Traffic & Transportation

Women in the Railway Sector – A Bibliometric Analysis of the Last Ten Years' Scientific Production

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Original Scientific Paper
Submitted: 9 Sep 2025
Accepted: 26 Nov 2025
Published: 29 Jan 2026

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Publisher:
Faculty of Transport and Traffic Sciences, University of Zagreb

ABSTRACT
Gender equality has become a priority for governments, institutions and companies that are fostering inclusive environments. In this context, the historically male-dominated railway sector has begun a process of transformation. However, women continue to encounter persistent barriers to working, accessing and utilising rail transport. These challenges are closely linked to the complexity of travel chains, safety concerns, and mobility constraints that are shaped by prevailing social and gender structures. Considering this, the study employs a quantitative bibliometric analysis of scientific production on women in the railway sector (2015–2024), using data from the Web of Science Core Collection and Scopus, to map the status, identify research gaps, and inform future studies and policies. The analysis reveals a growth in research on women in the railway sector over the past decade, though the field remains in consolidation. Output is diverse and multidisciplinary but often fragmented, underscoring the need for stronger international collaboration. Impact is concentrated in a few publications, highlighting the importance of more effective dissemination strategies. While quantitative approaches predominate, greater use of qualitative and mixed methods is needed to capture women's experiences. Future research should enhance collaboration, diversify methodologies, and strengthen dissemination to achieve greater influence on policies and practices.

KEYWORDS
women; gender studies; railway; bibliometric analysis; research trends.

1. INTRODUCTION

Gender equality has become an increasingly relevant issue in many social spheres, generating sustained interest on the part of institutions, companies and governments in seeking to create diverse, inclusive and equitable spaces [1]. There is a rising demand for concrete measures to guarantee equality between women and men in all sectors. People are rejecting unethical practices such as tokenism and symbolic inclusion, which allow institutions to appear progressive while factors such as gender and race continue to influence access and growth within them [2]. Such insufficient actions often result in the reproduction of existing hierarchies, incorporating minority groups only superficially and without providing them with genuine decision-making power [3]. This is a key factor in the perpetuation of epistemic injustice, as the knowledge, experiences and perspectives of underrepresented groups continue to be undervalued and excluded from institutional agendas [4]. Consequently, addressing gender inequality requires recognising the legitimacy of diverse forms of

wisdom and ensuring that all voices can significantly influence knowledge production, policies and organisational practices [4].

The railway sector is no exception to this reality [5-6]. Aware of its traditional male-dominated status and lack of gender diversity, it has begun to make efforts to promote its transformation. In this context, various initiatives have been developed and promoted over the last few years with the aim of improving the situation of women in the sector. Thus, the first annual Women in Rail Awards, organised by the European Commission in cooperation with the European rail sector, took place in March 2022. These awards recognised initiatives by various entities in the sector that drove improvements in women's representation, as well as the promotion of an inclusive, diverse and safe working environment [7]. A year later, the Australasian Railway Association launched the Women in Rail strategy to increase the participation of women in the rail industry and ensure its sustainability [8]. Also in 2023, the Sustainable Mobility for All Consortium launched the "Gender Imbalance in the Transport Sector: A Toolkit for Change", which aimed to provide guidance and resources for integrating a gender approach in transport [9]. Similarly, initiatives have been developed to generate knowledge on the situation of women in the sector, such as the report "Mujeres en el Ferrocarril" (Women on the Railway) launched by the Fundación de Ferrocarriles Españoles (Spanish Railway Foundation) [5, 10]. Furthermore, the UIC (International Union of Railways), the global professional association that represents the sector and promotes rail transport, launched projects such as TRAIN 2B EQUAL. This collaborative platform fosters the exchange of good practices and peer learning to transform the experience of women in the rail sector [11]. These efforts represent just some of the initiatives that have been undertaken by the sector in recent years, reflecting the recognition of the importance of gender diversity and the need to create a more inclusive and equitable industry. This growing concern is also reflected in the report prepared by the European Commission's expert group in 2019, which emphasised the need to break the glass ceiling and recommended using public communication to attract young people and promote female employment in the railway industry, highlighting the sector's role in addressing social challenges [12].

From an academic perspective, gender equality in the transport sector has also become a topic of recent interest, and conceptual frameworks are increasingly being applied to better understand and address systemic inequalities. Approaches such as gender mainstreaming in transport planning highlight the need to transform organisational practices and remove barriers, incorporating gender considerations at all stages of the process and not just as an afterthought [13]. Similarly, intersectional analyses in mobility studies also demonstrate how overlapping social categories (gender, race, age, disability, etc.) shape access to transport and user experiences [14]. These perspectives are essential tools for identifying structural barriers and guiding initiatives focused on creating a more inclusive and equitable industry.

Despite the above-mentioned efforts, recent data show that the number of women employed in the railway sector remains low. In Spain's primary railway entities, the proportion of female employees in 2023 was 20.4% [10]. This scenario is similar across other European countries, where the proportion of women working in the transport sector ranges from 15% in Malta, Greece and Romania to 30% in France, Latvia and Cyprus [15]. The number of female railway drivers in Europe is even lower: 1.5% in Spain, 5% in France and Norway, and 5.2% in the UK [16], among others. Female presence in the railway industry is characterised by a clear horizontal and vertical segregation [17], which means that women remain outside technical areas and leadership positions [10, 16, 18, 19]. The exclusion of women from decision-making positions often results in the ineffectiveness of the measures taken to improve their situation in the sector, as their real needs are not adequately known and considered [17, 19]. This has resulted in a discrepancy between the actions taken by the sector and the actions that women consider to be effective, due to a lack of understanding of women's needs and experiences [20]. Furthermore, their specific needs are not always considered in the design of services and infrastructure [21]. As a result, these inequalities also affect female rail users, who, despite accounting for more than 50% of passengers, continue to face specific challenges and barriers since the design and operation of the rail system often fail to consider their mobility patterns, safety concerns and needs [11].

