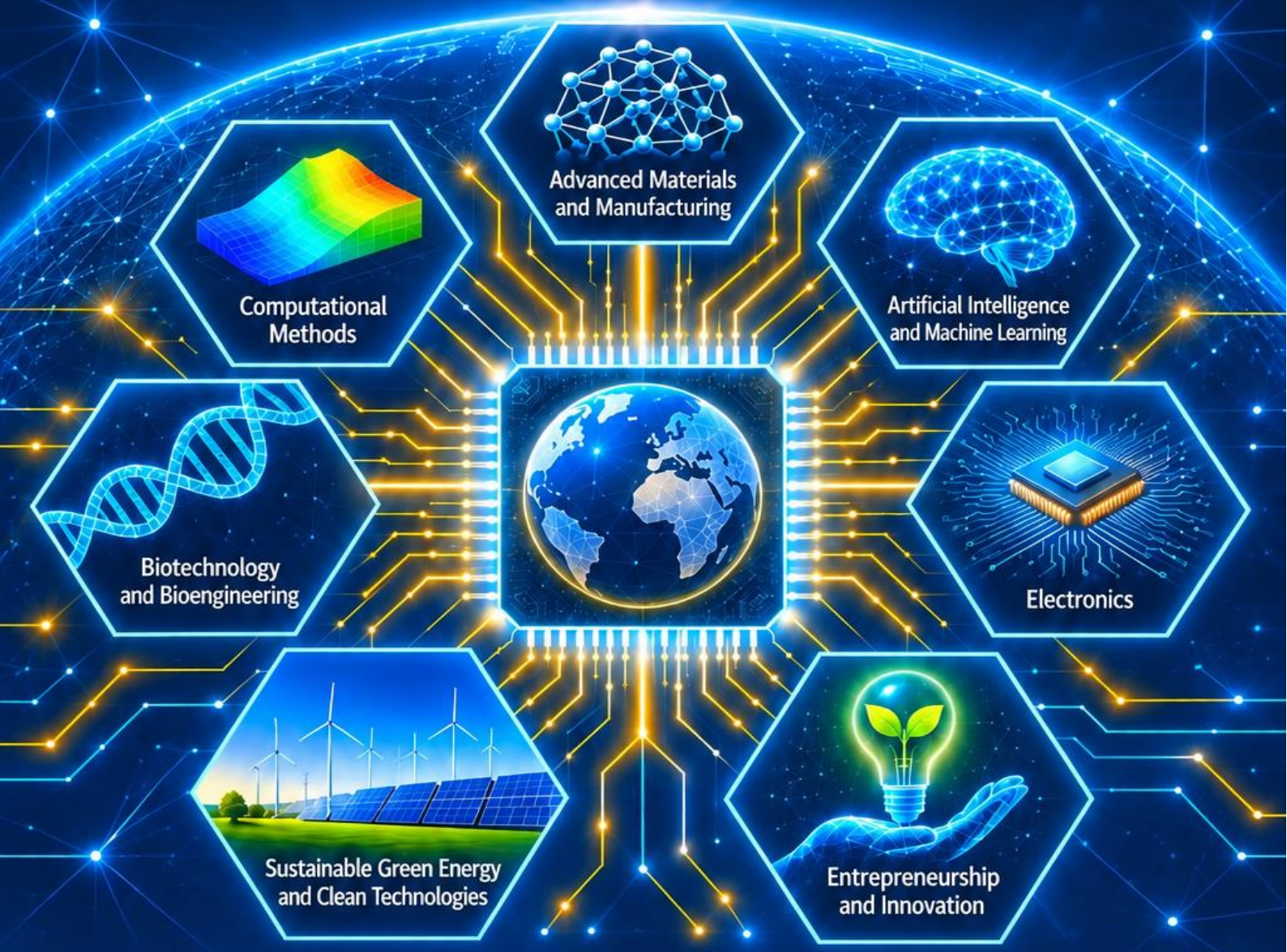
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DeepTech Connect 2026

INTERNATIONAL CONFERENCE



CONFERENCE PROCEEDINGS



Kragujevac, Serbia | Dublin, Ireland | Ioannina, Greece | Tours, France
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April 24, 2026

DEEPTECH CONNECT 2026

The First DeepTech Connect International Conference 2026

April 24, 2026

Kragujevac, Serbia, Dublin, Ireland, Ioannina, Greece, Tours, France, Bergamo, Italy, Mondragon, Spain, Zvornik, Bosnia and Herzegovina, Gebze, Turkey

