al. (2007) analyzed the effectiveness of local governments in Comunitat Valenciana, Spain. Their study used two analysis techniques, DEA and the Free Disposable Hull (FDH) model. They found that large municipalities had high efficiency scores, indicating that they used their resources more effectively.

Güneş and Akdoğan (2007) used the DEA method for the relative efficiency analysis of 16 metropolitan municipalities. The analysis considered certain service indicators, such as water and sewage, public transportation, law enforcement, and welfare services. The analysis conducted based on three different service indicators of the 16 metropolitan municipalities revealed differences in the effectiveness scores. The study provided recommendations on how municipalities could use their resources more effectively.

Afonso and Fernandes (2008) utilized the DEA method in determining the relative efficiency of 276 municipalities in Portugal. The results from the DEA method indicated that many municipalities could make improvements without increasing expenditures.

İlkay and Doğan (2009) conducted a comparative efficiency analysis of municipalities in the Cappadocia region. The study compared the years 2004 and 2008, applying four different models covering financial, waste, water, and zoning services. The results identified effective and non-effective municipalities and provided recommendations on how municipalities could become effective.

Sarı (2010) used the DEA method in measuring the effectiveness of public transportation services in 16 metropolitan municipalities. As a result of the study, the effectiveness scores of the municipalities were determined. It was emphasized that these effectiveness scores help to assess the municipal administrations in an impartial manner and to identify their current situations.

Yıldırım (2010) examined the financial effectiveness of 32 district municipalities affiliated with the Istanbul Metropolitan Municipality (IMM) using the DEA method. In the conclusion of the study, information about the municipalities with the highest and lowest effectiveness is provided, along with recommendations.

Kaygısız and Girginer (2011a) measured the efficiency of the Eskişehir Odunpazarı Municipality by making use of the DEA method. In the 2008 activity report of the municipality, the performance levels of eight service units classified according to functional classification were determined using the DEA method, and cost-effectiveness values, which represent the proportion of each service unit's share in the total annual cost, were calculated using the efficiency scores obtained from DEA.

Kaygısız and Girginer (2011b) aimed to measure how accurately metropolitan municipalities in Türkiye performed their services with the allocated budget using the DEA method. The study established DEA models to determine efficiency scores and conducted a Cost Effectiveness Analysis based on these results. They determined that cost-effectiveness scores provided more realistic results than efficiency scores, but achieving efficiency did not guarantee cost-effectiveness.

Kabakuş (2014) measured the effectiveness of district municipalities affiliated with metropolitan municipalities in Türkiye based on e-municipality services using the DEA method. The websites of 30 metropolitan municipalities and 519 district municipalities affiliated with them were examined. The analysis identified effective and non-effective municipalities.

Karahan and Akdağ (2014) measured the service effectiveness of DİSKİ, an organization affiliated with the Diyarbakır Metropolitan Municipality, over the years using the DEA method. The study compared effectiveness for the years 2000-2012 and identified non-effective municipalities. The study, which used the BCC model, found that the institution was not effective in 2003, 2005, and 2008.

Kaygısız Ertuğ and Girginer (2015) used the DEA and Goal Programming (GP) methods to calculate the financial service efficiency and performance of metropolitan municipalities in Türkiye. According to the DEA results applied to 14 municipalities, 8 municipalities were found to be effective.

Cumhur (2017) aimed to measure the economic effectiveness of provincial municipalities in

Türkiye concerning the 2009 elections. The study conducted economic analyses for the years 3 months before and 4 months after 2009. The DEA method was used as the analysis method, and 51 provincial municipalities were evaluated. Three models were created for each municipality to evaluate effectiveness: water services model, solid waste services model, and park and garden services model. According to the study results, 7 municipalities changed management, 2 municipalities maintained their effectiveness, 3 municipalities increased their effectiveness, and 2 municipalities decreased their effectiveness.

Güner et al. (2017) measured the service effectiveness of public and private sector public transportation routes in Sakarya city center using the DEA method. The study concluded that private sector routes had higher efficiency values than public sector routes.

Aydemir and Bayram (2018) studied the financial efficiency of 16 metropolitan municipalities in Türkiye using the DEA method. The study found that 11 metropolitan municipalities were effective, while 5 metropolitan municipalities were not.

Avcı et al. (2020) evaluated the solid waste management of municipalities at the NUTS Level 1 statistical region classification in Türkiye. The study used 3 input and 2 output variables. The inputs were the number of municipalities in the region, environmental expenditures of municipalities, and average waste per capita, while the outputs were the amount of waste disposed of in landfills and municipal environmental revenues. The study ranked effective and non-effective units using the super-efficiency model.

Ergülen et al. (2020) addressed the effectiveness of metropolitan municipalities in Türkiye using the DEA method. The study found that 16 of the 30 municipalities were fully effective, while 14 were not fully effective.

Vatansever and Öztemiz (2020) measured the effectiveness of service units of Alanya Municipality using the DEA method. The study evaluated 14 service units and found that 6 service units achieved efficiency scores, while 8 service units did not.

Çağlar Onbaşıoğlu (2021) analyzed the efficiency of Turkish municipalities in Cyprus by making use of the DEA and Tobit models. The study used 4 input and 4 output variables in the DEA method. The input variables were wage and salary expenses, operating expenses, current and capital transfers, and capital expenditures, while the output variables were population, the number of lighting points, the number of collected waste, and houses with clean water. The study, covering the period from 2004 to 2018, identified the Gazimağusa municipality as the most efficient among 5 municipalities.

Park et al. (2021) used the DEA method to determine the efficiency of 90 municipalities in Korea. The input variables of the study were budget, manpower, organization, planned projects, and research training, while the output variables were program, network, and project performance. The study found that 22 municipalities were fully effective, while 68 municipalities were not fully effective.

Pereira and Marques (2021) measured the water and sanitation services of 2,160 municipalities in Brazil using the DEA method. They utilized 1 input and 7 output variables. The annual OPEX was the single input variable, while the output variables were the number of active water connections, the number of active sewage connections, the volume of consumed water ($km^3$), the volume of collected wastewater ($km^3$), the volume of treated wastewater ($km^3$), the length of the water network (km), and the length of the wastewater network (km). The study found that 39 municipalities were technically efficient.

Ergülen et al. (2022) studied the efficiency of municipalities in the Konya Plain Project for the year 2020 using the DEA method. The study found that 2 municipalities were fully effective, while 6 municipalities were not fully effective.

Evin and Özdemir (2022) used the DEA method to determine the effectiveness of solid waste management in metropolitan cities in Türkiye. The study used 2 input and 2 output variables. The input variables were the average amount of waste collected per capita and the number of municipalities providing waste services. The output variables were the amount of waste sent to sanitary landfill facilities and the amount sent to recycling facilities. The BCC model was used in their study, and the analysis results indicate that 7 out of 30 metropolitan municipalities were effective, while 23 were not fully effective.

Lima et al. (2022) aimed to establish a connection between human development and environmental sustainability using data from 645 municipalities in Brazil. The analysis method of the study was DEA. The study concluded that no municipality was fully effective.

Some studies in the literature using the DEA method, including the study's location, scope, and the input and output variables, are presented in Table 1.

