# Empowering the Circular Economy in Albania through Big Data Analytics: Opportunities, Case Studies, and Regional Insights

**Elena Myftaraj**
University of Tirana, elenatomori@yahoo.com

**Irena Fata**
University of Tirana, irena.fata@luarasi-univ.edu.al

*Abstract: The adoption of a circular economy, which is defined by the concepts of reduction, reuse, and recycling, is essential for achieving sustainable development. Big data analytics is becoming a powerful tool in this transformation, providing outstanding knowledge into optimizing resources, managing waste, and implementing sustainable practices in many industries. This article examines the use of big data analytics to promote the circular economy in Albania, a country facing distinct problems and opportunities in the Western Balkans region. The study conducts a thorough examination of big data methods, including data mining, machine learning, and predictive analytics. It suggests specific sectors, such as manufacturing, healthcare, waste management, agriculture, and tourism, as areas where intervention should be focused. The article showcases three case studies that demonstrate the successful incorporation of big data analytics into circular economy plans, drawing on international best practices. Moreover, it examines the present condition and future prospects of Albania and the Western Balkans in embracing new technologies, relying on existing secondary data and success stories from the region. The results indicate that Albania has considerable potential to utilize big data analytics in promoting a more sustainable and efficient economy. Additionally, recommendations are provided for policy makers, industry leaders, and academic stakeholders to effectively address the difficulties associated with this revolutionary process.*

*Keywords: Circular Economy; Big Data Analytics; Sustainability; Resource Optimization; Waste Management*

# 1 Introduction

The need for sustainable development is more evident than ever as global economies face the dual challenges of resource depletion and environmental degradation. The circular economy, characterized by waste reduction and efficient resource utilization, presents a promising approach to achieving sustainability [1]. However, fully harnessing the circular economy's potential requires inventive data management and analysis methodologies. Big data analytics is a powerful tool in this context because it can handle large datasets and generate practical insights [2], [3]. This article examines the use of big data analytics to enhance the circular economy in Albania, which is located in the distinct socio-economic and environmental context of the Western Balkans.

# 2 Understanding Big Data Analytics

Big data analytics is a methodical process of analyzing vast and intricate datasets to uncover valuable hidden insights and patterns. It involves various methods and approaches designed to extract useful information from large amounts of organized and unorganized data. The primary goal of big data analytics is to discover significant correlations, trends, and linkages that can provide information for decision-making, improve procedures, and stimulate innovation in many fields. This section encompasses several strategies and methodologies designed to extract practical insights from large amounts of organized and unorganized data. The primary goal of big data analytics is to discover significant correlations, trends, and linkages that might provide valuable insights for decision-making, streamline processes, and foster innovation in many fields. These technologies can be directly used in Albania's waste management system to optimize waste collection routes, increase recycling rates, and forecast waste generation patterns. This will significantly enhance resource efficiency and promote environmental sustainability.

## 2.1 Key Tools and Technologies

### 2.1.1 Data Mining

Data mining involves exploring and analyzing vast datasets to identify patterns, anomalies, and relationships. Through techniques such as clustering, classification, and association rule mining, data mining algorithms can uncover hidden insights that are not readily apparent through traditional data processing methods [4].

### 2.1.2 Text Mining

Text mining, also known as text analytics or natural language processing (NLP), focuses on extracting valuable information and insights from unstructured text data.

Text mining algorithms can sift through large volumes of textual data to extract meaningful patterns and sentiments by applying sentiment analysis, entity recognition, and topic-modeling techniques [5], [6].

### 2.1.3 Machine Learning & Deep Learning

Machine learning and deep learning techniques enable computers to learn from data and make predictions or decisions without being explicitly programmed. Machine learning algorithms like linear regression, decision trees, and neural networks can analyze large datasets to identify patterns and make predictions. Deep learning, a subset of machine learning, involves training artificial neural networks with multiple layers to perform more complex tasks, such as image recognition and natural language processing [7], [8].