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DeepTech CONNECT

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PREFACE

The **FIRST DEEPTECH CONNECT INTERNATIONAL CONFERENCE 2026** was established as an international platform for presenting scientific research, showcasing technological innovations, connecting academia with industry, and promoting the transformation of research results into practical applications and market-oriented innovations. Building on the concept of research fairs and scientific exhibitions, the Conference provides an opportunity for researchers, students, companies, entrepreneurs and other innovation ecosystem stakeholders to exchange knowledge, demonstrate new technologies, establish partnerships and explore opportunities for scientific and technological cooperation.

Deep Tech encompasses advanced scientific and technological developments with the potential to generate significant breakthroughs and address major societal, environmental and industrial challenges. The Conference brings together interdisciplinary research and innovation across seven major thematic areas:

- **Advanced Materials and Manufacturing**, covering advanced and functional materials, additive manufacturing, architected materials, smart materials, mechanical behaviour, manufacturing processes, tribology, surface engineering, structural monitoring and sustainable manufacturing.
- **Artificial Intelligence and Machine Learning**, including machine learning algorithms, explainable AI, deep learning, computer vision, image processing, natural language processing, speech recognition, generative AI and AI applications in healthcare, engineering, manufacturing, energy and environmental systems.
- **Computational Methods**, encompassing numerical modelling, finite element analysis, computational simulation, engineering design optimization, manufacturing process modelling, structural and biomechanical simulation, virtual twins and advanced mathematical methods.
- **Biotechnology and Bioengineering**, including biological resources, food biotechnology, biomaterials, polymeric scaffolds, tissue engineering, engineered living materials, molecular and cellular research, biomedical instrumentation, healthcare technologies and rehabilitation.
- **Electronics**, addressing electronic circuit design, antennas, embedded systems, sensors, digital communications, wireless networking, Internet of Things (IoT), vehicle-to-everything (V2X) communications and cybersecurity.
- **Sustainable Green Energy and Clean Technologies**, covering waste management, circular economy, resource recovery, bioenergy, hydrogen production, energy efficiency, sustainable buildings, environmental monitoring, renewable energy, solar technologies, sustainable materials and digital energy systems.
- **Entrepreneurship and Innovation**, focusing on deep-tech entrepreneurship, start-up development, innovation ecosystems, technology transfer, knowledge valorisation, university–industry cooperation, management, education and skills development, green and social innovation, and digital and cultural innovation.

The scientific programme reflects the increasingly interdisciplinary nature of contemporary research, where advanced materials, computational methods, artificial intelligence, biotechnology, electronics and sustainable technologies contribute to the development of new products, processes and services.

Particular attention is given to the connections between scientific discovery, technological development, industrial applications and the commercialisation of research results.

The **First DeepTech Connect International Conference 2026** was held on **April 24, 2026**, simultaneously at eight university locations across Europe: University of Kragujevac (Serbia), Dublin City University (Ireland), University of Tours (France), Mondragon University (Spain), University of Ioannina (Greece), University of East Sarajevo (Bosnia and Herzegovina), Gebze Technical University (Türkiye) and University of Bergamo (Italy). This multi-location concept enabled participants to attend in person at their respective universities while connecting with researchers, students, companies and other participants across all locations through online networking. The simultaneous organisation of the Conference created an international environment for exchanging research capacities, identifying complementary expertise and initiating cross-border academic and industrial cooperation.

A distinctive feature of DeepTech Connect 2026 was its **research fair and exhibition format**. Instead of relying exclusively on conventional oral presentations, the Conference encouraged the presentation of scientific and technological contributions through physical exhibits, prototypes, experimental models, posters, computer simulations and interactive demonstrations. This approach provided opportunities for direct engagement with research results, enabling visitors to discuss scientific challenges, explore practical applications and interact with the researchers behind the innovations.

