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MAPPING THE SCIENTIFIC LANDSCAPE OF URBAN EMISSIONS IN PORT CITIES: A BIBLIOMETRIC REVIEW

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Abstract

Port cities face increasing pressure due to their significant role in global greenhouse gas emissions and air pollution, impacting both environment and public health. This study conducts a systematic bibliometric review of 220 Scopus-indexed publications from 2014 to 2025 to map the evolving scientific landscape of urban emissions in these maritime hubs. Findings reveal a "productivity paradox": while research output has surged by 660%, the average citation impact has declined by 96%, indicating thematic fragmentation. The analysis identifies a critical disconnect between technical maritime engineering—such as port electrification and "cold ironing"—and urban spatial governance frameworks. Furthermore, advanced digital tools like artificial intelligence for real-time monitoring remain underutilized. Theoretically, this study advances urban environmental governance by positioning emission mitigation as a central variable in municipal spatial growth rather than a localized technical issue. The review calls for a paradigmatic shift toward "Integrated Port-City Governance" to align maritime decarbonization with resilient urban planning. By bridging environmental engineering and spatial policy, this research provides a strategic foundation for transforming port cities into low-carbon, sustainable urban ecosystems.

Keywords: Decarbonization, Air Quality Management, Maritime Logistics, Urban Sustainability, Environmental Policy

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INTRODUCTION

Port cities serve as strategic spatial entities that integrate global logistics functions with the complexities of urban dynamics. Approximately 80% of international trade volume is transported via maritime routes, positioning port cities as critical nodes in global supply chains and distribution systems (Amdaoud et al., 2022; Fauzi & Ispandiani, 2024; Setyaningsih et al., 2024). However, the high intensity of economic and maritime transport activities in these areas disproportionately contributes to greenhouse gas (GHG) emissions and air pollution, posing severe environmental and public health challenges (Meng et al., 2022; Mindroiu et al., 2025; Wang et al., 2021).

Key emission sources include vessel berthing, cargo handling, and heavy vehicle traffic, which collectively account for up to 45% of fine particulate matter (PM_{2.5}) emissions in European coastal regions and are linked to 14,500–37,500 premature annual deaths globally (Amdaoud et al., 2022; Ducruet et al., 2024; Logothetis et al., 2021). The shipping sector alone contributes 2.89% of global CO₂ emissions (2018 baseline), with projections indicating a 90–130% increase by 2050 if no mitigation measures are implemented (IMO, 2021). These emissions degrade air quality, exacerbate climate change, and elevate public health risks (Girard & Nocca, 2020; Shen et al., 2024; Sun et al., 2025), necessitating integrated spatial planning approaches that align energy policy, environmental management, and low-carbon urban development.

While existing studies have examined the environmental impacts of port activities, most focus narrowly on technical aspects (e.g., emission measurements, localized air quality analyses) (Abbass et al., 2022; Fei et al., 2025; Türkistanlı et al., 2025; UNCTAD, 2009), with limited integration into urban planning frameworks or spatial policy (Chib et al., 2015; Shim & Shin, 2022). Furthermore, research remains geographically skewed toward developed nations, leaving a gap in understanding emissions from small-to-medium ports in rapidly urbanizing regions like Southeast Asia (Merk, 2013; Qu et al., 2023; Roy & Chakraborty, 2025).

This study employs a bibliometric analysis of 220 Scopus-indexed publications (2014–April 2025) to: Map global research trends on port-city emissions, analyze collaboration patterns and knowledge distribution and Identify policy-relevant research gaps and opportunities for sustainable port-city development. By synthesizing interdisciplinary insights from environmental science, engineering, and governance, this review aims to bridge the divide between technical emission studies and actionable urban planning strategies.