### 2.1.4 Predictive Analysis

Predictive analysis uses historical data, statistical algorithms, and machine learning techniques to forecast future trends and behaviors. By analyzing past patterns and behaviors, predictive analytics algorithms can generate insights and predictions that inform decision-making and drive proactive strategies [9].

### 2.1.5 Artificial Intelligence (AI)

Artificial intelligence encompasses a range of technologies and methodologies that enable computers to perform tasks that typically require human intelligence. From machine learning algorithms to natural language processing and computer vision, AI techniques are increasingly applied in big data analytics to automate tasks, uncover insights, and drive innovation [10].

### 2.1.6 Business Intelligence (BI)

Business intelligence involves data collection, integration, analysis, and visualization to inform decision-making and drive business strategy. BI tools and technologies enable organizations to transform raw data into actionable insights, facilitating data-driven decision-making and performance optimization [11].

## 2.2 Applications and Implications

Data analytics is widely used in multiple businesses and sectors, such as healthcare, banking, retail, manufacturing, and government. Big data analytics has exceptional prospects for innovation, effectiveness, and value generation, encompassing predictive maintenance, fraud detection, tailored marketing, and supply chain optimization. Nevertheless, along with these prospects arise obstacles such as apprehensions regarding data privacy, ethical deliberations, and the requirement for proficient expertise and resilient infrastructure. Organizations must effectively

address the problems associated with big data analytics to fully capitalize on data-driven decision-making.

Big data analytics holds immense promise for revolutionizing the circular economy by optimizing resource utilization, reducing waste generation, and fostering sustainable practices across various sectors. In manufacturing, predictive analytics can forecast equipment failures, minimize downtime, and optimize resource usage [12], [13]. These insights also aid in designing sustainable products. In waste management, big data improves collection, sorting, and recycling efficiency by optimizing routes and predicting demand [14].

Additionally, in agriculture, big data enables more sustainable practices by optimizing resource use and improving crop yields through detailed analysis of soil health data, weather patterns, and crop performance metrics. This helps farmers make informed irrigation and pest management decisions, promoting efficiency and reducing wastage [15]. Integrating these analytics into circular economy practices offers significant environmental, economic, and social benefits, supporting a sustainable future.

In Albania's waste management context, these technologies can be directly applied to optimize waste collection routes, improve recycling rates, and predict waste generation patterns, contributing significantly to resource efficiency and environmental sustainability.

## 2.3 Best Practices and Case Studies from Around the World

Three global case studies illustrate the successful application of big data analytics in circular economy practices focusing on waste management:

1. Food-Waste Reduction in Global Businesses
2. Enevo in Belgium
3. Sensoneo in Slovakia

**Waste Management: Food-Waste Reduction in Global Businesses**

**Literature Review and Case Study Analysis**

Research emphasizes the critical role of big data in enhancing supply chain efficiencies and reducing food waste. Studies such as those by [16] illustrate how predictive analytics can forecast discrepancies in demand and supply, thereby minimizing overproduction and excess inventory, which are primary contributors to food waste [16]. In this case, 41 global businesses utilized big data analytics to optimize operations and reduce waste. These businesses effectively used big data to streamline production schedules, manage inventory, and optimize distribution paths, reducing food waste and enhancing profitability [17].

| | |
|---|---|
| **Objective** | To explore how global businesses across the food supply chain use big data analytics to reduce waste and enhance resource efficiency. |
| **Methodology** | Through internet searches and expert referrals, researchers found 41 companies. Using business data, they examined the usage of big data analytics and its impact on food waste reduction. Companies were assessed by their supply chain position and waste hierarchy—prevention, redistribution, reuse, recycling, and recovery. |
| **Findings** | Companies optimizing linear supply networks for material efficiency reduced waste best with big data. It optimizes operations, resource allocation, and efficiency for these firms. Companies that sold cosmetically damaged food or turned food waste into new goods were less likely to use big data but could benefit from it. |
| **Implications** | The study emphasizes the need for tailored big data applications based on a company's supply chain function. It shows how big data may be expanded to have greater environmental and economic implications. |