The Conference proceedings bring together contributions covering a broad spectrum of scientific disciplines and innovation activities. The **Advanced Materials and Manufacturing** section presents research on additive manufacturing, shape-memory materials, functional ceramics, structural design, manufacturing processes, tribology, coatings, sensing and monitoring, and engineering applications. The **Artificial Intelligence and Machine Learning** section demonstrates the growing role of intelligent computational approaches in prediction, image analysis, speech and language processing, healthcare, industrial systems, environmental monitoring and smart applications. Complementing these developments, the **Computational Methods** section addresses numerical and analytical modelling, finite element analysis, manufacturing simulation, engineering optimization, structural dynamics and virtual twin technologies. The proceedings also highlight the contribution of biological and medical sciences to technological innovation. The **Biotechnology and Bioengineering** section includes research on natural biological resources, food applications, biomaterials, polymeric scaffolds for bone regeneration, tissue engineering, engineered living materials, molecular biomarkers, biomedical instrumentation, cancer care and rehabilitation. The **Electronics** section presents developments in antennas, electronic circuits, embedded sensing, digital communications, wireless positioning, connected vehicles and automotive cybersecurity. In response to the increasing importance of environmental responsibility and the transition towards sustainable economic and industrial systems, the **Sustainable Green Energy and Clean Technologies** section addresses waste management, circular resource utilisation, bioenergy, hydrogen production, energy-efficient buildings, geothermal systems, environmental monitoring, solar energy, protective coatings and digitally enabled energy

communities. These contributions demonstrate how technological innovation, resource efficiency and digital solutions can support the development of more sustainable energy and environmental systems.
Beyond scientific and technological developments, the Conference recognises the importance of creating effective pathways for translating research into innovation and economic and societal value. The **Entrepreneurship and Innovation** section therefore addresses deep-tech enterprise development, entrepreneurial opportunities, prototyping, technology transfer offices, university–industry cooperation, innovation ecosystems, business competitiveness, project management, education and workforce development, green entrepreneurship, ESG approaches and user-driven, digital and cultural innovation. This section reinforces the importance of connecting research excellence with entrepreneurial capabilities, industrial needs and the wider innovation ecosystem.

An important objective of the Conference was to promote research careers and doctoral education by bringing students and young researchers into direct contact with experienced scientists, research groups, companies and innovation ecosystem representatives. The event provided opportunities to explore research topics, identify potential PhD supervisors and collaborators, learn about emerging technologies and better understand the opportunities associated with scientific and technological development.

International networking was an integral part of the Conference concept. Participants were encouraged to use the dedicated Conference web application, https://dtc.lineupr.com/dtc/ to connect with other attendees before and during the event, exchange information about their research interests and identify potential partners across the participating universities. This digital networking dimension complemented the physical exhibitions and enabled interaction beyond geographical and institutional boundaries.

The Conference was organised within the framework of the **A-SIDE project**, supported by the European Institute of Innovation and Technology (EIT) Higher Education Initiative. It contributed to the broader objectives of strengthening innovation and entrepreneurial capacity in higher education institutions, promoting knowledge valorisation, fostering university–industry cooperation and supporting the development of regional and international innovation ecosystems.

The **Conference Proceedings** provide a multidisciplinary overview of the research, technological developments and innovation activities presented at DeepTech Connect 2026. The contributions demonstrate the diversity of contemporary research, from fundamental scientific investigations and computational approaches to experimental developments, engineering applications, biomedical solutions, sustainable technologies and innovation-oriented business and educational models. Their thematic organisation also highlights important connections between the different fields, demonstrating how advanced materials and manufacturing, computational methods and artificial intelligence can support technological development, while biotechnology, electronics and sustainable energy provide pathways towards practical applications and solutions to societal challenges.

The First DeepTech Connect International Conference 2026 represents an important step towards establishing a sustainable international platform for connecting science, technology, education, entrepreneurship and industry. Its distinctive multi-university format and exhibition-oriented approach demonstrate the value of bringing research closer to students, companies and society, while creating opportunities for new partnerships, interdisciplinary cooperation and the commercialisation of deep-tech innovations.

The Conference was highly successful, attracting a large number of young people, early-career researchers, aspiring researchers, and PhD students. The scientific research fair format demonstrated that this innovative approach to presenting scientific work was very well received by young participants, who remained actively engaged throughout the Conference.

We hope that this publication will inspire further scientific research, encourage international and interdisciplinary collaborations, strengthen connections between academia and industry, and contribute to transforming scientific knowledge into innovative solutions with meaningful economic, environmental and societal impact.