Despite the growing literature on maritime emissions, a significant gap persists in aligning technical advancements with urban spatial governance. To address this, this bibliometric review explores four key research questions: (1) how have scientific landscape and publication trends evolved over the past

decade; (2) what are the dominant research clusters regarding the integration of technology and urban planning; (3) to what extent does current research address spatial governance challenges for low-carbon transitions; and (4) what emerging frontiers can inform holistic, evidence-based environmental frameworks? By addressing these questions, this study bridges environmental engineering and urban governance, providing a structured foundation for future interdisciplinary policy and research

RESEARCH METHODOLOGY

This study employs a bibliometric approach to systematically map and analyze the evolution of scholarly research on emissions in port cities. Bibliometric methods allow for quantitative and visual exploration of publication patterns, scientific collaboration, and thematic development within academic discourse. Data were sourced from the Scopus database, selected for its comprehensive multidisciplinary coverage, reliable metadata quality, and international recognition (Elkhayat et al., 2024; Lim et al., 2024). To ensure transparency, certain methodological boundaries are acknowledged. This study is restricted to English-language publications to maintain terminological consistency, which may introduce a linguistic bias by overlooking local-scale research from specific maritime regions. Additionally, the exclusive reliance on Scopus-indexed literature may exclude "grey literature" or emerging regional journals, potentially affecting regional coverage and thematic representation.

The dataset includes journal articles, conference papers, and reviews published between January 2014 and April 2025. A structured search strategy used Boolean combinations of keywords such as "port city," "emission," "air pollution," and "GHG." Inclusion criteria focused on publications explicitly addressing emissions in port-city contexts, while exclusions removed unrelated or incomplete records.

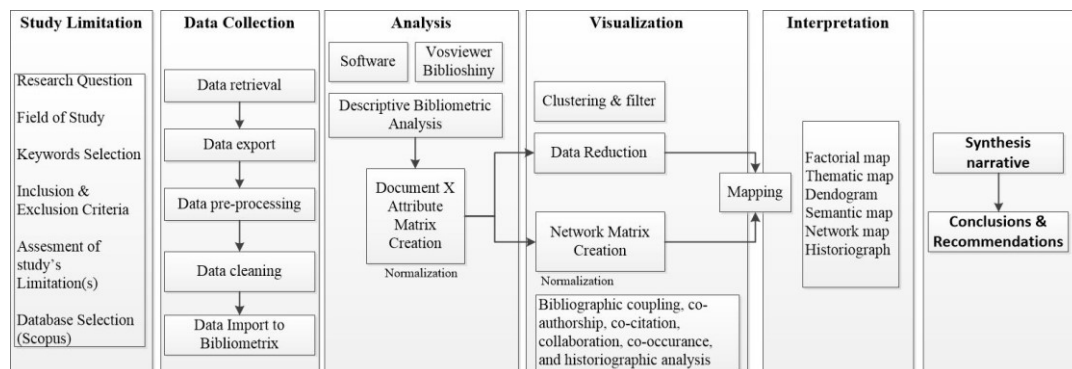


Figure 1. Research flow diagram

The research workflow (Figure 1) ensures traceability and reproducibility. Data were analyzed using Bibliometrix (R package) and VOSviewer to generate citation metrics, co-authorship networks, and keyword co-occurrence maps. These analyses reveal patterns of knowledge production and highlight gaps linking emission research with spatial planning and environmental policy. The approach offers a rigorous and replicable framework for evaluating scholarship on sustainable urban emissions management. As the study uses publicly available metadata without human subjects, formal ethical approval was not required, while academic integrity was maintained.

ANALYSIS AND DISCUSSION

Growth and Trends in Scholarly Publications

The analysis identifies a consistent upward trajectory in academic interest regarding port-city emissions over the past decade. Between 2014 and April 2025, a total of 220 documents were published, reflecting an average annual growth rate of 8.28%. As illustrated in Figure 2, publication output surged dramatically from only five articles in 2014 to a peak of 38 in 2022, representing a 660% increase. This sharp growth, particularly between 2019 and 2022, suggests heightened scholarly attention toward the environmental challenges inherent in maritime and port activities.