Considering this, there is an urgent need for in-depth and detailed knowledge of the current situation of women in this field, both as current and potential workers and users. This knowledge should form the basis for the design of future strategies to promote a real and sustainable change. For this reason, the aim of this article is to provide a comprehensive bibliometric analysis of the academic production on the situation of women in the railway industry, which delves into the topics and issues studied in the sector. The objective is to map the current state of research, identifying gaps and generating a solid foundation for the development of future studies and policies. Before this bibliometric analysis, a literature review was conducted. In this process, no previous publications were found that provided a quantitative and systematic bibliometric analysis of the

existing literature on this topic, as proposed in the present study. Consequently, a bibliometric approach is especially relevant in emerging or underexplored fields such as this, as it allows for a structured, objective and data-driven overview of how knowledge has been produced, what areas have been prioritised, and which ones remain insufficiently addressed [22]. At the same time, bibliometric analysis facilitates the detection of representation gaps and the orientation of strategies that promote the effective influence of women in the sector's policies and projects.

The analysis is based on a bibliometric study of scientific literature on women in the railway sector, covering the period from 2015 to 2024. Bibliometric analyses, which are widely used in various disciplines, enable the identification of patterns of scientific production, predominant lines of research, applied methodologies, main works, authors and institutions, and geographical areas with the highest concentration of studies. Furthermore, it facilitates the identification of thematic gaps and potential avenues for future research [23-24]. This is of particular importance when aiming to support evidence-based policymaking and inform stakeholders committed to fostering gender equality in the railway. In this paper, data were obtained from the Web of Science Core Collection and Scopus databases, using a defined set of keywords and search criteria to ensure consistency across both sources. This was followed by data merging, duplicate removal and a manual screening process to refine the final sample. This analysis will contribute to synthesising existing knowledge on women in rail, generating a new perspective on the issue and building a solid basis for the development of more effective and appropriately contextualised proposals to promote gender equality in the railway sector. The article is structured as follows: Section 2 details the methodology employed in this research; Section 3 collects and analyses the data obtained from the bibliometric analysis; Section 4 discusses the main findings; and Section 5 offers conclusions and suggestions for future research.

2. METHODOLOGY

A quantitative methodology was employed to conduct this work, and a bibliometric analysis was carried out on the scientific production regarding the current situation of women in the railway sector over the last decade (2015–2024). Following the identification of the object of study, the research questions to which this work aims to respond were formulated as follows:

1) What is the volume of academic production on women in the railway sector over the last ten years, and how has it evolved during this period?
2) What are the key themes, citation patterns, areas of knowledge, main entities, authors and countries identified in the academic production of women in the railway sector?
3) What are the main trends in methodology and future research directions of the studies that have been conducted to date?

The information sources used for the analysis were the Web of Science Core Collection and Scopus databases, the two most widespread international platforms for scientific literature at the present time [25]. Following careful consideration, it was agreed that both databases would be used to ensure comprehensive and representative coverage of the topic. On the one hand, Web of Science offers a more exhaustive selection of publications [26], providing accurate and reliable results [27]. On the other hand, Scopus is more varied and broader in terms of content, as it includes a larger number of unique indexed journals [25], which results in extensive research outputs. By combining the two, it is possible to ensure a complete overview of the scientific production regarding our research topic: the role of women in the railway sector. The following steps were taken to obtain the data for the analysis:

1) Keywords: the keywords used to collect the data were selected based on research questions. The search was formulated by combining two groups of words. The first category, which refers to women, included the terms "woman", "women", "female" and "gender". The second, relating to the sector, encompassed the terms: "railway" and "railroad". The selection of these terms was made after testing different combinations, as these provided the most relevant and pertinent results in relation to the objectives of the analysis.
2) Search criteria: to ensure the results obtained from the two databases were comparable, criteria were defined for the queries made. The advanced search engine of both platforms was used. Since the aim was to gain an overview of recent academic production, the time range of the last ten years was established, specifically from 2015 to 2024. The review was restricted to articles and proceeding papers to guarantee a consistent framework based on academic research that has undergone peer or editorial evaluation processes. Only publications written in English were selected, as it is the dominant language in scientific

production. The search was conducted in the title, abstract and keyword fields (in Web of Science, the topic field encompasses these three elements).

3) Search: the keywords were searched for in both databases using the previously established filters. The exact query applied was: ("woman" OR "women" OR "female" OR "gender") AND ("railway" OR "railroad"). Web of Science provided 415 results, and 1,125 results were retrieved from Scopus, bringing the total to 1,540.
4) Merging databases and eliminating duplicates: following the export of results from Web of Science and Scopus, they were unified in a single database. The Bibliometrix Toolkit was used to carry out the analysis. Following the acquisition of the combined database, the process of removing duplicates was conducted using Excel software, identifying matches by DOI and, when missing, by title. Finally, a manual review was carried out to check that there was no duplicate data. After this process, the sample was reduced to 1,238 documents.
5) Manual review: Once the combined database was obtained, it was observed that it contained several records unrelated to the research topic, such as works that, while related to the railway industry, did not specify the participation of women, or studies that mentioned women only from a demographic perspective without providing specific results. Therefore, a manual review was carried out to purify the sample and eliminate irrelevant records. The review was conducted in two phases. Firstly, the results that were not related to the topic under study were eliminated after carefully reading the title and abstract, and, if necessary, the whole paper. Following this, three additional experts in the field reviewed the articles that had passed the initial selection process to ensure their relevance. Each expert evaluated a subset of the records independently and identified articles for potential exclusion or further discussion. Subsequently, a joint meeting was convened with all reviewers to deliberate on discrepancies and borderline cases until a collective consensus was achieved. This qualitative consensus procedure ensured coherence and reliability across reviewers' judgments. To carry out the manual review, it was established that those texts about the situation of women in any dimension related to the railway sector were to be included. Similarly, studies focused on the railway sector that included women in their analysis, offering specific knowledge and results about their role or realities, were also considered relevant. Following the completion of the filtering process, the final sample comprised 129 documents. *Table 1* outlines the search process and data collection.

Table 1 – Search criteria and documents retrieved, providing an overview of the methodological process and the volume of literature identified across both databases

Sources	Search conducted	Search criteria	Documents obtained	Date of download
Web of Science Scopus	#1=Women OR Woman OR Female OR Gender. #2=Railway OR Railroad #1 AND #2	Period: 2015-2024 Type of documents: Articles and proceeding papers Language: English Search fields: Title, abstract and keywords	WOS: 415 Scopus: 1,125 Total: 1,540 Total after review: 129	26/06/2025

Source: Own elaboration.

