Pol. J. Environ. Stud. Vol. 34, No. 1 (2025), 563-571
DOI: *10.15244/pjoes/186580* ONLINE PUBLICATION DATE: 2024-07-10

Review

Waste Transportation Environmental Impact Using Life Cycle Assessment: Bibliometric Analysis and Systematic Review

Hessy Rahma Wati[1], Mochamad Arief Budihardjo[2*], Pertiwi Andarani[2]

[1]Master of Environmental Engineering, Diponegoro University, Semarang, Indonesia 50275
[2]Department of Environmental Engineering, Diponegoro University, Semarang City 50275, Indonesia

Received: 6 November 2023
Accepted: 27 March 2024

Abstract

The transportation stage contributes to greenhouse gas (GHG) emissions, which vary according to collection type and transportation system. The aim of this research is to identify the environmental impact of waste transportation vehicles using various fuels by reviewing the literature in various countries. This study also examines striking research trends and themes, critical elements, and evolution to provide future study direction. The Bibliometric method uses research trends and in-depth content analysis to identify the relevant and most influential articles. This study compares waste transportation using diesel fuel, compressed natural gas, biomethane, and pneumatic collection, finding that vehicles using diesel fuel had the highest environmental impact compared to others. Replacing diesel fueled vehicles with CNG fueled vehicles can minimize GHG emissions. Meanwhile, seen from a renewable electricity perspective, stationary pneumatic collection is a positive step towards more sustainable and environmentally friendly transportation and waste management.

Keywords: life cycle assessment, waste collection vehicles, vehicles emission inventory, carbon emission

Introduction

The increase in the world's population is driving greater rates of food and product consumption related to waste production, which has an impact on the environment and may endanger a sustainable future [1]. Therefore, many climate agreements are internationally agreed upon as a source of sustainable development to the strategies of developed and developing countries, where greenhouse gas emissions are considered the main cause of environmental degradation today [2]. The increase in world population can exert significant pressure on local governments because of increased waste generation [3, 4]. Solid waste management can be divided into two parts: collection and processing [5]. The transportation stage contributes to GHG emissions, which vary according to the collection type and transportation system (pneumatic or conventional systems using trucks), as well as the most expensive aspect due to the large number of trucks used [6-9]. The fuel used by garbage collection vehicles significantly influences their CF and urban air quality. CNG fuel-powered vehicles, hydraulic hybrid trucks, electric trucks, and others can be a solution

e-mail: m.budihardjo@ft.undip.ac.id

to reduce environmental impacts and operational costs [10].

Waste transportation is a high-cost waste management process and one aspect that influences waste collection and processing effectiveness [11]. Waste transportation activities have a significant impact on urban air quality [12-14]. The type of vehicle used for transporting waste exhibits ecological characteristics. If the environmental burden released during the transportation process is high without proper treatment, it will cause serious environmental problems. A quantitative vehicle environmental impact assessment must consider several factors, namely, internal combustion engine operating conditions, pollutant emissions [15, 16], GHG emissions [17, 18], and vehicle service life after it has been decommissioned [11]. Based on the agreement, GHGs are the main cause of environmental degradation today [2, 19].

A general approach to calculating urban fleet emissions with a life cycle assessment (LCA) was conducted to understand the carbon emissions generated during waste transportation [20]. Holistic or comprehensive calculations must be considered in evaluating and assessing environmental impact, vehicle fuel economic effects, and valid vehicle technology use, which makes it possible to obtain a more complete and accurate picture [21]. LCA measures the potential impact of a process or product on the environment by considering its entire life cycle, including the production, distribution, use, and eventual disposal stages [11]. LCA can be used to analyze the potential environmental impacts of cradle-to-grave, cradle-to-gate, raw power-to-plant and gate-to-gate levels [22]. Recently, various fuel energy sources have been discussed using LCA [23-26], including conventional diesel [27, 28], CNG [29, 30], renewable bioenergy [31, 32], and electricity [33]. Currently, there is a need for more effective legislation to promote waste transportation applications, despite overwhelming evidence that alternative energy sources are beneficial for reducing carbon emissions [34]. Therefore, it is crucial to explore mechanisms to incentivize governments and stakeholders regulating MSW disposal to consider waste collection with minimal environmental impact.

This article reviews the environmental impacts in the form of GHG emissions from the use of fuel in waste transportation vehicles as well as its trends, prominent research themes, critical elements, evolution, and in-depth study content. Bibliometric analysis is a combination of statistical methods and quantitative techniques used to identify a large number of scientific studies and focuses on metrics, including trends and citations [35]. Bibliometric analysis provides information on the status of knowledge development and research trends in the exploration field by analyzing academic literature and can provide a clear picture of the relationships among indicators through different network nodes, allowing access to the importance of each existing node [36]. To the best of our knowledge, only a few comprehensive studies have discussed the environmental impact of waste transportation using a combination of bibliometric and content analyses. Therefore, this research contributes to revealing hotspot identification using co-words, patterns, and structures, as well as in-depth content analysis of relevant and influential articles.

Materials and Methods

This study uses bibliometric analysis combined with an in-depth content analysis of several influential articles to determine scientific development, map the contribution and focus of research, and assist in mapping the best practices and analyses that have been published [37]. Pizzi S. [38] stated that bibliometric combination with a literature review enables the researcher to gain a comprehensive understanding of scientific knowledge evolution in a field while providing in-depth topical analysis through a qualitative systematic review. Content analysis can be used to identify current hotspots through keyword concurrent characteristics, which differs from citation analysis. Network analysis can be conducted using images and relationship visualization to elucidate the relationships between units [36]. The analysis process as represented in Fig.1.