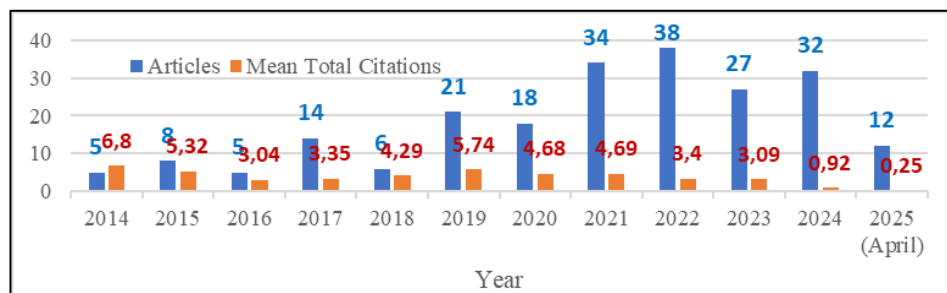


Figure 2. Annual Scientific Production and Average Citations per Year

As shown in Figure 2, publication output has increased significantly, yet this growth has not produced a comparable academic impact. Average citations per document declined by 96%, dropping from 6.8 in 2014 to only 0.25 in 2025. This paradox indicates that rising productivity coincides with diminishing scholarly influence. The trend likely reflects thematic fragmentation, an overemphasis on narrow engineering technicalities, and weak integration with urban planning or spatial policy. These findings highlight the need for interdisciplinary research linking environmental science and spatial governance to strengthen the relevance and impact of port-city decarbonization studies.

Most Active and Influential Countries and Institutions

The bibliometric analysis reveals significant disparities in research contributions across nations and institutions. While China dominates total publication volume with 408 articles, it demonstrates a relatively low citation impact of 16.9 citations per publication. In contrast, the United Kingdom achieves the highest scholarly influence, averaging 108.5 citations across its 52 publications, which indicates a focus on high-impact, high-quality research. Other notable performers include Greece (48.9 citations/article) and Malaysia (41 citations/article), both exhibiting strong impact-to-volume ratios

Table 1: Top Journals, Contributing Countries, and Leading Institutions

Journal	Freq	H	Country	#Pub	#Cit	Avg Cit	Institution	Inst Country	#Art
Science of The Total Environment	831	13	China	408	1163	16.9	Shanghai Maritime University	China	57
Transportation Research Part D	392	8	Italy	113	680	35.8	Zhejiang University	China	18
Sustainability (Switzerland)	164	7	Spain	72	438	31.3	Lingnan Normal University	China	17
Atmosphere	59	5	Greece	67	391	48.9	Shanghai	China	17
Journal of Environmental Management	115	5	Korea	55	355	20.9	Institute of Atmospheric Sciences and Climate	Italy	16
Atmospheric Environment	171	4	United Kingdom	52	217	108.5	Shanghai Jiao Tong University	China	16
Journal of Cleaner Production	164	4	Malaysia	38	123	41.0	Xiamen University	China	16
Journal of Environmental Sciences (China)	215	4	Poland	25	103	17.2	National Kaohsiung University of Science and Tech.	Taiwan	15
Marine Pollution Bulletin	61	4	USA	24	88	29.3	University of Rijeka	Croatia	14
Aerosol And Air Quality Research	104	3	Canada	21	85	14.2	Nankai University	China	13

At the institutional level, Shanghai Maritime University leads in productivity with 57 publications. However, European institutions—most notably Italy’s ISAC-CNR and Croatia’s University of Rijeka—demonstrate outsized influence per publication. As shown in Table 1, *Science of the Total Environment* emerges as the most cited outlet with 831 co-citations, reflecting the heavy environmental science orientation of this domain. These patterns underscore a concentration of research capacity in East Asia and Europe, yet suggest growing opportunities for ASEAN-based researchers to address context-specific emission challenges in rapidly urbanizing tropical port regions.

Most influential Article, Authors and Collaboration Networks

The analysis of scholarly collaboration networks reveals significant fragmentation in port-city emissions research. As presented in Table 2, Beatriz Tovar from TIDES emerges as the most influential researcher with eight publications and 496 citations (H-index 8), followed by Chen Jihong (seven publications, 284 citations) and Contini D. (six publications, 406 citations), the latter demonstrating the highest impact per publication (67.7 citations/article). In contrast, researchers such as Mifka Boris and Dinoi A. exhibit high productivity (4–5 publications) but low citation impact (19 citations), indicating variability in research quality.