**Table 1.** Summary of Some Studies in the Literature

| Author and Year | Location and Scope | Input Variables | Output Variables |
|---|---|---|---|
| De Borger et al., 1994 | 589 municipalities in Belgium | • Number of white-collar employees<br>• Number of blue-collar employees<br>• Total number of employees | • Number of minimum wage earners<br>• Number of services provided to non-residents<br>• Length of roads within municipal boundaries<br>• Size of public recreation areas<br>• Number of students enrolled in local state schools |
| Çağlar, 2003 | Metropolitan cities and provincial centers in Türkiye | • Current expenses<br>• Number of garbage trucks<br>• Garbage personnel<br>• Storage capacity<br>• Daily water capacity<br>• Number of drinking water personnel<br>• Planning personnel<br>• Length of sewer network<br>• Number of containers<br>• Total number of vehicles<br>• Total length of drinking water network<br>• Total staff<br>• Transfer expenses<br>• Investment expenses | • Area within municipal boundaries (km²)<br>• Population<br>• Total number of subscribers<br>• Total consumption amount<br>• Total building permits<br>• Amount of garbage collected<br>• Non-tax revenues<br>• Tax revenues<br>• Aids and funds |
| Tupper and Resende, 2004 | Water and sewage service providers in Brazil (1996-2000) | • Other operating costs<br>• Labor costs<br>• Operating costs | • Treated wastewater<br>• Population served by water and sewage services<br>• Amount of water produced |

**Table 1.** (Continued)

| **Author and Year** | **Location and Scope** | **Input Variables** | **Output Variables** |
|---|---|---|---|
| Woodbury and Dollery, 2004 | Cities in Australia | • Maintenance and operating costs<br>• Energy costs<br>• Capital replacement costs<br>• Management expenses | • Number of households served<br>• Water quality and service index<br>• Annual water consumption |
| Sousa and Stošić, 2005 | 4796 municipalities in Brazil | • Infant mortality rate<br>• Municipal expenditures<br>• Number of hospitals<br>• Number of teachers | • Number of households receiving garbage service<br>• Continuity rates (per school)<br>• Number of students at the correct grade level<br>• Number of households with access to sewage services<br>• Number of registered students<br>• Literate population<br>• Number of households with access to clean water<br>• Total population<br>• Number of students progressing to the upper class |
| Kaplan et al., 2006 | 16 metropolitan municipalities in Türkiye | • Wages paid<br>• Social assistance and education expenses<br>• Transfers<br>• Investment expenses | • Daily water consumption (liters)<br>• Public green space ($m^2$)<br>• Population<br>• Road construction (m)<br>• Passenger carrying capacity (at peak hours) |
| Afonso and Fernandes, 2008 | 278 municipalities in Portugal | • Municipal expenditures (per capita) | • Infrastructure services<br>• Land arrangement services<br>• Education services<br>• Cultural services<br>• Social services<br>• Cleaning services |
| Sarı, 2010 | 16 metropolitan municipalities in Türkiye | • Number of buses<br>• Number of staff | • Number of trips per line<br>• Number of bus lines |
| Yıldırım, 2010 | 32 district municipalities affiliated to IMM | • Current expenses<br>• Transfer expenses | • Non-tax revenues<br>• Aids and funds<br>• Investment expenses |
| Kaygısız and Girginer, 2011 | 9 service units under Eskişehir Osmangazi Municipality | • Annual budget of each unit<br>• Number of personnel working in service units<br>• Annual purchase amount | • Citizen satisfaction within the boundaries served by the municipality |
| Kabakuş, 2014 | 519 district municipalities of 30 metropolitan municipalities in Türkiye | • Municipalities with a website | • Ability to perform online transactions<br>• Ability to collect online |
| Karahan and Akdağ, 2014 | Diyarbakır Water and Sewerage Administration under Diyarbakır Metropolitan Municipality (2002-2012) | • Length of wastewater network<br>• Length of drinking water network<br>• Total amount of water supplied to the city<br>• Total number of staff | • Amount of wastewater<br>• Billed water<br>• Total number of people with water subscriptions |

**Table 1.** (Continued)

| Author and Year | Location and Scope | Input Variables | Output Variables |
|---|---|---|---|
| Kaygısız Ertuğ and Girginer, 2015 | 14 metropolitan municipalities in Türkiye | • Current expenses<br>• Transfer expenses<br>• Investment expenses | • Non-tax revenues<br>• Tax revenues<br>• Aids and funds |
| Güner et al., 2017 | Urban public transport lines in Sakarya province | • Rotation time (minutes)<br>• Number of trips<br>• Total service provided (minutes) | • Number of daily trips |
| Aydemir and Bayram, 2018 | 16 metropolitan municipalities in Türkiye | • Current expenses<br>• Population<br>• Investment expenses | • Operating and property revenues<br>• Tax revenues<br>• Other revenues |
| Avcı et al., 2020 | Level 1 municipalities according to statistical region classification in Türkiye | • Municipal environmental expenditures<br>• Number of municipalities in the region<br>• Average waste amount per capita | • Municipal environmental revenues<br>• Amount of waste disposed of in landfill sites |
| Ergülen et al., 2020 | 30 metropolitan municipalities in Türkiye | • Goods and services procurement expenses<br>• Personnel expenses<br>• Capital expenses | • Enterprise and property revenues<br>• Tax revenues<br>• Other revenues |
| Çağlar Onbaşıoğlu, 2021 | Turkish municipalities in Cyprus | • Current and capital transfers<br>• Operating expenses<br>• Capital expenditure<br>• Wage and salary expenses | • Number of lighting points<br>• Population<br>• Houses with clean water<br>• Amount of waste collected |
| Park et al., 2021 | 90 municipalities in Korea | • Budget<br>• Manpower<br>• Organization<br>• Planned projects and research training | • Network and project performance<br>• Program |
| Pereira and Marques, 2021 | 2160 municipalities in Brazil | • Annual OPEX | • Number of active sewage connections<br>• Number of active water connections<br>• Volume of treated wastewater ($km^3$)<br>• Length of wastewater network (km)<br>• Length of water network (km)<br>• Volume of collected wastewater ($km^3$)<br>• Volume of consumed water ($km^3$) |
| Ergülen et al., 2022 | Provinces in the Konya Plain Project | • Goods and services procurement expenses<br>• Personnel expenses | • Tax revenues |
| Evin and Özdemir, 2022 | 30 metropolitan municipalities in Türkiye | • Average amount of waste collected per capita<br>• Number of municipalities providing waste services | • Amount of waste sent to sanitary landfill facilities<br>• Amount sent to recycling facilities |

Considering the studies in the literature review section, each study has examined the efficiency of municipalities using the input and output variables determined according to the study's purpose through the DEA method and has tried to provide economic, environmental, and social contributions to the municipalities. These studies have focused on economic aspects such as cost and pricing and environmental aspects such as waste management, water, sewage, and environmental services. The common point in these studies is to ensure that municipalities manage the use of their resources correctly.

