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DATA ENVELOPMENT ANALYSIS APPLIED TO SOLID WASTE MANAGEMENT IN THE 21ST CENTURY: A BIBLIOMETRIC ANALYSIS

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Abstract

The increase in solid waste generation and the necessity for more efficient management are issues of modern society. Nonetheless, its multifactorial nature makes this problem complex and searching for solutions not simple. In this way, this type of study requires tools that allow simultaneous incorporation of multiple variables. Data Envelopment Analysis (DEA) is a multivariate and non-parametric technique that analyzes a unit's efficiency by comparison. The bibliography indicates that this technique applied to solid waste management systems is already a reality. However, there has been no bibliometric reports on current and future research trends about the theme. Thus, this paper aims to fill this gap through a bibliometric analysis, using the literature from the Scopus database, considering articles from journals and conferences published until February 2022. The results indicate that this topic research began in the 21st century, with an expressive rise since 2016, highlighting the topic's relevance and potential for future research application. In addition, China, Spain, Italy, and the USA are the most productive countries, but cooperation is still weak. Hence, there is a potential to disseminate this research field and promote greater interinstitutional cooperation. Moreover, the findings reveal that DEA is an adequate tool to analyze solid waste management systems. Lastly, this study offers some future research suggestions, based on the results obtained through the bibliometric analysis.

Keywords: bibliometric analysis, data envelopment analysis, solid waste, waste management.

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Introduction

The search for maximizing the efficiency of engineering systems is a modern problem, especially when considering the lower availability of resources and the increase in society's demands. Thus, the concept of efficiency must be understood, which in the simplest case is defined by the ratio between outputs and inputs (Boussofiane *et al.*, 1991). However, to portray the reality we must incorporate as many relevant factors as possible simultaneously.

Data Envelopment Analysis (DEA) is a multifactorial, non-parametric, and deterministic technique. For this reason, it is adequate to resolve this type of problem. DEA analyzes each production unit's efficiencies by comparing them with other units of the set evaluated (Araújo, 2017). The tool was introduced by Charnes, Cooper, and Rhodes in 1978 (CCR model), and an extension of the model was developed by Banker, Charnes, and Cooper in 1984 (BCC model). The difference between these models is the return to scale of the outputs. The CCR model considers a constant return, meaning that the increase in outputs will be proportional to the increase in inputs (COOPER *et al.*, 2011). Meanwhile, the BCC model considers variable returns in scale. Zhou *et al*. (2018) list the diversity of models and applications of this technique, such as studies focused on industry, energy, transport, logistics, and agriculture problems.

As Pereira and Marques (2022) pointed out, seeking more sustainable management of water and sanitation for all is an admirable Sustainable Development Goal. In the solid waste management (SWM) case, data points to the current critical context with projections that are not positive if there is no behavioral change in society (Kaza *et al.*, 2018; Kaza *et al.*, 2021). In this way, DEA is considered relevant since sustainable SWM encompasses society's different sector and depends on combination of factors and individual parameters such as technology, service users, institutional units, governance and strategic policy framework (Iyamu *et al.*, 2020). Several studies have already illustrated the feasibility of applying DEA in the SWM field. Yeh (2020) showed the solid waste incineration plants' efficiency, aiming to analyze the revenue generated by electricity sale in Taiwan. Arsu and Umarusman (2020) applied the technique to verify the efficiency of 14 sorting and collection units for recyclable packaging in Turkey. And Clercq *et al.* (2019) explored the determinants of efficiency on an industrial scale of anaerobic organic waste co-digestion units.

In this way, this article aims to present a portrait of this research area through a bibliometric analysis to answer the following question: what is the article's profile available in Scopus that applied Data Envelopment Analysis on Solid Waste Management? The main contribution of this analysis lies in being a recent research field and still poorly explored by the scientific literature in recent decades. In addition, it will provide a qualitative and quantitative overview and a global notion of hotspots, indicating potential future research directions.

The structure of this paper is as follows. The introduction presents an overview of DEA and its applications in the SWM context. The next section presents the methodology used to select the papers and extract the sample's bibliometric information. The Results and Discussion section first presents authors, year of publication, sources, and countries, followed by a section discussing the content of these papers, as keywords, titles, and theme of the study case (only of the ten more relevant). The last section concludes this paper.

Methodology
Data sources and search strategy
Bibliometric data was collected from the Scopus database on February 10, 2022, covering articles and conference papers without time limitations. The string used for the search was: TITLE-ABS-KEY ("data envelopment analysis" AND "solid waste" OR "waste management") AND (LIMIT-TO (LANGUAGE, "English")), resulting in 150 documents. Citation and bibliographic information were exported as a BIB file for further analysis. It is noteworthy that a step of document content analysis was not carried out, aiming to verify whether such terms were adequate for the search and whether they would be sufficient to direct bibliographic research on the subject.

Bibliometric Analysis
R Studio software (bibliometrix package and biblioshiny interface) is used, it allows visualization of numerical data such as the number of publications per year, the number of authors, most relevant journals, and country scientific production (Aria and Cuccurullo, 2017). Furthermore, the VOSviewer version 1.6.16, developed by the Center for Science and Technology Studies (from Leiden University of the Netherlands), was used for bibliometric mapping, based on the abstracts´ content, authors' keywords, and co-authorship network (Van Eck and Waltman, 2007).

Review of the ten most relevant articles
After identifying the most relevant articles according to the number of citations, their content was analyzed and grouped considering the type of study and theme. These ten papers were compared to each other to identify the similarities between the methodology, data source, and application most used by the authors was verified.

