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INTERMODAL TRANSPORT IN 2015-2025: A SYSTEMATIC LITERATURE REVIEW

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Purpose: The aim of this article is to analyse the evolution of research on intermodal transport in the years 2015-2025 by identifying the dominant thematic clusters, methodological approaches, and research gaps.
Design/methodology/approach: The study combines a systematic literature review (SLR) with a bibliometric analysis using data retrieved from the Web of Science Core Collection. Out of 1,071 articles, 152 publications were analysed. The study includes (1) article selection based on the PRISMA protocol, (2) manual preparation and cleaning of 902 keywords in Excel, and (3) creation of co-occurrence maps, clusters, and time visualizations in VOSviewer.
Findings: The study revealed an interdisciplinary research area within intermodal transport, including four main thematic clusters that reflect both the traditional foundations of intermodal transport and emerging research directions.
Research limitations/implications: The review is limited to publications indexed in the Web of Science, published between 2015 and 2025 and written in English, and the analysis did not include a methodological assessment of individual articles. Future research could broaden the database scope and apply methodological triangulation.
Practical implications: The findings contribute to a better understanding of how intermodal transport systems may evolve to become more efficient, resilient, and environmentally sustainable.
Originality/value: This article is one of the few comprehensive analyses that combine SLR and bibliometric methods to assess 11 years of research on intermodal transport. It offers new insights into the thematic evolution of the field, identifies methodological patterns, and highlights research gaps.
Keywords: intermodal transport; bibliometric analysis; systematic literature review; VOSviewer.
Category of the paper: Research paper/Literature review.

1. Introduction

Intermodal transport – defined as the movement of goods in a single loading unit using at least two different modes of transport without handling the goods themselves – has for many years been regarded as a key component of transport systems (OECD, 2001; Crainic, Kim, 2006; European Commission, 1997; Gajdzik et al., 2023; Fikus, Liszka, 2024). Intermodality has become not only an alternative to road transport but also one of the pillars of strategies for sustainable development, integration, and supply chain optimization. The role of intermodal transport is growing both in practice and in research, which is reflected in the expanding body of academic work. As the volume of studies on intermodal transport increases, so does the need for syntheses that consolidate existing knowledge and highlight emerging research directions – an observation that motivated the development of this article. Intermodal transport plays a particularly important role in maritime logistics, where the efficient connection between seaports and inland transport modes determines the fluidity of global supply chains. Moreover, intermodality significantly contributes to reducing the environmental impact of transport systems, enabling a shift towards more sustainable transport solutions.

Early approaches in the literature on intermodal transport focused primarily on issues related to the integration of transport modes, and it was crucial to understand the "basics" of intermodality – definitions, system components, relationships between modes of transport, and the impact on transport efficiency, such as the review of intermodal transport by Hanssen and Mathisen, 2014, or earlier in the study by Bontekoning et al., 2004. Early considerations of intermodal transport also included issues related to the organization of intermodal transport (Mindur, Hajdul, 2011), the location of terminals, and transport planning (Pierre et al., 2004; Caris et al., 2008) and the problem of supporting intermodal transport policy decisions (Macharis et al., 2011; Mostert et al., 2017), or aspects of the costs of intermodal transport networks (Janic, 2007; Bierwirth et al., 2012) and cost efficiency (Jaržemskienė, Jaržemskis, 2010). An important analytical element in the literature is research on cargo consolidation models (Bierwirth et al., 2012), innovative elements combining production planning and intermodal transport in supply networks (Meisel et al., 2013), and service quality in intermodal terminals (Abramović et al., 2012).

In recent years, research directions have expanded considerably. New studies increasingly focus on the integration of logistics chains in an international context, taking into account environmental aspects and the multidimensional implications of intermodality. Attention should also be paid to the literature addressing intermodal transport in the context of international issues, such as Polish-Ukrainian relations (Jacyna-Gołda et al., 2024), regional perspectives (Przybylska et al., 2023), environmental considerations (Ferguson et al., 2025; Bairam, Shadab, 2025), environmentally oriented modal choice (Bayramoğlu et al., 2025), analyses of maritime–rail systems (Abu Aisha et al., 2024), and cost modelling (Kovalenko

et al., 2024). Recent studies also highlight innovation and digital solutions supporting planning processes (Zając et al., 2025), the use of Internet of Things technologies to predict cargo arrival times (Balrogis et al., 2025), and route selection supported by machine learning methods (Xinyu, 2025). Research increasingly addresses tactical planning that incorporates logistical factors affecting planning efficiency (Vieira, 2024; Chupin et al., 2025), the location of dry ports as key components of intermodal systems (Li et al., 2025), as well as business models for intermodal transport of perishable goods, with particular emphasis on digitalisation and stakeholder cooperation (Barranco et al., 2025). An important extension of this research stream is the treatment of terminals as key nodes coordinating logistics within intermodal networks, as emphasised by Monios and Bergqvist (2025).