Following a process similar to that described in [28], the bibliometric analysis was performed using the open-source Bibliometrix package in version 5.0. This software provides the set of tools necessary to carry out complete studies in the field of bibliometrics and scientometrics [29]. Developed in the R programming language, Bibliometrix incorporates efficient statistical algorithms, high-quality numerical routines and integrated data visualisation tools. This allows the user to follow the complete workflow without needing to use other programs. The data obtained have been processed using Biblioshiny, the application that provides a web interface for Bibliometrix, facilitating access to and use of the different functions it offers.

3. RESULTS

This section presents the findings through bibliometric analysis. They have been grouped into three main sections corresponding to the research questions posed.

3.1 Volume and evolution of academic production on women in the railway sector

Following a thorough review and filtering process, the final database comprises 129 scientific documents published between 2015 and 2024. *Table 2* summarises the information obtained from an overview of this dataset. These publications appeared in 106 different sources. An annual growth rate of scientific production of 16.65% is observed. This reflects an upward trend in research activity, consistent with the growing interest of the sector in gender equality. On average, the documents are 4.22 years old, indicating that this is a topic of recent interest. The average number of citations per document is 9.031. The data on authorship show that a total of 453 authors contributed to the 129 documents. Twenty-one documents were written by a single author. In contrast, most of the texts (108) were produced through collaboration among multiple authors, as evidenced by the average number of co-authors per document of 4.19. The collaborative nature of most of the papers suggests a significant degree of interdisciplinarity and teamwork in the research carried out. However, the number of single-authored papers indicates that, despite the prevalence of collaborative efforts, individual contributions remain significant in this field of study. Regarding the thematic content of the documents, the dataset includes 598 Keywords Plus and 526 Author's Keywords (the former are algorithmically generated from cited references, whereas the latter are chosen by the authors themselves). This suggests a wide thematic variety in the collected data, indicating that the topic is interconnected with multiple areas of knowledge and is approached from diverse perspectives.

Table 2 – Main information overview of the dataset

Main information about the data	
Timespan	2015-2024
Documents	129
Sources	106
Annual Growth Rate %	16.65
Document Average Age	4.22
Average Citations per Doc	9.031
Main information about the data	
Authors	453
Single-authored Docs	21
Co-authored Docs	108
Co-Authors per Doc	4.19
International co-authorships %	15.5
Document contents	
Keywords Plus	598
Author's Keywords	526

This table summarises key characteristics of the analysed documents, providing a general view of the scope, productivity and citation patterns of research on women in the railway sector. Source: Own elaboration.

Distribution of publications by year

Figure 1 shows annual scientific output from 2015 to 2024. The temporal distribution of publications indicates a growing scientific interest in the role of women in the railway sector. During the first half of the period analysed (2015-2019), 41 documents were published, representing 31.78% of the total sample. In these early years, annual output remained relatively stable, with slight peaks in 2016 and 2019, with 10 and 13 publications respectively. The trend varies significantly between 2020 and 2024, with 88 documents, representing 68.21% of the total. From 2021 onwards, there has been a marked increase in production, which has been consistently rising over time.

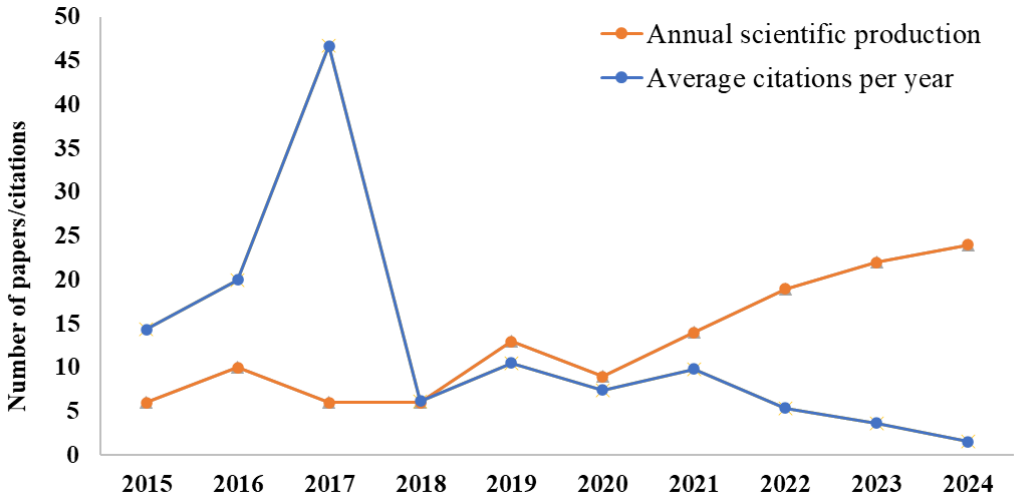

Figure 1 – Annual scientific production and average citation per year
Source: Own elaboration. This figure illustrates an increase in publications since 2020, alongside a decline in average citations in recent years due to the shorter citation window of newer studies.

Citations report per year

The 129 documents that constitute the selection have been cited a total of 1,165 times, which translates into an average of 9.03 citations per publication. *Figure 1* shows how the average number of citations per year is distributed. The annual averages are higher during the first years of the period analysed. In 2015, they reached 14.33, 20 in 2016, and a very notable maximum in 2017 with 40.67 citations per document. This exceptional value can be attributed to the publication in that year of the article that accumulates the highest number of citations (216) of the entire dataset [30], which significantly raises the average. From 2018 onwards, the average number of citations per document declines, falling to 6.17 in 2018, 10.54 in 2019, 7.44 in 2020, and 9.86 in 2021. In more recent years, this figure decreases more noticeably, reaching 5.37 in 2022, 3.86 in 2023, and 1.54 in 2024, likely due to the shorter time span for citations in newer publications. In addition, among the 129 documents, 34 have never been cited, while 185 have at least one citation. The median number of citations per document is 3, indicating an asymmetrical distribution influenced by articles with a high number of citations. A small number of documents have attracted a significant level of attention, with 16 out of the 129 (12.4%) receiving over 20 citations.

3.2 Key themes, actors and citation patterns in research on women in railways

This section highlights the main themes explored in the literature, identifies the prominent actors involved, and examines citation patterns that reveal influential contributions and trends in this field.

