

## Mapping the intersection of road safety education and performance assessment: a bibliometric analysis

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## Mapping the intersection of road safety education and performance assessment: a bibliometric analysis

### Abstract:

**Background:** Road traffic injuries are the world's leading cause of preventable death and disproportionately affect young people. Research on road safety education and on performance assessment in road safety has developed largely in parallel, and the intersection between the two remains only loosely formalised, particularly from a management and social science perspective, where, to the authors' knowledge, no focused bibliometric mapping of this intersection has yet been proposed (Section 7). **Research purpose:** this study conducts a bibliometric analysis of the scientific literature on this intersection, identifying publication patterns, the most represented authors and journals, thematic clusters, and collaboration networks. **Data source and methods:** bibliometric data were retrieved from Scopus and Web of Science up to the end of November 2024 following the PRISMA protocol; 24 documents were retained from an initial pool of 85 records, processed using VOSviewer (version 1.6.20) and Zotero. **Results:** the analysis identifies five thematic clusters built around twenty-six terms, twenty-five of which explicitly structure these clusters. The most-cited documents concern hazard-perception training for young novice drivers and machine-learning applications to road performance; a keyword-driven construct-drift phenomenon affecting two of these documents is identified and discussed (Section 5.4). Accident Analysis and Prevention, Sustainability, and the International Journal of Environmental Research and Public Health jointly account for 37.5% of retained papers. **Scientific contribution:** this paper offers one of the first focused bibliometric mappings of this intersection from a management and social science perspective, intended to inform future research agendas. **Managerial implications:** the results are directly relevant to educators, road safety agencies, government bodies, and youth associations. Given the modest corpus size and reliance on a single bibliometric technique, these findings should be read as an exploratory map rather than a definitive synthesis.

**Keywords:** Road safety; Education; Performance assessment; Bibliometric analysis; Road collisions.

**JEL Classification:** R41; I28

**Paper type:** Bibliometric Research

## 1. Introduction

Road traffic crashes are one of the world's most intractable public health problems. The World Health Organization (WHO) estimates that 1.19 million people are killed annually on the world's roads, with a further 20 to 50 million non-fatal injuries each year (World Health Organization, 2023). This problem disproportionately affects young people: road traffic injuries are the leading cause of death among 5-29-year-olds, a period during which people are completing primary and secondary schooling, entering the labour market, and participating in community life (World Health Organization, 2023; Bohdidi et al., 2024; Salmon & Lenné, 2015). For most countries, road traffic injuries cost around 3% of gross domestic product (World Health Organization, 2023). The burden is also highly uneven across income levels: the WHO estimates that 92% of road traffic deaths occur in low- and middle-income countries, which account for a much smaller share of the world's motorised vehicle fleet (World Health Organization, 2023), an asymmetry that matters directly for how the evidence base reviewed in this article should, and should not, be generalised, as discussed further in the Limitations section.

In early road safety literature, the analytical focus was placed on road accidents as a matter of individual human factors, principally driver error. The current literature shows that this individualistic explanation of the human factor is insufficient to explain road safety outcomes: human error is better understood as a systemic, organisational, and environmental phenomenon that both limits and enables safe behaviour (Larsson & Tingvall, 2013; Topolšek et al., 2019). This system-wide view has led to the development of broader governance frameworks such as the Safe System approach, which distributes responsibility for the safety of the road network across infrastructure design, vehicle safety, speed management, and regulatory enforcement (International Transport Forum, 2022). The Safe System approach is directly relevant to the object of the present study because it reframes road safety education and performance assessment as two interdependent management levers within a single governance system, rather than as separate technical or pedagogical activities: education builds the capabilities of individual and institutional actors, while performance assessment supplies the evidence that allows the wider system to be steered and corrected (see Figure 1, presented in Section 2). Understanding how these two levers relate to one another in the scientific literature is therefore a necessary complement to the Safe System approach itself, and is the specific gap this article addresses.

Road safety education and performance assessment occupy an important, but comparatively under-examined, place within this policy shift. Education operates at multiple levels of the system. At the level of the individual road user (drivers, pedestrians, cyclists, and other road users), it conveys the knowledge, skills, and attitudes necessary for safe travel on potentially complex and unfamiliar road systems. At the level of the institution (traffic engineers, police, urban planners, and policymakers), it performs an analogous function for the design, implementation, and evaluation of safety interventions (Acquiring Road Safety Knowledge, Skills, and Abilities, 2007; Machin & Sankey, 2008). The interaction between these two levels is increasingly seen as central to sustainable improvement in road safety outcomes. Throughout this article, the term road safety is used deliberately rather than the broader synonym traffic safety: road safety more precisely designates the sub-field concerned with the safety of road users, infrastructure, and vehicles, as distinct from the wider transport-safety literature, which also spans rail, maritime, and aviation contexts. This choice narrows the analytical scope to the literature most directly relevant to the intersection studied here; its implications for the size and composition of the retrieved corpus are made explicit in Section 3.3 and revisited in the Limitations.

Without evaluation, it is not possible to know whether educational and policy interventions are effective. Rigorously conducted performance evaluation provides the evidentiary infrastructure needed to ensure that even well-designed safety programmes do not simply perpetuate poorly targeted, poorly conceived, or scientifically unproven practices. Performance measures enable comparison of relative safety and of the effectiveness of interventions within and across contexts, and constitute an essential evidence-based governance tool for safety management (Gul et al., 2024; Yannis et al., 2008).

Many of the foundational issues at the intersection of road safety education and performance assessment have not yet been systematically integrated into the academic literature. This article reviews that literature and highlights how the two fields, road safety education and performance assessment, have developed largely in parallel, treated independently and rarely systematically compared. This fragmentation constrains the ability of researchers, educators, and policymakers to build on findings across domains, identify cross-cutting patterns, and make full use of the available evidence base. At its core, this fragmentation is a question of institutional coordination and knowledge management: the two fields draw on largely disjoint pools of specialised knowledge that are not being systematically integrated across organisational and disciplinary boundaries, which is precisely the coordination problem that management scholarship on knowledge-based organisations addresses (Grant, 1996). Framed in this way, the fragmentation identified here is squarely a management-science concern rather than a purely technical or pedagogical one.

Bibliometric analysis offers a systematic and increasingly widely used way of addressing this fragmentation, since it can map publication channels, citation patterns, authorship, and thematic clusters within a literature domain, producing a picture of the intellectual structure of a research area, including its main themes and gaps (Donthu et al., 2021; Passas, 2024). The bibliometric mapping approach has already been applied in safety-adjacent fields, where it has helped identify avenues for future research (Gou et al., 2022).

Stakeholders that may benefit from such a mapping include governments and transport ministries responsible for national road safety strategies; schools, universities, and training institutes responsible for the education of young road users and future transport professionals; non-governmental and youth organisations engaged in advocacy for safer road environments; and international organisations working to build evidence standards for safety policy. A bibliometric portrait of the field may provide these stakeholders with a shared empirical basis for policy discussion and, more broadly, for the governance of road safety education as a public-management function.

Against this background, the central research question guiding this study is the following: what is the intellectual structure of the scientific literature situated at the intersection of road safety education and performance assessment, and what does this structure reveal about the field's thematic organisation, productivity patterns, and collaboration networks? To address this question, the present study conducts a systematic bibliometric review of 24 publications indexed in Scopus and Web of Science up to 21 November 2024 within the terminological frame of road safety education and performance evaluation, with three operational objectives that follow directly from the central question: (i) to describe the overall publication trend and the leading journals publishing in this area; (ii) to visualise the thematic structure of the field based on keyword co-occurrence; and (iii) to characterise the collaboration patterns evident in the retrieved corpus and to identify emerging clusters and future directions for research and policy, particularly with respect to youth safety and stakeholder accountability.

The remainder of this article is organised as follows. Section 2 reviews the literature on road safety education, stakeholder engagement, performance assessment, and bibliometric analysis as a research methodology. Section 3 details the research design, search strategy, screening process, and data-processing tools. Section 4 presents the bibliometric results: journal and

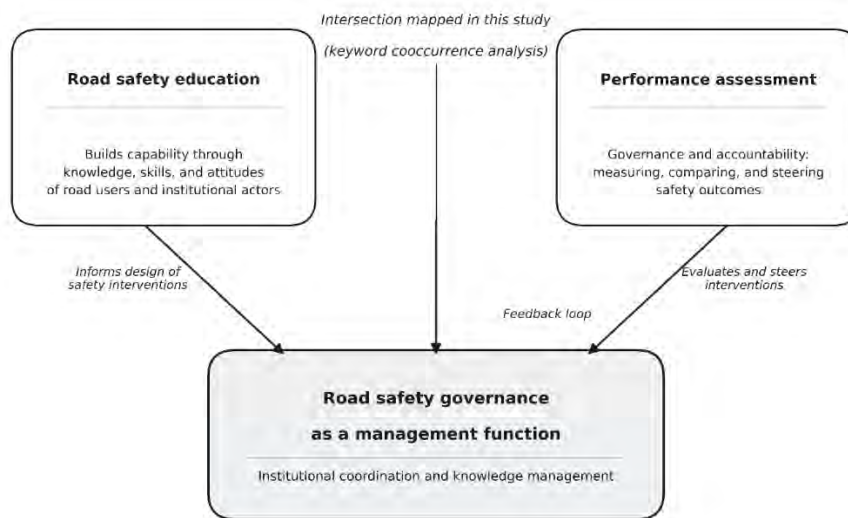
publication trends, thematic clusters, author collaboration, and the most-cited documents. Section 5 discusses these results in relation to the field's overall structure, its leading journals, its thematic architecture, and the construct-drift phenomenon identified in the corpus. Section 6 sets out practical implications, Section 7 the study's theoretical contribution, Section 8 its limitations, and Section 9 avenues for future research, before Section 10 concludes.