This study provides a comprehensive review of the literature on intermodal transport, with particular emphasis on the dominant research trends and changes occurring between 2015 and 2025. The work is based on a bibliometric analysis of 152 scientific publications from the Web of Science database, covering the period 2015-2025. The aim was to systematize the most important and reliable research results and to identify potential areas requiring further exploration. The analysis was conducted in accordance with the systematic literature review (SLR) approach, including the stages of defining research questions, identifying and selecting publications, and synthesizing their evaluation according to the PRISMA model.

The following sections of the article will present the detailed research methodology, including the literature search and selection procedure and the tools used for data analysis. This will be followed by a presentation of the research results, including a visualised bibliometric network prepared in VOSviewer, showing key thematic clusters and the evolution of research over time. The next section will cover the discussion of the results and interpretation of the obtained relationships. The conclusion will present the prospects for future research as well as the limitations of the study.

2. Methodos

2.1. Dynamics of Academic Literature Development

The dynamic growth of academic output confirms the increasing interest in the field of intermodal transport. As indicated by an analysis of publications indexed in the Web of Science database, the number of articles devoted to intermodal transport has been steadily rising – from fewer than 10 publications per year in 2015-2017 to as many as 24 publications in recent years. The growth in citation counts is even more pronounced, highlighting the increasing relevance of this topic in the international academic discourse. The peak citation level recorded in 2024 suggests that this research area has reached a stage of academic maturity and resonates strongly with other fields (Figure 1).

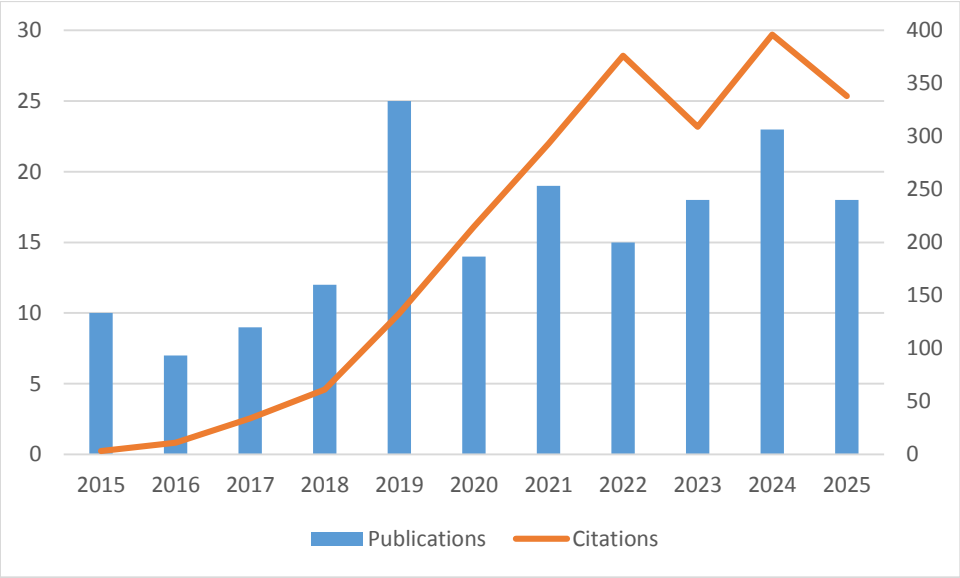

Figure 1. Total number of publications and citations by year.

Source: own elaboration based on Web of Science.

The field of intermodal transport research is highly diverse and covers topics ranging from technical analyses and optimization processes, through environmental perspectives and modern technologies, to political and systemic approaches. However, there is a lack of up-to-date review studies in the literature that would capture the dominant research directions, emerging thematic clusters, and potential analytical gaps in a structured and visual manner.

2.2. Research protocol

The study is based on the methodology of a systematic literature review (SLR), following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta – Analyses) guidelines as one of the established standards (Liberati et al., 2009). This approach enables a deeper understanding of the methodological aspects of the research domain, and as scholars emphasize – a rigorous and well-executed review provides a solid foundation for knowledge development (Synder, 2019). Systematic literature reviews are characterised by high methodological value in academic research (Višić, 2022). SLR allows for the identification of key publications, their thematic classification, and critical assessment (Mengist et al., 2020; Mohamed Shaffril et al., 2022), which makes this method particularly suitable for introducing research on intermodal transport.

In this article, a PRISMA flow diagram (Preferred Reporting Items for Systematic Reviews and Meta – Analyses) was used to visualise the publication selection process (Page et al., 2021). Although the review was not formally registered and some elements of the PRISMA 2020 checklist (e.g. assessment of risk of bias in primary studies) were not applied, the structure of the diagram was adapted to ensure transparency and a systematic approach to the processes of searching, selecting, and excluding articles (Figure 2).