When comparing the studies in the literature with our research, a similar study was conducted by Ergülen and others in 2020, which measured the effectiveness of 30 metropolitan municipalities in Turkey using the DEA method. The similarity of our study to this work lies in the use of input-oriented CCR and BBC-DEA models with the same input and output values. The difference, however, is in the choice of the geographical region. While Ergülen and others selected 30 metropolitan municipalities across Turkey, our study focuses on the municipalities in the Black Sea Region. Both studies identified effective and non-fully effective municipalities based on the selected units. Another distinguishing feature of our study from others is that no previous study has evaluated the effectiveness of municipalities in the Black Sea Region in the context of regional municipalities in Turkey. Additionally, the primary reason for choosing the Black Sea Region in this study is its unique geographic features, which encompass the western, central, and eastern provinces of Turkey. This characteristic leads to differences in the region's geographical structure, surface area, population density of the provinces, the number of districts attached to the municipalities, the socio-economic development levels of the provinces, the size of the municipalities, the decisions made in their management, their budgets, and their own revenues compared to other regions. For these reasons, the decision was made to select the Black Sea Region for the DEA application in this study.

This study, conducted to determine the efficiency of 18 municipalities in the Black Sea Region compared to each other, aims to provide information on which municipalities are fully effective and which are not fully effective and to show the regional efficiency of municipalities. Identifying how effectively municipalities carry out their services according to whether they are fully effective or not will contribute to the future economic planning of municipalities.

Recently, the importance of concepts such as efficiency, effectiveness, productivity, and performance assessment has started to increase in both the public and private sectors. There are many international and national studies on this subject. When the literature within the public scope in Türkiye is examined and limited to municipalities within the public scope, it is observed that many studies have been conducted on this subject. When the scope of the studies related to municipalities is checked, studies from different regions other than the Black Sea Region are also encountered. The results obtained from this study are expected to contribute to the examination and development of municipalities regionally. At the same time, it is believed that this study will provide a source for and give ideas to researchers for future studies on this subject.

## 3. METHOD

### 3.1. Data Envelopment Analysis Method

The primary objectives of businesses or organizations today are high productivity, effectiveness, maximizing profit while minimizing costs, being reputable, and growing by improving quality (Elitaş and Ağca, 2006: 346). One of the most frequently used parameters in performance measurement is effectiveness. Effectiveness is a tool that measures how much of a resource is utilized, where, and how it should be used. Performance management has recently become one of the most important elements of public administration, and it has started to be frequently used for local governments in Türkiye as well (İlkay and Doğan, 2009: 193). For a business to provide services to its customers, it must first create the product and, while doing so, use its resources in the most efficient way. In this context, measurement is possible through effectiveness (Yükçü and Atağan, 2009:3). Since the concept of effectiveness is related to resource utilization, conducting a proper effectiveness analysis will also ensure more efficient use of resources in the future (Cavlak, 2021:104).

DEA is a "data-oriented" approach developed to evaluate the performance of a series of comparable entities called Decision-Making Units (DMUs) that convert multiple inputs into multiple outputs (Charnes et al., 1978: 2). The definition of a decision-making unit (DMU) is general and flexible. In recent years, various DEA applications have been conducted to evaluate the performance of different types of organizations in many countries across different contexts and industries (Kocakalay and Işık, 2003: 164). The application area of DEA is quite broad, and numerous studies have been conducted regarding the internal structures of service-producing companies, universities, hospitals, and other public organizations (Sarı, 2010:24). Initially focusing on the efficiency analysis of non-profit public institutions, DEA later became widely used for the efficiency analysis of service-producing companies and other private sector entities with a profit motive (Bowlin, 1998: 3). At its core, DEA involves selecting homogeneous DMUs and obtaining the same output variables by making use of the same input variables (Vatansever and Öztemiz, 2020:1510). Therefore, the selection of DMUs and input-output variables is very important. One of the basic principles of this analysis is having a sufficient number of decision variables. The general view on this matter is that the number of DMUs should be at least two or three times the total number of input and output variables (Colbert et al., 2000: 657; Haas and Murphy, 2003: 538). The fundamental philosophy of the DEA method is to measure the distance of decision-making units from the efficiency frontier and determine their efficiency levels (Charnes et al., 1978: 430). To apply the DEA method, similar DMUs should first be selected, and then input and output variables of these units must be identified. The most important consideration during these steps is the necessity that all DMUs use the selected input and output elements. If the number of inputs is denoted by m and the number of outputs by p, then the minimum required number of decision-making units for the reliability of the study is $m + p + 1$ (Boussofiane et al., 1991:7). Considering the usage conditions and possibilities, different DEA models can be constructed. Generally, input-oriented and output-oriented models, which form the two main approaches of DEA, are the most commonly used models (Öncel and Şimşek, 2011: 95). In the input-oriented model, a specific output is selected, and the amount by which the inputs of non-fully effective DMUs need to be reduced to become effective is determined. In the output-oriented model, similarly, a particular input is selected, and the amount by which the outputs of non-fully effective DMUs must be increased to achieve effectiveness is examined (Başar et al., 2015: 848).

Some strong points of DEA are as follows (Ayanoğlu et al., 2010: 49; Başkaya and Öztürk, 2005: 20; Charnes et al., 1978: 429; Tepe, 2006: 66; Yolalan, 1993: 86):

- DEA performs performance analysis of organizations with multiple inputs and outputs and can express this in numerical terms. It provides managers with information about what kind of improvements should be made in the organizational structure of businesses by comparing them without requiring specific assignments or functional connections between the inputs and outputs.
- When calculating relative efficiency, DEA maximizes the objective functions for each decision-making unit and identifies the optimum solution for each. In parametric methods, the average efficiency of the entire sector is considered.
- During the application of DEA, since all inputs and outputs are defined, decision-makers can closely monitor and properly define the production process.
- Since the data required for DEA applications are recorded in the infrastructure and contain the

results of the analysis, converting this data into documentation in the database becomes easier.

- DEA offers multiple options to improve the performance of inefficient DMUs by bringing them to the level of efficient ones within their group. The selection of which DMU is more appropriate or will improve more is left to the knowledge, experience, and authority of the practitioner.
- Efficiency analysis in DEA uses multiple inputs and outputs, generating many alternatives for which input or output values a decision-making unit should focus on to become effective. Ultimately, the choice of which alternative to select is left to the discretion and experience of the managers.

Some weaknesses of DEA are as follows (Başkaya and Öztürk, 2005: 20; Kıyıldı and Karaşahin, 2006: 393; Oruç, 2008: 35; Yolalan, 1993: 87):

- DEA identifies which decision-making units are efficient and which are not, but it may not be sufficient for comparing the decision-making units forming the efficiency frontier.
- When determining the observation set for DEA, decision-making units with excessively large or small input and output values may cause problems. Excessive values may lead decision-makers to incorrect conclusions.
- DEA applications assess the performance of decision-making units at a particular point in time, but in reality, converting some input values into outputs for DMUs may take a long period. As a result, businesses' production processes are more dynamic and active. Therefore, it may be necessary to reduce the data from different tables to suitable ratios.
- The difference between efficient and non-fully effective decision-making units is often interpreted as inefficiency. This leads to overlooking potential measurement errors.
- DEA is a good method for estimating the relative efficiency of decision-making units, but it lags behind in measuring absolute efficiency. In other words, it cannot provide a comparison with the theoretical maximum when comparing identical values.