## 2. Literature Review

Road safety as a discipline has evolved from a purely technical engineering problem into a multi-faceted field encompassing behavioural science, public health, education, management, and policy analysis. This reflects a growing understanding that improvements in road safety can only be achieved by acting at all levels of society. Within this broader context, education and performance assessment constitute two of the most relevant and interdependent components of any road safety strategy, and both are, fundamentally, management functions: education is a form of capability-building and institutional coordination, while performance assessment is a form of governance and accountability.

Figure 1 makes this relationship explicit before the literature is reviewed in detail. Road safety education and performance assessment are represented as two distinct but interdependent management functions that jointly feed into road safety governance: education informs the design of interventions, performance assessment evaluates and steers them, and the results of assessment feed back into the design of future educational interventions. It is the intersection of these two functions, rather than either function taken in isolation, that this study maps bibliometrically.

**Figure 1. Conceptual Framework: Road Safety Education and Performance Assessment as Interdependent Management Functions.**



*Source: authors' elaboration.*

### 2.1. Road safety education and young road users

Road safety education refers to the formal and informal education of road users about the knowledge, skills, and attitudes that promote safer road use (Acquiring Road Safety Knowledge, Skills, and Abilities, 2007; Machin & Sankey, 2008). It is particularly relevant for young people: novice drivers are over-represented in crashes, and inexperience explains only part of this pattern. Developmental characteristics such as inaccurate risk perception,

heightened conformity to peers, and increased risk-taking behaviour also contribute (Machin & Sankey, 2008; Meir et al., 2014). A thorough road safety education programme therefore combines the transmission of knowledge, the development of skills, and the reinforcement of safe behaviour.

Using a structured hazard-perception intervention (Act and Anticipate Hazard Perception Training, AAHPT), Meir et al. (2014) demonstrated that training novice drivers in anticipatory strategies is effective in narrowing the safety gap between novice and experienced drivers. Using simulative workshops for recently licensed drivers, Rosenbloom and Eldror (2014) present empirical evidence that such workshops can produce meaningful gains in safety-relevant attitudes and behaviours, supporting experiential approaches to driver training. Their findings reinforce a broader point in the literature: knowledge transfer alone is not sufficient; training must also be engaging and relevant to the operational context in which it will be applied.

Read critically, these two studies also illustrate a recurring methodological constraint of the intervention-evaluation literature in this field: both are based on relatively contained samples of newly licensed or novice drivers, assessed over a comparatively short post-intervention window. This limits the extent to which their findings can be generalised to broader driver populations, or interpreted as evidence of durable, long-term behavioural change, rather than of short-term gains that may fade over time. This is not a criticism specific to Meir et al. (2014) or Rosenbloom and Eldror (2014); it reflects a broader pattern in the road safety education literature, in which longer-horizon, larger-sample evaluation designs remain comparatively rare, a gap revisited in Section 9.

## **2.2. Stakeholder engagement in road safety**

Stakeholder engagement is increasingly recognised as a key enabler of road safety policy, since road safety management depends on coordinated decisions across a wide range of institutional actors, including vehicle and infrastructure designers, educators, employers, community organisations, and road safety practitioners (International Transport Forum, 2022). This is especially true in the education sector, where partnerships among schools, universities, government agencies, and non-governmental organisations broaden and deepen the reach of road safety education programmes.

Youth participation is a related and important dimension: youth-centred approaches, which draw on young road users' own perspectives and experiences to inform intervention design, have been shown to produce more culturally appropriate and behaviourally effective interventions (Annam et al., 2023). Annam et al.'s (2023) study of gaps in safe-driving knowledge in India reinforces the need for context-sensitive adaptation, showing that the design of road safety education interventions cannot be separated from the specific populations being targeted.

## **2.3. Performance assessment in road safety education**

Performance measurement can be used to evaluate the effectiveness of training and education programmes, the safety performance of road networks and systems, and to provide an evidence base for allocating safety resources and setting safety priorities (Gul et al., 2024; Yannis et al., 2008). A performance measurement framework that supports comparison across location, time, and type of intervention is valuable for identifying effective practices and for the optimal allocation of scarce safety resources (Kang, 2024).

The centrality of performance-indicator practices to institutional management is not specific to road safety. In the education sector more broadly, similar questions have been raised about whether and how the introduction of performance indicators actually improves institutional outcomes. In the Moroccan context, for instance, Mazzine and Achibane (2020) examine the

effect of performance-indicator practices on the output of schools within the regional education academy of Guelmim Oued Noun, illustrating how the instrumentation of public educational institutions through indicators, a hallmark of New Public Management, is itself an active area of management research independent of the road safety domain. This reference lies outside the 24-document bibliometric corpus analysed in this study (see Section 3.4) and is mobilised here solely as contextual evidence situating the present study's questions within the broader public-management literature on performance indicators, not as part of the bibliometric sample itself. This parallel underlines that the questions raised in the present study about the evaluation of road safety education programmes belong to a wider family of performance-evaluation problems in public-sector education management, reinforcing the relevance of the present bibliometric mapping to management science rather than to road engineering alone.

Machine learning and data science have also increasingly reshaped performance-evaluation methods within the transport-safety literature. Justo-Silva et al. (2021), for example, demonstrated that machine-learning applications on long-term pavement performance datasets can generate precise predictions of how road-surface condition evolves. Damirchilo et al. (2021) applied a related approach to predicting pavement roughness, a measure of road-infrastructure safety, using XGBoost, and Kang (2024) extended this line of work to road safety assessment across Chinese provinces, highlighting inter-provincial differences relevant to resource allocation. Collectively, these studies illustrate a broader shift toward data-driven transport-management performance monitoring, even where, as discussed in Section 5.4, their substantive connection to road safety education specifically is more indirect than their appearance in this dataset might suggest.

#### **2.4. Bibliometric analysis as a research methodology**

Bibliometric analysis provides a systematic, reproducible, and quantitatively grounded method for mapping the intellectual structure of scientific fields (Donthu et al., 2021; Passas, 2024). By analysing co-authorship patterns, citation networks, keyword co-occurrence, and journal publication data, bibliometric studies reveal the dominant themes, influential actors, and structural dynamics that characterise a body of literature. Donthu et al. (2021) distinguish between performance analysis, which evaluates the productivity and impact of authors, journals, and institutions, and science mapping, which examines the relationships between research constituents such as keywords, citations, or co-authors; the present study draws primarily on the science-mapping tradition. VOSviewer has become a widely used instrument for constructing and visualising bibliometric networks across diverse research domains, supporting nuanced insight into the organisation and evolution of scientific knowledge (Meng et al., 2020; Van Eck & Waltman, 2014).

Within this broader methodological toolkit, keyword co-occurrence, co-citation analysis, and bibliographic coupling each answer a different question: keyword co-occurrence maps the thematic content of a literature (what a field talks about), co-citation analysis maps its intellectual lineage (which works are jointly treated as foundational), and bibliographic coupling maps shared-reference patterns between documents (which works draw on the same evidentiary base). Following the guidance of Donthu et al. (2021) on matching bibliometric technique to research objective, the present study relies exclusively on keyword co-occurrence, the technique best suited to exploratory thematic mapping of an emerging or under-studied intersection, because its primary objective is to characterise the thematic structure of the road safety education and performance-assessment literature rather than to trace its citation lineage. This is a deliberate methodological choice rather than an oversight. Still, it is also a genuine scope limitation: co-citation analysis and bibliographic coupling were not conducted, and triangulating the keyword-derived cluster structure against either technique remains an explicit avenue for future replication of this mapping exercise and is revisited in the Limitations section.

In road safety and adjacent transport-safety research specifically, bibliometric methods have increasingly been used to chart the landscape of subfields, identify emerging topics, and reveal gaps in collaboration. Gou et al. (2022) applied bibliometric mapping to safety and security research, demonstrating the approach's utility for revealing systemic dynamics and identifying under-represented areas, and Aziz et al. (2022) mapped the broader road-user-behaviour literature using VOSviewer, identifying schools and cross-sectional study designs as recurring motor themes over a 47-year window. Neither study, however, targets the specific intersection between road safety education and performance assessment that is the object of the present analysis. The present study applies keyword co-occurrence mapping to this previously unmapped intersection, contributing an additional layer of analytical clarity to this domain within the management and social sciences.

### 3. Research Methodology

#### 3.1. Research design

This study employs bibliometric analysis as its primary research design. Bibliometric analysis is a well-established quantitative approach for evaluating research output, mapping knowledge structures, and identifying intellectual trends within a defined scientific domain (Passas, 2024). It has been adopted with increasing frequency across management and social science disciplines as a rigorous complement to systematic reviews, particularly for mapping broad research landscapes where the volume and heterogeneity of the literature preclude comprehensive qualitative synthesis. The search and screening procedure described below follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) reporting framework (Page et al., 2021).

#### 3.2. Bibliometric indicators

The bibliometric indicators considered in this study are the number of publications (NP), the total number of citations (TC), and the Hirsch index (h-index). The h-index is a composite measure of a researcher's or a journal's output, based on the number of publications (h) that have each received at least h citations (Bornmann & Daniel, 2007). Together, these metrics help characterise the relative visibility and impact of journals, authors, and documents in the field. In this study, the NP/TC/h-index metrics reported in Table 2 describe the journals themselves at the aggregate, whole-journal level; they are used only to situate the venues in which the sampled literature appears within the broader scientific publishing landscape, and are not properties of the 24-document dataset analysed here (see Section 4.1).

#### 3.3. Database and search strategy

Data were retrieved from the Scopus and Web of Science databases. Scopus and Web of Science are the two largest bibliographic databases in terms of coverage of peer-reviewed research literature and are widely regarded as standard bibliometric sources (Mongeon & Paul-Hus, 2016). As explained in the Introduction, the search was deliberately built around the term road safety rather than the broader synonym traffic safety, in order to focus the corpus on the sub-field most directly relevant to the intersection studied here. The following Boolean search logic was applied to the title, abstract, and keyword fields:

*("road safety") AND ("education" OR "learning" OR "training") AND ("performance evaluation" OR "performance assessment")*

This logical structure is presented here in simplified, illustrative form; the exact field-level syntax differed slightly between platforms (Scopus advanced search versus Web of Science topic search). The authors commit to providing the exact, platform-specific query strings executed on each database as supplementary material at the proof stage, so that the search can

be replicated verbatim; this information could not be reconstructed with full confidence from the records retained for the present manuscript and is therefore not reproduced in the main text, to avoid presenting an approximate string as though it were the literal query executed.