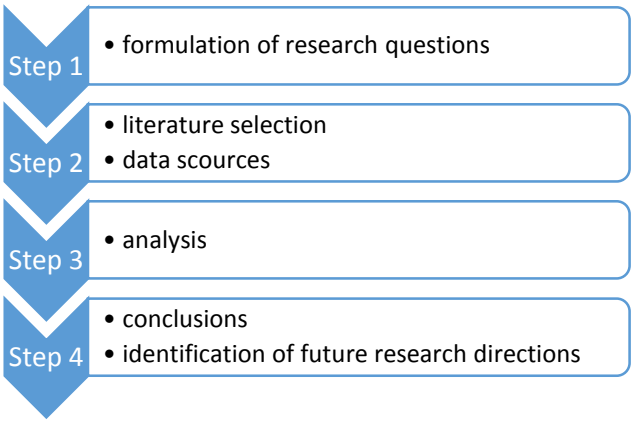

Figure 2. Research protocol.

Source: own elaboration.

2.3. Research questions

As highlighted in the literature, clearly formulated research questions constitute the foundation of a systematic literature review – they define the scope of the review, guide the process of searching and selecting publications, and frame the analysis of the findings. In evidence-based reviews, the formulation of an appropriate research question determines the relevance of selected sources and the overall quality of the review (Ziemba et al., 2025; Bellucci et al., 2022).

Accordingly, to address the overarching objective, three key research questions were formulated:

1. What are the main thematic clusters in the literature on intermodal transport?
2. Which methodological approaches and perspectives dominate research on intermodality?
3. Which areas require further exploration?

2.4. Data collection

The analysis covered publications indexed in the Web of Science database for the years 2015-2025. The choice of 2015 as the starting point of the examined period stems from the noticeable shift in the development dynamics of the sector, as well as its convergence with the launch of several EU initiatives related to sustainable development. Including data up to 2025 makes it possible to capture the most recent trends, including the growing interest in topics such as digitalization, EU climate policy, and geopolitical considerations. Recent years have also seen an intensive expansion of research on supply chain resilience, which has been reflected in the literature on intermodal transport. Thus, the selected time horizon allows for a more comprehensive representation of development dynamics and provides an up-to-date basis for identifying both dominant and insufficiently explored research directions.

The keyword search used the term TS = ("intermodal transport"), applied to titles, abstracts, and author keywords. A total of 1071 publications were identified. Subsequently, in accordance with the methodology of the systematic literature review (SLR), predefined inclusion and exclusion criteria were applied.

Inclusion criteria:

- language of publication: English,
- document type: scientific articles,
- publication period: 2015-2025,
- Web of Science categories: Transportation; Transportation Science & Technology; Management; Green & Sustainable Science & Technology; Economics; Environmental Sciences; Environmental Studies; Operations Research & Management Science,
- availability: All Open Access.

After applying the above restrictions, 169 publications remained in the Web of Science database.

In the subsequent selection phase, to ensure substantive relevance, the titles, keywords, and abstracts of all 169 articles retained after applying the predefined criteria were analysed. The selection process was conducted manually to minimise the risk of systematic bias and to ensure high thematic consistency of the review.

The main exclusion criterion in this stage was the direct relevance of the study to the issue of intermodal transport, particularly in the context of topics such as the integration of transport modes, intermodal terminals, logistics, benefits and barriers of modal shift, infrastructure strategies, EU policy, and the digitalization of processes within intermodal freight transport.

Following this stage, 17 publications were excluded, as their thematic focus despite occasional terminological overlaps did not correspond to the core objectives of the study. The primary reasons for exclusion included:

- tourism and passenger-oriented topics, such as studies on public transport, urban mobility, or tourist travel (e.g. “urban tourism and intermodal public transport”),
- air transport and its integration with airport access, without reference to classical freight intermodality (e.g. “air–rail intermodality”, “airport access”),
- pandemic related research (COVID-19) focusing on changes in trade structure, urban logistics, or personal mobility,
- environmental or health-related studies, in which intermodality appeared only as a minor component of broader analyses on biodiversity, public health, or energy systems,
- topics unrelated to logistics, such as ride-sharing, car-sharing, biodiesel, electric vehicles, etc.

Figure 3 below presents the detailed process of identifying, selecting, and qualifying publications in accordance with the PRISMA structure, including each stage of dataset reduction and the number of studies excluded at each step.