**Waste Management: Enevo in Belgium**

**Literature Review and Case Study Analysis**

The integration of sensor technology and data analytics in waste management has been increasingly studied, and it has shown significant improvements in operational efficiency and environmental sustainability [18]. Enevo implemented an intelligent waste management system in Brussels, utilizing sensors to monitor dumpster fill levels and optimize collection routes. This led to fewer collection trips, reduced emissions, and improved recycling rates, demonstrating the effective use of big data in urban environments [19].

| | |
|---|---|
| **Objective** | To evaluate the impact of sensor-based data analytics on urban waste management efficiency and sustainability. |
| **Methodology** | The study analyzed waste collection data before and after implementing Enevo's system. Metrics such as the number of collections, vehicle emissions, and recycling rates were tracked to assess improvements. |
| **Findings** | Implementing Enevo's technology resulted in a 20% reduction in waste collection trips and a significant improvement in recycling compliance, highlighting big data's role in enhancing resource efficiency and reducing environmental impact. |

| | |
|---|---|
| **Implications** | This case shows how intelligent waste management solutions may change cities. Further study and investment in such technology could improve city sustainability worldwide. |

**Waste Management: Sensoneo in Slovakia**

**Literature Review and Case Study Analysis**

Big data's role in enhancing the efficiency of waste management systems through better decision-making and operational adjustments is well-documented [20]. Sensoneo's deployment in Slovakia involved using sensors and data analytics to monitor waste levels and optimize collection routes, reducing operational costs and increasing recycling efficiency.

| | |
|---|---|
| **Objective** | To investigate the effectiveness of data-driven technologies in improving waste management practices in mid-sized European cities. |
| **Methodology** | The study involved continuously monitoring waste management activities in selected Slovak cities and analyzing data collected from Sensoneo's sensors regarding waste levels and collection frequencies. |
| **Findings** | Sensoneo's technology enabled a 30% reduction in collection costs and improved the recycling rate by optimizing the collection schedule based on actual waste generation data. |
| **Implications** | The successful application of Sensoneo's system illustrates the critical role of big data in modernizing waste management. It could serve as a model for other cities seeking similar efficiency and sustainability improvements. |

# 3 Methodology

**Data Collection**

The study used secondary data from Eurostat, covering recycling rates and waste management metrics across Western Balkan countries, focusing on Albania from 2000 to 2022. This dataset was supplemented by local waste management data from the Albanian government and relevant NGOs involved in waste management and environmental sustainability initiatives.

**Data Analysis**

The analysis involved several steps: initially, a descriptive analysis was conducted to understand waste generation and recycling rate trends, calculating the mean, median, and standard deviation to assess the distribution and variability over the years. Trend analysis using time series techniques identified trends in Albania's recycling rates, highlighting significant improvements and periods of notable change. The comparative analysis placed Albania's data against that of neighboring Western Balkan countries to evaluate its performance in regional environmental efforts, providing insights into its progress in waste management. Finally, a gap analysis identified data gaps, particularly in the early years, discussing their potential implications on the accuracy and reliability of the trend analysis.