#### 3.1.1. Data Envelopment Analysis Models

The CCR model, introduced into the literature by Charnes, Cooper, and Rhodes in 1978, and the BCC model, developed by Banker, Charnes, and Cooper in 1984, are the main DEA models used. The CCR model is defined as a model assuming constant returns to scale, whereas the BCC model is based on the assumption of variable returns to scale. More specifically, the CCR model is used to calculate relative total efficiencies under the assumption of constant returns to scale, which assumes that all DMUs operate at optimal scale. On the other hand, since systems in real life exhibit varying returns to scale, the BCC model is used to determine the efficiency of systems with variable returns to scale. In addition to these, there are many DEA models available to be used according to the aim and scope of the analysis (Banker et al., 1984; Charnes et al., 1978; Cooper et al., 2004: 4; Özden, 2008: 169-170, 173).

The two main DEA models, CCR and BCC, can be established in two ways: input-oriented and output-oriented. These methods are fundamentally very similar to each other. The input-oriented DEA model aims to reveal the optimal combination of inputs that should be used to produce any combination of outputs most efficiently. The output-oriented DEA model, on the other hand, investigates how to produce the maximum combination of outputs with any given combination of inputs (Behdioğlu and Özcan, 2009: 305).

In this study, the efficiency analysis of municipalities using the DEA method was calculated by applying input-oriented CCR and input-oriented BCC models. As indicated in the implementation part of the study, to determine the efficiency of municipalities using the DEA method, the input variables were defined as goods and services procurement expenses, personnel expenses, and capital expenses, while the output variables were defined as enterprise and property income, tax income, and other income. The study employed input-oriented CCR and input-oriented BCC models to help municipalities control their expense items and consider activities aimed at reducing these expense items. Therefore, information on the input-oriented CCR and input-oriented BCC models is provided in this study.

**3.1.1.1.** ***Input-oriented CCR model***

The input-oriented CCR model provides information on the extent to which input quantities need to be reduced in order to achieve the same level of output (Cumhur, 2017: 12).

The primal representation of the input-oriented CCR model is presented in formulas (1)-(4), and the dual representation is shown in formulas (5)-(9) (Charnes et al., 1978: 430; Bolayır and Keyifli, 2022: 7).

Primal model

Objective function

$$maxh_k = \sum_{r=1}^{s} u_{rk} y_{rk} \tag{1}$$

Constraints

$$\sum_{r=1}^{s} u_{rj} y_{rj} - \sum_{i=1}^{m} v_{ij} x_{ij} \leq 0, j = 1,2, \dots, n \tag{2}$$

$$\sum_{i=1}^{m} v_{ik} x_{ik} = 1 \tag{3}$$

$$u_{rk}, v_{ik} \geq 0, r = 1,2, \dots, s, i = 1,2, \dots, m \tag{4}$$

Dual model

Objective function

$$minq_k \tag{5}$$

Constraints

$$\sum_{j=1}^{n} \lambda_{kj} y_{rj} \geq y_{rk}, r = 1,2, \dots, s \tag{6}$$

$$q_k x_{ik} - \sum_{j=1}^{n} \lambda_{kj} x_{ij} \geq 0, i = 1,2, \dots, m \tag{7}$$

$$\lambda_{kj} \geq 0, j = 1,2, \dots, n \tag{8}$$

$$-\infty \leq q_k \leq +\infty \tag{9}$$

In the formulas above, the variables are defined as follows: $u_{rk}$ refers to the weight of the r-th output of the k-th DMU, $v_{ik}$ to the weight of the i-th input of the k-th DMU, $y_{rk}$ to the amount of the r-th output produced by the k-th DMU, $x_{ik}$ to the amount of the i-th input used by the k-th DMU, $y_{rj}$ to the amount of the r-th output produced by the other (j-th) DMU, $x_{ij}$ to the amount of the i-th input used by the other (j-th) DMU, m to the number of inputs, s to the number of outputs, and n to the number of DMUs. Additionally, in the dual model, unlike the primal model, there are λ and q variables. Since the solution approach for both models is the same, $q_k$ is equivalent to the efficiency of the k-th DMU (Bolayır and Keyifli, 2022: 7-8).

**3.1.1.2. *Input-oriented BCC model***

The input-oriented BCC model is derived by adding a "$\sum_{j=1}^{n} \lambda_j = 1$" convexity constraint to the input-oriented CCR model. This added constraint allows the input-oriented BCC model to measure the efficiency of DMUs relative to their own activities. In other words, this constraint enables the measurement of a DMU's efficiency by comparing it with another DMU that is similar to it. In contrast, the CCR model does not include this constraint and measures efficiency by comparing a DMU with those that are either larger or smaller than it (Kabakuş, 2014: 316).

The primal representation of the input-oriented BCC model is shown in formulas (10)-(14) and the dual representation is shown in formulas (15)-(20) (Banker et al., 1984: 1085; Bolayır and Keyifli, 2022: 8).

Primal model

Objective function

$$max h_k = \sum_{r=1}^{s} u_{rk} y_{rk} - u_0 \tag{10}$$

Constraints

$$\sum_{r=1}^{s} u_{rj} y_{rj} - \sum_{i=1}^{m} v_{ij} x_{ij} \leq 0, j = 1,2, \dots, n \tag{11}$$

$$\sum_{i=1}^{m} v_{ik} x_{ik} = 1 \tag{12}$$

$$u_{rk}, v_{ik} \geq 0, r = 1,2, \dots, s, i = 1,2, \dots, m \tag{13}$$

$$u_0 \text{ is unconstrained in sign} \tag{14}$$

Dual model

Objective function

$$minq_k \tag{15}$$

Constraints

$$\sum_{j=1}^{n} \lambda_{kj} y_{rj} \geq y_{rk}, r = 1,2, \ldots, s \tag{16}$$

$$q_k x_{ik} - \sum_{j=1}^{n} \lambda_{kj} x_{ij} \geq 0, i = 1,2, \ldots, m \tag{17}$$

$$\sum_{j=1}^{n} \lambda_{kj} = 1 \tag{18}$$

$$\lambda_{kj} \geq 0, j = 1,2, \ldots, n \tag{19}$$

$$-\infty \leq q_k \leq +\infty \tag{20}$$

When comparing the input-oriented CCR model with the input-oriented BCC model, it is observed that the BCC model includes the variable $u_0$, which is not present in the CCR model. In the BCC model, the $u_0$ variable is used to assess the efficiency of DMUs. Depending on whether the $u_0$ variable is positive, zero, or negative, the model determines whether there are decreasing, constant, or increasing returns to scale, respectively. Specifically, if $u_0$<0, it indicates increasing returns to scale; if $u_0$=0, it indicates constant returns to scale; and if $u_0$>0, it indicates decreasing returns to scale (Altın, 2015: 174). In other words, $u_0$<0 refers to increasing returns to scale, where a one-unit increase in input results in an increase in output greater than 1; $u_0$=0 refers to constant returns to scale, where a one-unit increase in input results in a one-unit increase in output; and $u_0$>0 refers to decreasing returns to scale, where a one-unit increase in input leads to an increase in output smaller than 1 (Ergülen et al., 2019: 1409-1410).