Results and discussion
Evolution of the research on DEA and SWM
The quantitative distribution of publications on DEA and SWM by year reflects the development status, knowledge accumulation, and this field's maturity. Although the initial search did not limit the period of interest, this research area began in 2000, indicating it is a recent field of study.

Thus, Figure 1 shows that the number of publications increases over time, with a growth rate of 6.82% per year between 2000 and 2022. In the first decade, the number of publications increased slightly and fluctuated, representing 14% of the entire sample. Therefore, 2010 can be regarded as a crucial year in the efficiency analysis of SWM through the DEA technique. Since 2011, 129 papers were published, 83 out of which between 2017 and 2021. This research domain has been on focus since the past decade, and the creation of the Sustainable Development Goals in 2016 (United Nations, 2022) may be responsible for the growth rate after 2017, considering it is based on economic growth, social inclusion, and environmental protection.

Sarkis (2000) made the earliest publication in the collected data, entitled "Comparative analysis of DEA as a discrete alternative multiple criteria decision tool". Despite this article's focus on the tool rather than on the efficiency of SWM per se, it is the third most cited paper in this sample (132 citations). The author concluded that DEA seemed to perform well as a discrete alternative to the Multicriteria Decision Making tool and was necessary to promote more research in this area.
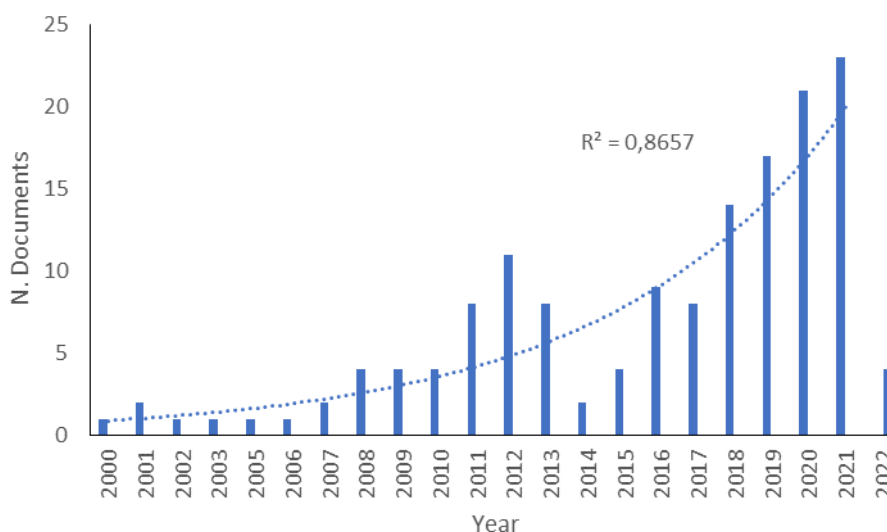
Figure 1. The annual number of research articles on DEA and SWM from 2000 to 2022 (till February), the dashed line is an adjusted exponential function to illustrate the growth tendency of publications from 2000 to 2021.

The data collection was realized considering publications till February 2022, which explains the small number of articles published this year (data for 2022 was not considered during the fit of the exponential curve shown in Figure 1). The fitted curve suggests an exponential increase over the years, expecting 50 publications by 2027. However, the R^2 value, which shows how well a fitted curve represents the data, is not entirely satisfactory because it is

lower than 0.9 (0.8657). It is associated with the small number of publications in 2014 and 2015. The publications' increase in the following years is expected because the concern about environmental quality and the need to promote sustainable SWM increases, considering the growing solid waste generation scenario.

Author Performances

In Table 1, out of the 150 documents, 136 were articles, and 14 were conference papers. Only 18 documents (around 10%) have a single author, demonstrating a network of multi-author publications (n=335) in investigations about the application of DEA in Solid Waste Management studies.

**Table 1.** Quantitative summary of the bibliometric survey.

Text characteristics		Quantity
Document types (150)	Article	136
	Conference Paper	14
Authorship	Single	18
	Multiple	335

Despite the quantity of multi-authored documents, Figure 2, obtained through VOSviewer, by considering the authors with at least three publications, shows a small co-authorship network. The software identified 17 authors, and some of these were not connected or have only one connection. The largest group with connected nodes summed 6 authors. Each node represents an author and the links between them indicate cooperation. The linearity of the largest group shows that there is still low interaction among researchers, most of whom have recent publications. It highlights the potential to spread this network, developing studies with more heterogeneous solutions and interpretations. It would also contribute to increasing technical-scientific knowledge through information sharing, which is one of the objectives of scientific cooperation.