Sources

The journal Sustainability has published the largest number of documents (7) on the role of women in the railway sector, with a total of 82 citations. Its focus is on environmental, cultural, economic and social issues. In terms of productivity, it is followed by Environment International (58 citations), Transport Policy (16) and Transportation Research Procedia (6), each with three documents. The publications of the first focus on environmental health. The second focuses on transport improvement policies and strategies, while the third specialises in transport research from the social sciences.

Of the 10 main sources (see *Figure 2*), the rest contain two published articles. However, it is worth highlighting the journals Transportation Research Part A: Policy and Practice; Traffic Injury Prevention; and Journal of Transport & Health, as they have 59, 48 and 26 citations, respectively. These journals cover transport policies and strategies; safety; and the interaction between health and transport. The journal Gender, Place and Culture (2 documents and 7 citations) is also noteworthy given that its thematic focus on feminist geographies and gender studies differs the most from the rest of the sources.

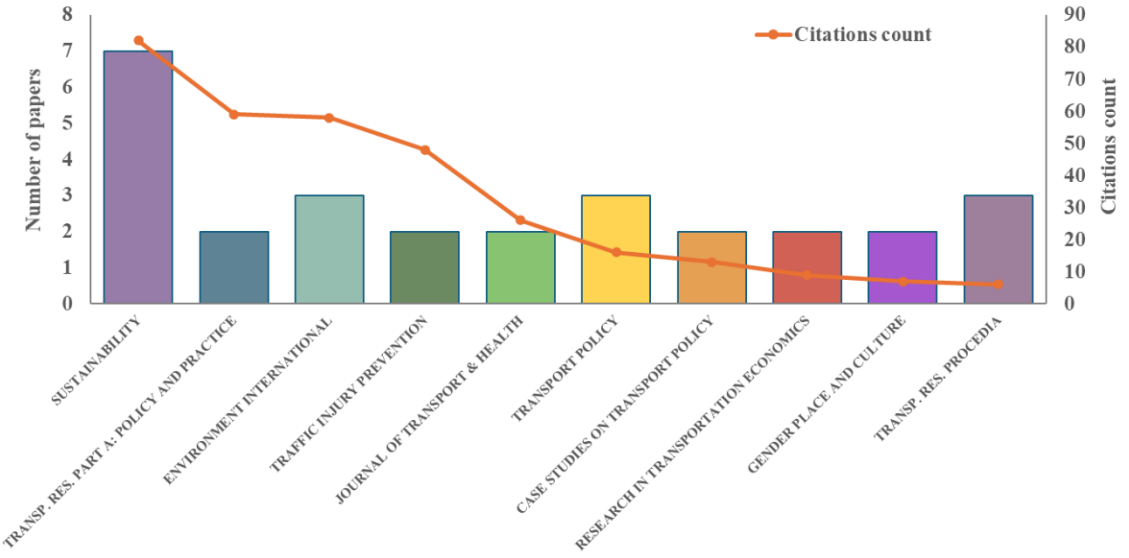

Figure 2 – Summary of the ten main sources and citation count
Source: Own elaboration. The distribution reveals that Sustainability leads in both output and citations, reflecting the interdisciplinary nature of the field, which bridges environmental, policy and social dimensions of transport research.

Dynamics of authorship in research

In terms of scientific output, the most prolific authors are Raaschou-Nielsen, Ole (Denmark), with 7 papers and 97 citations; followed by Sorensen, Mette (Denmark), with 6 papers and 55 citations; and Roswall, Nina (Denmark), with 5 papers and 47 citations. The number of fractionalised articles indicates that their individual contributions are 0.75, 0.58 and 0.33, respectively, suggesting that these are highly collaborative works involving a significant number of authors. This coincides with the shared thematic focus of these authors, centred on railway noise and its impact on women's health. In fact, 13 of the 20 most prolific authors focus their research activity on this same line and are also among those with the highest number of citations.

For their part, the authors Ceccato, Vania; Gliori, Gabriel; and Sundling, Catherine, all affiliated with Sweden, each have 3 documents and 11 citations, with a fractional value of 1, indicating their co-authorship in the three articles. These publications focus on women's safety in transport. A similar situation is observed with the Spanish researchers Poveda-Reyes, Sara; Santarremigia, Francisco; and Molero, Gemma, who have 3 documents and 20 citations, and whose repeated collaboration examines the impact of gender on women's mobility. The main difference is that, in this case, their research has a greater number of co-authors.

It is also remarkable that the author Arundhathi (India) has published two papers that focus on the inclusion of women in the railway sector as workers and users. These documents have a fractional figure of 2, indicating that they are solo publications. *Table 3* presents the scientific output, citation count and degree of collaboration (measured through fractionalised articles) of the most relevant authors.

Table 3 – Production and collaboration of the main authors

No.	Author	Country	Documents	Citations	Articles fractionalised
1	Raaschou-Nielsen, Ole	Denmark	7	97	0,75
2	Sørensen, Mette	Denmark	6	55	0,58
3	Roswall, Nina	Denmark	5	47	0,33
4	Jensen, Steen	Denmark	4	41	0,31
5	Ketzel, Matthias	United Kingdom	4	70	0,53
6	Leva, Maria	Ireland	4	20	0,64
7	Thacher, Jesse	Denmark	4	44	0,22
8	Andersen, Zorana	Denmark	3	14	0,16

No.	Author	Country	Documents	Citations	Articles fractionalised
9	Brandt, Jørgen	Denmark	3	30	0,14
10	Ceccato, Vania	Sweden	3	11	1,00
11	Gliori, Gabriel	Sweden	3	11	1,00
12	Molero, Gemma	Spain	3	20	0,44
13	Poulsen, Aslak	Denmark	3	38	0,20
14	Poveda-Reyes, Sara	Spain	3	20	0,44
15	Santarremigia, Francisco	Spain	3	20	0,44
16	Sundling, Catherine	Sweden	3	11	1,00
17	Wang, Yun	China	3	25	0,73
18	Aasvang, Gunn	Norway	2	11	0,05
19	Albin, Maria	Sweden	2	11	0,05
20	Arundhathi	India	2	2	2,00

Source: Own elaboration. The predominance of Danish authors among the most productive and cited highlights the influence of geographically concentrated collaborative networks in this research area.