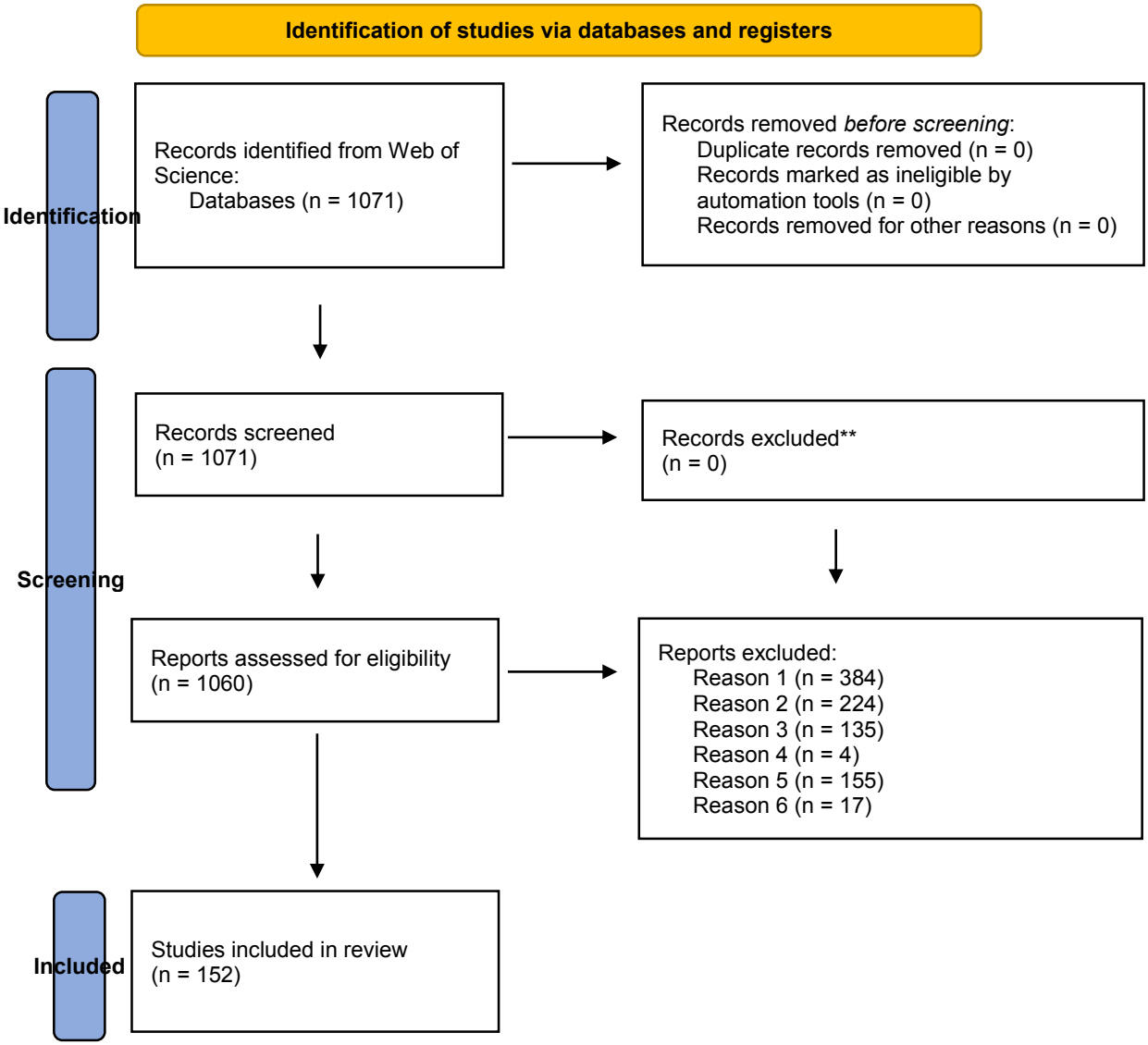

Figure 3. Flow diagram of the study selection process based on the PRISMA model.
Source: own elaboration.

3. Data analysis

3.1. Keywords

As a preliminary stage of the analysis, before conducting a bibliometric analysis in VOSviewer, a separate, fully independent data preparation stage was created, involving the manual compilation of keywords in Excel spreadsheets. In order to identify research trends in

the field of intermodal transport and sustainable logistics, a set of 902 keywords obtained from the records of 152 publications in the Web of Science (WoS Core Collection) database was analyzed. The data preparation process consisted of several stages:

1. exporting metadata from the WoS database,
2. aggregating all keywords from publication records,
3. manually cleaning the collection of duplicates, spelling errors, and semantic variants (e.g. intermodal transport/intermodal transportation),
4. standardization of keyword terminology,
5. preparation of the final set for frequency and co-occurrence analysis.

The preliminary exploratory stage also included the preparation of a graphical summary illustrating the evolution of selected keywords across the analysed publications. These charts complement the subsequent bibliometric analyses conducted in VOSviewer and provide an initial overview of the key terms appearing in studies published between 2015 and 2025.

The first chart (Figure 4) presents the total number of occurrences of the Top 10 keywords throughout the entire study period. The most frequently used term is *intermodal transport*, which confirms its central role in the analysed academic discourse. Significant prominence is also given to terms related to rail transport, ports, logistics of transshipment centres, supply chains, and modal shift. This overview highlights the broad thematic scope of the research area and confirms its interdisciplinary nature.