Kragujevac, Serbia, 2026

Conference General Chair
Prof. Dr. Fatima Zivic
Faculty of Engineering
University of Kragujevac, Serbia

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Evaluating municipal waste management efficiency in the context of sustainable development: A DEA-based analysis

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Abstract

Efficient municipal waste management represents an essential element of sustainable urban development. Municipalities are responsible for delivering waste collection, treatment, and disposal services while being constrained by financial and operational limitations. Effective waste management practices play an important role in achieving the Sustainable Development Goals defined by the United Nations, specifically those related to sustainable cities and responsible production and consumption patterns. This study assesses the efficiency of municipal waste management systems within the Šumadija district in the Republic of Serbia using Data Envelopment Analysis. Seven municipalities are analysed as decision-making units. The analysis includes two input variables representing service coverage and the number of containers for separate waste collection, and two output variables reflecting environmental performance through the total amount of municipal waste collected and the amount of separately collected waste. The results indicate that Kragujevac and Lapovo operate at the efficiency frontier according to both applied DEA models, while other municipalities showed different levels of efficiency, mainly related to limited recycling infrastructure. The results provide useful insights for local policymakers and highlight the significance of improving recycling infrastructure and resource allocation to support more sustainable municipal waste management systems.

Keywords: municipal solid waste management (MSWM); data Envelopment Analysis (DEA); eco-efficiency; recycling; sustainable development; UN SDG 11; UN SDG 12

1. Introduction

Municipal solid waste management (MSWM) represents one of the basic public services usually provided by local governments [1]. Rapid urbanization, increasing living standards, and environmental pressures require

municipalities to manage waste systems in a more efficient and sustainable manner since MSWM system is one of an essential component of sustainable urban development [2]. Municipal authorities are responsible for organizing and managing waste activities through collection, treatment, and disposal services while operating under limited financial and operational resources.

Improving the efficiency level of MSWM system is particularly key in the context of sustainable development. Efficient systems allow municipalities to provide adequate services while minimizing environmental impacts and optimizing the use of available resources, which indicates eco-efficiency. Eco-efficiency is defined as generating more products while using less resources and minimizing environmental impact [3]. Eco-efficient waste management systems play an important role in attaining Sustainable Development Goals (SDGs) defined by the United Nations, particularly those related to sustainable cities (SDG 11) and responsible consumption and production (SDG 12). At the same time, the rapid growth in global waste generation represents a major challenge for achieving several SDGs, including those related to health, clean water, sustainable cities, and the protection of marine and terrestrial ecosystems (SDG 3, SDG 6, SDG 14, and SDG 15) [4-5]. In this context of sustainability, reusing, recycling, and waste separation play an important role in reducing landfill disposal and promoting circular economy principles. Policymakers and researchers are seeking solutions to promote the efficient management of municipal solid waste (MSW) from economic and environmental perspective [3, 6]. Municipalities differ in terms of financial capacity, infrastructure, population size, and institutional organization, which often results in heterogeneous performance levels, making it essential to evaluate the efficiency of MSWM system. Different analytical methods have been used to determine efficiency in public services, among which Data Envelopment Analysis (DEA) has proven to be particularly useful due to its ability to evaluate multiple inputs and outputs simultaneously [7-8]. DEA provides a non-parametric framework for evaluating performance and comparing efficiency of decision-making units [9].

The aim of this study is to evaluate the efficiency of MSWM system in municipalities within the Šumadija district of the Republic of Serbia, using the DEA methodology. Two DEA models (CCR and BCC) are employed to distinguish between technical efficiency and pure technical efficiency. Based on the selected input and output variables, the DEA model evaluates efficiency level of MSWM system in transforming available operational resources into environmental outputs, allowing decision-makers to identify municipalities in which improvement of waste management system is feasible.

2. Materials and methods

The methodological steps used in this study are summarized graphically in the Figure 1.

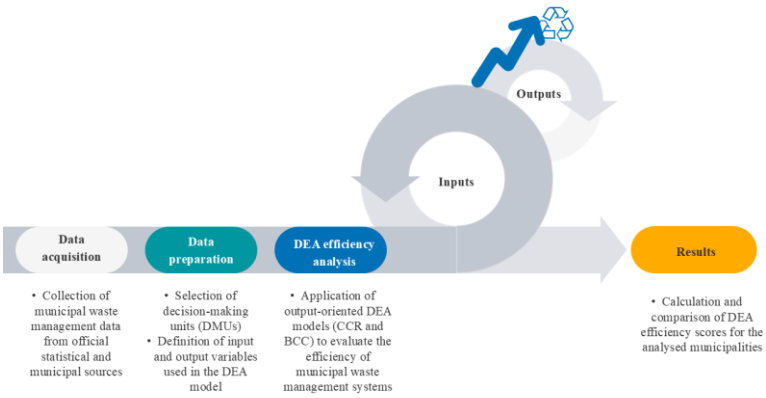
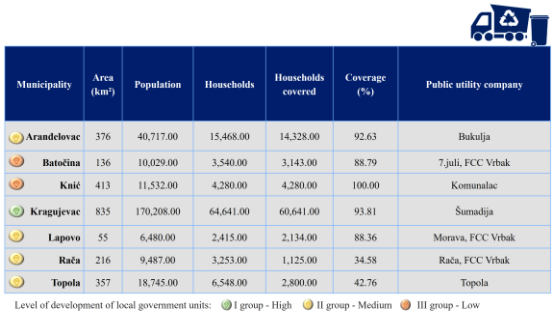