Data Collection and Networking Process

The Scopus database developed by Elsevier was used for data collection. Scopus was chosen because it has broad coverage, provides objective and representative insight into research development, helps reduce analysis bias and omission risks, and supports the reliability and validation of the findings [38]. Data collection focused on articles published over the last 10 years, namely, 2023-2013. The query combination explores article titles, abstracts, and keywords. Before a combination query was performed, exclusion criteria were applied and discussed. First, "TITLE-ABS-KEY (life cycle assessment)": only documents of the type "article" and published in "2013-2023" are used, and 28,660 articles are selected. Second, "TITLE-ABS-KEY (waste transport)": only documents of the type "article" and published in "2013-2023" are used, and 323 articles are selected. Third, "TITLE-ABS-KEY (life cycle assessment AND waste transport)": only documents of the type "article" and published in "2013-2023" are used, and 48 articles are selected. A total of 27 sample articles were represented by several types of bibliographic information, such as keywords, citations, and abstracts, from the Scopus database using the comma-separated value format. Data cleansing is a basic step in advanced bibliometrics and text mining analysis. The obtained data was cleaned using Excel to overcome inconsistencies and errors.

Data Analysis

Bibliometric Analysis

Bibliometric analysis has been increasingly used in various studies, such as end-of-life vehicle reverse logistics [36], the bioethanol life cycle [39], and trends in carbon emissions in the transportation sector [40]. Bibliometric analysis allows researchers to analyze datasets larger than general reviews and construct structural reviews for specific fields [41-43]. In addition, bibliometric analysis provides inclusive relationship visualization between critical elements in future research [37, 44]. After Excel cleaning, the next step was bibliometric analysis using VOSviewer 1.6.17. VOSviewer is software developed to visualize and explore scientific maps by considering keywords [37]. The primary advantage of this software is that it focuses on graphical map representation with a network of links between authors, journals, countries, institutions, and keywords. These graphical maps work when visualizing large maps, are easy to interpret, and are primarily used as maps based on network data.

Content and Co-Occurrence Analysis

Text mining is a method for extracting meaningful information from text in a document collection, which helps simplify and accelerate the process of identifying patterns and valuable findings in the literature [45]. In its widespread application, text mining has been used in many studies to measure text data size, determine ideas through text, and overcome semi- and unstructured data problems [46]. Text mining provides deep insight into the semantic structure and phrase patterns that characterize text in large document sets, which aid in content understanding, identifying trends, and supporting more informed decision-making. [47]. Content analysis is a flexible approach that allows researchers to plunge deeply into texts and gain in-depth insights from the literature or qualitative data [48]. Qualitative content analysis was then performed for each cluster's 5 most influential and relevant articles to investigate the theoretical orientation [47].

Results and Discussion

Bibliometric Mapping Process Analysis

This section presents the indicators used in the analysis (Fig. 2) to provide a direct overview of this study.

Descriptive Publication Evolution Analysis

Based on publication development analysis, waste transportation environmental impact disclosure has been stable over the last 10 years. Fig. 2 shows the trend in research publications related to waste carrier environmental impact from 2013–2023. There was a decline between 2013–2017. In 2018, there was an increase; however, by 2023, there was no significant increase. The number of publications over the last six years was 55.5% of the total publications, indicating that the waste transportation environmental impact disclosure topic will grow in future research. Although the number of publications in 2023 is the same as that in 2022, this trend is still increasing, judging by annual developments. Studies related to this topic will develop

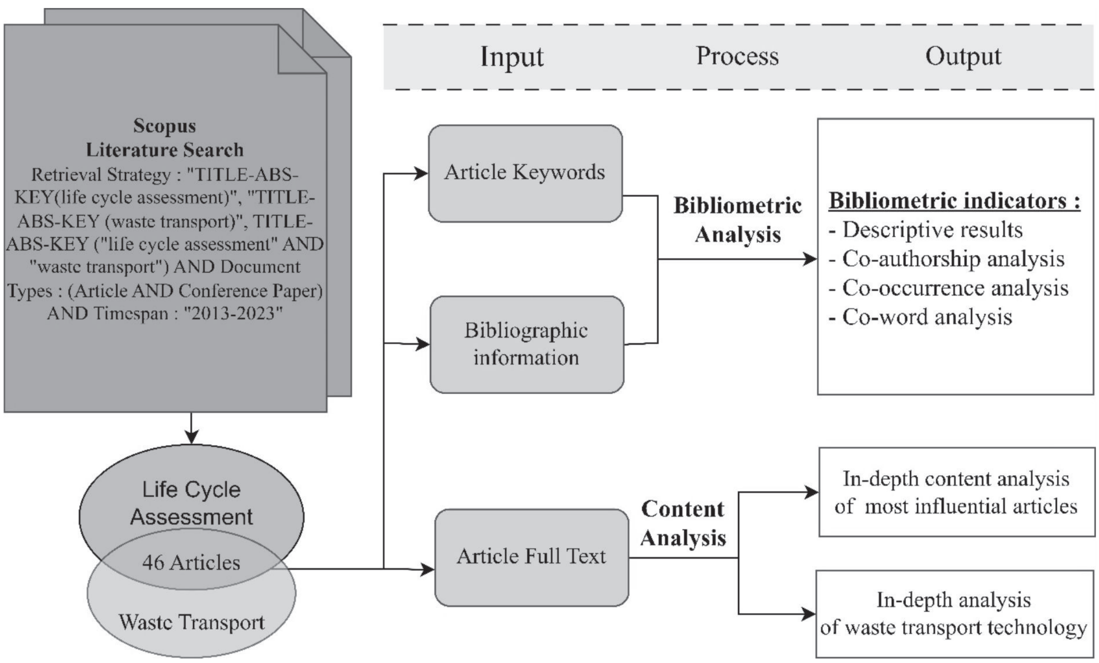

Fig. 1. Analysis process and literature review.