Figure 3 shows the production through the time of the ten most relevant authors in the analyzed sample, according to the number of publications. Except for Sarkis, the other most relevant authors began to publish articles after 2009, and the majority after 2010. It strengthens the previous result and the hypothesis that the subject under analysis is recent, relevant, and has potential for future research. In this way, the results demonstrate that the research field is still limited to a small group of researchers, showing the need for more research with a preference for cooperation among researchers.
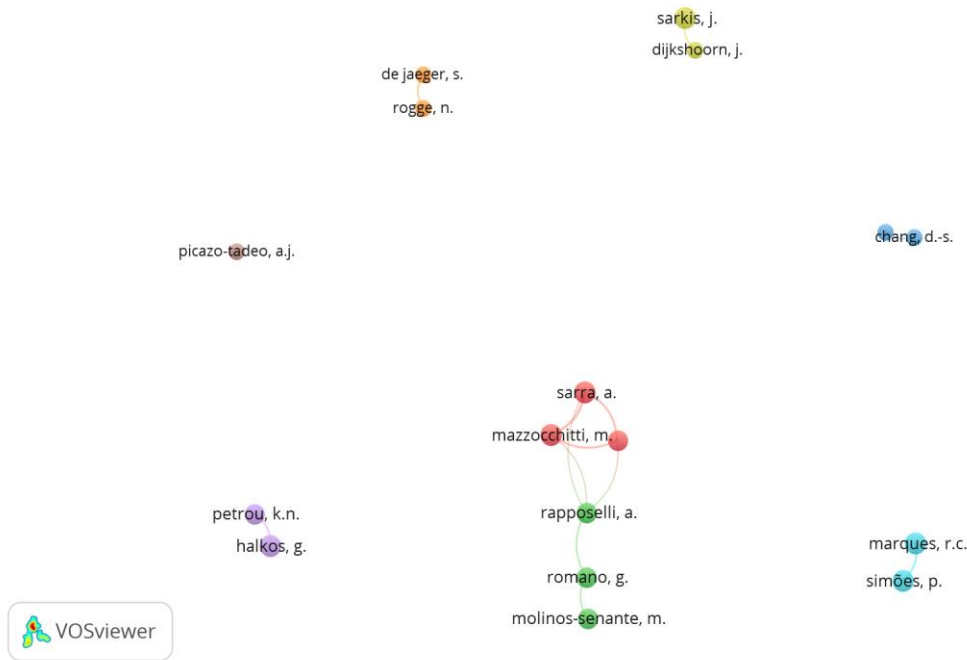
Figure 2. Co-authorship network (minimum 3 articles per author – VOSviewer).
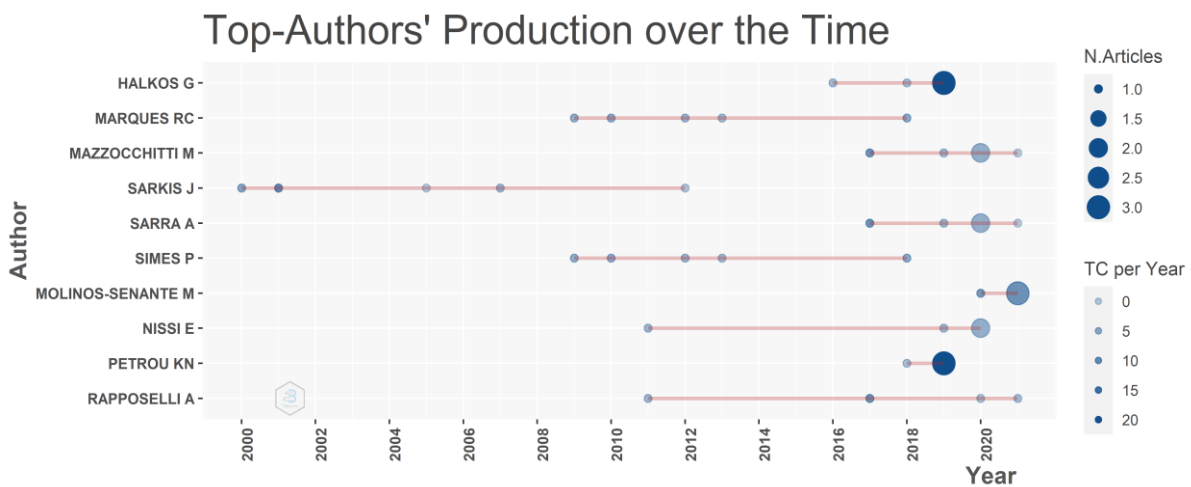

Figure 3. Top ten authors' production over time (biblioshiny).

The four top authors published five articles each. Marques R. C. also had the highest H-index score, indicating that he was an outstanding researcher focusing on the DEA applied to SWM. Despite Romano, G. not being among the top ten authors, she had the highest number of citations (48 citations and four articles published in the past two years). It allows us to infer that the subject studied by Romano has received attention from other researchers. Based on the title of her articles, she focuses on recent concepts, such as eco-efficiency and circular economy.

Sources and countries

Figure 4 shows the list of ten journals with more publications on the subject. The first four journals published almost 30% of the papers in the data, and the "Waste Management" journal published more than 10%. This journal focuses on research that discusses solid waste management solutions, being indexed in 22 international databases and with an increasing impact factor in the last decade. In addition, it is noteworthy that the first three journals represent around 25% of publications (38 articles) and have a high impact factor, ranking among the top 30 journals on Environmental Sciences in the World. They are indexed to several international databases, such as ScienceDirect, Web of Science, Scopus, and INSPEC, facilitating access and citation by researchers across the planet. We highlight that all top five journals' publications were dated after 2010, suggesting a current relevance of the theme.
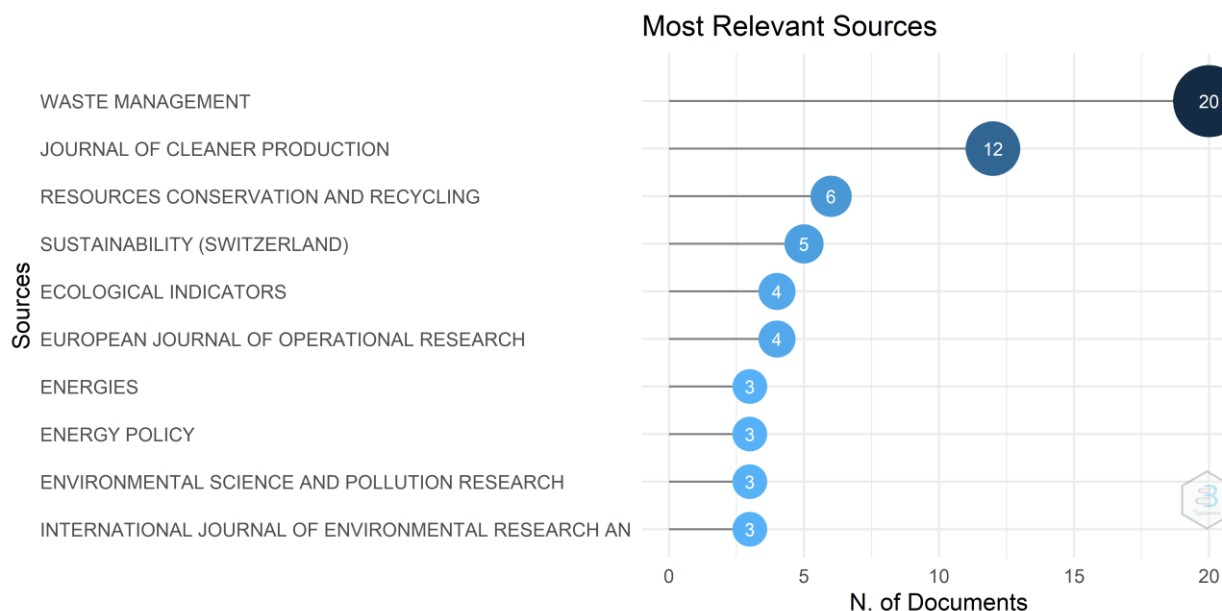
Figure 4. Most relevant sources according to the number of publications (biblioshiny).