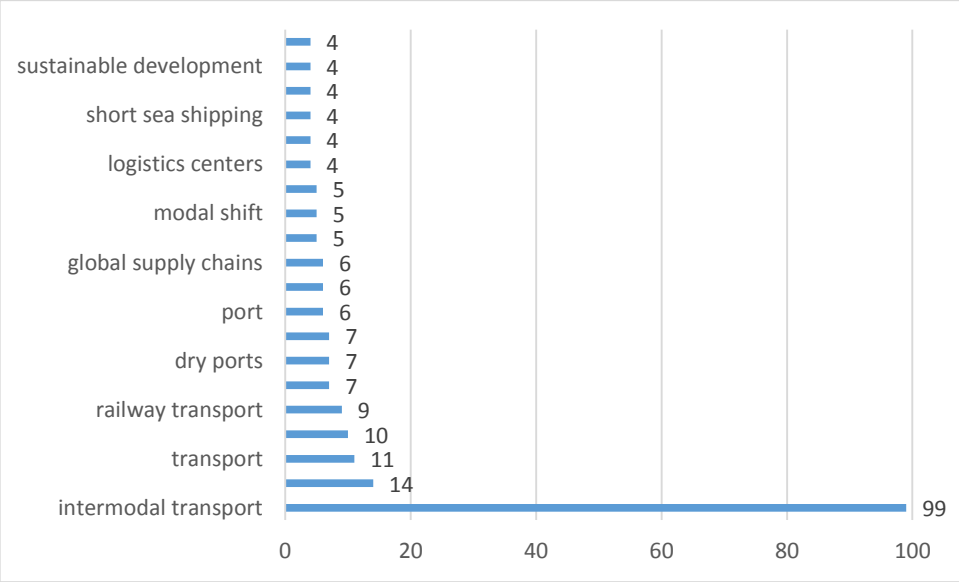

Figure 4. Top 10 keywords.

Source: own elaboration.

The second chart (Figure 5) illustrates the number of occurrences of the Top 5 most frequently used terms between 2015 and 2025. The term *intermodal transport* clearly dominates, with its frequency markedly exceeding the remaining categories (blue line). A gradual increase in interest is also observable in topics such as sustainability, multi-criteria decision making, and railway transport.

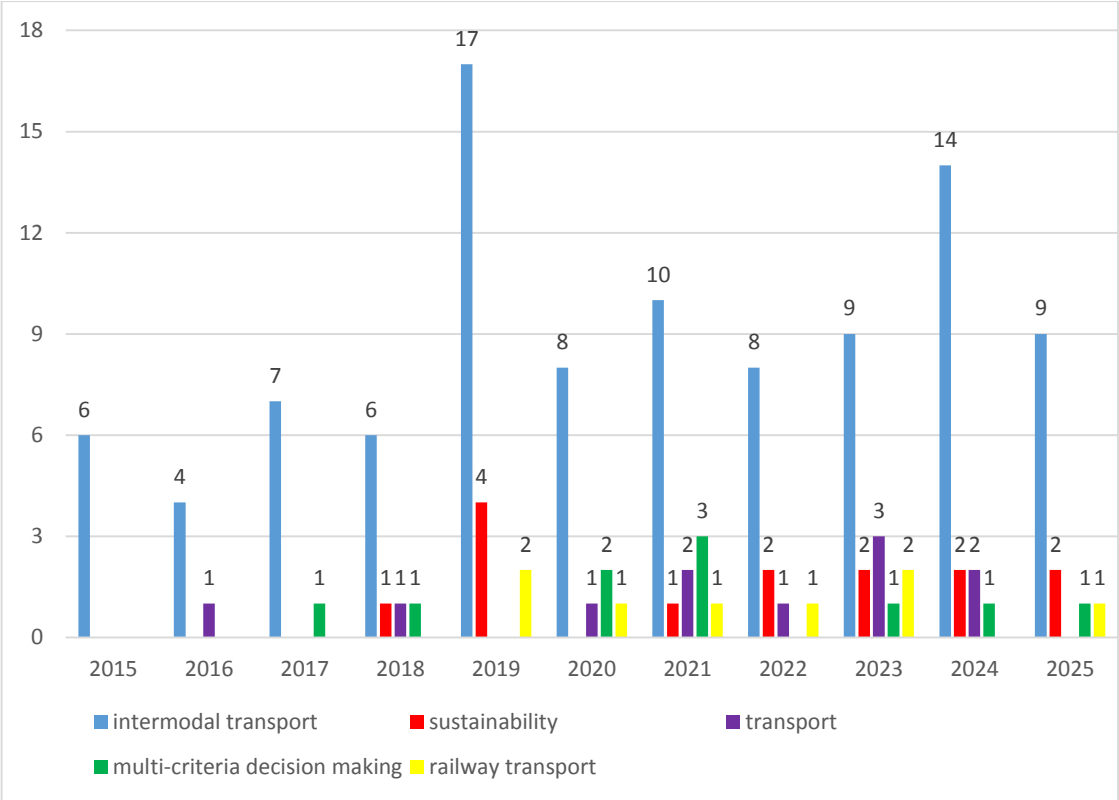

Figure 5. Top 5 most frequently used keywords in 2015-2025.