Institutional affiliations: production and frequency of appearance

To understand the contribution made by the 220 different institutions included in the dataset to scientific production on the role of women in the railway sector, affiliations have been analysed from two different perspectives. On the one hand, the number of different documents in which each affiliation appears has been considered, and on the other, the total frequency of appearances of these affiliations in the database (see *Figure 3*). This facilitates the identification of the most relevant institutions in terms of frequency of appearance and quantity of output.

The institutions with the highest number of unique documents published are *Aarhus University* and the *Danish Cancer Society*, both located in Denmark, with seven publications each. The next two affiliations on the list, the *Roskilde University* and the *University of Copenhagen*, share the same nationality, with 6 and 5 documents, respectively. China's contributions are also significant, particularly from *Southeast University*, with 5 documents, and *Beijing Jiaotong University*, with 4. The *Indian Institute of Technology* and the *Technological University of Ireland* each contributed a total of 4 documents. The following organisations have each published 3 papers: *AITEC* (Spain); *Bispebjerg and Frederiksberg Hospital* (Denmark); the *Environmental Department of the City of Malmö* and the *KTH Royal Institute of Technology* (both from Sweden); the *Norwegian Institute of Public Health* (Norway); the *University of Surrey* (United Kingdom); and the *Bangladesh University of Engineering and Technology* (Bangladesh).

In terms of frequency of appearance (the number of times each affiliation appears in the database) or, in other words, participation, the most prominent affiliations are the *University of Copenhagen*, with 12 appearances, and *Aarhus University*, with 11. These are followed, with 7 appearances, by Sweden's *Karolinska Institutet* and the *University of Southampton* in the United Kingdom. The following 5 organisations have each made 5 appearances: *Curtin University* (Australia), the *Danish Cancer Society*, the *Indian Institute of Technology*, the *Research Centre for Transportation Technology* (Indonesia) and *Roskilde University* (Denmark). Cases such as *Curtin University* and *Hasselt University* are noteworthy, as despite their relatively high frequency of appearance, both have published only 1 paper. This suggests that their relevance is more due to the participation of multiple authors affiliated with these institutions in the same document than to high institutional productivity.

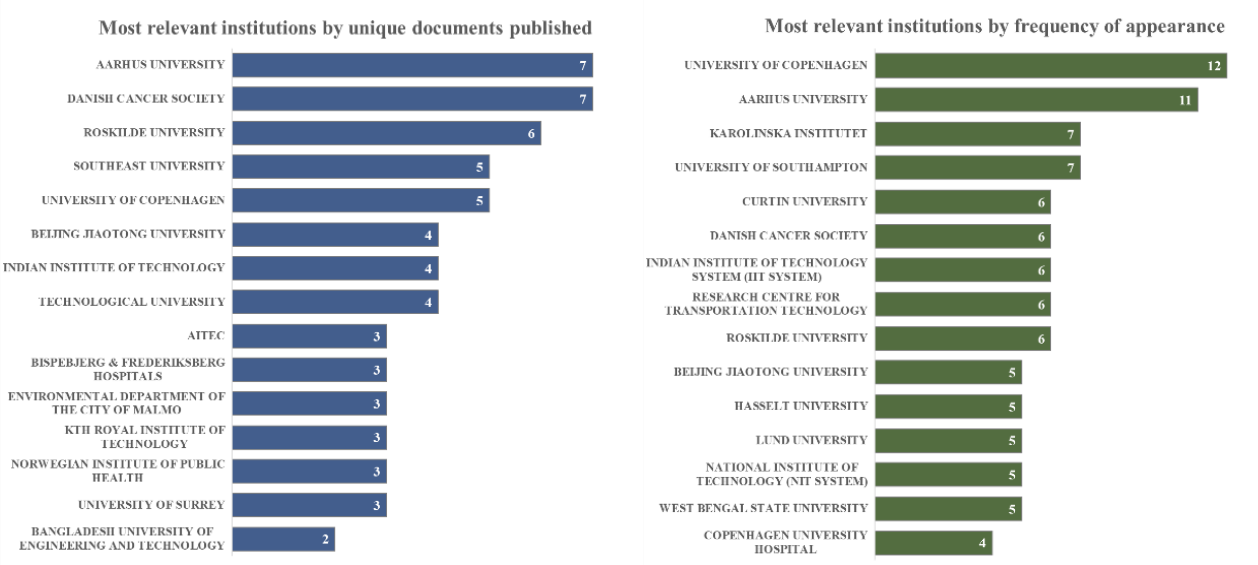

Figure 3 – Most relevant institutions by unique publications and frequency of appearance
Source: Own elaboration. Danish institutions lead the field, with Aarhus University and the Danish Cancer Society ranking highest in unique publications, and the University of Copenhagen and Aarhus University showing the greatest participation.

Scientific production and citation count by country

The database analysed includes contributions from 42 different countries, showing the wide geographical variety of studies on women in the railway sector. The scientific production is led by Asia and Europe. India has generated the highest number of unique documents, with a total of 25. China and the United Kingdom are currently tied at the top with 19 documents each, while the United States is in fourth place with 14. Australia and Denmark have 7, Italy and Spain 6 each, Sweden 5 and Canada, Germany and Ireland 4 each. It is important to note that this metric refers to the number of documents in which each country appears at least once as an affiliation, without counting repetitions within the same article. China, with 367, and the United States, with 305, are the countries with the highest number of citations, followed by the United Kingdom (174) and India (151). Denmark and Australia, with seven documents each, have accumulated 97 and 81 citations, respectively, revealing the high impact of these publications. In the case of Italy and Spain, the impact is more moderate, with 6 publications accounting for 49 and 37 citations. Canada (4 documents, 55 citations) and Bangladesh (3 documents, 47 citations), in addition to other countries, despite having a smaller output, demonstrate noteworthy performance in terms of impact. *Figure 4* shows the countries with the highest production and the most citations.