### 3.2. Data Envelopment Analysis Application

The flowchart followed in the application part of the study is given in Figure 1.

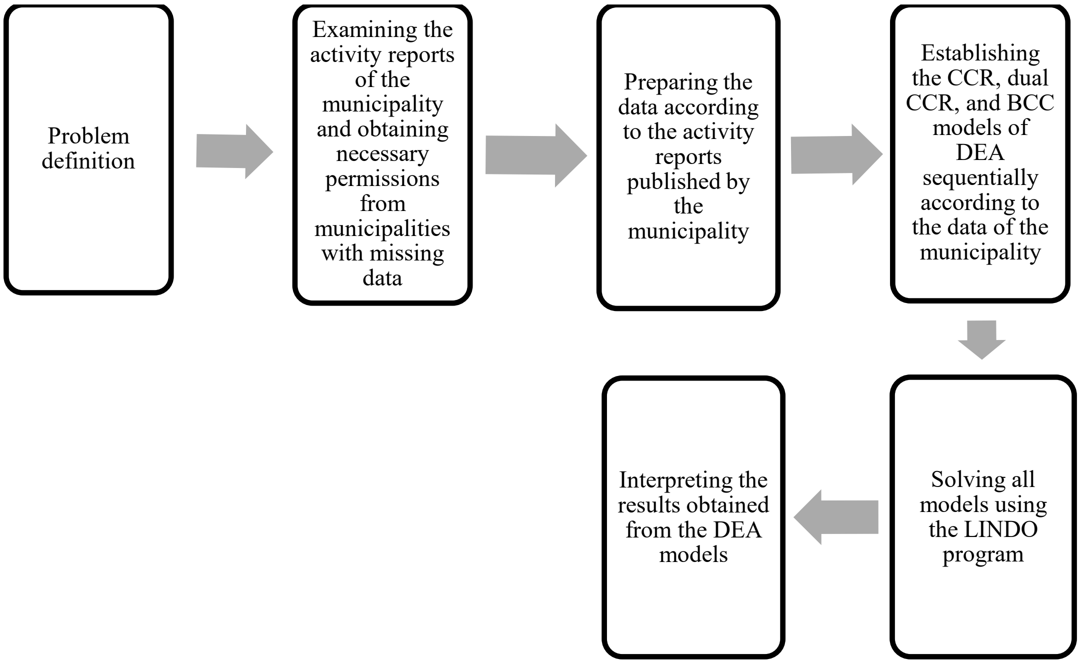


**Figure 1.** Flowchart for Application

### 3.2.1. Data Set and Variables of the Study

In the study, Data Envelopment Analysis (DEA) was conducted to analyze the efficiency of municipalities in 18 provinces of the Black Sea Region. When determining the input and output variables for the DEA application, studies in the literature evaluating the efficiency of municipalities using the DEA method and the highest income and expenditure items that would allow for the examination of efficiency in municipal activities were considered. Accordingly, in this study, the input variables were selected as follows: goods and services procurement expenses, personnel expenses, and capital expenses; while the output variables were selected as: enterprise and property revenues, tax revenues, and other revenues.

The explanations of the input and output variables determined in the study are given below (Arıkboğa, 2016:281-282; Çiçek et al., 2015:63):

- Goods and services procurement expenses: All billed goods and services acquired by municipalities in compliance with regulations.
- Personnel expenses: Salaries, Social Security Institution (SGK) contributions, etc., for personnel.
- Capital expenses: Goods and services procurement with a lifespan of more than one year and payments exceeding the minimum values set by law.
- Enterprise and property revenues: Revenues from the sale or lease of real estate by the state and from commercial and industrial trade activities.
- Tax revenues: Revenues from municipal services as defined by law.
- Other revenues: Revenues such as interest and fines not covered by the above categories.

The data for the municipalities in 2019 (Table 2) were used according to the determined input and output variables. Using these data, the CCR model (constant returns to scale) and the BCC model (variable returns to scale) were established. The efficiency values of the municipalities were obtained as a result of solving these models. Additionally, for municipalities identified as inefficient through the CCR model, dual CCR models were established, and the new input adjustment ratios required for achieving full efficiency were calculated. The CCR and BCC models used in the study were established as input-oriented. The LINDO 6.1 program was used for the analysis of the models.

The data in Table 2 were obtained from the 2019 activity reports of municipalities in the Black Sea Region. The activity reports of Bayburt Municipality and Gümüşhane Municipality, which were not published on their official websites, were obtained through the university after receiving permission from the Scientific Research and Publication Ethics Board of Gümüşhane University with decision number 2020/11 dated 11.18.2020.

**Table 2.** 2019 Data for Decision Units

| | | VALUES OF INPUT VARIABLES | | | VALUES OF OUTPUT VARIABLES | | |
|---|---|---|---|---|---|---|---|
| **Unit Code** | **Municipality Name** | **Goods and Services Procurement Expenses (x1)** | **Personnel Expenses (x2)** | **Capital Expenses (x3)** | **Enterprise and Property Revenues (y1)** | **Tax Revenues (y2)** | **Other Revenues (y3)** |
| KB1 | Amasya Municipality | 63,798,603.65 | 26,768,943.32 | 18,818,836.57 | 23,649,138.78 | 15,942,671.73 | 88,742,418.56 |
| KB2 | Artvin Municipality | 22,809,294.29 | 11,864,898.98 | 5,938,157.86 | 9,284,816.82 | 3,394,408.46 | 25,683,202.18 |
| KB3 | Bartın Municipality | 57,707,462.39 | 21,571,454.32 | 10,659,013.56 | 38,609,442.91 | 9,647,215.90 | 55,852,196.16 |
| KB4 | Bayburt Municipality | 24,333,037.92 | 13,928,918.57 | 6,534,942.74 | 13,080,195.02 | 4,220,352.10 | 1,982,365.15 |
| KB5 | Bolu Municipality | 99,248,259.11 | 33,103,592.46 | 37,332,849.41 | 66,318,388.35 | 30,904,197.01 | 139,454,545.99 |
| KB6 | Çorum Municipality | 170,342,259.30 | 40,399,169.66 | 31,206,608.14 | 83,163,888.23 | 34,157,142.81 | 191,547,806.86 |
| KB7 | Düzce Municipality | 115,331,364.23 | 33,744,802.75 | 9,990,756.49 | 45,983,813.30 | 21,307,823.58 | 139,659,449.14 |
| KB8 | Giresun Municipality | 109,583,270.46 | 44,799,055.77 | 39,415,151.38 | 41,335,568.96 | 20,891,177.86 | 90,194,817.48 |
| KB9 | Gümüşhane Municipality | 31,931,643.06 | 15,634,306.50 | 6,545,132.84 | 10,841,046.42 | 4,445,449.16 | 32,309,340.65 |
| KB10 | Karabük Municipality | 66,643,788.36 | 22,611,505.15 | 55,397,689.03 | 27,498,000.00 | 26,370,000.00 | 88,618,000.00 |
| KB11 | Kastamonu Municipality | 81,517,650.98 | 31,009,716.87 | 65,184,090.32 | 33,755,189.22 | 15,605,595.94 | 93,374,448.11 |
| KB12 | Ordu Metropolitan Municipality | 253,680,235.75 | 54,701,381.68 | 103,438,395.97 | 40,432,096.35 | 7,643,997.77 | 410,013,577.00 |
| KB13 | Rize Municipality | 105,525,616.16 | 24,979,953.06 | 20,806,716.09 | 28,055,948.71 | 20,780,986.24 | 84,771,832.26 |
| KB14 | Samsun Metropolitan Municipality | 276,385,846.37 | 76,846,741.05 | 191,654,987.62 | 45,875,854.32 | 11,588,901.82 | 646,824,091.45 |
| KB15 | Sinop Municipality | 27,416,210.12 | 26,572,113.76 | 525,485.72 | 18,287,706.03 | 4,760,622.49 | 38,148,746.39 |
| KB16 | Tokat Municipality | 90,040,902.12 | 35,124,636.90 | 3,137,754.52 | 23,072,995.88 | 13,640,340.25 | 123,013,040.98 |
| KB17 | Trabzon Metropolitan Municipality | 272,299,195.01 | 59,659,647.31 | 141,521,809.64 | 51,061,642.72 | 7,737,406.38 | 393,364,105.57 |
| KB18 | Zonguldak Municipality | 79,867,096.30 | 32,341,530.60 | 15,970,982.88 | 30,187,286.74 | 11,876,391.23 | 87,255,629.88 |