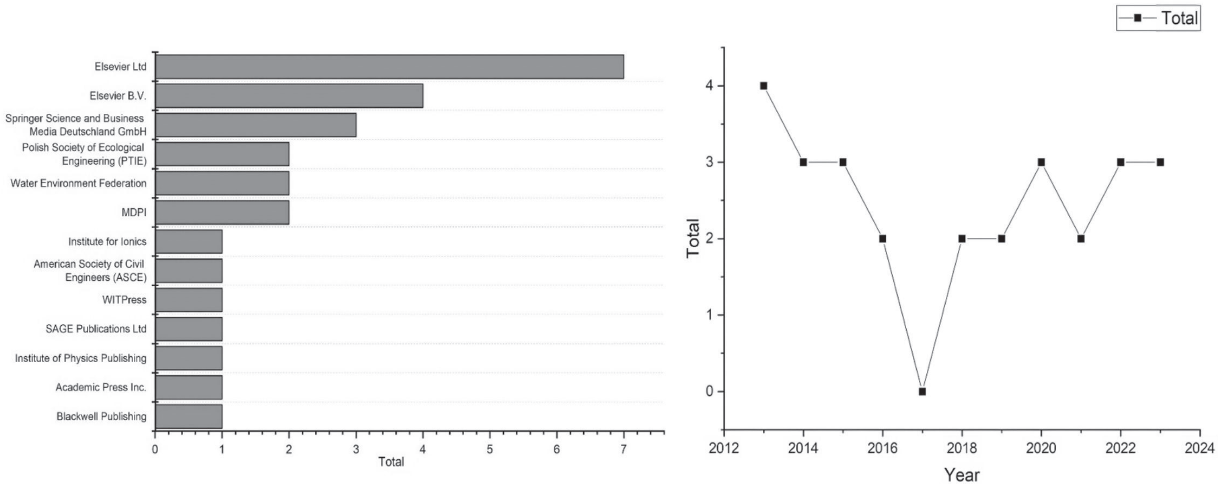

Fig. 2. The number of annual publications between 2013-2023 and the most productive journals on the environmental impact of waste transport disclosure.

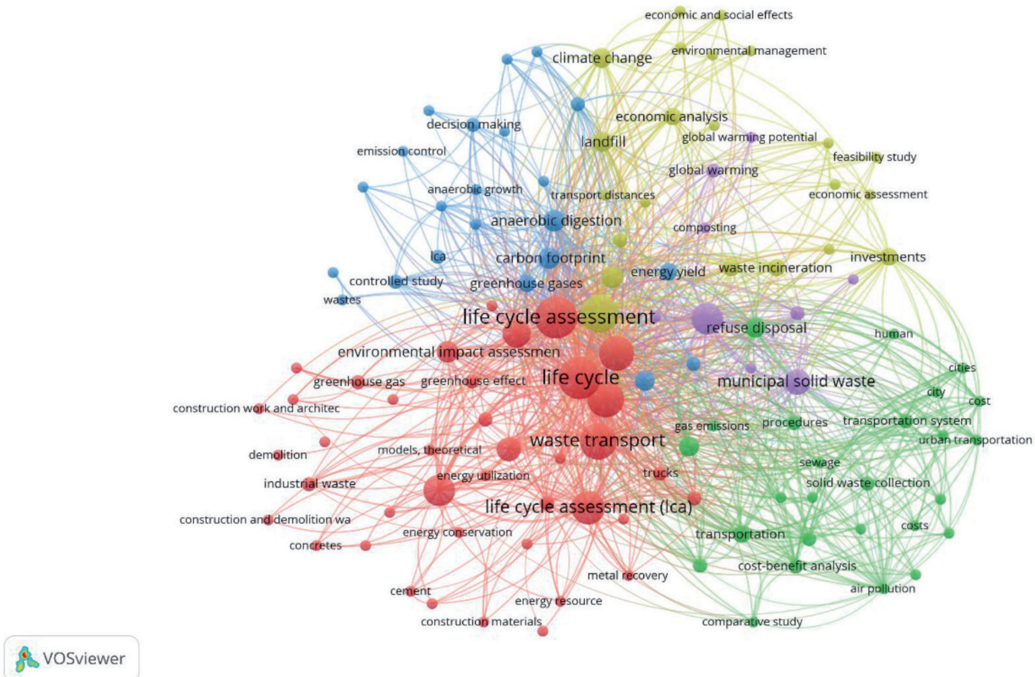

Fig. 3. Keyword co-occurence based on clusters.

and become opportunities for increased research in the coming period, with an increase in environmental impact problems, especially in the transportation sector, and an increase in the number of studies over the previous year.

Fig. 2 shows the 10 most prolific journals disclosing environmental waste transportation impacts. The most prominent journal is Elsevier Ltd., which published 25.9% of the articles. This journal discusses topics related to LCA and transportation waste management. The other two that stand out are Elsevier B.V. (14.81%), which emphasizes research on garbage-collection vehicle CF analysis. Springer Science and Business Media Deutschland GmbH (11.11%) discussed the carbon waste transportation business.

Hotspot Identification Analysis with Co-Words

Keyword analysis can pinpoint the most critical past and current research hotspots [37]. All keywords were included in the 27 selected publications. Four hundred and fifty-six keywords were identified, 101 of which reached the minimum two-occurrence limit. Normalization was performed on several keywords with the same meaning to avoid duplication and provide a more accurate representation of the research topic.