Table 2: Top 10 researchers by publications and citation counts

Author	Affiliation	Number of Publications	Number of Citations	Articles Fractionalized	H-index	M-index
TOVAR, BEATRIZ	The University Institute for Tourism and Sustainable Economic Development (TIDES)	8	496	3,7	8	0,73
CHEN, JIHONG	Shenzhen University, College of Management, China	7	284	1,35	6	0,86
CONTINI, D.	Institute of Atmospheric Sciences and Climate (ISAC-CNR), Italy	6	406	0,83	6	0,5
ALEBIĆ-JURETIĆ, ANA	University of Rijeka, Faculty of Medicine, Department of Environmental Medicine, Croatia	5	258	1,05	5	0,42
MERICO, EVA	Institute of Atmospheric Sciences and Climate (ISAC-CNR), Italy	5	418	0,69	5	0,45

Author	Affiliation	Number of Publications	Number of Citations	Articles Fractionalized	H-index	M-index
MIFKA, BORIS	University of Rijeka, Faculty of Medicine, Department of Environmental Medicine, Croatia	5	19	1,05	4	0,67
TICHAVSKA, MILUŠE	MarineTraffic, London, UK	5	117	2,2	4	0,67
DINOI, A.	Institute of Atmospheric Sciences and Climate (ISAC-CNR), Italy	4	19	0,56	4	0,67
HE, HONG-DI	School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University	4	112	0,76	3	0,33
SCHWAB, JAMES J.	Atmospheric Sciences Research Center, University at Albany	4	75	0,66	3	0,6

Figure 3 visualizes five dominant collaboration clusters centered in China, Italy, and the UK, with Xiao Hang as the primary node (link strength 38, 117 citations). However, cross-cluster collaboration remains weak, evidenced by low link strength (<10) for 90% of authors. While Chinese institutions like Shanghai Maritime University dominate publication volume (Table 3), European institutions such as Italy's ISAC-CNR excel in per-publication impact. These findings underscore the need for global collaboration platforms to integrate cross-regional perspectives, particularly from underrepresented developing regions.

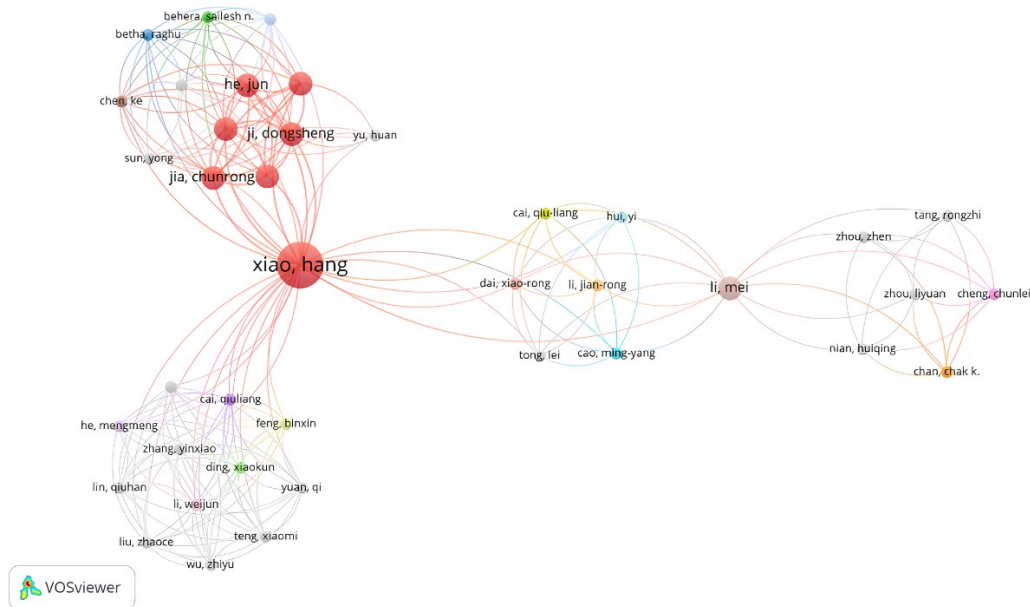


Figure 3. Science mapping of co-authorship network

Analysis and Mapping of Research Keywords

The keyword co-occurrence analysis, visualized through VOSviewer (Figure 4), reveals five dominant thematic clusters in port-city emissions research. The green cluster, centered on air pollution (26 occurrences, TLS: 29), underscores the primary focus on atmospheric contaminants. The red cluster highlights analytical approaches like source apportionment (11 occurrences) and particulate matter (6 occurrences), while the blue cluster emphasizes technological solutions (cold ironing, electrification). Spatial dynamics (ship emissions, port-city nexus) dominate the yellow cluster, whereas emerging trends (COVID-19, machine learning) form the purple cluster.