*Municipalities are listed in alphabetical order.
*All inputs and outputs are in TL (Turkish Lira).
*Data were obtained from the 2019 activity reports of municipalities in the Black Sea Region published to the public in 2020.

## 4. FINDINGS

The solution results of the CCR models established for the analysis of the efficiency of municipalities in the Black Sea Region are given in Table 3.

**Table 3.** CCR Results Table

| Unit Code | Goods and Services Procurement Expenses (x1) | Personnel Expenses (x2) | Capital Expenses (x3) | Enterprise and Property Revenues (y1) | Tax Revenues (y2) | Other Revenues (y3) | Efficiency Value |
|---|---|---|---|---|---|---|---|
| KB1 | 0.000012 | 0.000001 | 0.000009 | - | 0.000017 | 0.000008 | 0.967 |
| KB2 | 0.000027 | 0.000017 | 0.000031 | 0.000022 | - | 0.000021 | 0.746 |
| KB3 | 0.000010 | 0.000010 | 0.000018 | 0.000016 | - | 0.000007 | 1 |
| KB4 | 0.000045 | -0.000006 | - | 0.000069 | 0.000028 | -0.000009 | 1 |
| KB5 | 0.000011 | -0.000001 | - | 0.000016 | 0.000007 | -0.000002 | 1 |
| KB6 | 0.000002 | 0.000005 | 0.000017 | 0.000007 | 0.000032 | -0.000004 | 1 |
| KB7 | 0.000003 | 0.000009 | 0.000034 | 0.000013 | 0.000063 | -0.000007 | 1 |
| KB8 | 0.000005 | -0.000004 | 0.000015 | -0.000006 | 0.000061 | -0.000004 | 0.688 |
| KB9 | 0.000020 | 0.000014 | 0.000024 | 0.000007 | -0.000002 | 0.000016 | 0.693 |
| KB10 | 0.000007 | 0.000007 | 0.000006 | -0.000005 | 0.000024 | 0.000006 | 1 |
| KB11 | 0.000030 | -0.000010 | -0.000017 | 0.000031 | - | -0.000001 | 1 |
| KB12 | 0.000001 | 0.000005 | 0.000004 | 0.000004 | -0.000007 | 0.000002 | 1 |
| KB13 | -0.000004 | 0.000052 | 0.000006 | -0.000010 | 0.000036 | 0.000006 | 1 |
| KB14 | -0.000001 | 0.000013 | 0.000001 | -0.000002 | 0.000009 | 0.000002 | 1 |
| KB15 | 0.000022 | 0.000015 | 0.000026 | 0.000019 | -0.000003 | 0.000017 | 1 |
| KB16 | 0.000008 | 0.000006 | 0.000010 | 0.000007 | -0.000001 | 0.000007 | 1 |
| KB17 | -0.000003 | 0.000040 | -0.000004 | 0.000003 | 0.000009 | 0.000002 | 1 |
| KB18 | 0.000008 | 0.000007 | 0.000010 | 0.000011 | -0.000008 | 0.000006 | 0.792 |

According to the CCR efficiency results in Table 3, municipalities with efficiency values of "1" are fully effective. These include municipalities with the following codes: KB3 (Bartın), KB4 (Bayburt), KB5 (Bolu), KB6 (Çorum), KB7 (Düzce), KB10 (Karabük), KB11 (Kastamonu), KB12 (Ordu), KB13 (Rize), KB14 (Samsun), KB15 (Sinop), KB16 (Tokat), and KB17 (Trabzon). Municipalities with efficiency values other than "1" are not fully effective. These include municipalities with the following codes: KB1 (Amasya), KB2 (Artvin), KB8 (Giresun), KB9 (Gümüşhane), and KB18 (Zonguldak). In summary, 13 municipalities are fully effective, while 5 municipalities are not fully effective.

The solution results of the dual CCR models established for the municipalities that are not effective according to the CCR results are provided in Table 4.

**Table 4.** Dual CCR Results Table

| Unit Code | Efficiency Value | Reference Set | Weights of Reference Set |
|---|---|---|---|
| KB1 | 0.967 | K5. K14. K15. K16 | 0.423962-0.009893-0.283680-0.100779 |
| KB2 | 0.746 | K5. K14. K15. K16 | 0.075259-0.007501-0.180661-0.027996 |
| KB3 | 1 | K3 | - |
| KB4 | 0.805 | K3. K5. K15 | 0.110393-0.063014-0.253658 |
| KB5 | 1 | K5 | - |
| KB6 | 1 | K6 | - |
| KB7 | 1 | K7 | - |
| KB8 | 0.625 | K5. K15 | 0.658234-0.115297 |
| KB9 | 0.693 | K5. K14. K15. K16 | 0.080800-0.006072-0.179118-0.083571 |
| KB10 | 1 | K10 | - |

**Table 4.** (Continued)

| Unit Code | Efficiency Value | Reference Set | Weights of Reference Set |
|---|---|---|---|
| KB11 | 0.727 | K5. K10. K14 | 0.473522-0.019468-0.039599 |
| KB12 | 1 | K12 | - |
| KB13 | 0.967 | K5. K6 | 0.124183-0.496040 |
| KB14 | 1 | K14 | - |
| KB15 | 1 | K15 | - |
| KB16 | 1 | K16 | - |
| KB17 | 1 | K17 | - |
| KB18 | 0.785 | K5. K14. K15. K16 | 0.300279-0.001357-0.167404-0.309855 |

According to the dual CCR efficiency results in Table 4, municipalities with efficiency values of "1" are fully effective. These include municipalities with the following codes: KB3 (Bartın), KB5 (Bolu), KB6 (Çorum), KB7 (Düzce), KB10 (Karabük), KB12 (Ordu), KB14 (Samsun), KB15 (Sinop), KB16 (Tokat), and KB17 (Trabzon). Municipalities with efficiency values other than "1" are not fully effective. These include municipalities with the following codes: KB1 (Amasya), KB2 (Artvin), KB4 (Bayburt), KB8 (Giresun), KB9 (Gümüşhane), KB11 (Kastamonu), KB13 (Rize), and KB18 (Zonguldak). In summary, 10 municipalities are fully effective, while 8 municipalities are not fully effective. Table 4 also provides the reference sets and their corresponding weights for the 8 inefficient municipalities, indicating how these municipalities can become effective by reducing their inputs by the ratios specified in the reference sets. The input reductions for these municipalities, based on the reference sets and weights, are presented in Table 5.