Fig. 3 shows the relationship between the keywords and events related to waste carrier LCAs. The main subcategories included waste transport, life cycle assessment, life cycle analysis, waste management, and life cycle. Waste transportation and management were the most researched areas, and waste transportation was the most common topic. The keywords greenhouse effect, ozone depletion, global warming, and eutrophication dominated the environmental impact subcategory. Among the transportation modes, trucks, transportation routes, traffic, and transport were the most common subtopics. Considering LCA, its relationship to waste transportation was generally used to analyze and measure GHG emissions.

Top Article In-Depth Analysis

Table 1 shows the five relevant and most-cited publication results. The authors compared fuel effectiveness in engines to determine which fuel had the least environmental impact.

The publications compared fuel in waste transportation, three of which compared diesel-fueled transportation vehicles with CNG vehicles. In article 1, Rose L. [21] compared diesel-powered refuse collection vehicles (RCVs) with CNG vehicles [21]. It was found that there were no net energy savings from converting diesel-powered RCVs to CNG-powered RCVs. Although there are no net energy savings from replacing diesel RCVs with CNG RCVs, there are significant reductions in GHG emissions of up to 24% CO_2 eq. In addition, CNG-powered RCVs are more cost-effective for CO_2 reduction. Therefore, CNG-powered RCVs have less impact on climate change and provide significant cost savings compared to diesel-powered RCVs. Rose L. [21] and Perez J. [49] compared diesel-fueled waste transportation vehicles with those using CNG. However, this study included the fuel life cycle (FLC) and vehicle life cycle (VLC). GHG emissions from CNG-fueled vehicles were 18.5% lower than in the diesel scenario, and the CF for the diesel scenario was 29.7 kg CO_2 eq/tMSW. This study showed the same results as those of Rose L. [21]. The third study that compared CNG, diesel, and 30% biodiesel-fueled vehicles was by Lopez J.M. [50]. CNG-fueled vehicles produced the lowest GHG emissions in the TtW analysis and emitted the lowest CO_2 in the well-to-wheel analysis. Peng H. [34] compared electric- and diesel-powered garbage collection vehicles. The results showed a 94.40% carbon emission reduction (CO_2 equivalent) for electric fleets compared to that of diesel fleets and achieved 63.13% cost savings when carbon trading offsets were used.

Chàfer M. [51] stated that a key factor in achieving cleaner production and reducing GHG and other pollutant emissions into the environment is the cleaner energy guarantee. The results showed that energy sources significantly affected LCA results, with up to 80% variation. The use of diesel trucks should be

Table 1. Top journal in-depth analysis.

No	Reference/ Journal	Aim Of The Study	Methods	Conclusion
1	[21] /Energy Policy	Life cycle analysis of CNG use and diesel-powered RCVs.	GHGenius and GREET	GHG emissions and air pollution (GAC) values decreased significantly by around 24%, and there were cost savings in using CNG vehicles. Therefore, the use of CNG RCVs is beneficial in reducing the impact of climate change and is cost-effective compared to diesel RCVs.
2	[49]/ Transportation Research Part D	Estimating the CF of a waste collection fleet considering life cycle stages.	ISO 14040/14044, ISO/TS 14067, carbon footprint standards	Aramad's CF value is 92% from FLC and 85% from VLC. FLC CF comes from TtW, and 14% comes from WtT. The CNG scenario produces 18.5% lower emissions than the diesel scenario.
3	[34]/ Transportation Research Part D	Use of the cap-and-trade system in making strategic decisions on carbon use in the carbon cost life cycle.	GHGenius Vehicles	Overall vehicle value is lower by 63.13% compared to diesel and diesel-CNG hybrid fleets.
4	[50]/ Applied Energy	Comparing two types of engines with three different fuels based on energy consumption and the impact of GHG emissions produced during waste transportation.	Well to Wheel Analysis	CNG-powered waste collection vehicles emit the lowest CO_2 and have the lowest GWP environmental impact. The VTT study compared European CNG buses with average CO_2 emissions of 1,224 g/km for diesel buses and 1,077 g/km for CNG buses.
5	[51]/ Journal of Cleaner Production	Analyze the sensitivity of municipal solid waste collection systems with five different scenarios based on energy sources.	Ecoinvent v.3.0	The energy source has a big influence on the analysis results, up to 80%. Truck collection has the lowest environmental impact due to lower electricity usage. Stationary pneumatic system waste collection shows the best performance.

reconsidered because they have the greatest impact on the environment. In comparison, the lowest emissions were from trucks using CNG fuel. Renewable electricity use in pneumatic waste collection systems is a positive step toward more sustainable and environmentally friendly waste transportation and management.

In previous research, diesel fueled waste transport vehicles were often compared with CNG and pneumatic waste transport vehicles. Based on the ten articles that were analyzed in depth, the majority of articles stated that diesel fueled waste transport vehicles contributed the most to the environmental impact, especially CO_2, which is a contributor to GHG. Several studies show that CNG fueled vehicles are one of the vehicles that have the lowest contribution to environmental impacts. Quiros D.C. [29] states that a net GHG emission reduction of 10-20% can be achieved by CNG vehicles compared to diesel technology. Graham L.A. [52] stated that heavy vehicles fueled by natural gas, whether compressed, liquefied, or mixed with hydrogen, can reduce GHG emissions compared to diesel fuel.