Figure 4. Network visualization of Keywords analysis

The tree map (Figure 5) reinforces these findings, with air pollution and related terms occupying 12–15% of the area, followed by shipping emissions (8%). Notably, the absence of urban planning and land use keywords in core clusters indicates a disconnect between technical emission studies and spatial policy discourse. The thematic map (Figure 6) further polarizes these trends, classifying air pollution and particulate matter as motor themes, while sustainability and climate change remain niche, underdeveloped themes. This fragmentation underscores the need for interdisciplinary integration, particularly linking emission science with urban governance and public health frameworks.

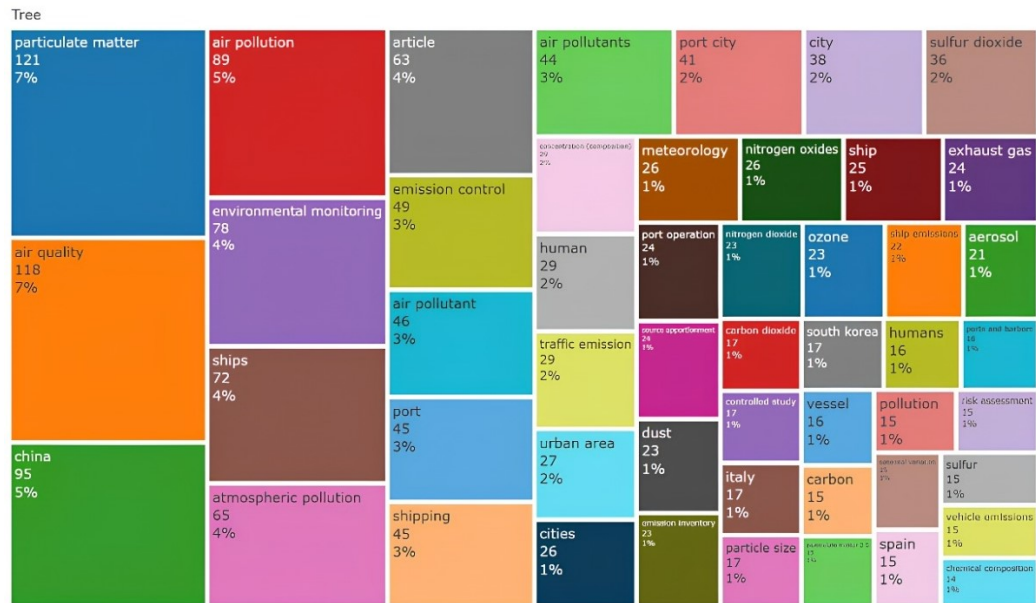


Figure 5. Top 20 authors' keywords Illustrated in a tree map

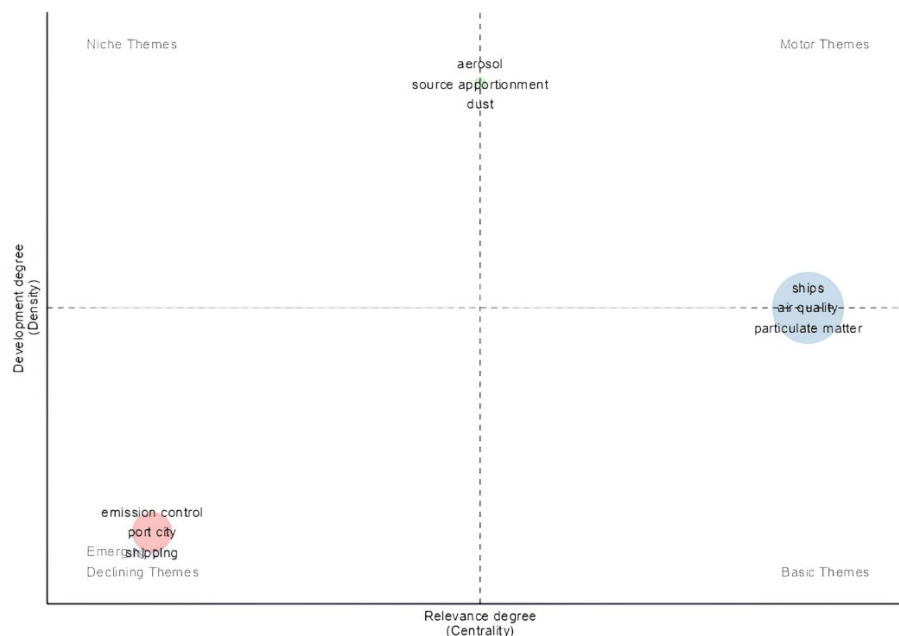


Figure 6. Thematic map of keywords

Research Gaps and Opportunities

This subsection was developed through a triangulated approach, integrating findings from performance analysis, science mapping, and a close examination of the top ten most-cited publications in the domain of port-city emissions. By combining bibliometric evidence with qualitative review, the aim was to identify underexplored areas and guide future research directions that intersect with urban planning, environmental governance, and smart port development.

Table 3: Top 10 Most Cited Studies (2014–April 2025)

Author	Method	Findings	Relevance to Spatial Planning	Total Citations
(Grange & Carslaw, 2019)	Machine learning (random forest) used to normalize time series and assess impacts of air quality interventions.	Normalized data revealed pollution reductions linked to fuel sulfur limits and traffic policies.	Demonstrates how advanced statistical methods improve assessment of spatial air quality interventions in urban environments.	212
(Tichavska & Tovar, 2015b)	Bottom-up exhaust emission model using AIS data for cruise and ferry operations in Las Palmas.	Passenger vessels identified as key air pollution sources; cruise and ferry emissions spatially mapped.	Enables emission zoning and prioritization of mitigation strategies in port-city urban planning.	154
(Cesari et al., 2014)	PMF receptor model with chemical and meteorological data for source apportionment.	Ship emissions contribute 2.8% to primary PM _{2.5} and 11% to secondary PM _{2.5} via oil combustion.	Helps quantify maritime contributions to air pollution, supporting urban-industrial port land-use regulation.	148