**Table 5.** New Input Change Ratios for Inefficient Decision Units

| Unit Code | Municipality Name | Goods and Services Procurement Expenses (x1) | Personnel Expenses (x2) | Capital Expenses (x3) |
|---|---|---|---|---|
| KB1 | Amasya Municipality | 0.03 | 0.03 | 0.03 |
| KB2 | Artvin Municipality | 0.25 | 0.25 | 0.25 |
| KB4 | Bayburt Municipality | 0.20 | 0.20 | 0.44 |
| KB8 | Giresun Municipality | 0.37 | 0.45 | 0.37 |
| KB9 | Gümüşhane Municipality | 0.31 | 0.31 | 0.31 |
| KB11 | Kastamonu Municipality | 0.27 | 0.38 | 0.60 |
| KB13 | Rize Municipality | 0.08 | 0.03 | 0.03 |
| KB18 | Zonguldak Municipality | 0.22 | 0.22 | 0.22 |

As shown in Table 5, there is an excess of input values in the municipalities. Specifically: KB1 (Amasya Municipality): 3% excess in all inputs. KB2 (Artvin Municipality): 25% excess in all inputs. KB4 (Bayburt Municipality): 20% excess in purchase and service expenses and personnel expenses; 44% excess in capital expenses. KB8 (Giresun Municipality): 37% excess in purchase and service expenses and capital expenses; 45% excess in personnel expenses. KB9 (Gümüşhane Municipality): 31% excess in all inputs. KB11 (Kastamonu Municipality): 27% excess in purchase and service expenses; 38% excess in personnel expenses; 60% excess in capital expenses. KB13 (Rize Municipality): 8% excess in purchase and service expenses; 3% excess in personnel expenses and capital expenses. KB18 (Zonguldak Municipality): 22% excess in all inputs. These municipalities will achieve full efficiency if they reduce their input values by the specified percentages in Table 2.

The previous analyses used the CCR model, a constant returns-to-scale approach, to determine a set of efficiency values. Following this, dual CCR models were used to identify reference sets and their weights, and calculations were made to determine how inefficient Decision Units could reach effective values by reducing inputs by specific ratios. Now, the BCC model, which allows for more flexibility and a variable returns-to-scale approach, will be used for further analysis. The results from the BCC models are presented in Table 6.

**Table 6.** BCC Results Table

| Unit Code | Efficiency Value | $u_0$ | Unit Code | Efficiency Value | $u_0$ |
|---|---|---|---|---|---|
| KB1 | 0.967 | 0 | KB10 | 1 | 0 |
| KB2 | 0.746 | 0 | KB11 | 1 | 0 |
| KB3 | 1 | 0 | KB12 | 1 | 0 |
| KB4 | 1 | 0 | KB13 | 1 | 0 |
| KB5 | 1 | 0 | KB14 | 1 | 0 |
| KB6 | 1 | 0 | KB15 | 1 | 0 |
| KB7 | 1 | 0 | KB16 | 1 | 0 |
| KB8 | 0.688 | 0 | KB17 | 1 | 0 |
| KB9 | 0.693 | 0 | KB18 | 0.785 | 0 |

According to the BCC efficiency results in Table 6, municipalities with efficiency values of "1" are fully effective. These include municipalities with the following codes: KB3 (Bartın), KB4 (Bayburt), KB5 (Bolu), KB6 (Çorum), KB7 (Düzce), KB10 (Karabük), KB11 (Kastamonu), KB12 (Ordu), KB13 (Rize), KB14 (Samsun), KB15 (Sinop), KB16 (Tokat), and KB17 (Trabzon). Municipalities with efficiency values other than "1" are not fully effective. These include municipalities with the following codes: KB1 (Amasya), KB2 (Artvin), KB8 (Giresun), KB9 (Gümüşhane), and KB18 (Zonguldak). In summary, 13 municipalities are fully effective, while 5 municipalities are not fully effective.

Additionally, it is noted that the efficiency values for the KVBs, excluding KB18, in Table 6 are the same as the efficiency values in Table 3, which are the results from the CCR models. The efficiency of the KB18 decision unit shows only a slight difference. Furthermore, unlike the CCR model, the BCC model also calculates the $u_0$ values. Table 6 shows that the $u_0$ value is "0" for all decision units. This indicates a constant returns to scale. In other words, any change in inputs will affect the outputs in the same proportion. More explicitly, this means that if inputs increase by a certain proportion, outputs will also increase by the same proportion, and if inputs decrease by a certain proportion, outputs will decrease by the same proportion.

## 5. CONCLUSION AND EVALUATION

In this study, the efficiency of 18 municipalities in the Black Sea Region was measured by making use of Data Envelopment Analysis (DEA). The municipalities analyzed were Amasya, Artvin, Bartın, Bayburt, Bolu, Çorum, Düzce, Giresun, Gümüşhane, Karabük, Kastamonu, Ordu, Rize, Samsun, Sinop, Tokat, Trabzon, and Zonguldak. Input-oriented CCR, dual CCR, and BCC models were established for DEA, and the LINDO 6.1 software was used for solving the models.

Based on the solutions from the input-oriented CCR models for the 18 municipalities in the Black Sea Region, 13 municipalities were found to be fully efficient, while 5 municipalities were not fully efficient. In other words, the municipalities that are not fully efficient do not utilize their inputs as effectively as those that are fully efficient. The municipalities identified as fully efficient were Bartın, Bayburt, Bolu, Çorum, Düzce, Karabük, Kastamonu, Ordu, Rize, Samsun, Sinop, Tokat, and Trabzon, while those not fully efficient were Amasya, Artvin, Giresun, Gümüşhane, and Zonguldak.

To determine the reference sets and weights for municipalities not fully efficient in the input-oriented CCR model, input-oriented dual CCR models were established. Unlike the previous input-oriented CCR models, the dual CCR models revealed that 10 municipalities were fully efficient, and 8 municipalities were not. The fully efficient municipalities were Bartın, Bolu, Çorum, Düzce, Karabük, Ordu, Samsun, Sinop, Tokat, and Trabzon, while Amasya, Artvin, Bayburt, Giresun, Gümüşhane, Kastamonu, Rize, and Zonguldak were identified as not fully efficient. Input-oriented dual CCR model results showed that the inefficient municipalities had not used their inputs effectively compared to the fully efficient ones. Consequently, reference sets and weights were established to identify the required reductions in input quantities for these municipalities to achieve full efficiency.