The ideal response to the underlying research question would consider road safety, education or training methods and practices, and evaluation or assessment components jointly within the same piece of work. In the search process, conducted up to November 2024, Scopus yielded 57 results and Web of Science yielded 28 results ( $n = 85$ ). This scope decision, and its implications for the corpus relative to a broader “traffic safety” search, are revisited in the Limitations section.

### 3.4. Inclusion and exclusion criteria

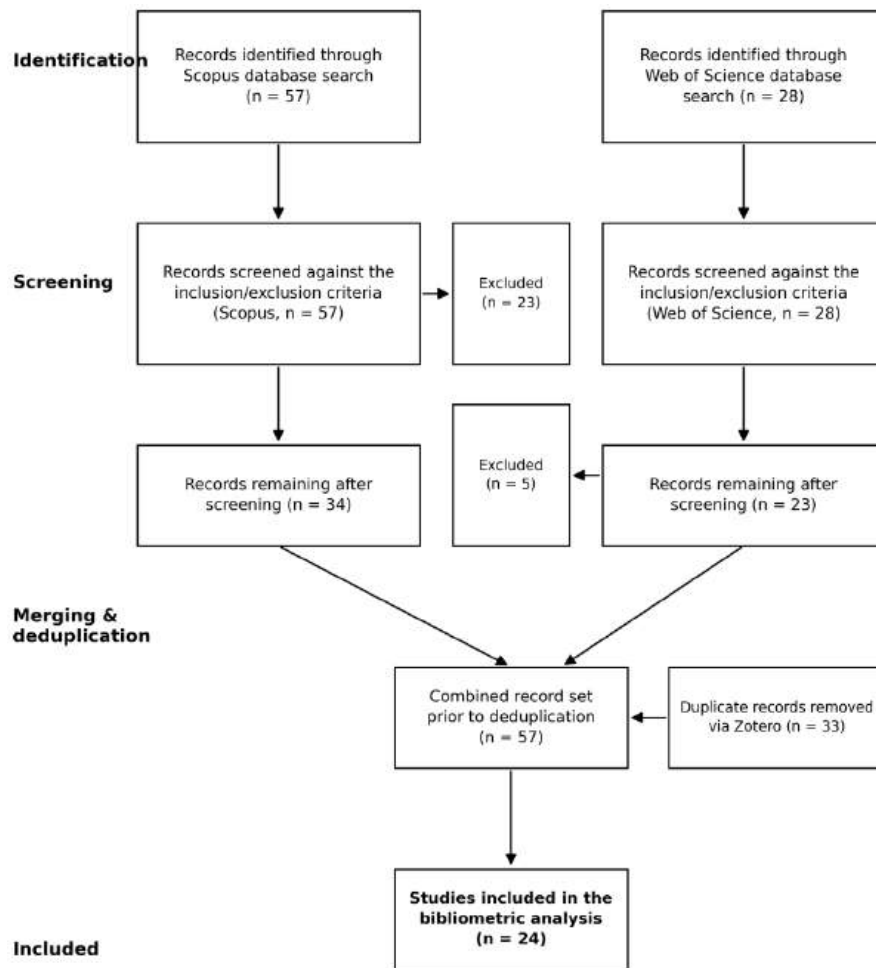
To ensure the scientific rigour and thematic coherence of the dataset, a structured set of inclusion and exclusion criteria was applied. Publications were included if they were written in English; classified as journal articles, conference articles, reviews, or conference reviews; and fell within research areas consistent with the social and management science orientation of this study, specifically transportation, public and environmental health, social sciences, business, management, and ergonomics, while directly addressing the intersection of road safety with educational, training, or evaluative perspectives.

Publications were excluded if they were written in languages other than English; belonged to research domains not directly relevant to the study's scope, including pure engineering, computer-science hardware, biochemistry, and materials science; or lacked sufficient thematic alignment with the management and social science perspective guiding this analysis. Applying these criteria at the screening stage excluded 23 of the 57 Scopus records and 5 of the 28 Web of Science records (see Figure 2). In practice, the Boolean logic used to operationalise “performance evaluation” and “performance assessment” also admits studies whose primary subject is pavement engineering or vehicular routing performance rather than driver education; several such studies survived the exclusion filters despite this domain mismatch, and their presence in the final dataset and its implications for interpretation are discussed explicitly in Section 5.4. Scopus is recognised to cover more journals than Web of Science, though both databases share a comparable tendency to favour the natural sciences, engineering, and biomedical research over the social sciences and humanities (Mongeon & Paul-Hus, 2016).

### 3.5. Screening process

The screening process followed the PRISMA framework (Page et al., 2021), as illustrated in Figure 2. After the initial identification of 85 records (57 from Scopus and 28 from Web of Science), each database subset was screened separately against the inclusion and exclusion criteria described in Section 3.4: 23 Scopus records and 5 Web of Science records were excluded at this stage, leaving 34 records from Scopus and 23 records from Web of Science, for a combined total of 57 records. These 57 records were then merged and checked for cross-database duplicates using Zotero; 33 duplicate records were identified and removed, yielding a final dataset of 24 unique documents that satisfied all inclusion criteria and were judged directly relevant to the study's objectives. Despite its modest size, this dataset provides a focused and analytically coherent foundation for identifying the field's structural dynamics and knowledge gaps from a management and social science perspective, a point of interpretation, and a limitation, that is developed further in Section 8.

**Figure 2. PRISMA Flow Diagram of the Search and Screening Process.**



*Source: authors' elaboration, based on the search and screening protocol described in Sections 3.3–3.5.*

### 3.6. Research areas and scope

Table 1 presents the research areas considered from both Scopus and Web of Science, together with the subject areas selected for inclusion in this study. The selected areas reflect the interdisciplinary character of road safety research while maintaining a primary focus on management, social science, and transport-policy perspectives. This deliberate restriction of scope is intended to ensure analytical coherence and practical relevance for audiences most concerned with the educational and policy dimensions of road safety, rather than the full range of engineering and computational literature.

**Table 1. Research Areas from Scopus and Web of Science.**

| Subject Areas of WoS                 | Selection (WoS)                                                                                                                                                                                               | Subject Areas of Scopus | Selection (Scopus)                                                                                                                                             |
|--------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Engineering Electrical Electronic    | <ul style="list-style-type: none"> <li>✓ Transportation</li> <li>✓ Public</li> <li>Environmental</li> <li>Occupational Health</li> <li>✓ Social Sciences</li> <li>✓ Business</li> <li>✓ Management</li> </ul> | Computer science        | <ul style="list-style-type: none"> <li>✓ Social Sciences</li> <li>✓ Environmental Science</li> <li>✓ Decision Sciences</li> <li>✓ Materials science</li> </ul> |
| Transportation                       |                                                                                                                                                                                                               | Engineering             |                                                                                                                                                                |
| Telecommunications                   |                                                                                                                                                                                                               | Social Sciences         |                                                                                                                                                                |
| Computer Science Information Systems |                                                                                                                                                                                                               | Medicine                |                                                                                                                                                                |
| Transportation Science Technology    |                                                                                                                                                                                                               | Environmental Science   |                                                                                                                                                                |

| Subject Areas of WoS                                  | Selection (WoS) | Subject Areas of Scopus                          | Selection (Scopus) |
|-------------------------------------------------------|-----------------|--------------------------------------------------|--------------------|
| Public Environmental<br>Occupational Health           |                 | Energy                                           |                    |
| Automation Control<br>Systems                         |                 | Mathematics                                      |                    |
| Computer Science<br>Hardware Architecture             |                 | Physics and Astronomy                            |                    |
| Computer Science<br>Software Engineering              |                 | Biochemistry, Genetics,<br>and Molecular Biology |                    |
| Computer Science<br>Theory Methods                    |                 | Decision Sciences                                |                    |
| Engineering Civil                                     |                 | Chemistry                                        |                    |
| Engineering<br>Multidisciplinary                      |                 | Materials science                                |                    |
| Ergonomics                                            |                 |                                                  |                    |
| Social Sciences<br>Interdisciplinary                  |                 |                                                  |                    |
| Biochemistry Molecular<br>Biology                     |                 |                                                  |                    |
| Biophysics                                            |                 |                                                  |                    |
| Business                                              |                 |                                                  |                    |
| Chemistry Analytical                                  |                 |                                                  |                    |
| Computer Science<br>Artificial Intelligence           |                 |                                                  |                    |
| Computer Science<br>Cybernetics                       |                 |                                                  |                    |
| Computer Science<br>Interdisciplinary<br>Applications |                 |                                                  |                    |
| Engineering Mechanical                                |                 |                                                  |                    |
| Imaging Science<br>Photographic<br>Technology         |                 |                                                  |                    |
| Instruments<br>Instrumentation                        |                 |                                                  |                    |

*Source: authors' elaboration, based on Scopus and Web of Science subject-area classifications.*

### 3.7. Data processing and software

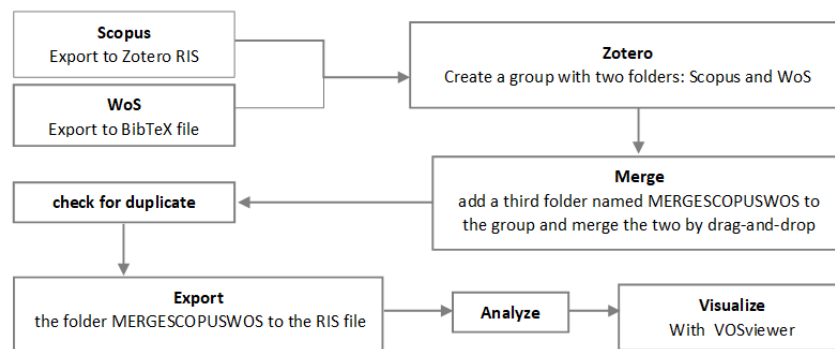
The exported bibliographic records were uploaded into VOSviewer version 1.6.20 as RIS files. VOSviewer is an open-source tool for constructing, visualising, and analysing bibliometric networks through measures of co-authorship, co-citation, bibliographic coupling, and keyword co-occurrence (Van Eck & Waltman, 2014). Its visualisation capabilities were used to detect thematic clusters, collaborative networks, and conceptual patterns within the literature (see Section 4.3). For full replicability, the specific VOSviewer parameters applied, namely the minimum keyword occurrence threshold, counting method (full versus fractional counting), normalisation method, and layout/clustering resolution, should be reported here; these settings

must be retrieved from the original VOSviewer session file by the authors and inserted before the final version is submitted to the journal, as they cannot be reliably reconstructed from the manuscript as drafted and reporting an approximate or default value in their place would risk misrepresenting the analysis actually performed.