(Maragkogianni & Papaefthimiou, 2015)	Activity-based emissions inventory and external cost estimation for five cruise ports.	Cruise ship emissions cost up to €24.3 million annually; hotelling responsible for 88.5% of emissions.	Emphasizes the need for spatial policies to manage tourist port emissions and health impacts.	136
(Lee et al., 2014)	Combined bottom-up emissions inventory and top-down external cost estimation.	Maps emission hotspots and eco-efficiency indicators across port activities.	Supports spatially-informed cost-benefit strategies for emission reduction in dense port-city areas.	124
(Yau et al., 2020)	Literature review of smart port ICT applications, including IoT and emissions reduction technologies.	Highlights ICT role in energy efficiency, emissions reduction, and port automation.	Frames smart port development as central to spatial planning for sustainable urban logistics hubs.	120
(Chen et al., 2019)	Fuzzy DEMATEL model used to identify and rank 12 barriers to AMP implementation.	Policy support, standardization, and legal frameworks are key barriers in China.	Reveals systemic barriers to clean port technology adoption, crucial for spatial environmental and infrastructural policy.	116
(D'Amico et al., 2021)	Systematic literature review building a multidimensional	Identifies enabling factors, domains, and goals for smart,	Provides a framework for integrating digital technologies into spatial port planning and urban logistics.	110

Author	Method	Findings	Relevance to Spatial Planning	Total Citations
	framework of logistics elements.	sustainable port logistics.		
(Tichavska & Tovar, 2015a)	Full bottom-up emission inventory and top-down cost estimation integrated with eco-efficiency analysis.	Ferry and tanker sectors are least eco-efficient; emissions cost €180 million.	Offers a spatial emission assessment to guide planning and mitigation in densely populated port cities.	98
(Tichavska et al., 2019)	STEAM model with AIS data to analyze emissions under different regulatory regimes.	Ports with strict regulations like Hong Kong show lower emissions.	Supports differentiated regulatory strategies in port design and zoning for emission abatement.	91

As summarized in Table 3, the most influential studies emphasize advanced quantitative techniques, such as machine learning (Grange & Carslaw, 2019), bottom-up emissions modeling (Tichavska & Tovar, 2015b), and receptor-based PM2.5 apportionment (Cesari et al., 2014). These works contribute significantly to technical understanding and air quality management. However, only a few studies explicitly integrate spatial planning dimensions or assess implications for urban zoning, health-oriented land-use, or regulatory frameworks—gaps particularly relevant to the Planning Malaysia Journal’s focus on urban and regional planning and environmental infrastructure.