Source: own elaboration.

3.2. Bibliometric Analysis

For the bibliometric analysis, which encompassed 152 articles from the Web of Science database selected according to the predefined criteria, the VOSviewer software was used. This enabled:

- co-occurrence analysis,
- co-authorship analysis,
- overlay visualization.

3.2.1. Keyword Co-occurrence Analysis

To identify the dominant research themes, a keyword co-occurrence analysis was conducted using the VOSviewer software. The analysis covered 152 articles from the Web of Science database selected according to the predefined criteria. Based on the results, a conceptual map was generated (Figure 6), illustrating the cluster structure of the terms most frequently appearing in the analysed publications.

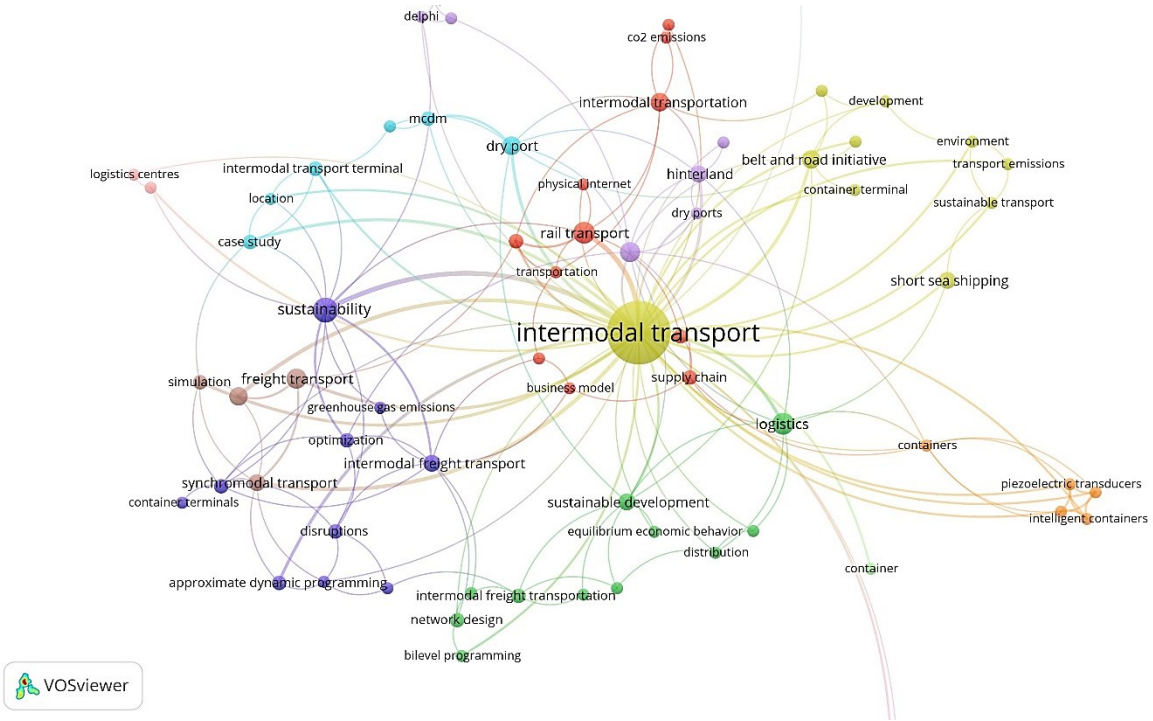

Figure 6. Keyword co-occurrence clusters in intermodal transport research.

Source: own elaboration.

The red cluster is centred around terms such as: *business model, CO_2 emissions, environmental impact, governance, intermodal transportation, physical internet, rail transport, road transport, supply chain, transport, and transportation.*

The green cluster, comparable in size to the red cluster, includes terms such as: *bilevel programming, cost–benefit analysis, distribution, equilibrium economic behavior, foreign trade, integration, intermodal freight transportation, intermodal terminals, logistics, network design, and sustainable development.*

The purple cluster is represented by keywords such as: *approximate dynamic programming, container terminals, disruptions, greenhouse gas emission, intermodal freight transport, optimization, reinforcement learning, resilience, simulation–optimization, and sustainability.*

The yellow cluster is represented by terms such as: *Belt and Road Initiative, container terminal, development, digitalization, environment, infrastructure, intermodal transport, short sea shipping, sustainable transport, and transport emissions*.

3.2.2. Overlay Visualization

Figure 7 presents a conceptual map generated using the overlay visualization technique, which reflects the average publication year of individual terms in the analysed literature. The colour scale corresponds to chronological progression – from purple, indicating older publications, to yellow, representing the most recent ones.