In-Depth Analysis of Waste Transport Technology

Some of the studies analyzed regarding the environmental impact of waste transport did not publish them in a format that allows comparison of results on a per ton (MSW) basis. Table 2 lists and explains the energy involved in the process or segment. The life cycle process in vehicles is divided into three segments, as shown in Fig. 4 [50], namely:

(a) Well-to-Tank (WTT), which takes into account energy use and GHG emissions resulting from the resource recovery process and the delivery of usable fuel to the vehicle tank.

(b) Tank-to-Wheel (TTW), which takes into account energy use and GHG emissions resulting from fuel use in vehicles.

(c) Global Well-to-Wheel (WTW) analysis, which takes into account the energy use of GHG emissions from the resource recovery process to the use of fuel in vehicles.

The scenario analyzed in this research uses the TTW segment, which takes into account GHG emissions produced in the process of using fuel in waste transport vehicles. The environmental impacts compared are based on an analysis of CO_2 emissions, which are the main contributors to GHG emissions and global warming (GWP).

Table 2 shows the comparison results of GHG (CO_2) emissions in the TTW process in several articles analyzed. The results of several studies show that the GHG emission values of diesel-fueled waste transportation vehicles have the highest environmental impact [6, 33, 49]. GHG emissions in CNG are 18.9% lower compared to the diesel scenario [49]. However, emissions from waste collection and transportation are influenced by system boundary conditions and initial assumptions established in a study, as well as local, regional, and national conditions [53-55]. The CNG waste collector has the lowest value of 17.5136 $kgCO_2eq/km$ during use, which means the global environmental impact (greenhouse effect) is lower [50]. Meanwhile, in Iriarte's research, Iriarte A. [56] showed that the mobile pneumatic collection system had the largest environmental impact in several categories, one of which was global warming, with a value of 13.1 kgCO2eq.100 years/FU. And door-to-door systems using diesel vehicles have 38% higher energy requirements than pneumatic mobile systems, but provide higher waste recovery rates. The analysis proves that replacing

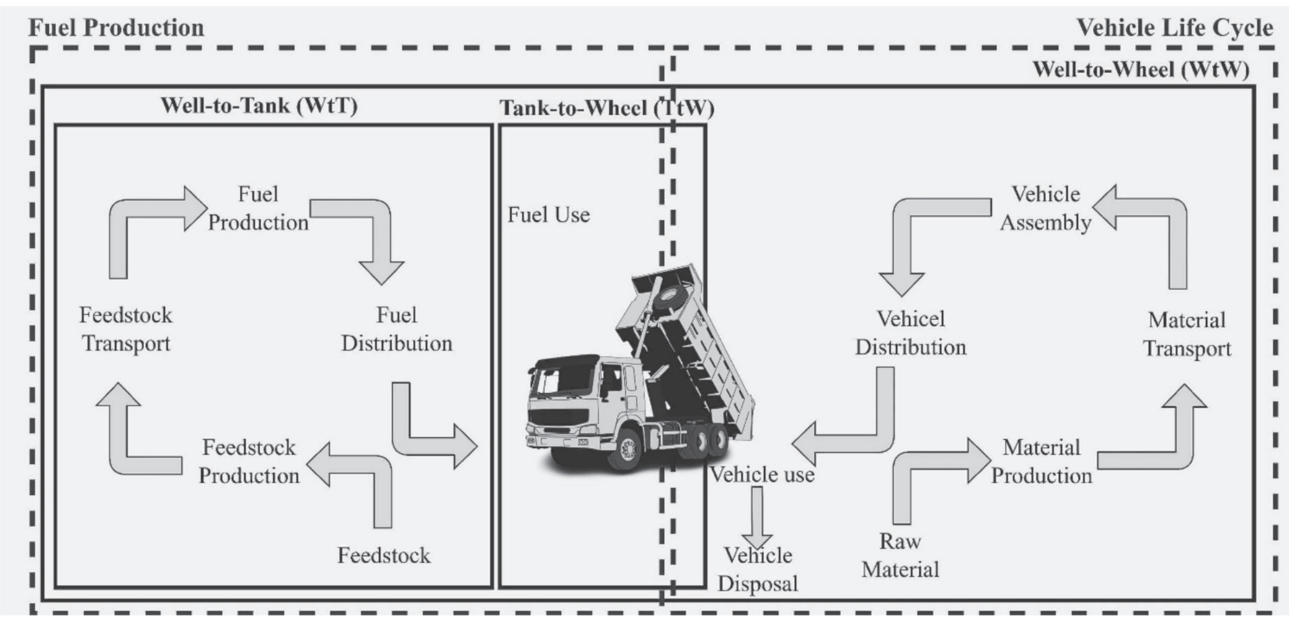

Fig. 4. System boundaries and LC of vehicle technology.

Table 2. Waste transportation environmental impact in-dept analysis.

Unit	Diesel	Biogas	CNG	Pneumatic	Process	Reference
Kg CO_2 eq/t_{MSW}	29.7	20,7	25.1	NA	Tank-to-wheel	[49]
Kg CO_2 eq/km	20.0977	22.982	17.5136	NA	Tank-to-wheel	[50]
Kg CO_2 eq	4.9	NA	NA	NA	Tank-to-wheel	[11]
Kg CO_2-eq/t	37.15	NA	NA	NA	Tank-to-wheel	[28]
Kg CO_2 eq/t_{MSW}	48.1	NA	NA	NA	Tank-to-wheel	[58]
Kg CO_2 eq.100 years/FU	9.5	NA	NA	13.1	Tank-to-wheel	[56]
Kg CO_2 eq/t_{MSW}	11.3	NA	NA	NA	Tank-to-wheel	[59]
Kg CO_2 eq/t_{MSW}	16	NA	NA	4.76	Tank-to-wheel	[6]
Kg CO_2-eq/mi	2.22	NA	2.248	NA	Tank-to-wheel	[29]
Kg CO_2-eq/t	18	NA	9.2	NA	Tank-to-wheel	[33]

[a] NA: Not available

diesel vehicles with CNG fueled vehicles can contribute to reducing GHG emissions, this is in line with other research, such as [21, 50, 57].