Table 4 elaborates key research gaps within the literature. A critical disconnect is observed between rising publication quantity and declining citation impact, suggesting a need for higher-quality, policy-relevant research. Furthermore, the dominance of studies from China and Europe highlights the underrepresentation of Southeast Asia and other developing regions—areas where rapid port urbanization calls for context-specific planning frameworks. Thematic fragmentation is also evident; keywords such as "climate change," "sustainability," and "public health" remain peripheral in the bibliometric mapping, reflecting a missed opportunity for interdisciplinary integration.

Equally concerning is the underutilization of artificial intelligence and real-time monitoring technologies, despite their potential for spatial modeling and emissions forecasting. Finally, institutional and regulatory factors are insufficiently explored, with only one or two studies addressing policy implementation challenges. Overall, this analysis calls for a paradigmatic shift toward integrative, policy-responsive, and regionally contextualized research. Bridging emission studies with urban planning, governance, and digital infrastructure will not only enhance scholarly impact but also contribute directly to sustainable development strategies in port cities worldwide

Table 4: Research Gaps and Opportunities in Port-City Emission Studies

Identified Research Gaps	Bibliometric Evidence	Research Opportunities
Polarization between publication quantity and scientific impact	Figure 2 shows an increase in publications (2014–2025) but a decline in average citations from 6.8 to 0.25 (2025)	New research should focus on the quality of contributions, with strong theoretical approaches and comparative empirical studies across regions.
Fragmentation of scientific collaboration networks	Co-authorship network (Figure 3) and VOSviewer analysis indicate regional collaboration, not yet globally integrated	Significant opportunities exist to build international cross-institutional consortia for more coordinated maritime urban emission projects.
Lack of integration between public health themes and spatial modeling	Thematic map (Figure 6) shows “exposure” and “modeling” in the emerging/declining quadrant, not in core themes	Developing spatial models of health risk based on port emissions is a promising research area.
Limited socio-political and regulatory approaches	Among the top 10 cited articles (Table 5), most are technical and quantitative; only one or two address policy aspects like AMP adoption (Chen, 2019)	Interdisciplinary studies are needed on policy barriers, socio-economic dynamics, and adoption of green technologies.
Dominance of research by certain institutions and countries (particularly China)	Table 1: China leads in volume; the UK excels in quality	Expansion of studies to other developing countries with different port contexts, e.g., Southeast Asia, Africa, and Latin America.
Sustainability and climate change issues not yet integrated into core themes	Figure 6 shows “sustainability” and “climate change” as niche themes, not strongly connected to motor themes	Opportunities to integrate sustainability and climate change perspectives into emission models and mitigation strategies.
Inequality in researcher-level publication impact	Table 2: Some prolific researchers (e.g., Mifka and Dinoi) have low citations, indicating relevance or niche topic issues	Future research should address broader impact topics with high policy relevance.
Imbalance between quantitative approaches and artificial intelligence in emission mitigation	Table 3 notes the use of AI and deep learning only in a few studies	Greater integration of machine learning technologies for real-time port emission prediction and detection is encouraged.

CONCLUSION

This bibliometric review of 220 Scopus-indexed publications (2014–2025) provides a critical synthesis of the port-city emissions landscape, revealing a significant "productivity paradox" where a 660% increase in output is countered by a 96% decline in citation impact. This study's unique contribution lies in uncovering the systemic disconnect between technical maritime engineering and urban spatial governance. While the literature is saturated with localized technical measurements, this review identifies a profound lack of integration into broader

urban planning and land-use frameworks. Theoretically, this study advances urban environmental governance by positioning emission mitigation not merely as a technical challenge, but as a central variable in municipal spatial growth. It highlights that current research fails to bridge the gap between "hard" port infrastructure (e.g., electrification, cold ironing) and the "soft" institutional-regulatory policies required for sustainable transitions.

To align with the needs of urban planners, the findings call for a shift toward Integrated Port-City Governance. This framework suggests that emerging digital frontiers—such as AI-based spatial monitoring—must be coupled with health-oriented zoning and cross-sectoral policy assessment to be effective. By mapping these gaps, particularly in the underrepresented contexts of rapidly urbanizing tropical port regions, this study provides a strategic foundation for planners to transform port cities from isolated logistics hubs into low-carbon, resilient urban ecosystems.

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