Figure 1. Methodological framework of DEA efficiency analysis

DEA is a non-parametric approach used to measure the relative efficiency of comparable decision-making units (DMUs) with the use of linear programming techniques [10]. The method evaluates how efficiently units transform inputs (resources) into outputs (results). Failure of a DMU to produce maximal output levels with minimal input consumption results in a worsened efficiency score [11]. This approach defines an efficiency frontier, or envelope, that encompasses all analysed DMUs. DEA estimates efficiency by comparing each DMU with the others DMUs in the sample [12].

Šumadija district has a central position in Serbia [13]. Seven municipalities from Šumadija district were analysed as DMUs: Aranđelovac, Batočina, Knić, Kragujevac, Lapovo, Rača and Topola (Figure 2). According to commonly used DEA methodological guidelines, the number of DMUs should be sufficiently larger than the total number of input and output variables in order to ensure the validity of the results. A general rule suggests that the number of DMUs should be at least twice the total number of inputs and outputs together [14]. Although the number of DMUs is below literature recommendation, the ratio remains acceptable given the limited number of municipalities within the observed district. Municipalities differ in size, economic capacity, and waste management infrastructure, which allows for a meaningful assessment of relative efficiency across heterogeneous local systems using DEA approach.

In this study, seven municipalities were analysed using two input and two output variables. The inputs and outputs used in this analysis are shown in Table 1.



Municipality	Area (km²)	Population	Households	Households covered	Coverage (%)	Public utility company
Aranđelovac	376	40,717.00	15,468.00	14,328.00	92.63	Bukulja
Batočina	136	10,029.00	3,540.00	3,143.00	88.79	7.juli, FCC Vrbak
Knić	413	11,532.00	4,280.00	4,280.00	100.00	Komunalac
Kragujevac	835	170,208.00	64,641.00	60,641.00	93.81	Šumadija
Lapovo	55	6,480.00	2,415.00	2,134.00	88.36	Morava, FCC Vrbak
Rača	216	9,487.00	3,253.00	1,125.00	34.58	Rača, FCC Vrbak
Topola	357	18,745.00	6,548.00	2,800.00	42.76	Topola

Level of development of local government units: I group - High II group - Medium III group - Low

Figure 2. Basic characteristics of municipalities included in the DEA analysis

Table 1. Input and output variables used in DEA analysis

DMU (Municipality)	x_1: Households covered	x_2: Containers for separate	y_1: Collected waste (t/year)	y_2: Separately collected waste
Aranđelovac	14,328.00	20.00	18,619.00	16.00
Batočina	3,143.00	0.00	3,861.00	0.00
Knić	4,280.00	0.00	6,500.00	0.00
Kragujevac	60,641.00	400.00	55,496.00	854.00
Lapovo	2,134.00	0.00	3,659.00	0.00
Rača	1,125.00	0.00	1,722.00	0.00
Topola	2,800.00	9.00	3,081.00	17.00

When determining the level of efficiency of the MSWM systems in Šumadija district, an output-oriented DEA model was applied. The output-oriented approach was considered appropriate because the objective of MSWM system is not primarily to reduce existing resources, but rather to improve waste management performance and increase desirable environmental outputs, such as the total amount of collected waste and separately collected waste for recycling, while keeping the available inputs at their current level. The analysis is based on data obtained from publicly available statistical sources and official municipal reports [15-16]. Given inputs represent the operational capacity of municipalities, measured through service coverage and the number of containers for separate waste collection, while the outputs reflect the performance of waste management systems in terms of the total amount of collected MSW and the amount of separately collected waste which can be further treated by the recycling process.