Conclusion

An integrated study based on a bibliometric review was conducted to gain research interest in evaluating the environmental impact of waste transportation using LCA. This study was conducted to obtain a baseline for waste transportation vehicle environmental impact using different fuel types. Based on a comprehensive systematic literature review (2013-2023), 46 articles were published in journals on waste transportation environmental impact from different fuels using LCA studies. Based on the keywords, the most common research themes in waste transportation environmental impact analysis disclosure from 2013-2023 were related to LCA, waste transport, industrial transport, waste management, municipal solid waste, economic assessment, waste-to-energy, and environmental impact. This trend could be used as a reference for future research.

Several findings were found based on the content analysis results, such as: (1) Transportation contributes to various GHG emissions. Reducing GHG emissions and pollutants is an energy guarantee and the primary factor in clean production. (2) Based on seven studies comparing waste transportation using diesel, compressed natural gas, biomethane, and pneumatic fuel, it shows that vehicles using diesel fuel produce the highest environmental impact compared to others, especially on CO2, which is a contributor to GHG emissions. Several studies show that CNG fueled vehicles are one of the vehicles that have the lowest contribution to environmental impact. (3) Transportation environmental impact is derived from a combination of distance traveled and amount transported. Replacing diesel fueled vehicles with alternatives such as CNG fueled vehicles can minimize the environmental impact. Meanwhile, seen from a renewable electricity perspective, stationary pneumatic collection is a positive step towards more sustainable and environmentally friendly transportation and waste management. There are some limitations to this study. First, consider only databases sourced from Scopus. Using data from multiple databases can provide more information for future bibliometric analyses. Second, query or keyword combinations can limit search results because of sample differences, so further investigation is required to select appropriate queries/keywords.

Acknowledgments

The authors acknowledge Annisa Sila Puspita for their review of this work.

Conflict of Interest

The authors declare no conflict of interest.

References

1. SEVERO E.A., DE GUIMARÃES J.C.F., DORION E.C.H. Cleaner production, social responsibility and eco-innovation: Generations‘ perception for a sustainable future. Journal of Cleaner Production, **186**, 91, **2018**.
2. SAEED A., ZAFAR M.W., MANITA R., ZAHID N. The role of audit quality in waste management behavior. International Review of Economics & Finance, **89**, 1203, **2024**.
3. KHANDELWAL H., DHAR H., THALLA A.K., KUMAR S. Application of life cycle assessment in municipal solid