### 3.8. Reference management

The free, open-source reference-management program Zotero was used to store, deduplicate, and export bibliographic records; records exported from Scopus and Web of Science were added to separate folders within a Zotero group library. The merged folder was then deduplicated using Zotero's built-in deduplication tool, producing a final set of 24 unique documents, consistent with the counts reported in section 3.7. This step reduced manual workload and ensured record integrity, streamlining the subsequent bibliometric analysis conducted in VOSviewer (see Figure 3 below).

**Figure 3. Zotero Database Combination and Deduplication Process.**



*Source: Zotero reference-management software, screen capture by the authors.*

## 4. Results

### 4.1. Journal analysis and scientometric indices

Table 2 reports the ten most productive journals represented in the sample, based on whole-journal NP, h-index, and TC values, and characterises the general publishing landscape from which the 24 sampled documents are drawn. It is important to state clearly what this table does and does not show: the NP, h-index, and TC values in Table 2 describe each journal's aggregate, cross-disciplinary output and impact as a publishing venue, and are unrelated to the number of documents each journal contributed specifically to this study's 24-document dataset (that count is instead shown in Figure 4). To avoid any risk of confusion between these two distinct quantities, Table 2 is explicitly labelled below as describing the host journals outside the perimeter of the study sample, and is included only to situate the relative visibility of the venues in which the sampled literature appears.

Read on those terms, IEEE Access had the highest whole-journal publication count (NP = 86,680) and the highest h-index (242), reflecting its broad, multidisciplinary scope. The International Journal of Environmental Research and Public Health had the highest total citation count (TC = 840,100), followed by IEEE Access (TC = 722,700). As a dedicated transport-safety journal, Accident Analysis and Prevention shows a strong h-index (198) despite a comparatively small whole-journal NP (8,400), suggesting a stable, long-standing citation density consistent with decades of sustained activity in road safety research. Sustainability (Switzerland) is also among the leading venues, with an h-index of 169, a whole-journal NP of 56,000, and a growing volume of interdisciplinary safety-and-transport research.

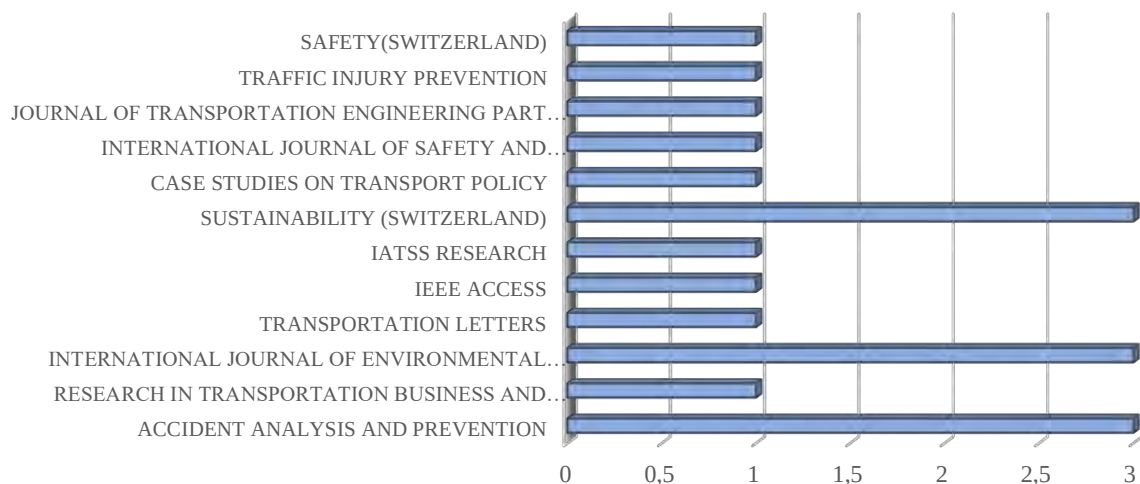
**Table 2. Scientometric Indices of the Host Journals, Outside the Scope of the 24-Document Sample.**

| Journal                                                           | Impact factor | Publication year (est.) | NP (whole journal) | H-Index (whole journal) | TC (whole journal) |
|-------------------------------------------------------------------|---------------|-------------------------|--------------------|-------------------------|--------------------|
| Accident Analysis and Prevention                                  | 5.7           | 1969                    | 8,400              | 198                     | 345,200            |
| Research in Transportation Business and Management                | 4.71          | 2011                    | 934                | 52                      | 13,100             |
| International Journal of Environmental Research and Public Health | 4.614         | 2004                    | 63,200             | 198                     | 840,100            |
| Transportation Letters                                            | 4.12          | 2009                    | 800                | 36                      | 4,400              |
| IEEE Access                                                       | 3.4           | 2013                    | 86,680             | 242                     | 722,700            |
| IATSS Research                                                    | 3.5           | 1977                    | 778                | 22                      | 5,600              |
| Sustainability (Switzerland)                                      | 3.3           | 2009                    | 56,000             | 169                     | 624,123            |
| Case Studies on Transport Policy                                  | 2.606         | 2013                    | 1,021              | 40                      | 6,193              |
| International Journal of Safety and Security Engineering          | 2.41          | 2011                    | 547                | 18                      | 2,043              |
| Journal of Transportation Engineering Part B: Pavements           | 2.36          | 2017                    | 526                | 22                      | 1,100              |

**Source: authors' elaboration based on Scopus/Web of Science journal metrics. NP = whole-journal number of publications; TC = whole-journal total citations. These metrics describe the journals as publishing venues, not the 24-document study sample.**

Of the 24 articles in the final combined dataset, three journals accounted for the majority of the sample: Accident Analysis and Prevention, Sustainability (Switzerland), and the International Journal of Environmental Research and Public Health, each contributing three documents. These three journals collectively accounted for 37.5% of the dataset. Figure 4 shows the distribution of the 24 documents across the represented journals. No single journal dominated the sample, which is consistent with the interdisciplinary nature of this research area at the intersection of education, assessment, and road safety, and with the absence of a dedicated journal for this specific sub-field.

**Figure 4. Number of Publications by Journal.**



**Source: authors' elaboration from the 24-document dataset.**

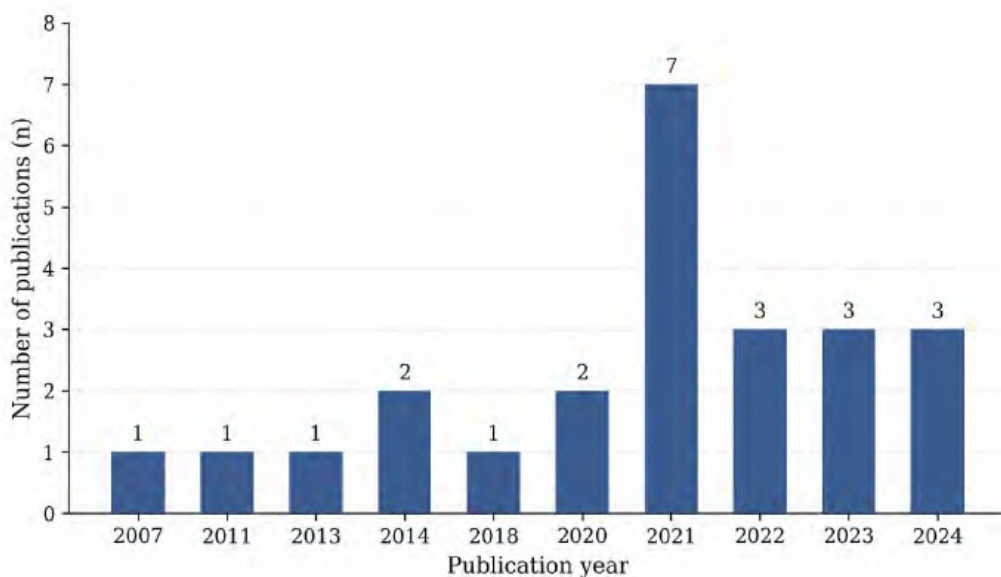
## 4.2. Annual publication trends

Figure 5 shows the year-by-year distribution of the 24 documents included in this analysis. The earliest publication in the dataset appeared in 2007, followed by isolated single publications in

2011 and 2013, two publications in 2014, one in 2018, and two in 2020, before a marked increase to seven publications in 2021 (the highest annual count in the dataset), followed by a plateau of three publications per year in 2022, 2023, and 2024. The dataset therefore spans 2007 to 2024, an eighteen-year window.

The sharp increase in 2021 may reflect several concurrent developments: a post-pandemic reorientation of academic attention toward public-health and safety systems, expanding institutional investment in data-driven traffic control, and the growing use of machine-learning methods in safety analysis. These are offered as plausible interpretations rather than as findings directly supported by the 24-document dataset, which does not itself contain the evidence needed to adjudicate between them. The subsequent plateau at three publications per year from 2022 through 2024 suggests that the field has moved past an initial emergence phase into a more sustained, if still modest, level of productivity, consistent with a research area of continuing but not yet mainstream policy salience.