# 4 Results and Discussions

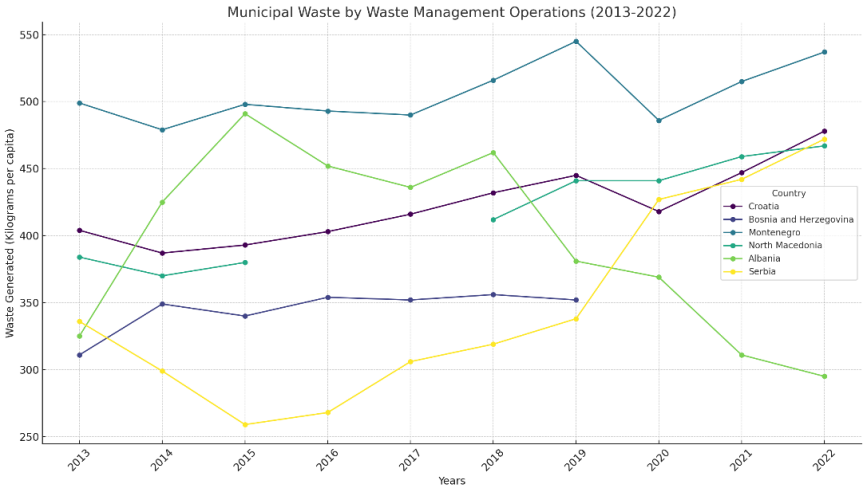


Figure 1.

Municipal water by waste management operations in Western Balkans Countries

Source: Eurostat[8]

This analysis examines per capita waste generation across Western Balkan countries—Croatia, Bosnia and Herzegovina, Montenegro, North Macedonia, Albania, and Serbia—over ten years from 2013 to 2022. The study uses descriptive statistics and visual trend analysis to reveal patterns and implications of waste management practices in these nations. The data shows an upward trend in waste generation over the decade. Albania's waste generation increased from 376.5 kg per

8 https://ec.europa.eu/eurostat/databrowser/view/env_wasmun/default/table?lang=en

capita in 2013 to 449.8 kg per capita in 2022. The standard deviation values indicate significant variability within each country annually and across the region. Serbia recorded the minimum waste generation at 259 kg per capita in 2015, while Montenegro had the maximum at 537 kg in 2022. This range highlights the impact of local management efficiencies and policy effectiveness on waste production levels.

| Country | Croatia | Bosnia and Herzegovina | Montenegro | North Macedonia | Albania | Serbia |
|---|---|---|---|---|---|---|
| Count | 10 | 7 | 10 | 8 | 10 | 10 |
| Mean | 425.3 | 377.89 | 498.1 | 416.33 | 388.8 | 366.6 |
| StdDev | 29.78 | 60.19 | 23.62 | 37.37 | 78 | 76.8 |
| Min | 387 | 311 | 479 | 370 | 295 | 259 |
| 25th Percentile | 403 | 340 | 490 | 380 | 325 | 299 |
| 50th Percentile (Median) | 418 | 352 | 499 | 412 | 369 | 336 |
| 75th Percentile | 445 | 356 | 516 | 445 | 436 | 427 |
| Max | 478 | 478 | 545 | 467 | 491 | 472 |
| CAGR | 0.02 | 0.06 | 0.01 | 0.03 | -0.01 | 0.05 |

Table 1
Descriptive statistics and Compound Annual Growth Rate (CAGR) for the trend components of municipal waste for each country

**Visual and Trend Analysis**

Graphs illustrate diverse trajectories in waste generation among Balkan countries. Albania shows fluctuations, indicating variability in policy effectiveness and economic conditions. Croatia and Montenegro display consistent increases in waste production, aligning with their economic development and urbanization. In contrast, Bosnia, Herzegovina, and Serbia demonstrate stability in their waste generation, suggesting practical but static waste management systems.

Trend component analysis, performed using time series decomposition, highlights underlying annual waste generation data trends. This method, applied using Python and the **statsmodels** library, separates the data into trend, seasonality, and residuals. The focus on the trend component reveals Albania's need for improved waste

management strategies. While Montenegro and Croatia experience a steady rise in waste production, other countries show no significant directional trends, reflecting the complex interplay of economic, policy, and societal factors. The absence of clear trends in several countries indicates potential counteracting factors, such as improved waste reduction strategies or economic downturns, influencing overall waste generation.