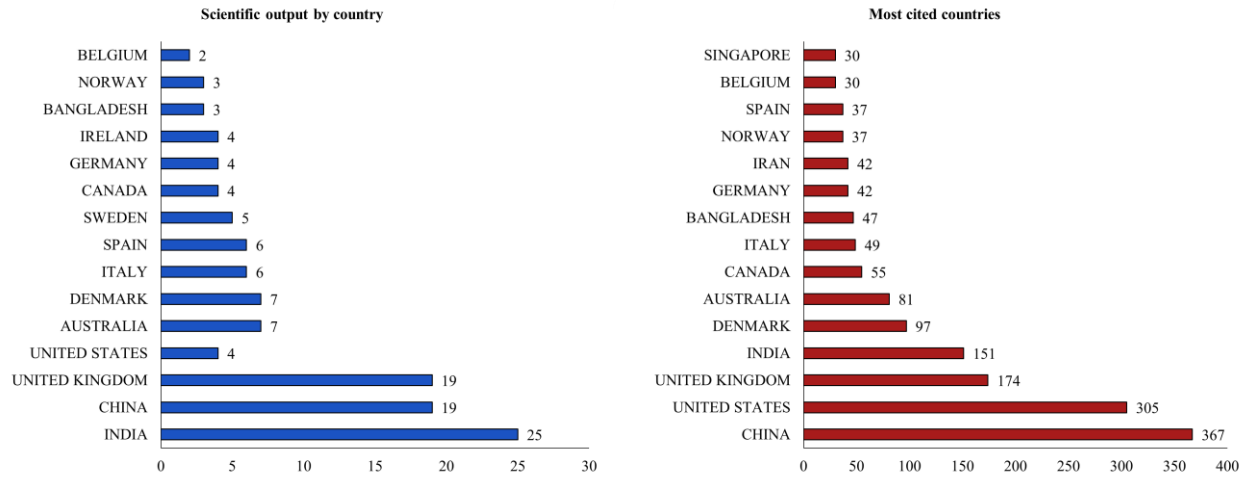

Figure 5 – Scientific output and citation impact by country
Source: Own elaboration. Contributions from 42 countries show a wide geographical spread, with Asia and Europe leading in both production and citation impact.

Most cited documents

After analysing the data presented above, it is particularly revealing to highlight the articles with the highest number of citations, as this enables the identification of the texts with the greatest academic impact, as well as the main lines of research about women in the railway sector. The most frequently cited text [30] is a joint project between China and the United States that focuses on modal choice. This topic is reiterated four times among the ten most cited articles (see *Table 4*), demonstrating its relevance. Other relevant topics include safety [31-32], health related to traffic noise [33-34], satisfaction with railway quality [35], and the economic impact of rail transport on users [36]. Three of the most frequently cited publications were produced in India with the exclusive participation of national institutions. A similar situation occurs with publications from Australia and Norway. In contrast, there have been international collaborations between China and the United States; Denmark and the United Kingdom; Iran and Canada; and the United States and Bangladesh. A thorough review of the most frequently cited papers (specifically, the 37 articles with citation counts above the database mean) reveals that only a small subset of 9 articles explicitly address the role or experiences of women within railway systems. These include works focused on gender differences in service quality perceptions, safety and security in railway stations, and the broader social and cultural dimensions of women's mobility in rail contexts. The remaining papers primarily address tangential topics, including the health impact of railway noise, mode choice behaviour and travel satisfaction.

Table 4 – Most cited publications

No.	Paper	Countries	Citations	Topic
1	[30]	China; United States	216	Mode choice
2	[37]	Australia	50	Mode choice
3	[31]	China	46	Safety and security
4	[33]	Denmark; United Kingdom	42	Traffic noise
5	[32]	Iran; Canada	39	Safety and security
6	[35]	India	38	Rail quality satisfaction
7	[38]	India	30	Mode choice
8	[39]	United States; Bangladesh	27	Mode choice
9	[34]	Norway	26	Occupational health
10	[36]	India	26	Rail users' economy

Source: Own elaboration. The table highlights the ten most cited articles, with the topic "modal choice" appearing in four of them, indicating its prominence in the field.

Thematic analysis of the keyword co-occurrence map

The analysis of the frequency and co-occurrence of keywords allows the identification of the main topics addressed in academic publications on women in the railway sector. The largest thematic group, represented in green, includes the terms *railway, public transport, gender, mobility* and *transport*. The set of these terms constitutes the dominant trend in the reviewed literature, focused on the use of rail transport and public transport from a gender perspective. The texts belonging to this group examine differences in use between the two genders, equity of access, and the specific preferences, concerns and characteristics of women when travelling by rail. In a similar way, the term *women* is used to group together works that explore gender inequality in the sector and the structural barriers that limit women's access to railway jobs. The words travel behaviour and mode choice (in red) belong to a group of publications that seek to identify gender-differentiated travel patterns and understand the socio-economic factors that influence the choice of transport mode. It is also noted that railway activity related to women's health and environmental impact, especially in terms of noise and pollution, is another relevant issue, although this group (in blue) is more peripheral to the concepts that form the focus of the analysis. As demonstrated in *Figure 7*, there has been a thematic evolution from 2015 to 2024, which reveals a progressive diversification of research focuses. Established and high-frequency lines, such as travel behaviour, remained relevant throughout much of the period, while key terms like mobility and public transport gained prominence in the central years of the analysis. In the most recent stage, there has been a notable emergence of themes related to safety and well-being, reflecting a shift from general transport-oriented discussions towards more socially and behaviourally driven perspectives.