**Figure 5. Annual Publication Distribution (2007–2024).**



*Source: authors' elaboration from the 24-document dataset.*

#### **4.3. Keyword co-occurrence analysis and thematic clusters**

The keyword co-occurrence network generated using VOSviewer, illustrated in Figure 6, identifies five thematic clusters. Twenty-five keywords are explicitly enumerated across these five clusters below; a twenty-sixth, low-frequency term (“driving ability”) is also visible in the network map, in close visual proximity to the novice-driver and driving-performance theme of Cluster 4, but falls below the level of detail elaborated in the cluster descriptions that follow. As keywords co-occur, they are treated as conceptually related, and the closeness of terms in the map reflects the strength of their co-occurrence (Van Eck & Waltman, 2014). The algorithm partitioned the network into five thematic clusters, represented by different colours.

Cluster 1 (red) forms the central core of the map and comprises seven keywords: accident prevention, decision making, learning systems, performance evaluation, road safety, roads and streets, and safety performance. These correspond to the evaluative and governance dimensions of road safety management. It is important to note, however, that the prominence of terms such as “performance evaluation” in this cluster is not, by itself, an independent empirical discovery: because every document in the dataset was required by the search string to contain terms equivalent to “performance evaluation” or “performance assessment” (see Section 3.3), the centrality of this term to Cluster 1 partly reflects the sampling frame rather than an emergent

property of the literature. The same circularity applies, to a lesser extent, to the terms “education”, “learning”, and “training”, which were themselves inclusion criteria. This limitation does not invalidate Cluster 1 as a description of the corpus, but it means the cluster is better read as confirming that the search retrieved documents matching its own logic than as a novel finding about the field's governance orientation, a qualification that is carried through consistently to Sections 7 and 10 below, rather than confined to this subsection.

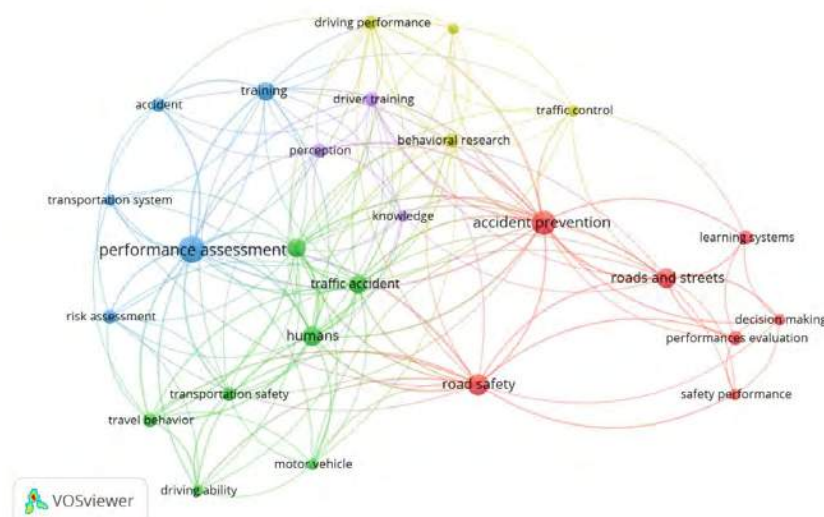
Cluster 2 (green) comprises six keywords: automobile driving, humans, motor vehicles, traffic accidents, transportation safety, and travel behaviour. This cluster reflects the behavioural and vehicular dimensions of road safety research, centred on human factors and mobility patterns in crash causation and prevention, a focus that is also relevant to youth-specific contexts, given age-related differences in travel behaviour.

Cluster 3 (blue) comprises five keywords: accident, performance assessment, risk assessment, training, and transport system. This cluster combines the evaluative and training dimensions of the field, illustrating an analytical symmetry between risk quantification and the design of associated training or retraining activities. The co-location of training and performance assessment within the same cluster is one of the less circular findings of the analysis, since it points to a substantive conceptual link between the two rather than merely restating the inclusion criteria in isolation.

Cluster 4 (yellow) comprises four keywords: behavioural research, driving performance, novice drivers, and traffic control. This cluster centres on the association between driving behaviour, driving performance, and traffic control among young and novice drivers. Its emergence as a distinct cluster reflects the considerable research attention given to young and novice drivers as a high-risk group warranting specialised research and intervention.

Cluster 5 (violet) comprises three keywords: driver training, knowledge, and perception, focusing on the cognitive and informational dimensions of driver preparation. Although the smallest of the five clusters, its distinctiveness underscores the conceptual importance of perception and knowledge acquisition as precursors to safe driving behaviour, complementing the applied focus of Cluster 4.

**Figure 6. Keyword Co-Occurrence Network.**



*Source: VOSviewer software (Van Eck & Waltman, 2014), authors' analysis of the 24-document dataset.*

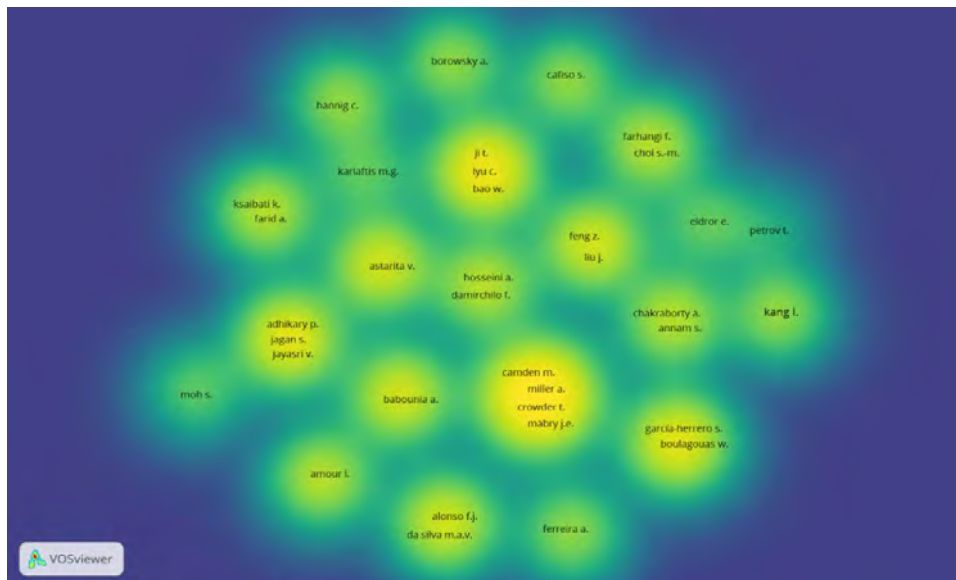
#### **4.4. Author collaboration and organisational impact**

Among the contributing authors identified through the Scopus and Web of Science queries, Kang, L. contributed the most publications (two) within the 24 included papers; every other

contributor is credited with only a single publication in the dataset. With only one author linked across two documents, and no other repeated authorship observed, the co-authorship network reduces almost entirely to isolated pairs or singletons rather than a connected structure, a pattern indicating that the field remains at an early stage of development, without yet having produced a dedicated, recurring research community around road safety education and performance evaluation. A precise network-density statistic (for example, the proportion of potential co-authorship ties that are actually realised, or the number of connected components in the co-authorship graph) would sharpen this observation further; computing it with confidence requires the complete author-affiliation matrix underlying the VOSviewer session, which the authors are best placed to extract and report before final submission.

Considered by document rather than by sustained individual output, the two highest citation counts among contributing authors are attached to the authors of the second- and third-ranked documents in Table 3: Justo-Silva, Ferreira, and Flintsch (TC = 90) and Nazib and Moh (TC = 78). This reflects the impact of two individual, highly cited papers rather than sustained collaborative output by these researchers, since apart from Kang, L., no author appears more than once in the dataset. The author collaboration network is shown in Figure 7 as a VOSviewer density visualisation. Density visualisations represent the concentration of co-authorship activity through colour intensity rather than partitioning authors into discrete, bounded clusters, and Figure 7 should be read accordingly: it highlights a visible concentration of collaborative activity among researchers publishing in the International Journal of Environmental Research and Public Health, several of whom are affiliated with United States institutions, rather than a formally demarcated group of a fixed size. The density of cited organisations is shown similarly in Figure 8, where the Research Center of National Safety and Emergency Management and Nanjing Normal University, Nanjing, China, register the highest visual density among cited organisations, consistent with substantial and growing Chinese institutional investment in transport-safety research, though this observation should likewise be read as a density pattern rather than as a discrete ranking of institutional clusters.

**Figure 7. VOSviewer Density Visualisation of the Author Collaboration Network.**

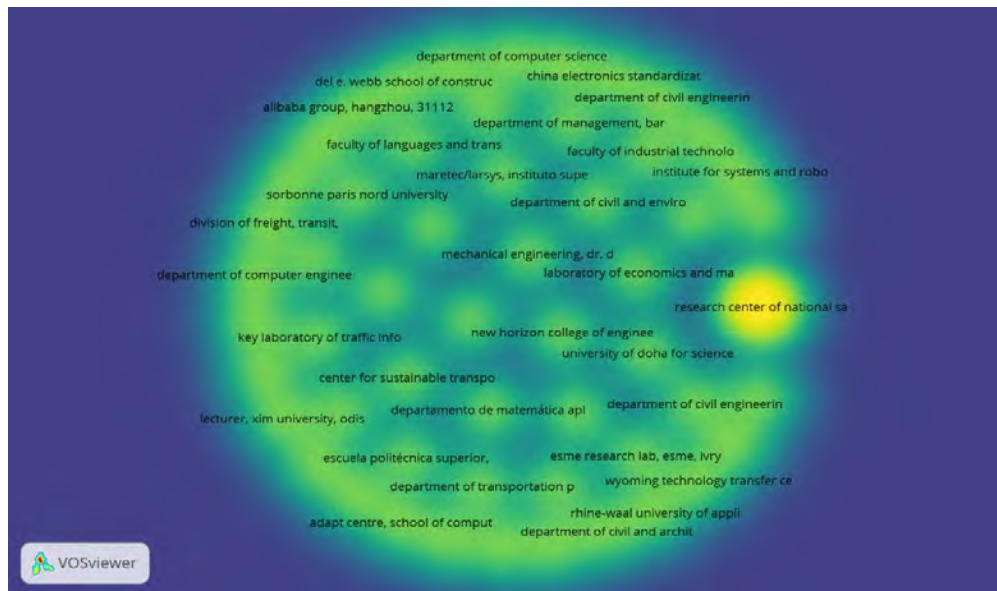


**Source:** VOSviewer software (Van Eck & Waltman, 2014), authors' analysis of the 24-document dataset.

It should be noted that Figures 8 and 9 describe density of authorship and of cited organisations respectively, not collaboration between countries as such. No dedicated country-level collaboration map was generated from the VOSviewer project underlying this study; producing one is a straightforward extension achievable from the same VOSviewer session (using the

“countries” unit of analysis rather than “authors” or “organisations”), and the authors are encouraged to add it before final submission so that the collaboration-pattern objective stated in the Introduction is fully documented visually as well as narratively.