A subject analysis of the journals (obtained directly from Scopus) indicates that DEA and SWM are not only in environmental sciences and engineering but also in studies of economics, management, business, marketing, energy, social sciences, decision sciences, and computer science, among others. For this reason, the interdisciplinarity of articles studying Solid Waste Management with Data Envelopment Analysis was identified.

Table 2 and Figure 5 show that the leader with expressive production on the subject is China (101). In sequence, there are Spain (29), Italy (27), the United States (18), and Iran (16). China has significantly increased the number of its publications because of its economic development and higher insertion in the international economy. In this case, China's production is associated with its more developed waste management system compared to other nations, like Brazil (10th in this rank). In Brazil, there is a scenario of financial and operational challenges related to an increase in separate collection, recycling, and environmentally appropriate waste disposal (BRASIL, 2021), summed to issues associated with the application of the national policy itself.

Even though China is the most productive country, it must be mentioned that there is no Chinese author among the top ten most relevant authors. Their countries are Italy (4), Greece (2), Portugal (2), the USA (1), and Chile (1). The top ten countries contributed to 71.33% (107 articles) of the total publications. Among them, China published the most articles, 23.33% (35). Furthermore, the USA is the most cited country (1435), representing more than double China's citations (695).

Table 2. Frequency of author's publications per country.

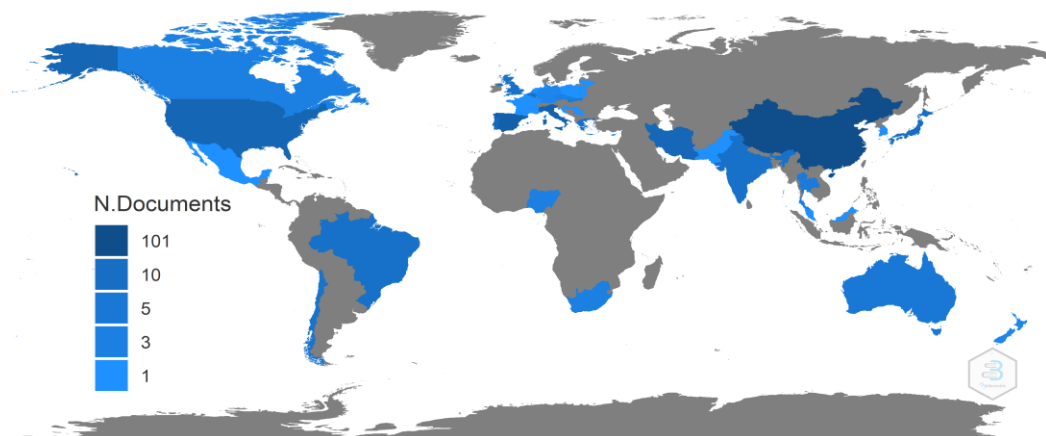| Country	Frequency
China	101
Spain	29
Italy	27
USA	18
Iran	16
Portugal	14
Japan	11
Greece	9
Belgium	8
Brazil	8

Country Scientific Production

Figure 5. Map of country scientific production (biblioshiny).

Most relevant words, keywords, and abstracts contents

Regarding the ten keywords used by the authors, Figure 6 shows the most relevant ones: "Data Envelopment Analysis", "efficiency", and "waste management", whose occurrences are related to the descriptors used in the Scopus platform to collect the documents. In addition, they show that data envelopment analysis has been used in the study of waste management at different scales, on aspects related to waste management, efficiency, eco-efficiency, and circular economy. The word "China" appeared because it was the study area of 27 out of 150 articles surveyed.

Figure 7 presents the keywords with occurrences equal to or higher than 10. It identifies the predominant terms that determine the central theme of this set of documents. The node size indicates that the main words were "efficiency", "waste management", and "data envelopment analysis", belonging to the same cluster (red color in the Figure). It suggests that studies focus on analyzing SWM efficiency by applying the DEA tool, which is this bibliometric analysis in scope, which is relevant. The municipal solid waste and efficiency measurement nodes are highlighted because they are the biggest ones in blue and green clusters.