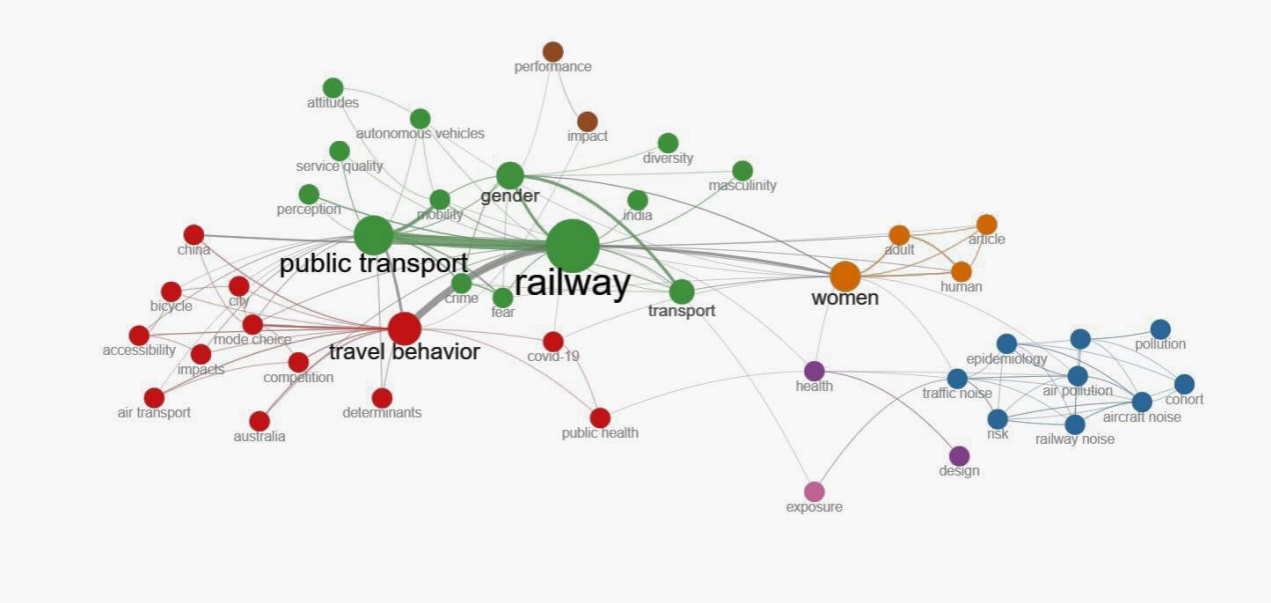

Figure 6 – Co-occurrence network
Source: Own elaboration. The network highlights the dominant thematic group, focusing on rail and public transport from a gender perspective.

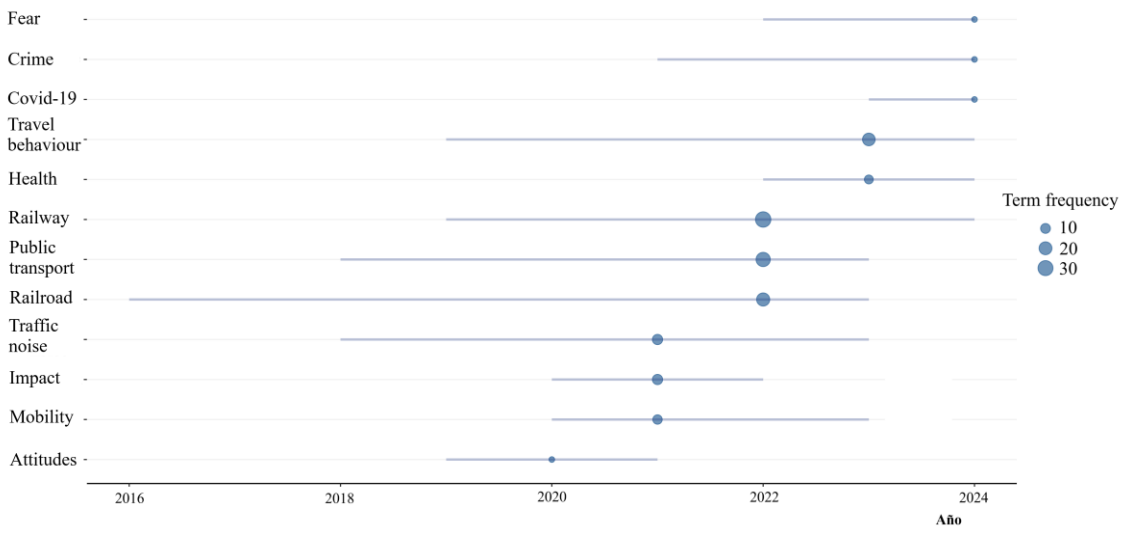

Figure 7 – Topics evolution over time
Source: Own elaboration. The figure illustrates the diversification of research topics, showing a shift from transport-centred terms to emerging themes related to health, safety and social dimensions.

3.3 Trends in research design and opportunities for further study

To identify trends in methodology and lines for future research, we reviewed the 37 documents included in the database whose number of citations exceeds the average, which is 9.03. These documents have also been reviewed to identify research gaps. Regarding the impact of these publications, it is worth noting that 28 of them were indexed in Web of Science, of which 10 were included in the Q1 quartile, 7 in the Q2 quartile and 8 and 3 in the Q3 and Q4 quartiles. Meanwhile, 9 were indexed in Scopus, of which 7 were included in Q1 quartile, 1 in Q2 quartile and 1 in Q4 quartile. This analysis has used the policy areas defined in the European Social Partner Agreement on Women in Rail [6] as a reference. This agreement was drawn up by the CER and the ETF with the support of the European Commission.

After analysing the 37 publications with the highest number of citations, it was found that 78% of the studies reviewed used quantitative approaches. These 29 studies use a variety of methodologies, including the use of surveys for data collection (present in 16 of the reviewed methodologies), the use of advanced statistical models, and the analysis of large administrative, medical or railway control databases. In this group, the use of discrete choice models and revealed or stated preferences (RP/SP) [40] is observed to analyse gender

differences in the perception of safety at railway stations. The implementation of innovative methodologies, including the random forest model and SHAP analysis [41], is particularly noteworthy. Qualitative methodologies are less frequently used (16.21%), but they appear in studies with a high degree of analytical depth that focus on issues of gender, work environment and social exclusion. These studies are carried out using ethnographic approaches, participant observation, textual and interpretive analysis, and semi-structured interviews. This research explores the experiences of women as users and workers in different contexts of the railway sector, especially from the perspective of marginalisation, and historical narratives about the presence of women in the railway industry. Mixed approaches, which represent a clear minority, combine statistical analysis with qualitative techniques, as in the study of older people's perceptions of public transport.

Future research lines proposed in the reviewed studies focus on methodological refinement and geographical and thematic expansion. There is a repeated call for the incorporation of broader contextual and demographic variables to increase the accuracy of analyses of modal choice and perceptions of public and rail transport. There is a clear interest in improving methodological accuracy by testing methods across different regions, countries and urban contexts to verify the replicability and generalisability of findings. There is also considerable interest in deepening knowledge on how exposure to railway noise affects women's health, linking it to conditions such as gestational diabetes and prenatal impacts. Further research is also required to determine how gender and other social factors influence the experience in the railway sector. The set of future proposals analysed demonstrates a commitment to employing more inclusive, multidisciplinary approaches that are sensitive to inequalities.