**Figure 8. VOSviewer Density Visualisation of Cited Organisations.**



**Source:** VOSviewer software (Van Eck & Waltman, 2014), authors' analysis of the 24-document dataset.

#### 4.5. Most cited documents

Table 3 identifies the five most highly cited documents in the dataset, offering insight into the contributions that have most substantially shaped the field's intellectual development to date. The most cited document is Meir, Borowsky, and Oron-Gilad's (2014) study of the Act and Anticipate Hazard Perception Training (AAHPT) intervention (TC = 96), published in Traffic Injury Prevention. Its prominence reflects the enduring scientific relevance of hazard-perception training for young novice drivers. The second-ranked contribution, by Justo-Silva, Ferreira, and Flintsch (2021) (TC = 90), demonstrates the growing influence of machine-learning methods in pavement-performance prediction, while Nazib and Moh's (2021) comparative survey of reinforcement-learning-based routing protocols (TC = 78) reflects the expanding technological frontier of transport-system management. Two of these five most-cited documents, Justo-Silva et al. (2021) and Nazib and Moh (2021), are, on inspection, substantively concerned with pavement engineering and vehicular routing protocols rather than with road safety education or youth road users as such; the reasons for their retention in the corpus and the interpretive caution this warrants are examined in full in Section 5.4, which is the single reference point for this issue elsewhere in the article. Collectively, the five documents span educational intervention, predictive modelling, and technology-driven assessment, illustrating the methodological diversity, and, as discussed in Section 5.4, the thematic heterogeneity, that characterises the most-cited research retrieved by this search strategy.

**Table 3. Top Five Cited Documents in the Dataset.**

| R | Document type   | Document title                                                                    | Authors                                | TC | Source                    |
|---|-----------------|-----------------------------------------------------------------------------------|----------------------------------------|----|---------------------------|
| 1 | Journal article | Formation and Evaluation of Act and Anticipate Hazard Perception Training (AAHPT) | Meir, A.; Borowsky, A.; Oron-Gilad, T. | 96 | Traffic Injury Prevention |

|   |                 |                                                                                                              |                                                              |    |                                                         |
|---|-----------------|--------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|----|---------------------------------------------------------|
|   |                 | Intervention for Young Novice Drivers                                                                        |                                                              |    |                                                         |
| 2 | Journal article | Review on machine learning techniques for developing pavement performance prediction models                  | Justo-Silva, R.; Ferreira, A.; Flintsch, G.                  | 90 | Sustainability (Switzerland)                            |
| 3 | Journal article | Reinforcement Learning-Based Routing Protocols for Vehicular Ad Hoc Networks: A Comparative Survey           | Nazib, R. A.; Moh, S.                                        | 78 | IEEE Access                                             |
| 4 | Journal article | Machine Learning Approach to Predict International Roughness Index Using Long-Term Pavement Performance Data | Damirchilo, F.; Hosseini, A.; Mellat Parast, M.; Fini, E. H. | 53 | Journal of Transportation Engineering Part B: Pavements |
| 5 | Journal article | Effectiveness evaluation of simulative workshops for newly licensed drivers                                  | Rosenbloom, T.; Eldror, E.                                   | 44 | Accident Analysis and Prevention                        |

*Source: authors' elaboration from Scopus/Web of Science citation counts. R = rank; TC = total citations received by the document at the time of data extraction (November 2024).*

## 5. Discussion

### 5.1. Overall research trends and field evolution

The bibliometric results reviewed here suggest that the intersection of road safety education and performance evaluation is a developing, rather than a mature, intellectual domain. A corpus of 24 papers spanning an eighteen-year window (2007–2024) indicates that this specific nexus has not yet received sustained, coordinated research attention proportionate to its policy relevance for road safety practice.

A more granular reading of publication years reveals a field still finding its footing: after sporadic single publications between 2007 and 2018, activity intensified from 2020 onward, peaking at seven publications in 2021 before settling into a plateau of roughly three publications per year from 2022 to 2024. This pattern is consistent with a field that has moved beyond its earliest emergence phase but has not yet reached a stable, mainstream level of scholarly attention.

### 5.2. Leading journals and the epistemic community of the field

The three most represented journals in the dataset, Accident Analysis and Prevention, Sustainability (Switzerland), and the International Journal of Environmental Research and Public Health, jointly account for 37.5% of all sampled papers, underlining the interdisciplinary character of road safety education research and suggesting that these venues function as a focal point for much of the relevant literature. Among the documents in this dataset, the single most-cited article (TC = 96, Meir et al., 2014) appears in Traffic Injury Prevention rather than in Accident Analysis and Prevention; Accident Analysis and Prevention's prominence in this sample instead rests on its publication frequency within the dataset (three documents, tied for the highest count) and on its long-standing status, with articles reaching back to 1969, as a flagship venue for empirical road safety research more broadly. Journals of this kind serve not merely as passive repositories of knowledge but as institutional arbiters of a field's scientific norms and methods, a role plainly reflected in the concentration of this dataset's most-cited and most-frequent contributions within a small number of established venues.

The inclusion of Sustainability among the top journals also points to a gradual expansion of road safety education research into the sustainability literature, which sets an encouraging normative agenda for future research and advocacy. The link between road safety education research and the Sustainable Development Goals (SDG 3, Good Health and Well-Being; SDG 11, Sustainable Cities and Communities), formally adopted by the United Nations General

Assembly in its 2030 Agenda for Sustainable Development (United Nations, 2015), holds real potential for academics outside the core transport-safety community who wish to reach audiences interested in policy or development.

### **5.3. Thematic clusters and the architecture of the field**

The five-cluster structure emerging from the keyword co-occurrence analysis reveals a field organised around three broad intellectual axes: a governance axis (performance evaluation, safety policy, decision-making), a behavioural axis (driver behaviour, risk perception, novice drivers, travel behaviour), and a technological axis (machine learning, predictive modelling, vehicular communication systems). As discussed in Section 4.3, the prominence of the governance axis in Cluster 1 should be interpreted cautiously, since key terms within it were themselves part of the search string used to build the corpus; this qualification also bears directly on how the theoretical contribution of this study (Section 7) and its concluding synthesis (Section 10) should be read. The co-existence of all three axes within a relatively small corpus nonetheless underscores both the richness of the field's intellectual inheritance and the challenge of integrating these strands into a coherent, cumulative research programme.

The co-location of training and performance assessment within Cluster 3 is one of the more analytically informative findings, since it is not simply an artefact of the sampling frame. It suggests that training effectiveness is inherently an empirical question requiring systematic assessment, and that performance evaluation itself functions as a form of institutional learning that feeds back into the design of educational interventions, precisely the feedback loop represented in Figure 1. This interdependence appears insufficiently acknowledged in the wider literature, where studies of training-programme design and studies of performance measurement tend to proceed in parallel rather than in dialogue. Bridging this gap is a conceptually straightforward, yet practically significant, research priority.

Cluster 4's concentration on novice drivers and driving performance is the most directly youth-relevant finding of the analysis. The prominence of terms such as behavioural research, driving performance, novice drivers, and traffic control within a distinct cluster confirms the scientific community's recognition of young road users as a priority population for both research and intervention. Yet the relative separation of this cluster from the governance and assessment themes of Cluster 1 suggests that research on novice-driver performance has not been fully integrated with the broader discourse on road safety performance evaluation at the system or policy level. Connecting what is known about young drivers' behavioural characteristics and training needs with the institutional frameworks through which safety performance is measured and managed constitutes a significant and achievable research priority.

### **5.4. Corpus validity and construct drift: A consolidated assessment**

This section brings together, in one place, the study's full assessment of a single methodological issue that is only briefly flagged elsewhere in this article (Sections 3.4, 4.3, and 4.5) rather than re-argued there: the extent to which two of the most-cited documents in the dataset belong thematically to road safety education at all. Consolidating the discussion here, rather than distributing it across several sections, is intended to give the reader a single, complete argument to evaluate rather than a fragmented one.