The distance between the nodes indicates the strength of the word's relationship: the closer the nodes are to the three most used keywords, the stronger the relationship among them. For example, the blue cluster shows that "incineration" is less explored in the literature than "recycling". Figure 7 also shows that the red cluster is more related to efficiency, the blue represents solid waste treatments or destinations, and the green incorporates study cases. In this way, Figure 7 indicates that DEA applied in waste management to analyze efficiency is a hotspot of this research area, until the present.
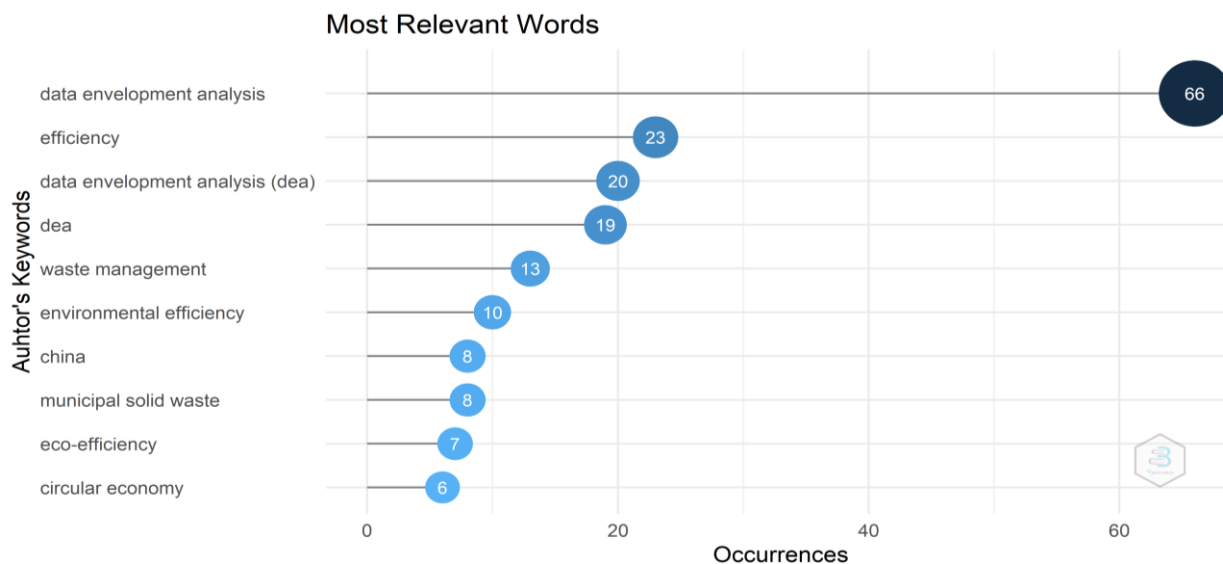
Figure 6. Most relevant author's keywords (biblioshiny).
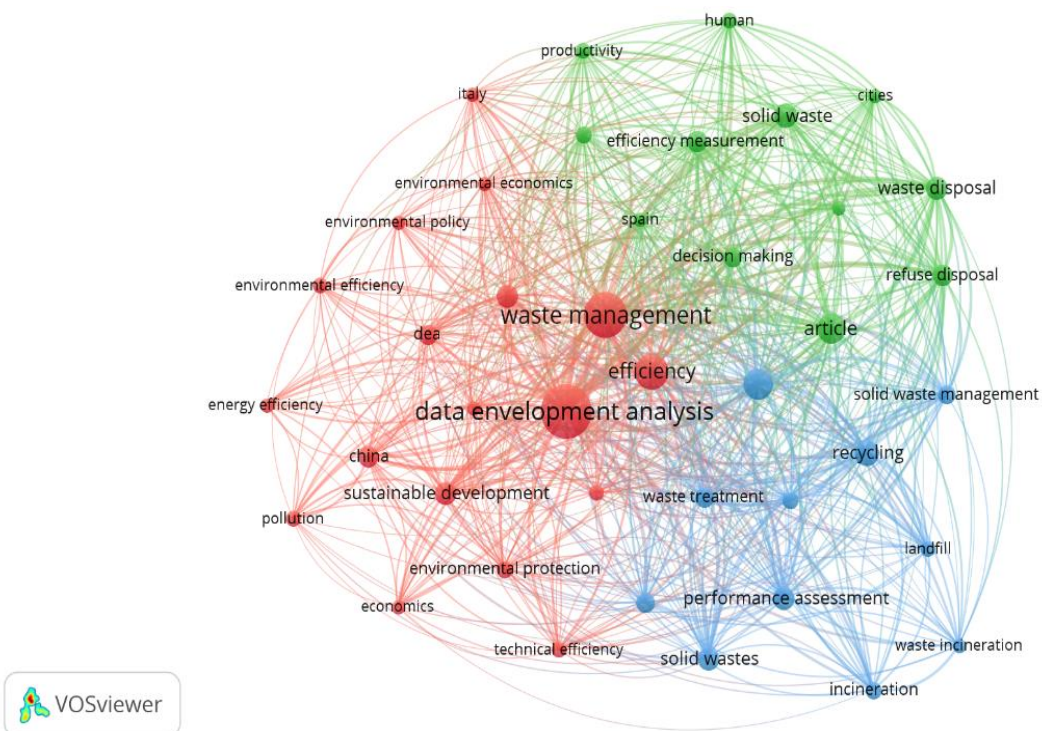

Figure 7. Author's keywords co-occurence network (VOSviewer).