waste management: A worldwide critical review. Journal of Cleaner Production, **209**, 630, **2019**.
4. RODRIGUES A., FERNANDES M., RODRIGUES M., BORTOLUZZI S., DA COSTA S.G., DE LIMA E.P. Developing criteria for performance assessment in municipal solid waste management. Journal of Cleaner Production, **186**, 748, **2018**.
5. PÉREZ J., LUMBRERAS J., DE LA PAZ D., RODRÍGUEZ E. Methodology to evaluate the environmental impact of urban solid waste containerization system: A case study. Journal of Cleaner Production, **150**, 197, **2017**.
6. PUNKKINEN H., MERTA E., TEERIOJA N., MOLIIS K., KUVAJA E. Environmental sustainability comparison of a hypothetical pneumatic waste collection system and a door-to-door system. Waste Management, **32** (10), 1775, **2012**.
7. JAUNICH M.K., LEVIS J.W., DECAROLIS J.F., GASTON E.V., BARLAZ M.A., BARTELT-HUNT S.L., JONES E.G., HAUSER L., JAIKUMAR R. Characterization of municipal solid waste collection operations. Resources, Conservation and Recycling, **114**, 92, **2016**.
8. PÉREZ J., LUMBRERAS J., RODRÍGUEZ E. Life cycle assessment as a decision-making tool for the design of urban solid waste pre-collection and collection/transport systems. Resources, Conservation and Recycling, **161**, 104988, **2020**.
9. HIDALGO D., MARTÍN-MARROQUÍN J.M., CORONA F., JUARISTI J.L. Sustainable vacuum waste collection systems in areas of difficult access. Tunnelling and Underground Space Technology, **81**, 221, **2018**.
10. ZHAO Y., TATARI O. Carbon and energy footprints of refuse collection trucks: A hybrid life cycle evaluation. Sustainable Production and Consumption, **12**, 180, **2017**.
11. GUZDEK S., MALINOWSKI M., RELIGA A., LISZKA D., PETRYK A. Economic and ecological assessment of transport of various types of waste. Journal of Ecological Engineering, **21**, (5), **2020**.
12. TIAN X., HUANG G., SONG Z., AN C., CHEN Z. Impact from the evolution of private vehicle fleet composition on traffic related emissions in the small-medium automotive city. Science of The Total Environment, **840**, 156657, **2022**.
13. GIECHASKIEL B., GIORIA R., CARRIERO M., LÄHDE T., FORLONI F., PERUJO A., MARTINI G., BISSI L.M., TERENGHI R. Emission factors of a Euro VI heavy-duty diesel refuse collection vehicle. Sustainability, **11** (4), 1067, **2019**.
14. GRIGORATOS T., FONTARAS G., GIECHASKIEL B., ZACHAROF N. Real world emissions performance of heavy-duty Euro VI diesel vehicles. Atmospheric Environment, **201**, 348, **2019**.
15. SUTHAWAREE J., SIKDER H.A., JONES C.E., KATO S., KUNIMI H., KABIR A. N.M.H., KAJII Y. Influence of extensive compressed natural gas (CNG) usage on air quality. Atmospheric Environment, **54**, 296, **2012**.
16. FONTARAS G., MARTINI G., MANFREDI U., MAROTTA A., KRASENBRINK A., MAFFIOLETTI F., TERENGHI R., COLOMBO M. Assessment of on-road emissions of four Euro V diesel and CNG waste collection trucks for supporting air-quality improvement initiatives in the city of Milan. Science of the Total Environment, **426**, 65, **2012**.
17. HABIB K., SCHMIDT J.H., CHRISTENSEN P. A historical perspective of global warming potential from municipal solid waste management. Waste Management, **33** (9), 1926, **2013**.
18. PASTORELLO C., DILARA P., MARTINI G. Effect of a change towards compressed natural gas vehicles on the emissions of the Milan waste collection fleet. Transportation Research Part D: Transport and Environment, **16** (2), 121, **2011**.
19. ALAM M.S., ATIF M., CHIEN-CHI C., SOYTAŞ U. Does corporate R&D investment affect firm environmental performance? Evidence from G-6 countries. Energy Economics, **78**, 401, **2019**.
20. SILVA V., CONTRERAS F., BORTOLETO A.P. Life-cycle assessment of municipal solid waste management options: A case study of refuse derived fuel production in the city of Brasilia, Brazil. Journal of Cleaner Production, **279**, 123696, **2021**.
21. ROSE L., HUSSAIN M., AHMED S., MALEK K., COSTANZO R., KJEANG E. A comparative life cycle assessment of diesel and compressed natural gas powered refuse collection vehicles in a Canadian city. Energy Policy, **52**, 453, **2013**.
22. BUDIHARDJO M., PRIYAMBADA I., CHEGENIZADEH A., AL QADAR S., PUSPITA A. Environmental impact technology for life cycle assessment in municipal solid waste management. Global Journal of Environmental Science and Management, **9**, 145, **2023**.
23. PERI G., FERRANTE P., LA GENNUSA M., PIANELLO C., RIZZO G. Greening MSW management systems by saving footprint: The contribution of the waste transportation. Journal of Environmental Management, **219**, 74, **2018**.
24. SALHOFER S., SCHNEIDER F., OBERSTEINER G. The ecological relevance of transport in waste disposal systems in Western Europe. Waste Management, **27** (8), S47, **2007**.
25. YILDIZ-GEYHAN E., YILAN-ÇIFTÇI G., ALTUN-ÇIFTÇIOĞLU G.A., KADIRGAN M.A.N. Environmental analysis of different packaging waste collection systems for Istanbul–Turkey case study. Resources, Conservation and Recycling, **107**, 27, **2016**.
26. DENIZ R.F., CHEN X., ORAK N.H. Investigation of greenhouse gas emissions from municipal solid waste management practices using an economic input-output life cycle analysis approach. Journal of Cleaner Production, **420**, 138450, **2023**.
27. FERRONATO N., MORESCO L., LIZARAZU G.E.G., PORTILLO M.A.G., CONTI F., TORRETTA V. Sensitivity analysis and improvements of the recycling rate in municipal solid waste life cycle assessment: Focus on a Latin American developing context. Waste Management, **128**, 1, **2021**.
28. YAMAN C., ANIL I., JAUNICH M.K., BLAISI N.I., ALAGHA O., YAMAN A.B., GUNDAY S.T. Investigation and modelling of greenhouse gas emissions resulting from waste collection and transport activities. Waste Management & Research, **37** (12), 1282, **2019**.
29. QUIROS D.C., SMITH J., THIRUVENGADAM A., HUAI T., HU S. Greenhouse gas emissions from heavy-duty natural gas, hybrid, and conventional diesel on-road trucks during freight transport. Atmospheric Environment, **168**, 36, **2017**.
30. RIAL M., PÉREZ J. Environmental performance of four different heavy-duty propulsion technologies using Life Cycle Assessment. Transportation Research Interdisciplinary Perspectives, **11**, 100428, **2021**.
31. RAMALHO J., CALMON J., COLVERO D., SIMAN R. Environmental assessment of municipal solid waste collection/transport using biomethane in mid-sized metropolitan areas of developing countries. International