Optimization problem was solved using the Simplex linear programming algorithm implemented in Excel Solver. Two DEA models were formed: the CCR model (Equation 1), which assumes constant returns to scale and measures overall technical efficiency, and the BCC model, which assumes variable returns to scale and measures pure technical efficiency [17]. An efficiency score equal to 1 indicates an efficient DMU, while values greater than 1 indicate inefficiency and the potential to increase outputs while maintaining the same level of inputs.

$$Max \quad \theta_k \qquad \text{(Eq. 1)}$$

Subject to:

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq x_{i0}; \qquad i = 1, \dots, m$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq \theta_k y_{r0}; \qquad r = 1, \dots, s$$

$$\lambda_j \geq 0; \qquad j = 1, \dots, n$$

In this formulation, x_{ij} and y_{rj} represent the input and output values of each municipality (Table 2), λ_j are intensity variables, and θ_k the efficiency score of each DMU_k. The formulation of the BCC model is achieved by adding the convexity constraint $\sum_{j=1}^{n} \lambda_j = 1$ to described CCR model [17]. The comparison of two observed models enables the calculation of scale efficiency $(\boldsymbol{\theta_{CCR}/\theta_{BCC}})$, which indicates whether inefficiency is caused by operational performance or by the scale of operations. Given that an output-oriented DEA model was applied, in this study, scale efficiency was calculated as the ratio of pure technical efficiency (BCC) to overall technical

efficiency (CCR) to ensure that scale efficiency values range between $0 \leq \theta_k \leq 1$, where a value of 1 indicates complete efficiency.

3. Results and discussion

The results of the DEA analysis reveal differences in performance among the analysed municipalities. The CCR model shows that Kragujevac and Lapovo achieve full efficiency, indicating that these municipalities operate at the efficiency frontier and serve as benchmarks for other municipalities. The remaining municipalities show varying degrees of inefficiency. Batočina shows the lowest efficiency score, suggesting that improvements in recycling infrastructure and operational organization may be necessary. According to the BCC model, several municipalities, including Aranđelovac, Knić, Kragujevac, Lapovo and Rača, achieve pure technical efficiency, indicating that their operations are relatively well managed, but may not be operating at optimal scale. The calculated scale efficiency values indicate that the part of inefficiency observed in some municipalities is related to the scale of operations, rather than purely operational inefficiency.

The results highlight small differences in the performance of solid waste management systems in the municipalities of Šumadija District (Figure 3). Comparing the CCR and BCC efficiency scores provides additional insight into the sources of inefficiency among the analysed municipalities. While the CCR model measures overall technical efficiency assuming constant returns to scale, the BCC model estimates pure technical efficiency by allowing for variable returns to scale. When a municipality is efficient under the BCC model but inefficient under the CCR model, the inefficiency can be attributed primarily to scale effects rather than poor resource management. In this case, municipalities such as Aranđelovac, Knić, and Rača show pure technical efficiency under the BCC model, indicating that their waste management systems are relatively well managed but not operating at optimal scale. In contrast, Kragujevac and Lapovo achieve full efficiency according to both models, positioning them as reference municipalities within the analysed sample. The Figure 3 shows the geographical location of municipalities in Šumadija district and their efficiency results obtained using the DEA models. Kragujevac stands out as the most developed waste management system within the analysed group. Given that Kragujevac is the largest city in central Serbia, it has a significantly higher number of separate waste collection containers and the largest amount of separately collected waste [15-16], which contributes to its position at the efficiency frontier. Similarly, Lapovo achieves full efficiency despite its smaller size. This suggests that efficient organization and resource management can compensate for limited infrastructure and scale. Municipalities such as Aranđelovac, Knić and Rača show good management performance, but may operate under sub-optimal conditions.