An examination of the most-cited documents reveals a field in which quantitative, data-driven methodologies have achieved particular prominence, but also, on closer inspection, a corpus whose composition is shaped as much by keyword overlap as by substantive thematic focus. Two of the five most-cited contributions in Table 3, Justo-Silva, Ferreira, and Flintsch's (2021) review of machine-learning techniques for pavement-performance prediction and Nazib and Moh's (2021) survey of reinforcement-learning routing protocols for vehicular ad hoc networks, were retained by the search and screening protocol because they satisfy its Boolean logic around

“performance evaluation” and “performance assessment”, even though their substantive content concerns pavement engineering and communication-network routing rather than road safety education or youth road users. Their retention is not an oversight: excluding them post hoc, without a principled and pre-registered rationale, would itself amount to altering the results of a search strategy that was applied consistently across the corpus. Instead, their prominent citation counts are best read as evidence of construct drift, a structural property of keyword-based corpus construction in an interdisciplinary field where the term “performance” carries different meanings across engineering, computing, and educational-management literatures, rather than as a substantive finding about the intellectual core of road safety education research. This also means that policy or managerial recommendations drawn from this dataset (Section 6) should be understood as most directly supported by the subset of documents that are substantively about road safety education and its evaluation, and treated more cautiously where they might be read as resting on the pavement-engineering or routing-protocol literature instead. Other high-citation contributions in the dataset are more clearly aligned with the study's substantive focus. Meir et al.'s (2014) AAHPT study achieves its top ranking (TC = 96) not through computational sophistication but through direct engagement with the behavioural challenges of young novice drivers and rigorous evaluation of a structured training programme. De Oliveira et al.'s (2020) study of feedback-based training using event data recorders in Brazil's road-freight sector, and Rosenbloom and Eldror's (2014) evaluation of simulative workshops for newly licensed drivers, represent two further contributions that place educational intervention at the centre of the analysis, without featuring among the five most-cited documents reported in Table 3. Farhangi et al.'s (2021) tree-based machine-learning approach to accident-risk mapping is a further example of the technological axis identified in Section 5.3, again without appearing among the top five by citation count. Together, these studies demonstrate that systematic, technology-enhanced training programmes can produce measurable improvements in safety-relevant behaviours, and that rigorous evaluation designs are feasible within real-world training constraints, reinforcing the case for embedding formal evaluation protocols within road safety education programmes regardless of technological complexity, while keeping the construct-drift caveat above firmly in view.

In sum, the practical implication of this section for the rest of the article is straightforward: wherever a claim in this article rests on the dataset's most-cited documents as a whole, that claim should be read with the composition described here in mind, and, wherever a claim is instead traceable to Meir et al. (2014), Rosenbloom and Eldror (2014), De Oliveira et al. (2020), or Farhangi et al. (2021), it can be read as resting on a document that is substantively, not merely nominally, about road safety education.

### **5.5. Emerging themes, research gaps, and future directions**

The bibliometric structure of the field indicates that, to date, there has been limited research into the institutional and policy processes through which road safety education programmes are designed, funded, and evaluated at national or regional level. Research into training interventions themselves appears comparatively well developed relative to research on their governance. There is also a shortage of cross-national comparative research, which makes it difficult to identify generalisable indicators of which models are best suited to which countries, given differing cultural, regulatory, and infrastructural contexts.

The dataset likewise contains no studies examining the specific developmental (cognitive, emotional, and social) factors that shape the effectiveness of road safety education for adolescents and young adults. Finally, while digital and simulation-based instruction methods are represented in the current dataset, their effectiveness has not yet been analysed in sufficient detail to allow systematic comparison with conventional instruction methods. These appear to be knowledge gaps that are practically important, scientifically tractable, and likely to be of

interest to transport scientists, behavioural and educational researchers, and policy analysts alike.

### **5.6. Contributions to youth-oriented road safety policy**

From a policy perspective, these findings carry particular significance for youth-oriented road safety programmes. The keyword analysis confirms that novice and young drivers constitute a distinct and recognised priority within the research retrieved by this search strategy, with a dedicated cluster of studies examining their behavioural profiles, perceptual capabilities, and specific training needs. The prevalence of hazard-perception training, feedback-based educational systems, and simulative instruction methods among the most-cited, education-focused contributions in the dataset suggests that these approaches are scientifically supported and practically adoptable by educational institutions and road safety agencies.

This study assembles evaluative evidence relevant to the governance of youth safety programmes. Kang's (2024) research on provincial road safety performance in China, and the related analysis by Kang and Wu (2022) of provincial performance based on output–input ratios, shows that systematic evaluation can reveal meaningful disparities across administrative units and provide a diagnostic foundation for targeted policy intervention, a model that could plausibly be adapted, in principle, to the evaluation of national and sub-national road safety education programmes, though this application has not itself been tested within the present dataset and should be treated as a hypothesis for future research rather than an established result. It is equally important to situate these findings against the global distribution of the road safety burden itself. The World Health Organization (2023) reports that 92% of road traffic deaths occur in low- and middle-income countries, which possess a much smaller share of the world's motorised vehicles than this figure might suggest; a stark disproportionality that the present dataset, restricted as it is to English-language publications in Scopus and Web of Science, is not well positioned to speak to directly. A preliminary reading of the institutional affiliations visible in the corpus (Section 4.4) suggests that the large majority of documents originate from high-income research systems in North America, Europe, and China, with only isolated exceptions, such as Annam et al.'s (2023) study set in India, situated in a lower- or middle-income research context; a precise proportion cannot be reported here with confidence without re-extracting author and fieldwork countries for all 24 documents, a step the authors are encouraged to complete and report before final submission. The English-language and database-coverage bias discussed in the Limitations section is therefore not a purely technical caveat: it means that the youth-oriented policy implications drawn from this corpus are likely to be most directly applicable to the high-income, English-publishing research contexts that dominate the sample, and should be extended to low- and middle-income settings only with considerable caution and, ideally, alongside evidence drawn from regional and non-English-language sources not captured here.

## **6. Practical implications**

The implications of this bibliometric analysis reach across a broad spectrum of stakeholders involved in road safety education and policymaking. Because the underlying evidence base is a descriptive, keyword-derived corpus of 24 documents, several of which, as discussed in Section 5.4, concern pavement engineering and routing protocols rather than education as such, the recommendations that follow should be read as plausible directions to be tested through targeted research and institutional experimentation, rather than as established prescriptions ready for direct implementation.

With that qualification, this knowledge map offers researchers and universities an overview of the field's key pillars and gaps. University departments and research centres in transport studies,

public health, or education sciences may wish to prioritise research designs that link individual-level training evaluation with system-level performance evaluation, and to pursue cross-national studies that would increase the generalisability of existing evidence. The relative absence of qualitative and mixed-methods studies in the dataset suggests an opportunity for the social sciences to complement bibliometric mapping with qualitative perspectives and insight. Structured, evidence-based curricula for road safety education, and rigorous evaluation of education and training programmes, are worth consideration by schools, universities, driver-education and training organisations, and professional-development providers. Hazard-perception training, simulated workshops, and feedback-based systems have shown promising effects among young road users in the studies reviewed here and may warrant piloting within institutional settings, subject to local evaluation. Rather than remaining at the level of general guidance, evaluation of such programmes could operationalise a small set of recurring indicator types documented in the programme-evaluation literature more broadly: pre/post hazard-perception or knowledge test scores, completion and retention rates, self-reported behavioural change measured at defined follow-up intervals (for example, three, six, and twelve months after training), and, where administrative data permit, linkage to downstream citation or crash records for participating cohorts. Prioritisation across competing programmes could, in turn, draw on straightforward criteria such as the size of the target population reached, the marginal cost per participant, and the strength of the existing evidence base for the intervention type, with a phased implementation timeline (pilot, controlled expansion, system-wide rollout) rather than a single-stage launch. Standardised competency frameworks for road safety education could, in principle, ease comparison and systematic evaluation across educational institutions and countries, though developing such frameworks lies beyond what this bibliometric mapping alone can establish.

National governments, transport ministries, and road safety agencies may find in this study a rationale for developing performance-monitoring systems that support evidence-based safety policy, informed by longitudinal data collection, national safety databases, and systems integration. Given that research at this intersection remains fragmented and comparatively under-represented in the literature, dedicated funding programmes to support research on road safety education and performance review are worth considering.

Given the youth over-representation in road-crash fatalities documented in the introduction, and the evidence-based interventions reviewed here (e.g., road safety education in schools and graduated-licensing provisions), non-governmental organisations and youth-advocacy organisations may find a basis for improving youth engagement in road safety governance and decision-making. International organisations and development-cooperation stakeholders may likewise draw on this evidence to inform technical-assistance programmes in low- and middle-income countries, bearing in mind the limitation, discussed in Section 5.6, that this dataset itself offers only indirect insight into those specific contexts.

## **7. Theoretical contribution**

This research offers several theoretical contributions to the overlapping areas of road safety research, bibliometrics, and youth studies. Most fundamentally, it offers one of the first focused bibliometric mappings of the literature converging on road safety education alongside performance assessment, from a combined management and social science perspective. Existing bibliometric mappings of road safety and adjacent fields have generally addressed broader safety themes rather than this specific intersection: Gou et al. (2022) mapped safety and security research as a whole, and Aziz et al. (2022) mapped the broader road-user-behaviour literature over a 47-year window, identifying schools and cross-sectional designs as recurring themes; neither study isolates the education–assessment nexus that is the specific object of the present analysis. By narrowing the analytical focus specifically to this nexus, while retaining

the breadth of the relevant interdisciplinary literature, this study produces an exploratory knowledge map intended to serve as a reference point for future research agenda-setting, a framing more measured than describing the study as a definitive or comprehensive blueprint for the field, given the corpus size and single-technique scope discussed in Section 8.

The five-cluster structure identified through keyword co-occurrence analysis contributes empirically to the conceptual organisation of the field, while also illustrating, through Cluster 1's circularity (Section 4.3), a broader methodological point about the limits of keyword-based corpus construction in interdisciplinary bibliometrics. This circularity qualifies how Cluster 1 in particular, and the governance axis it represents, should be read: as a confirmation that the search retrieved documents matching its own inclusion logic, rather than as an independently discovered structuring axis of the field. By revealing how governance, behavioural, and technological themes are distributed across the literature, the study identifies the relative isolation of novice-driver research from performance-evaluation frameworks, a testable proposition regarding the field's structural characteristics that future research, ideally triangulated with co-citation or bibliographic-coupling analysis, can engage with, challenge, or refine.

At the level of youth studies, this work supports the case for integrating road safety education into broader youth-policy frameworks. Young novice drivers constitute the most prominent youth-specific research cluster identified here, yet remain insufficiently linked to the discourse on system-level performance evaluation. This suggests that youth-centred road safety research would benefit from more deliberate engagement with governance and accountability frameworks, connecting micro-level literature on adolescent risk behaviour with macro-level discourse on sustainable transport policy, a connection that offers a meaningful, if still largely unrealised, opportunity for advancing both fields.