Journal of Environmental Science and Technology, **19** (10), 9991, **2022**.
32. RECEBLI Z., SELIMLI S., OZKAYMAK M., GONC O. Biogas production from animal manure. Journal of Engineering Science and Technology, **10** (6), 722, **2015**.
33. YAMAN A.B., SEVIMOGLU O. Assessment and modelling of greenhouse gas emissions from waste collection vehicles powered by different fuel types. International Journal of Global Warming, **23** (3), 274, **2021**.
34. PENG H., AN C., NG K.T.W., HAO J., TIAN X. Advancing cleaner municipal waste transport through carbon accounting in the cap-and-trade system. Transportation Research Part D: Transport and Environment, **114**, 103560, **2023**.
35. CABEZA L.F., FRAZZICA A., CHÀFER M., VÉREZ D., PALOMBA V. Research trends and perspectives of thermal management of electric batteries: Bibliometric analysis. Journal of Energy Storage, **32**, 101976, **2020**.
36. HE M., LIN T., WU X., LUO J., PENG Y. A systematic literature review of reverse logistics of end-of-life vehicles: Bibliometric analysis and research trend. Energies, **13** (21), 5586, **2020**.
37. WAHYUNINGRUM I.F.S., HUMAIRA N.G., BUDIHARDJO M.A., ARUMDANI I.S., PUSPITA A.S., ANNISA A.N., SARI A.M., DJAJADIKERTA H.G. Environmental sustainability disclosure in Asian countries: Bibliometric and content analysis. Journal of Cleaner Production, 137195, **2023**.
38. PIZZI S., CAPUTO A., CORVINO A., VENTURELLI A. Management research and the UN sustainable development goals (SDGs): A bibliometric investigation and systematic review. Journal of Cleaner Production, **276**, 124033, **2020**.
39. SANTOYO-CASTELAZO E., SANTOYO E., ZURITA-GARCÍA L., LUENGAS D. C., SOLANO-OLIVARES K. Life cycle assessment of bioethanol production from sugarcane bagasse using a gasification conversion Process: Bibliometric analysis, systematic literature review and a case study. Applied Thermal Engineering, **219**, 119414, **2023**.
40. TIAN X., GENG Y., ZHONG S., WILSON J., GAO C., CHEN W., YU Z., HAO H. A bibliometric analysis on trends and characters of carbon emissions from transport sector. Transportation Research Part D: Transport and Environment, **59**, 1, **2018**.
41. THANANUSAK T. Science mapping of the knowledge base on sustainable entrepreneurship, 1996–2019. Sustainability, **11** (13), 3565, **2019**.
42. HUERTAS-VALDIVIA I., FERRARI A.M., SETTEMBRE-BLUNDO D., GARCÍA-MUIÑA F.E. Social life-cycle assessment: A review by bibliometric analysis. Sustainability, **12** (15), 6211, **2020**.
43. GUO Y.-M., HUANG Z.-L., GUO J., LI H., GUO X.-R., NKELI M.J. Bibliometric analysis on smart cities research. Sustainability, **11** (13), 3606, **2019**.
44. PIWOWAR-SULEJ K., KRZYWONOS M., KWIL I. Environmental entrepreneurship–Bibliometric and content analysis of the subject literature based on H-Core. Journal of Cleaner Production, **295**, 126277, **2021**.
45. JUNG H., LEE B.G. Research trends in text mining: Semantic network and main path analysis of selected journals. Expert Systems with Applications, **162**, 113851, **2020**.
46. LINNENLUECKE M.K., MARRONE M., SINGH A.K. Conducting systematic literature reviews and bibliometric analyses. Australian Journal of Management, **45** (2), 175, **2020**.
47. RANJBARI M., SAIDANI M., ESFANDABADI Z.S., PENG W., LAM S.S., AGHBASHLO M., QUATRARO F., TABATABAEI M. Two decades of research on waste management in the circular economy: Insights from bibliometric, text mining, and content analyses. Journal of Cleaner Production, **314**, 128009, **2021**.
48. PRASHAR A. A bibliometric and content analysis of sustainable development in small and medium-sized enterprises. Journal of Cleaner Production, **245**, 118665, **2020**.
49. PÉREZ J., LUMBRERAS J., RODRÍGUEZ E., VEDRENNE M. A methodology for estimating the carbon footprint of waste collection vehicles under different scenarios: Application to Madrid. Transportation Research Part D: Transport and Environment, **52**, 156, **2017**.
50. LÓPEZ J.M., GÓMEZ Á., APARICIO F., SÁNCHEZ F.J. Comparison of GHG emissions from diesel, biodiesel and natural gas refuse trucks of the City of Madrid. Applied Energy, **86** (5), 610, **2009**.
51. CHÀFER M., SOLE-MAURI F., SOLÉ A., BOER D., CABEZA L.F. Life cycle assessment (LCA) of a pneumatic municipal waste collection system compared to traditional truck collection. Sensitivity study of the influence of the energy source. Journal of Cleaner Production, **231**, 1122, **2019**.
52. GRAHAM L.A., RIDEOUT G., ROSENBLATT D., HENDREN J. Greenhouse gas emissions from heavy-duty vehicles. Atmospheric Environment, **42** (19), 4665, **2008**.
53. CLEARY J. Life cycle assessments of municipal solid waste management systems: A comparative analysis of selected peer-reviewed literature. Environment International, **35** (8), 1256, **2009**.
54. LAURENT A., BAKAS I., CLAVREUL J., BERNSTAD A., NIERO M., GENTIL E., HAUSCHILD M.Z., CHRISTENSEN T.H. Review of LCA studies of solid waste management systems–Part I: Lessons learned and perspectives. Waste Management, **34** (3), 573, **2014**.
55. GENTIL E.C., DAMGAARD A., HAUSCHILD M., FINNVEDEN G., ERIKSSON O., THORNELOE S., KAPLAN P.O., BARLAZ M., MULLER O., MATSUI Y. Models for waste life cycle assessment: Review of technical assumptions. Waste Management, **30** (12), 2636, **2010**.
56. IRIARTE A., GABARRELL X., RIERADEVALL J. LCA of selective waste collection systems in dense urban areas. Waste Management, **29** (2), 903, **2009**.
57. MAIMOUN M.A., REINHART D.R., GAMMOH F.T., BUSH P.M. Emissions from US waste collection vehicles. Waste Management, **33** (5), 1079, **2013**.
58. FERNÁNDEZ-NAVA Y., DEL RIO J., RODRÍGUEZ-IGLESIAS J., CASTRILLÓN L., MARAÑÓN E. Life cycle assessment of different municipal solid waste management options: a case study of Asturias (Spain). Journal of Cleaner Production, **81**, 178, **2014**.
59. BURATTI C., BARBANERA M., TESTARMATA F., FANTOZZI F. Life Cycle Assessment of organic waste management strategies: an Italian case study. Journal of Cleaner Production, **89**, 125, **2015**.