4. DISCUSSION

The purpose of this study was to analyse, from a bibliometric and qualitative perspective, the scientific output on women in the railway sector between 2015 and 2024 to determine its volume, evolution and relevance during this period; identify the main agents and key topics in this area of study; and determine the main methodologies used, as well as future lines of study. The following section provides an interpretation of the obtained results.

The study of women in the railway sector has risen in recent years, particularly since 2021, when there was a slight annual increase in academic output, from 9 publications in 2020 to 24 in 2024. This growth may be attributable to the coincidental implementation of international actions and initiatives aimed at promoting gender equality in the railway sector, such as the European Union's Gender Equality Strategy 2020–2025 (2020) [9] and the European Social Partner Agreement on Women in Rail by CER (2021) [6]. These are, in turn, driven by the 2030 Agenda and its Sustainable Development Goals, particularly numbers 5 (gender equality), 8 (decent work and economic growth) and 9 (industry, innovation and infrastructure). Research on the subject analysed covers a wide range of topics, demonstrating that it is an issue that arouses the interest of the scientific community across various specialities due to its cross-cutting impact. Despite the increase in research activity, the documents analysed reveal a pattern of incipient and uneven development. The citation distribution is markedly asymmetrical, with the scientific impact concentrated in a small group of works that account for most citations. The primary focus of these works is on addressing issues related to noise impact, health and modal choice. In contrast, there is a significant proportion that is rarely or never cited, with limited impact and less visibility for the scientific community. These results suggest that the study on the reality of women in the railway sector is still in a consolidation phase, with limited impact, underlining the need to strengthen thematic cohesion and promote research in this field. Other areas of interest to the sector, such as specific education, promotion and public communication, or attracting talent, do not seem to spark the interest of researchers.

Furthermore, the presence of highly cited articles in prestigious journals in various fields indicates growing visibility. However, the limited output on topics related to women in the railway sector shows that this is a field with potential for further development. The production of academic literature on women in the railway sector is essentially a collaborative effort characterised by a high degree of co-authorship and a multidisciplinary nature. Research is mainly driven by collaborative groups, which are generally quite hermetic and often from the same country, with a specific thematic interest. This fact can be attributed to the concentration of funding and institutional resources, as well as a reliance on national or regional associations that promote local collaboration. Additionally, the structure of scientific networks is shaped by proximity, shared language and institutional affiliation. Consequently, much of the progress takes place in closed research clusters rather than in a broad and connected community. The existence of such well-defined collaborative structures reflects a high degree of thematic specialisation. These groups of experts are well established and

highly productive, resulting in a high number of citations, as is the case in Northern Europe, where countries such as Denmark and Sweden are very prominent.

The study reveals discrepancies in terms of the volume and impact of the 42 contributing countries. This reflects the global interest in the subject, but the research activity that attracts the most academic attention is concentrated in a few territories. From another perspective, high scientific output does not always have a direct relationship with impact. In the case of China and the United States, the countries that authored the article with the highest number of citations on the list, their success stems both from their collaboration and their subject matter, the modal choice, which is repeated in several of the most cited articles. However, international collaboration is not the only path to success. Countries such as India (the largest producer), Australia and Norway produce documents that accumulate a high number of citations through exclusively national collaboration.

The analysis indicates that quantitative approaches are prevalent in high-impact literature. These methodologies are advantageous in that they facilitate the management of substantial datasets, the identification of large-scale trends and the production of generalisable results. This is particularly beneficial when addressing issues such as modal choice, perceptions of safety or health. However, qualitative and mixed methodologies are not as widespread as they should be, even though they have also been shown to generate high-impact publications, hindering a deep understanding of the individual experiences and contexts of women in this industry. As was stated at the outset of this article, the objective is to solve a problem without first acquiring a comprehensive understanding of the underlying factors that influence women's decisions and requirements. In addition, many of the most cited studies under review emphasise the necessity to ensure the replicability of results, which calls for a cohesive and cooperative international research community.

Regarding the uneven impact and visibility of studies on women in the sector, there is an urgent need to actively disseminate academic work to increase its relevance and impact. It is vital that the scientific community not only generates knowledge but also develops and implements effective communication strategies. The objective is to ensure that articles are not confined to academic niches but instead serve as a guide for the development of political and sectoral actions and initiatives, as well as for decision-making. Communication should not be understood as a mere means of disseminating work, but as a powerful tool capable of maximising the practical and social impact of research.

Although this article focuses on tracing the bibliometric characteristics and thematic trends of research related to women in the railway sector, other topics, such as linguistic hegemony or barriers to dissemination, are possible directions for future research that would significantly complement the conclusions presented in this article.

5. CONCLUSIONS

The analysis indicates that academic literature on women in the railway sector has grown over the past decade, particularly since 2021. Despite this, it is an area that is still in a phase of consolidation, considering the level of scientific production in the field of railway studies. Research output is diverse, multidisciplinary, and often conducted by national groups specialised in specific topics. This underscores the importance of enhancing international collaboration to achieve a more comprehensive outlook, encourage the replication of studies and foster a more unified scientific community.

The results also reveal that the impact is concentrated in just a few publications, while the rest go largely unnoticed and have limited visibility. It is evident that effective communication strategies are essential to enhance the visibility of these projects, thereby ensuring a tangible impact on decision-making processes and the development of initiatives that promote women's representation in rail, both as current and potential workers and users.

Methodologically, the use of quantitative techniques predominates, providing valuable large-scale insights but often overlooking the contextual and experiential dimensions of gender dynamics in the sector. The implementation of qualitative and mixed methods tools helps to gain a deeper understanding of women's experiences, views and opinions, their needs, the barriers they face and the reasons behind the decisions they make.

In the future, research should focus on fostering international collaboration, implementing qualitative and mixed methodologies to a greater extent, ensuring the dissemination of results, and delving deeper into topics that remain largely unexplored. These guidelines are key to consolidating the field and ensuring that academic knowledge has a real impact on policy and practice towards gender equality in the railway sector.

ACKNOWLEDGEMENTS

Funded by the European Union. Views and opinions expressed are, however, those of the author(s) only and do not necessarily reflect those of the European Union or the Europe's Rail Joint Undertaking. Neither the European Union nor the granting authority can be held responsible for them. The project PhD EU-Rail is supported by the Europe's Rail Joint Undertaking and its members.
The authors would like to thank researcher Sara López Gómez for her advice on using the Bibliometrix tool.

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