## 8. Limitations

Several limitations affect the design and methods used in this research and should be considered when interpreting the findings. Setting these out in full, as this section does, is itself part of the contribution of the study: it clarifies precisely which claims the present corpus can and cannot support, so that the substantive findings reported in Sections 4 and 5, and the exploratory knowledge map they produce, can be assessed on their own, appropriately bounded, terms rather than read as more or less conclusive than the evidence warrants.

The most fundamental limitation concerns reliance on Scopus and Web of Science. Neither database contains the full corpus of peer-reviewed scholarly literature, and both are biased toward English-language content, with coverage strongest in the natural sciences, engineering, computer science, and biomedical disciplines, and comparatively weaker in the social sciences and humanities (Mongeon & Paul-Hus, 2016). As such, this study does not capture contributions published in other languages, in regional or national journals, or in grey literature such as government reports, technical documents, or policy briefs.

This English-language restriction is not a neutral methodological detail. The World Health Organization (2023) reports that 92% of road traffic deaths occur in low- and middle-income countries, where road safety research is plausibly under-represented in the English-language, Scopus/Web-of-Science-indexed literature relative to the scale of the problem. Because context- and language-specific education and policy interventions are often described in local languages and in regional or national outlets, the present corpus should be read as more representative of research produced in, or disseminated through, high-income and English-publishing research systems than of the settings where the burden of road traffic injury is heaviest. This limitation directly qualifies the reach of the youth-oriented policy implications discussed in Section 5.6, and any extension of these findings to low- and middle-income

contexts should be treated as provisional pending evidence from sources not captured by this search.

The search strategy itself introduces a further, related limitation. The Boolean logic used here retrieved documents matching “road safety” specifically, rather than the broader synonym “traffic safety”; a search incorporating that synonym, and potentially others, might surface a meaningfully different, and possibly larger, set of studies. An exploratory supplementary search quantifying the additional corpus that a “traffic safety” string would surface was not conducted for this manuscript and is recommended as a concrete, low-cost check the authors can perform before final submission, since it requires only an additional database query rather than a change to the analysis already reported. The findings reported here should therefore be read as a mapping of the literature framed around “road safety” education and performance evaluation specifically, rather than as an exhaustive census of the wider traffic-safety literature. The construct-drift issue affecting two of the five most-cited documents in the dataset, discussed fully in Section 5.4, compounds this limitation: readers should weigh the citation prominence of those particular documents accordingly, rather than treating it as evidence of their thematic centrality to road safety education.

The final sample of 24 papers reflects the narrow scope and inclusion criteria defined for this study: it is thematically coherent and supports the thematic analysis conducted here, but it does not support strong statistical inference on the bibliometric measures reported, and is not intended to be representative of the wider literature on road safety education or on performance assessment considered separately. With only 24 documents and a correspondingly sparse keyword co-occurrence matrix, the five-cluster structure reported in Section 4.3 should be understood as potentially sensitive to the inclusion or exclusion of individual papers; a small number of additional or removed documents could plausibly shift cluster boundaries. A formal sensitivity or robustness analysis was not conducted for the present study. Should the authors or future researchers wish to conduct one, a jackknife procedure of the following form is proposed as a concrete protocol: for each of the 24 documents in turn, remove that document from the corpus, re-run the VOSviewer keyword co-occurrence clustering on the remaining 23 documents using the same parameters as the main analysis (once these are finalised, per Section 3.7), and record whether the resulting five-cluster partition, and the assignment of each retained keyword to a cluster, remains stable relative to the full-corpus solution reported here; a natural stability threshold would flag any cluster whose membership changes by more than one keyword, or that merges with or splits from another cluster, under more than, for example, two of the twenty-four leave-one-out iterations. This protocol is offered as a specification for future work rather than as a result of the present study, and remains an important direction for methodological validation. Relatedly, this study relies exclusively on keyword co-occurrence analysis; as discussed in Section 2.4, triangulating this structure against co-citation analysis or bibliographic coupling, which VOSviewer also supports, was judged beyond the scope of this initial mapping exercise. The specific VOSviewer parameters used to construct the network (minimum occurrence threshold, counting method, normalisation, and resolution) should also be reported in full at the proof stage to support replication, as noted in Section 3.7.

A further methodological limitation concerns temporal scope: papers published toward the end of the study window (2022–2024) may not yet have accumulated citations proportionate to their eventual scientific impact, potentially underestimating their influence relative to earlier publications.

Finally, bibliometric analysis is, by its nature, a structural and quantitative form of analysis that makes no claim about the quality, validity, or practical implications of individual studies. The analysis of keyword and citation co-occurrence networks is an inductive exercise concerned with the structure of the scientific community rather than with the merits of individual research studies. Readers interested in assessing the quality or applicability of specific studies identified

through this analysis should consult the original publications directly. None of the limitations above diminishes the central, positive finding of this study: that the intersection of road safety education and performance assessment is real, identifiable, and thematically structured in the literature, even though it has not yet been mapped as a distinct field in its own right.

## 9. Future Research

The bibliometric framework presented in this study points to several high-priority avenues for future investigation. Cross-national comparative research designs that systematically examine the design, implementation, and outcomes of road safety education would substantially improve understanding of transferability across regulatory and cultural contexts. Comparative performance-evaluation frameworks across national and regulatory settings would help reveal which approaches generalise well and which require local adaptation, work that would be particularly valuable for international organisations and governments seeking scalable, evidence-based safety policies.

The current literature also under-represents qualitative and participatory methodologies. Future research should incorporate approaches that capture the experiential dimensions of road safety education from the perspective of young road users themselves; ethnographic, phenomenological, and co-design approaches could yield insights into how young people perceive and respond to safety education that survey-based or experimental methods alone may not capture.

The technological themes present in the dataset (reinforcement learning, machine-learning-based risk mapping, and vehicular communication systems) point to research frontiers where artificial intelligence and digital education technologies could improve the precision of road safety training, provided their substantive connection to education, rather than to engineering or routing performance alone, is established more directly than the present, keyword-driven corpus allows. Future studies should examine not only how such systems function technically but also how they teach effectively, and how they affect equity, ensuring that digitally mediated safety education remains accessible to young people across socioeconomic backgrounds.

Longitudinal research designs that follow cohorts of young novice drivers over extended periods after safety-education programmes would provide more rigorous, policy-relevant evidence on training effectiveness than the cross-sectional and short-term evaluation designs that dominate the current literature; such designs are needed to establish whether behavioural and attitudinal improvements are sustained over time and whether they translate into measurable reductions in crash risk.

In the nearer term, three concrete and comparatively low-cost extensions of the present analysis are worth prioritising, since each is achievable from data or software already used in this study rather than requiring new data collection: (i) an exploratory supplementary search using “traffic safety” alongside “road safety”, to quantify how much additional literature the present terminological choice excludes (Section 8); (ii) a country-level VOSviewer collaboration map, generated from the same bibliographic export already used to build Figures 8 and 9, to directly document the international collaboration patterns referenced in the Introduction (Section 4.4); and (iii) the jackknife cluster-sensitivity protocol specified in Section 8, to test the robustness of the five-cluster solution reported in Section 4.3. Beyond these near-term steps, future bibliometric studies, ideally using an expanded, multilingual search string, a larger corpus, and multiple bibliometric techniques including co-citation analysis and bibliographic coupling, could track the evolution of this field over a longer horizon and assess whether the gaps identified here are addressed by subsequent scholarship.

## 10. Conclusion

This study set out to map the intellectual structure of the scientific literature at the intersection of road safety education and performance assessment. Three messages, in order of importance, summarise what the analysis of 24 documents indexed in Scopus and Web of Science between 2007 and 2024 shows.

First, this intersection is a real and identifiable, if still emerging, area of research. Five thematic clusters, spanning governance, behavioural, risk-assessment, training, and knowledge-related dimensions, structure a corpus whose publication activity rose sharply in 2021 and has since settled into a modest but stable plateau. The novice-driver cluster, the most directly youth-relevant of the five, confirms the scientific community's recognition of young people as a priority population, while also exposing a gap between that recognition and its integration into system-level performance-evaluation frameworks.

Second, this structure should be read as a bounded, exploratory map rather than a settled account of the field. Two qualifications matter most. The centrality of the governance-oriented Cluster 1 partly reflects the terms used to build the search string rather than an independently discovered property of the literature (Sections 4.3 and 7). And two of the five most-cited documents in the dataset are, on inspection, substantively about pavement engineering and vehicular routing protocols rather than road safety education, a pattern of construct drift documented in full in Section 5.4. Neither qualification invalidates the mapping; both define how confidently its specific claims can be used.

Third, within these bounds, the study offers a dual contribution. Scientifically, it provides one of the first focused bibliometric syntheses of this specific intersection from a management and social science perspective (Section 7). Practically, it offers directional, rather than prescriptive, insight for governments, educational institutions, road safety agencies, and youth organisations designing, implementing, and evaluating road safety education programmes for young road users (Section 6).

Of the several directions for future research identified throughout this article (Sections 8 and 9), one should be prioritised above the others: expanding the corpus through a multilingual, multi-database search that also incorporates the “traffic safety” synonym and non-English-language sources. This single step would address the study's most consequential limitation at once, since it bears directly on both the representativeness of the evidence base for the low- and middle-income countries that carry 92% of the global road traffic death burden (World Health Organization, 2023), and on the robustness of the five-cluster structure reported here, which a larger, more diverse corpus would allow to be tested rather than assumed. Pursued alongside the nearer-term, lower-cost steps identified in Section 9, this recommendation defines the most direct path toward a more complete and policy-responsive evidence base for road safety education worldwide.

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**Data Availability Statement:**

*The data used in this study consist of bibliographic records retrieved from the Scopus and Web of Science databases. These records are available from Scopus and Web of Science directly. The search strategy and selection criteria are described in the manuscript to support replication of the study, subject to the caveats on verbatim query syntax noted in Section 3.3.*