Input-oriented BCC models were developed to examine increasing, constant, and decreasing returns to scale. Similar to the previous models, the input-oriented BCC model identified 13 municipalities as fully efficient and 5 as not fully efficient. The fully efficient municipalities were Bartın, Bayburt, Bolu, Çorum, Düzce, Karabük, Kastamonu, Ordu, Rize, Samsun, Sinop, Tokat, and Trabzon, while Amasya, Artvin, Giresun, Gümüşhane, and Zonguldak were not. The solution of the input-oriented BCC models showed that the $u_0$values for all municipalities were “0” indicating a constant return to scale. This implies that any increase in inputs will cause a proportional increase in outputs, and any decrease in inputs will lead to a proportional decrease in outputs.

The results of the methods used in this study indicate that various factors such as geographical structure, area, population density of the provinces, the number of districts within municipalities, the socio-economic development level of the provinces, the size of the municipalities, administrative decisions, budgets, and own revenues affect the efficiency of municipalities in the Black Sea Region. Municipalities need to manage their major expenditure items such as goods and services procurement expenses, personnel expenses, and capital expenses rationally. Efficient management of these items will contribute to local development and even national development. Additionally, the input-oriented dual CCR model results indicate that the inefficient municipalities (Amasya, Artvin, Bayburt, Giresun, Gümüşhane, Kastamonu, Rize, Zonguldak) need to reduce their input variables (goods and services procurement expenses, personnel expenses, and capital expenses) by certain proportions to achieve full efficiency. Among these municipalities, Artvin, Bayburt, Giresun, Gümüşhane, and Kastamonu need to make the most significant reductions. Specifically, Bayburt needs to reduce its capital expenses by 44%, Giresun needs to reduce its personnel expenses by 45%, and Kastamonu needs to reduce its capital expenses by 60%. Furthermore, the municipalities that were identified as fully efficient across all methods achieved this status by appropriately managing their inputs.

This study is expected to assist municipalities in analyzing the data obtained and providing insights for future planning, similar to previous studies. Municipalities can gain information on how to use their resources efficiently based on the plans and programs they follow in subsequent years. Future studies may evaluate the efficiency of the same or different municipalities in different years or regions using DEA with the same input and output values. Output-oriented CCR, output-oriented dual CCR, and output-oriented BCC models could be established using the specified input and output variables, and other software packages could be utilized instead of LINDO for solving the models.

**Ethical Statement**

In the writing and publication processes of the study titled “Evaluation of Effectiveness of Municipalities in Black Sea Region with Data Envelopment Analysis” research and publication ethics have been strictly adhered to, and no data manipulation has been conducted. Ethical approval for this study was obtained from the Scientific Research and Publication Ethics Board of Gümüşhane University with the decision dated 11.18.2020 and numbered 2020/11.

**Contribution Rate Statement**

All authors contributed to every stage of the process, from writing the study to drafting the manuscript, and they all read and approved the final version.

**Conflict of Interest Statement**

This study did not lead to any individual or institutional/organizational conflict of interest.

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## Extended Abstract

### Evaluation of Effectiveness of Municipalities in Black Sea Region with Data Envelopment Analysis

Municipalities, as vital components of local governments, play a crucial role in enhancing the quality of life. Given that the majority of the population resides in urban areas, municipalities are at the forefront of ensuring societal well-being. Due to their direct impact on people's lives, municipalities must efficiently allocate their resources. Thus, improving the efficiency of all local government units, starting from the smallest, will contribute to social welfare.

Resource utilization is an important issue that needs to be focused on in terms of people being able to sustain their lives. Efficient resource utilization contributes to quality of sustainable life. Therefore, municipalities' effectiveness is paramount in elevating the quality of life for residents. Measuring effectiveness relies on the analysis and evaluation of available data. This study aims to assess the effectiveness of 18 municipalities in the Black Sea Region by comparing them to one another, determining fully effective and non-fully effective municipalities, and providing information to this matter.

The Data Envelopment Analysis (DEA) method was employed in this study to measure the effectiveness of municipalities. Eighteen municipalities in the Black Sea Region were identified as decision-making units. Three input and three output variables were used in the DEAD, which was made using the data obtained from the annual reports for 2019 of these decision-making units. Input variables were determined as goods and services procurement expenses, personnel expenses, and capital expenses, while output variables were determined as enterprise and property revenues, tax revenues, and other revenues. Input and output values were determined based on selected revenue and expense categories. Input-oriented CCR, dual CCR, and BBC models were established based on input and output values. All models were solved using the LINDO software package, and evaluations were made according to the results obtained.

Two different DEA models, namely input-oriented CCR and input-oriented BBC, were used to find the effectiveness of the 18 municipalities in the Black Sea Region. Separate input-oriented CCR and BBC models were established for each municipality. The results from both DEA models revealed that 13 municipalities were fully effective, while 5 were non-fully effective. The fully effective municipalities were Bartın, Bayburt, Bolu, Çorum, Düzce, Karabük, Kastamonu, Ordu, Rize, Samsun, Sinop, Tokat, and Trabzon. The non-fully effective municipalities were Amasya, Artvin, Giresun, Gümüşhane, and Zonguldak. In addition, as a result of the solution of the BBC-DEA models, the $u_0$ value for all municipalities was found to be "0". This situation shows that there is a constant returns to the scale for all the municipalities. In other words, increase in inputs would lead to increase in outputs at the same rate, and decrease in inputs would lead to decrease in outputs at the same rate.

According to the results obtained from the input-oriented CCR model, dual CCR models were established to assist non-effective municipalities in becoming more effective by creating reference sets and decision variables. The solutions of the dual CCR models revealed that 10 municipalities were fully effective, while 8 were non-fully effective. The fully effective municipalities were Bartın, Bolu, Çorum, Düzce, Karabük, Ordu, Samsun, Sinop, Tokat, and Trabzon. The non-fully effective municipalities were Amasya, Artvin, Bayburt, Giresun, Gümüşhane, Kastamonu, Rize, and Zonguldak. Furthermore, based on the created reference sets and decision variables, it was found that Amasya Municipality had a 3% surplus in all inputs, Artvin Municipality had a 25% surplus in all inputs, Bayburt Municipality had a 20% surplus in goods and services procurement expenses and a 20% surplus in personnel expenses, a 44% surplus in capital expenses, Giresun Municipality had a 37% surplus in goods and services procurement expenses, and a 37% surplus in capital expenses, a 45% surplus in personnel expenses, Gümüşhane Municipality had a 31% surplus in all inputs, Kastamonu Municipality had a 27% surplus in goods and services procurement expenses, a 38% surplus in personnel expenses, and a 60% surplus in capital expenses, Rize Municipality had an 8% surplus in goods and services procurement expenses, and a 3% surplus in personnel expenses and a 3% surplus in capital expenses, and Zonguldak Municipality had a 22% surplus in all input values.

This study is expected to assist decision-makers in understanding how municipalities can effectively utilize their resources and improve their services to the public. Municipalities can use the findings of this study to inform their strategic plans and programs for future years, focusing on effective resource utilization. Additionally, future studies can employ the same input and output values to assess the effectiveness of the same or different municipalities in specific years or time frames using the DEA method. This will provide municipalities with the opportunity to monitor their progress over time. Unlike this study, future research may use different software programs for model solutions instead of the LINDO program.