Finally, the content of the abstracts was analyzed using the VOSviewer software. The criteria were a minimum word occurrence equal to or greater than 20. In Figure 8, 2015 is the time series' first year, in which studies sought a better quality of the model's input and output data. Over the years, the topic began to be analyzed through case studies (cities, regions, and countries), focusing on measuring efficiency and improving solid waste management. More recently, studies related to eco-efficiency and municipal scale began to emerge. Regarding the size of the nodes, "efficiency", "management", and "municipality" are identified as the most used terms, which was the same result obtained previously regarding the authors' keywords.

As pointed out at the beginning of this article, the search for maximizing the efficiency of engineering systems is a modern problem. For this reason, estimating efficiency to improve it is considered a relevant type of study, justifying the node size for this word in Figure 8. Even though this result presents a modern term (eco-efficiency), it is a potential study field to promote research aiming at preventive solutions and with a more holistic point of view.
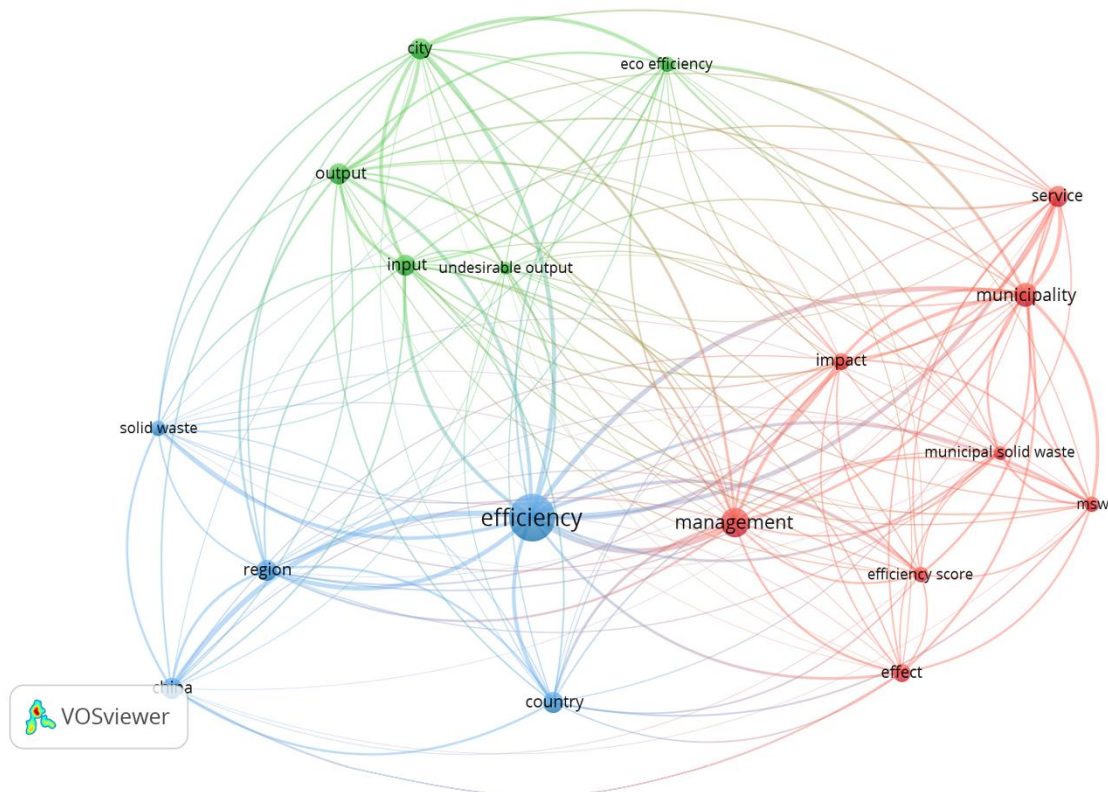
Figure 8. Main terms observed on abstracts' content analysis (VOSviewer).

Most Relevant Articles

Among the 150 articles, Table 3 presents the ten most relevant or most cited. The articles are organized in descending order of relevance, i.e., proportional to the number of citations. These ten papers will be detailed later according to the theme that each group studied.

Table 3. Top ten most cited articles grouped according to their subject. Font: Scopus.

Authors	Title	Year of publication	Number of citations	Group
Seiford L.M.; Zhu J.	Modeling undesirable factors in efficiency evaluation	2002	938	1
Sarkis J.; Cordeiro J.J.	An empirical evaluation of environmental efficiencies and firm performance: pollution prevention versus end-of-pipe practice	2001	224	2
Sarkis J.; Cordeiro J.J.	Comparative analysis of dea as a discrete alternative multiple criteria decision tool	2000	132	1
Worthington A.C.; Dollery B.E.	Measuring efficiency in local government: an analysis of new south wales municipalities' domestic waste management function	2001	89	3
Hernndez-Sancho F.; Sala-Garrido R.	Technical efficiency and cost analysis in wastewater treatment processes: a dea approach	2009	83	2
Rogge N.; Jaeger S.	Evaluating the efficiency of municipalities in collecting and processing municipal solid waste: a shared input dea-model	2012	74	1
Rogge N.; Jaeger S.	Measuring and explaining the cost efficiency of municipal solid waste collection and processing services	2013	73	1
Simões P.; Witte K.; Marques R.C.	Regulatory structures and operational environment in the portuguese waste sector	2010	64	3
Halkos G.; Petrou K.N.	Assessing 28 eu member states' environmental efficiency in national waste generation with dea	2019	62	3
Marques R.C.; Simões P.	Incentive regulation and performance measurement of the portuguese solid waste management services	2009	61	3

Review of the most relevant papers

The proposed groups for discussing the contents of the articles were:
1. Articles focused on tool modeling and analysis.
2. Articles whose application of the DEA focused on topics outside the desired (management and management of solid waste).
3. Articles that evaluated the efficiency of solid waste management through the DEA tool.