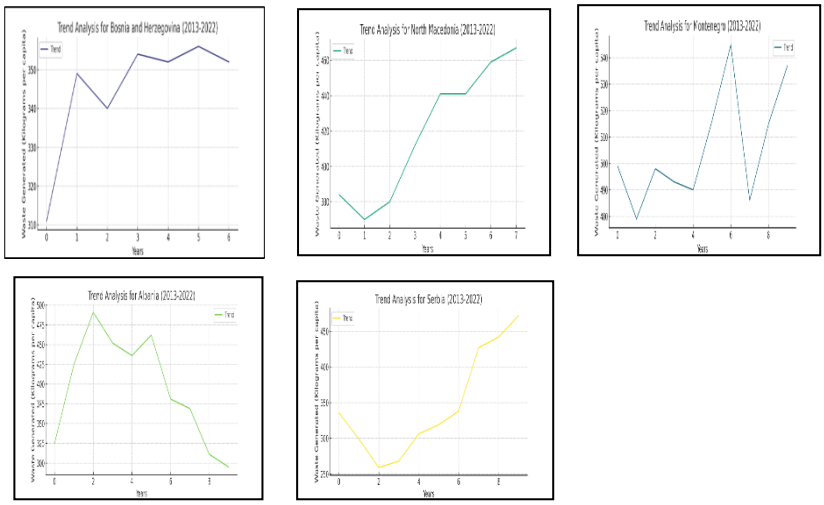


Figure 2

Trend Analysis of five Western Balkans Countries

## Discussion

The upward trends in waste generation in countries like Montenegro and Croatia underscore the need for proactive waste management strategies, including enhanced recycling programs, waste reduction at the source, and increased public awareness and engagement. The variable trends across the region suggest that one-size-fits-all policies may not be effective, necessitating localized strategies tailored to each country's specific conditions and needs. This study highlights the critical importance of continuous monitoring and adaptive policy frameworks to manage waste generation effectively in the Western Balkans, which is crucial for environmental sustainability and the health and well-being of the region's

populations.

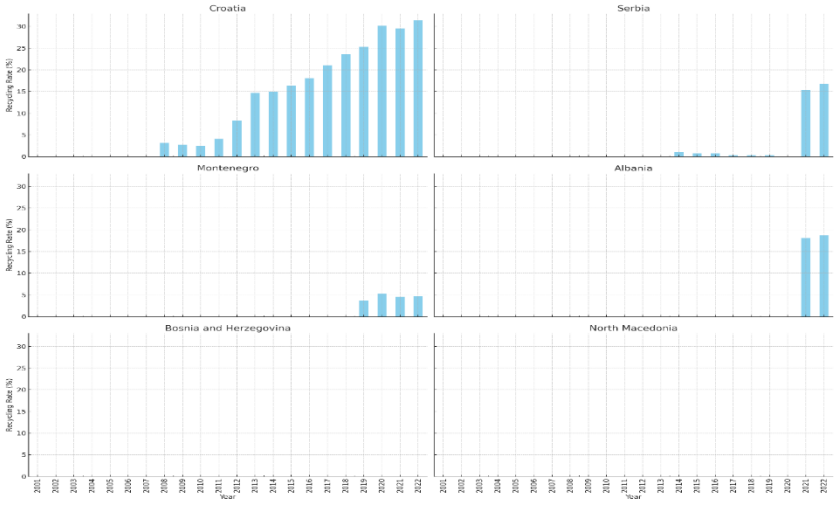


Figure 3.

Western Balkans countries' recycling rate of municipal waste

Source: Eurostat[9]

This other graph outlines the recycling rate of municipal waste. The statistics show a gradual increase in recycling rates over the years where data is available. Due to the very sparse data in the early years, many statistics (like mean and standard deviation) start becoming meaningful only later when more data points are available. Croatia and Serbia show measurable improvements and provide the most consistent datasets. Other countries like Montenegro, North Macedonia, and Albania show entries only in recent years, limiting trend analysis but indicating starting points for these countries about recycling initiatives. Bosnia and Herzegovina have minimal data, mostly zeros, indicating no reporting or significant recycling activity captured.

This analysis highlights the challenges and progress in recycling within the Western Balkans region, suggesting a general positive trend in recent years where data is more available. This could reflect increased efforts towards environmental sustainability in these countries.