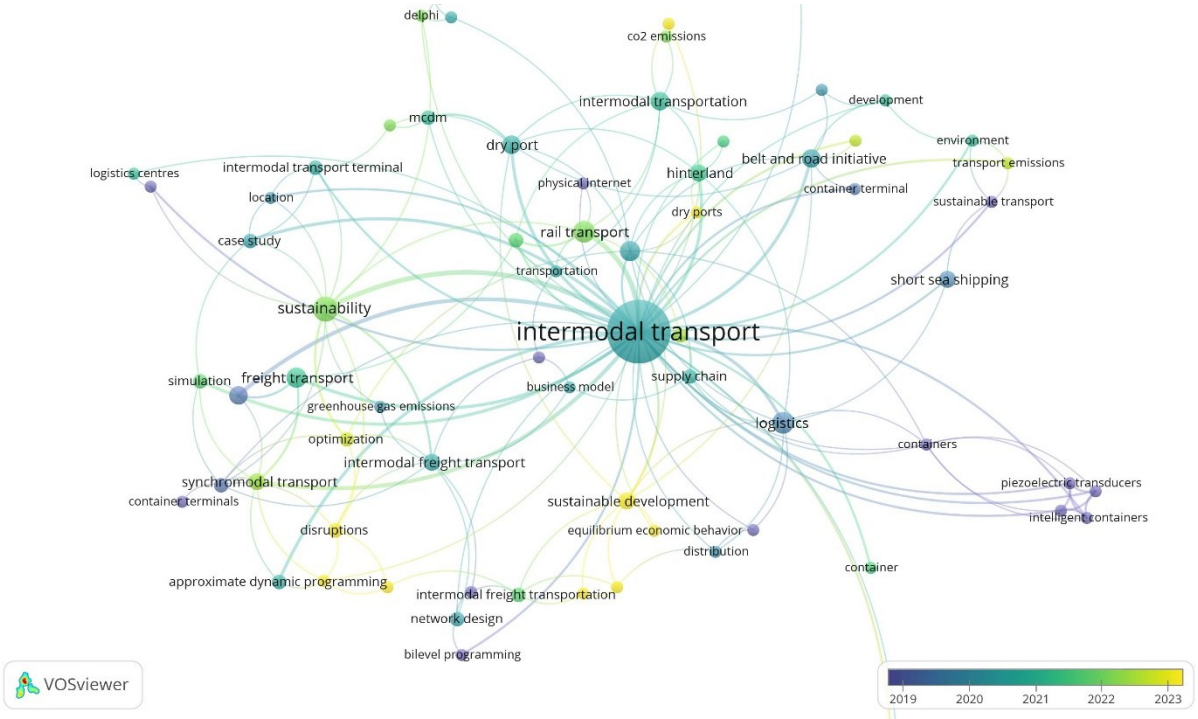

Figure 7. Overlay visualization of keyword co-occurrence by publication year.

Source: own elaboration.

The visualization shows that earlier studies, primarily from 2019-2020, cluster around classical concepts such as *logistics*, *container terminal*, *distribution*, *short sea shipping*, and *location*. Their prominence corresponds to traditional research areas focused on the structure of intermodal systems.

In contrast, newer publications from 2022-2023 highlight more advanced and multidimensional topics, including *disruptions*, *resilience*, *reinforcement learning*, *carbon tax*, and *simulation–optimization*. These themes align with research on machine learning, resilience, and sustainability, indicating a shift in research emphasis toward predictive analyses, planning, and optimization.

3.2.3. Co-authorship Analysis

The next stage of the analysis involved co-authorship visualisation, aimed at identifying the authors who collaborate most frequently in research on intermodal transport. The results generated using VOSviewer indicate that the author collaboration network is relatively dispersed, with limited connections between researchers (Figure 8).

Figure 8. Co-authorship network of researchers in intermodal transport.
Source: own elaboration.

The most notable collaborative relationship is formed by Mladen Krstić and Snežana Tadić, whose work focuses on intermodal transport, environmental aspects, and the selection of technologies and their impact on intermodal transport efficiency. Their studies employ methods such as multi-criteria decision-making models, the Delphi method, DEMATEL, Axial Distance-Based Aggregated Measurement (ADAM), fuzzy FARE, and fuzzy CODAS.

Another researcher who stands out is Sabine Limbourg, who collaborates with several different authors and is a co-author of a substantial number of publications. Her work focuses, among other topics, on instruments for managing intermodal transport, strategic-level analyses of modal split between road, intermodal rail, and inland waterway transport under various economic and environmental policies, as well as studies addressing economic and environmental objectives in relation to the benefits of intermodal transport.

4. Results

The analysis conducted in this study reveals substantial thematic and methodological diversity in research on intermodal transport. Combining bibliometric analysis with a systematic literature review made it possible to adopt a multidimensional perspective on the development of intermodal transport between 2015 and 2025. The results of the keyword co-occurrence analysis indicate a clearly formed structure of four main thematic clusters, reflecting

both classical themes and the foundations of intermodality, as well as new research topics arising from, among others, environmental and technological challenges.