Group 1, composed of four articles, presented research dedicated to the improvement of DEA models for decision making (Sarkis, 2000), the analysis of inputs to improve productive performance (Seiford and Zhu, 2002), and the evaluation of the efficiency of processes and costs (Rogge and Jaeger, 2012; Rogge and Jaeger, 2013).

All authors used secondary data, i.e., which was already analyzed by other researchers. Sarkis (2000) compared models obtained by DEA with models from Methods of Multicriteria Decision Support (MMDS). The author compared his results with Hokkanen and Salminen (1997), who analyzed the best location of a solid waste treatment facility in Oulu (Finland). He demonstrated that the main advantage of DEA models is the need to use less information from decision-makers to order the location alternatives.

Seiford and Zhu (2002) applied their method to paper mills, and the results were compared to the Färe *et al.* (1989), which had the same application and allowed the comparison of the results and supported their discussion about the new method of DEA proposed by Seiford and Zhu (2002). To improve the BCC model, they equalized the inputs and outputs through a DEA model that enabled the fulfillment of the proposed objective. The authors proposed a modification in the productive performance of paper to increase the desirable/good outputs (paper production) and reduce the undesirable/bad ones (ex: atmospheric pollutants).

Rogge and Jaeger (2012) and Rogge and Jaeger (2013) used the same input data to analyze municipal efficiency. It concerned the costs of collecting and processing municipal solid waste in the Flanders region (Belgium) in 2008. The first used costs as input and developed a DEA model with shared input. Meanwhile, Rogge and Jaeger (2013) demonstrated their application robustness considering new output data, such as geographic, demographic, and economic characteristics. Thus, both studies revealed that the municipalities of Flanders are, in general, inefficient in services for the collection and processing of their different portions of solid waste.

Group 2 comprises Sarkis and Cordeiro (2001) and Hernández-Sancho and Sala-Garrido (2009). In the first one, the authors compared the short-term financial performance between pollution

prevention and the application of "end-of-pipe" solutions by 482 North American companies in 1992. Hernández-Sancho and Sala-Garrido (2009) applied the DEA to analyze the efficiency of 338 sewage treatment plants in Valencia (Spain).

Sarkis and Cordeiro (2001) used two models, one for the prevention strategy and the other for the end-of-pipe. It demonstrated its negative correlation with the return on sales of companies, which is higher and more significant for those that adopted pollution prevention. However, they point out that the results do not necessarily indicate that environmentally proactive companies lose money in the long term, as their work is focused only on short-term assessment. They showed that the smaller the size of the stations, the lower their operational efficiency (therefore, there are improvements in scale), noting that maintenance costs and sewage sludge treatment are the factors that most influence efficiency. In addition, they ratify the usefulness and relevance of the DEA as a tool for sanitary sewage sector study.

Finally, group 3 indicates that the DEA technique applied to evaluate solid waste management efficiency is relevant and is not a brand-new study field, with articles from 2001, 2009, 2010, and 2019. Thus, a certain homogeneity regarding the orientation adopted for the technique application is observed. Most authors applied DEA with input orientation, arguing that local governments have more control over input variables, which relate to economic and financial factors (Worthington and Doller, 2001). In Portugal, all the operators must serve all the urban solid waste user and there is a demand minimization policy for this service (Simões *et al.*, 2010; Marques and Simões, 2009). Nonetheless, an output orientation appears acceptable once it is wanted to improve the service quality and provision, as determined in Brazil's National Solid Waste Policy.

Only Halkos and Petrou (2019) applied the tool with output orientation but did not present the justification for such a methodological choice. The case study aimed to analyze the efficiency of solid waste management in 28 European Union member countries, contrasting this result with the recycling rate and considering treatment options in search of the transition to the circular economy. Thus, it is inadequate to use an output-oriented technique once the objective is to maximize outputs without increasing inputs, with the output variables adopted: GDP, waste generation in tons, and atmospheric emissions (NOx, Sox, and GHG). In other words, from an environmental and circular economy point of view, as proposed by the authors, increasing the mass generated by waste and emissions is not coherent.

One of the common factors among the four articles is a complementary analysis beyond the results generated by the DEA. For example, Simões *et al*. (2010) and Halkos and Petrou (2019) applied the bootstrapping technique to the efficiencies obtained, intending to estimate the bias of the efficiencies and make statistical inferences about the DEA results. Another analysis

identified was the use of linear regression to identify relationships between the efficiencies and characteristics of the operational environments of each case study. All authors performed this last analysis, except Halkos and Petrou (2019). Figure 9 summarizes the methodology used by the four articles in group 3, highlighting that the study developed by Halkos and Petrou (2019) is the most divergent of the group.

This complementary analysis is also applied by other studies that were not listed in Table 3, suggesting that, despite the DEA being an adequate tool to support decision makers, there are other ways to improve the analysis and obtain better results. For example, Pereira *et al.* (2020) proposed a cutting-edge and original approach with an additive DEA model that considers criteria interactivity, determining their weights and decision-makers preference incorporation through an inference methodology by using the Choquet multiple criteria preference aggregation model.