9 https://ec.europa.eu/eurostat/databrowser/view/cei_wm011/default/table?lang=en

**Conclusions and Recommendations**

Allocate resources towards the implementation of robust data collection systems that are outfitted with Internet of Things (IoT) devices and sensors. This will enable the improvement of waste management practices and the establishment of standardized data reporting protocols across various municipalities. The utilization of machine learning and predictive analytics is employed to optimize the allocation of resources and deploy sensor-equipped smart receptacles that enable real-time monitoring of waste. Formulate policies grounded in empirical evidence by leveraging big data analytics and promoting public-private partnerships to foster innovation and improve waste management and recycling processes. These suggestions intend to improve the waste management practices in Albania to produce data-driven and sustainable solutions consistent with the circular economy. By implementing this proactive approach, achieving environmental sustainability goals concurrently with economic growth and improving community welfare would be possible.

This research underscores the substantial influence that big data analytics can exert in enhancing refuse management within the circular economy framework of Albania. A comprehensive data analysis from 2000 to 2022 has revealed significant advancements and trends that can potentially guide future endeavors.

Technological efficacy has been enhanced through the implementation of cutting-edge technologies like machine learning, predictive analytics, and IoT devices. These technologies have increased operational efficiencies, optimized recycling processes, and enhanced forecasting. International case studies substantiate these benefits, which illustrate reduced costs, increased recycling rates, and sustained feasibility.

Empirical evidence shows a notable increase in recycling rates and efficacy over the last three years. This implies that implementing strategies and technologies in adherence to global standards of excellence has yielded favorable results. Comparing Albania's performance to that of other nations reveals its progress and pinpoints regional cooperation and enhancement opportunities.

Integrating big data analytics into the waste management processes of Albania offers a promising pathway toward realizing a circular economy. Positive trends indicate a commitment to improving environmental management, offering a hopeful outlook on achieving sustainability goals. For Albania to fully actualize its environmental stewardship and waste management potential, advanced technologies and data-driven methodologies must be implemented.

**References**


[1] M. Del Giudice, R. Chierici, A. Mazzucchelli, and F. Fiano, "Supply chain management in the era of circular economy: the moderating effect of big data," The International Journal of Logistics Management, 32(2), pp. 337–356, Apr. 2021, doi: 10.1108/IJLM-03-2020-0119.

[2] A. Belhadi, K. Zkik, A. Cherrafi, S. M. Yusof, and S. El fezazi, "Understanding Big Data Analytics for Manufacturing Processes: Insights from Literature Review and Multiple Case Studies," Comput Ind Eng, 137, p. 106099, Nov. 2019, doi: 10.1016/j.cie.2019.106099.

[3] B. Fang et al., "Artificial intelligence for waste management in smart cities: a review," Environ Chem Lett, 21(4), pp. 1959–1989, Aug. 2023, doi: 10.1007/s10311-023-01604-3.

[4] Xindong Wu, Xingquan Zhu, Gong-Qing Wu, and Wei Ding, "Data mining with big data," IEEE Trans Knowl Data Eng, 26(1), pp. 97–107, Jan. 2014, doi: 10.1109/TKDE.2013.109.

[5] H. Hassani, C. Beneki, S. Unger, M. T. Mazinani, and M. R. Yeganegi, "Text Mining in Big Data Analytics," Big Data and Cognitive Computing, vol. 4, no. 1, p. 1, Jan. 2020, doi: 10.3390/bdcc4010001.

[6] A. K. Kushwaha, A. K. Kar, and Y. K. Dwivedi, "Applications of big data in emerging management disciplines: A literature review using text mining," International Journal of Information Management Data Insights, 1(2), p. 100017, Nov. 2021, doi: 10.1016/j.jjimei.2021.100017.

[7] H. El Bilali and M. S. Allahyari, "Transition towards sustainability in agriculture and food systems: Role of information and communication technologies," Information Processing in Agriculture, 5(4), pp. 456–464, Dec. 2018, doi: 10.1016/j.inpa.2018.06.006.