The review of 152 publications and the keyword analysis provide insight into the methodological approaches and research perspectives present in the literature. Most notably, modelling and optimization approaches dominate. Scholars frequently apply models for terminal location, transport planning, transport simulation, and cost analysis. This is consistent with the nature of operations research, which for decades has constituted a key component in the development of intermodality, as reflected by keywords found within the clusters, such as *bilevel programming, cost–benefit analysis, simulation–optimization,* and *network design*.

In addition, the importance of modern technologies such as machine learning is increasingly evident. Environmental analyses focusing on emissions and energy efficiency also remain essential. These research trends correspond to EU climate objectives and global tendencies toward sustainable transport. Equally important are topics related to international corridor integration, geopolitical conditions (e.g. Poland-Ukraine relations), port development, and the role of terminals as logistics nodes. The literature also includes case studies, which complement the review with a practical dimension.

5. Discussion

The results of this study are consistent with previous literature but also reveal a number of developments that have not been systematically synthesized so far. Authors such as Hanssen and Mathisen (2014) and Bontekoning et al. (2004) have explored the fundamentals of intermodal transport in their research. The cluster structure described in this paper confirms that these topics remain at the core of the field, as reflected in the green cluster, which brings together research on network modeling, optimization, and design. At the same time, bibliometric mapping indicates a clear thematic expansion towards environmental, digital, and resilience-oriented perspectives, which is consistent with recent work on sustainability (Ferguson et al., 2025; Bayramoğlu et al., 2025) and technological innovation (Zając et al., 2025; Balrogis et al., 2025). Compared to previous reviews, this study offers a broader and more integrated overview of eleven years of research. Identifying four clusters provides a structured representation of how research topics are organized within a given field. Importantly, this structure helps explain why certain research areas become priorities.

Based on the identified trends, several potential future research directions can be distinguished. First, there is a growing need for studies on the resilience of intermodal networks to disruptions. Topics such as *resilience* and *disruptions* appear with increasing frequency, yet they require deeper investigation, particularly in the context of accelerating geopolitical changes. Another important research direction concerns digital solutions and smart

technologies, given that the full integration of intermodal transport relies heavily on advanced technologies, standardisation, and international cooperation. Furthermore, the literature still lacks comprehensive models enabling effective management of intermodal transport networks.

Additional research is also needed on the environmental dimension of intermodality, including detailed emission assessments and analyses of the impact of climate policies. The literature on intermodal transport is currently undergoing a transformation – from technical and optimization-oriented approaches toward systemic, digital, and environmental perspectives. The results of this study indicate that future research will require broader interdisciplinary integration, drawing on economics, engineering, and transport policy, among other fields.

6. Limitations

Despite the broad scope of the analysis and the application of the SLR methodology based on the PRISMA framework, this study has several limitations that should be taken into account when interpreting the findings:

1. The analysis relies exclusively on publications indexed in the Web of Science database, which may result in the omission of certain literature, industry reports, and publications not indexed in major databases.
2. The selected time frame (2015-2025) – although justified by the development dynamics of the field—does not include earlier, historically oriented works that could further enrich the context of the evolution of the intermodality concept.
3. The choice of keywords was limited yet purposeful, aiming to clearly delineate the boundaries of the review.
4. The keyword co-occurrence analysis in VOSviewer is based on terminology assigned by the authors of the publications. Differences in indexing practices or terminology used (e.g. combined transport, multimodal logistics) may lead to partial discrepancies in classification.
5. The study did not include a methodological assessment of individual articles, such as data quality or model reliability.

Despite these limitations, the findings provide a coherent overview of the structure of research on intermodal transport and constitute a solid basis for further comparative analyses and in-depth case studies.

7. Summary

In summary, intermodal transport is currently one of the key areas of development in contemporary research, and scientific literature confirms its growing role. This review provides a systematic overview of the current state of knowledge in the years 2015-2025, while also identifying areas requiring further exploration.

The bibliometric analysis revealed four main thematic clusters that reflect the diversity of research approaches and the development of interdisciplinary discourse in the field of intermodality. Although the cluster map itself does not assess the completeness of research in each area, the identified clusters offer a useful framework for interpreting research gaps. Future research directions reflect topics that appear in clusters but are not yet widely developed, and the analysis confirms that intermodal transport is becoming the subject of interdisciplinary research. References to disruptions and resilience are concentrated within a single cluster, suggesting that resilience research continues to form a specialized rather than a broadly integrated research stream at the intermodal transport network level. Similarly, terms related to digitization and modern technologies appear in clusters, but only in a scattered manner, indicating growing but still limited interest. Environmental issues, on the other hand, appear in several clusters, and their dispersion suggests that research in this area needs to be more precisely targeted, given the importance of sustainable development in transport.

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