Another similarity between the four papers of group 3 is the use of secondary data. The advantage is the facility to obtain data about a municipality or a country that is also official. Since the quality of this information and how it was collected is not controlled by the researchers, it can be a false reality portrait. This limitation is the case of Brazil, where the main source to obtain SWM data - the Sanitation National Information System - presents various missing data. Moreover, it can be unreliable because the municipalities' governments are responsible for data inclusion, and there is no one data verification procedure. However, there are solutions to this problem, as proposed by Pereira *et al.* (2021), by using the Monte Carlo simulation method.
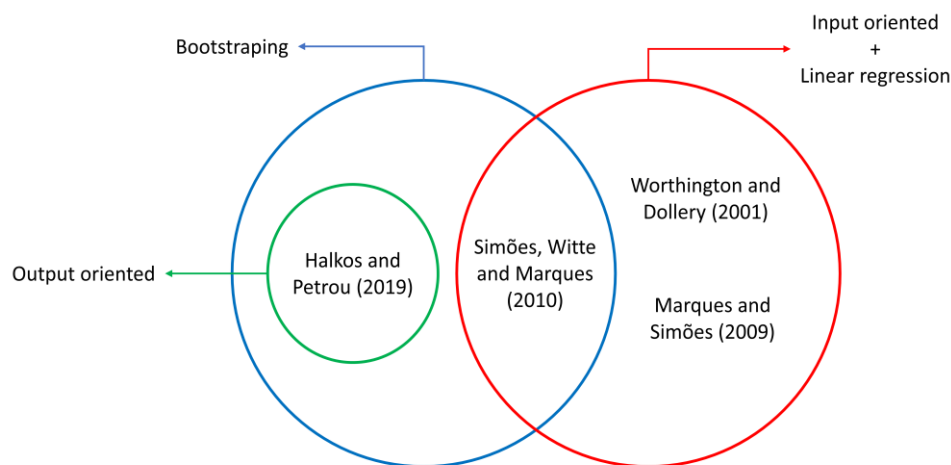
Figure 9. Summary of Group 3 Articles, according to the model orientation and complementary analysis.

Simões *et al*. (2010) and Marques and Simões (2009) are similar in the study area, data source, and methodology applied. The first paper aimed to identify the influence of operating environment factors on Portugal's waste management efficiency. Meanwhile, the second associated the performance with the country's regulatory model. Both articles presented the exact cost reduction estimate if the units operated efficiently. Interestingly, the savings in 2005 would almost double in 2007, considering the constant return to scale model. It collaborates with Halkos and Petrous (2019), who do not recommend comparing efficiencies obtained in different contexts or instants.

Halkos and Petrous (2019) are highlighted for bringing a more modern view of the problem and its solution. The authors considered circular economy premises, aiming for prevention actions. In addition, they include atmospheric emissions data, which is relevant to facing global warming and to the need for measures to control this scenario. There is a clear and urgent need to find ways to measure and improve environmental systems' efficiency, such as sanitation in general and specifically waste management. Mostly after World Bank reports publications (Kaza *et al.*, 2018; Kaza *et al.*, 2021), that presented alarming future scenarios if population's behaviors do not change, compromising the premise of sustainable development in guaranteeing the environmental quality to future generations.

Finally, the conclusion made by Worthington and Dollery (2001) was extremely important for the area, as they found it possible to build a uniform structure to measure the efficiency of local public services using the tool in the beginning of the century. Considering the sample of this study, other researchers were able to explore this area according to these authors' conclusions, suggesting improvements in methodology and waste management.

In this way, this paper allows the identification that the use of the DEA technique to evaluate the inefficiency reasons and suggest preventive actions, such as reducing generations or applying principles of circular economy, is a potential study field. Furthermore, there is a need to incorporate social aspects because an effective SWM system results in better environmental and health quality, more employment and income generation, and social inclusion. In addition, developing studies considering public policies are also suggested, integrating different society's sectors aiming at the sustainable development goals, as pointed out by Pereira and Marques (2022) for water and sanitation systems in Brazilian municipalities.

Conclusion

The main objective of the studies using DEA is to improve the efficiency of solid waste management seeking benefits for the environment and minimizing impacts resulting from the failure of efficiency. With the imposition of solid waste valorization, both by legal requirements and by economic (resources optimization) and market (image, responsibilities) imperatives, the need to improve its management will be greater.

The bibliometric results show that the number of studies on this topic has increased recently, and the subject is current and relevant. It gained notoriety in scientific production, given its importance in searching for better solid waste management scenarios. Therefore, this field of research is recent, with the first document surveyed dated 2000, with an accelerated increase in publications over time. The most relevant articles show that this tool is adequate to estimate solid waste management efficiencies and that DEA is a consolidated model. However, it is possible to improve the tool, as observed in the Group 3 review, which indicated the importance of complementary analysis to the DEA, such as bootstrapping or linear regression techniques.

However, there is potential to disseminate the studies around the world since a few regions of the map concentrate the scientific production, such as Asia and North America. Furthermore, despite the predominance of multi-author articles, insufficient global cooperation is observed, with few connections and too linear. The potential to promote cooperation between different authors and institutions aiming for science development is identified.

Through bibliometric and content analysis, the following research hotspots were identified: (1) to analyze SWM efficiencies aiming to propose preventive measures, (2) to incorporate social aspects, and (3) to integrate different society's sectors aiming the sustainable development goals. Finally, the main limitation of this paper is the search restriction to only one indexing base. For future research it is recommended to expand the consulted databases; to detail the content analysis of all articles and not just the most relevant ones; to identify which DEA model (BCC or CCR), guidance (input or output), and complementary analysis are mostly applied to the DEA technique when it comes to solid waste management ones; and consider more specific descriptors, or even that is only in the title, to avoid the appearance of papers that do not integrate the desired study theme.

Acknowledgement

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