[8] J. Kumari, E. Kumar, and D. Kumar, "A Structured Analysis to study the Role of Machine Learning and Deep Learning in The Healthcare Sector with Big Data Analytics," Archives of Computational Methods in Engineering, 30(6), pp. 3673–3701, Jul. 2023, doi: 10.1007/s11831-023-09915-y.

[9] M. Seyedan and F. Mafakheri, "Predictive big data analytics for supply chain demand forecasting: methods, applications, and research opportunities," J Big Data, 7(1), p. 53, Dec. 2020, doi: 10.1186/s40537-020-00329-2.

[10] N. N. Misra, Y. Dixit, A. Al-Mallahi, M. S. Bhullar, R. Upadhyay, and A. Martynenko, "IoT, Big Data, and Artificial Intelligence in Agriculture and Food Industry," IEEE Internet Things J9(9), pp. 6305–6324, May 2022, doi: 10.1109/JIOT.2020.2998584.

[11] Y. Niu, L. Ying, J. Yang, M. Bao, and C. B. Sivaparthipan, “Organizational business intelligence and decision making using big data analytics,” Inf Process Manag, 58(6), p. 102725, Nov. 2021, doi: 10.1016/j.ipm.2021.102725.

[12] A. Majeed et al., “A big data-driven framework for sustainable and smart additive manufacturing,” Robot Comput Integr Manuf, 67, p. 102026, Feb. 2021, doi: 10.1016/j.rcim.2020.102026.

[13] I. A. R. Moghrabi, S. A. Bhat, P. Szczuko, R. A. AlKhaled, and M. A. Dar, “Digital Transformation and Its Influence on Sustainable Manufacturing and Business Practices,” Sustainability, 15(4), p. 3010, Feb. 2023, doi: 10.3390/su15043010.

[14] F. Lucivero, “Big Data, Big Waste? A Reflection on the Environmental Sustainability of Big Data Initiatives,” Sci Eng Ethics, 26(2), pp. 1009–1030, Apr. 2020, doi: 10.1007/s11948-019-00171-7.

[15] A. Kamilaris, A. Kartakoullis, and F. X. Prenafeta-Boldú, “A review on the practice of big data analysis in agriculture,” Comput Electron Agric, 143, pp. 23–37, Dec. 2017, doi: 10.1016/j.compag.2017.09.037.

[16] E. Papargyropoulou, R. Lozano, J. K. Steinberger, N. Wright, and Z. bin Ujang, “The food waste hierarchy as a framework for the management of food surplus and food waste,” J Clean Prod, 76, pp. 106–115, Aug. 2014, doi: 10.1016/j.jclepro.2014.04.020.

[17] F. Ciccullo, R. Cagliano, G. Bartezzaghi, and A. Perego, “Implementing the circular economy paradigm in the agri-food supply chain: The role of food waste prevention technologies,” Resour Conserv Recycl, 164, p. 105114, Jan. 2021, doi: 10.1016/j.resconrec.2020.105114.

[18] T. Anagnostopoulos et al., “Challenges and Opportunities of Waste Management in IoT-Enabled Smart Cities: A Survey,” IEEE Transactions on Sustainable Computing, 2(3), pp. 275–289, Jul. 2017, doi: 10.1109/TSUSC.2017.2691049.

[19] M. Farooq, J. Cheng, N. U. Khan, R. A. Saufi, N. Kanwal, and H. A. Bazkiaei, “Sustainable Waste Management Companies with Innovative Smart Solutions: A Systematic Review and Conceptual Model,” Sustainability, 14(20), p. 13146, Oct. 2022, doi: 10.3390/su142013146.

[20] E. Park, A. del Pobil, and S. Kwon, “The Role of Internet of Things (IoT) in Smart Cities: Technology Roadmap-oriented Approaches,” Sustainability, 10(5), p. 1388, May 2018, doi: 10.3390/su10051388.