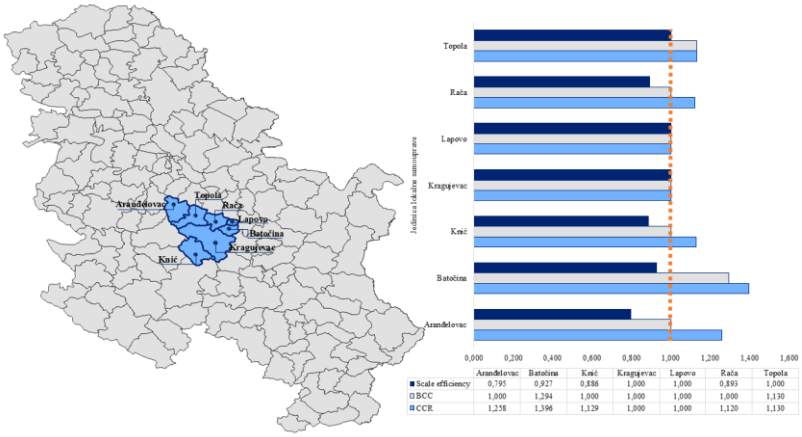


Figure 3. Efficiency of MSWM systems in the Šumadija district

To provide a spatial interpretation of differences in efficiency, municipalities were classified into efficiency categories based on BCC efficiency scores and visualized via a thematic map (Figure 4). The classification distinguishes between highly efficient municipalities operating at the efficiency frontier and municipalities exhibiting varying levels of inefficiency (High Efficiency = 1.00, Moderate Efficiency 1.01 - 1.15, Low Efficiency > 1.15). These findings notice the importance of investing in recycling infrastructure and improving operational efficiency to improve solid waste management system.

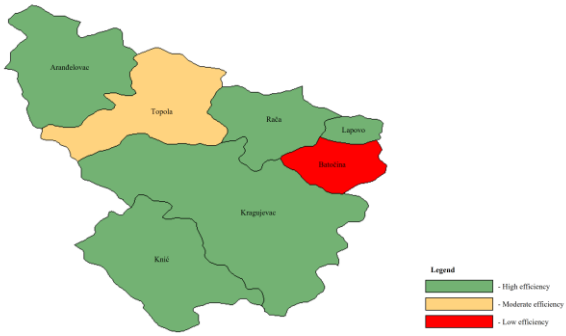


Figure 4. MSWM efficiency levels in the Šumadija district

Calculated efficiency scores show how efficiently municipalities use available resources compared to the other municipalities in the sample. Higher efficiency score indicates better resource utilization and more developed waste management systems, while lower efficiency levels indicate potential inefficiencies and opportunities for improving infrastructure, organization, and recycling performance. Therefore, the results provide insight into which municipalities are operating efficiently and which municipalities can improve their waste management performance through better resource allocation and development of recycling infrastructure.

The thematic map was constructed using BCC efficiency scores, as the BCC model measures pure technical efficiency while controlling for scale effects. This approach enables a more reliable comparison of operational performance between different sizes municipalities. The results suggest a clear relationship between waste management efficiency and sustainability-oriented outputs, particularly recycling performance. Municipalities with higher efficiency levels tend to achieve better environmental outcomes while using available resources more effectively, showing the role of efficiency as an important component of sustainable development.

4. Conclusions

This study examined efficiency of MSWM systems in municipalities of Šumadija district using DEA method. By applying the CCR and BCC models, the analysis provided insight into the technical efficiency and pure technical efficiency of the observed municipalities. Results show that Kragujevac and Lapovo operate at the efficiency frontier according to the CCR model, which assumes constant returns to scale. However, the BCC model, which allows for variable returns to scale and is therefore more suitable for comparing municipalities of different sizes, indicates that Batočina and Topola operate inefficiently. Among the analysed municipalities, Batočina stands out as the municipality with the lowest level of efficiency of municipal waste management in Šumadija district, suggesting that improvements in recycling infrastructure and operational organization may be necessary. A comparison of CCR and BCC results indicates that part of the observed inefficiency is related to the scale of operations. In other words, some municipalities may manage their resources relatively well, but do not operate at optimal level of waste management infrastructure and service provision. From a sustainable development perspective, the findings highlight the need to improve waste collection performance and further develop recycling infrastructure. Strengthening these aspects of municipal waste management could contribute to better environmental outputs and more efficient resource use, while supporting progress towards the United Nations Sustainable Development Goals, in particular SDGs 11 and 12.

However, the study also has certain limitations, mainly related to the availability of data at the municipal level. In several municipalities, some operational indicators were not fully reported in official sources, resulting in zero values for selected variables. These values do not necessarily imply the absence of waste management activities, but rather reflect limitations in data reporting. Despite these limitations, the analysis still provides valuable insights into the relative efficiency of municipal solid waste management system in Šumadija district. Overall, the results highlight the usefulness of DEA as a practical tool for assessing the performance of municipal waste management, and for supporting evidence-based decision-making in local environmental policy. Future research could apply system dynamics modelling to achieve more realistic evaluations of MSWM system efficiency.

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