The Indonesian Journal of Occupational Safety and Health
2025, 14 (1): 119-132
p ISSN: 2301 8046, e ISSN: 2540 7872
http://doi.org10.20473/ijosh.v14i1.2025.119-132

REVIEW ARTICLE

Global Disparities in Road Safety: Trends, Knowledge Gaps, and Strategic Interventions

Dina Lusiana Setyowati[1,2], Yuliani Setyaningsih[3], Chiswardani Suryawati[4], Daru Lestantyo[5], Hanifa M Denny[5], Bina Kurniawan[7], Muhammad Ashraf Fauzi[8], Muhammad Ahsan Siddiqui[9]

[1]Doctoral Program of Public Health, Public Health Faculty, Diponegoro University, Semarang, Central Java, Indonesia

[2]Public Health Faculty, Mulawarman University, Samarinda, East Kalimantan, Indonesia

[3,4,5,6,7]Public Health Faculty, Diponegoro University, Semarang, Central Java, Indonesia

[8]Faculty of Industrial Management, University Malaysia Pahang Al-Sultan Abdullah, Kuantan, Malaysia

[9]B.S in Electronics, Sir Syed University of Engineering & Technology, Karachi, Pakistan

ABSTRACT

Introduction: Traffic accidents remain a pressing global issue, disproportionately affecting low- and middle-income countries (LMICs) with higher mortality rates, socio-economic burdens, and persistent policy implementation challenges. This study conducts a bibliometric analysis to identify global trends, conceptual developments, and critical knowledge gaps in road safety research, with a focus on LMIC contexts. **Methods:** A total of 402 peer-reviewed journal articles published between 2014 and 2025 were retrieved from the Scopus database. Bibliometric coupling and co-word analysis were conducted using VOSviewer to explore research dynamics. **Results:** The analysis identified five thematic clusters: (1) gamification and technology integration, (2) behavioral insights and interventions, (3) risk perception and training, (4) equity and infrastructure design, and (5) cyclist crash risk mitigation. Global trends show increasing attention to digital tools such as virtual reality, machine learning, and simulation-based training. Conceptual developments include integrating behavioral science into traffic safety and designing inclusive infrastructure. However, critical gaps persist, particularly the limited representation of LMICs in the literature, lack of contextual adaptation, and minimal real-world validation of technological solutions. **Conclusion:** This study underscores the need for a multidimensional approach that unites technology, human behavior, and infrastructure improvements. Strengthening research in LMICs, validating emerging tools in real-life scenarios, and fostering cross-sectoral collaborations are key to reducing global traffic injuries and fatalities through evidence-informed policies.

Keywords: road safety; bibliometric analysis; low- and middle-income countries (LMICs); traffic accidents; emerging technologies

Corresponding Author:
Dina Lusiana Setyowati
Email: dinalusiana@fkm.unmul.ac.id
Telephone: +62 8132 8292 303

INTRODUCTION

Traffic accidents constitute a global public health crisis, causing approximately 1.35 million fatalities each year and leaving 20–50 million individuals with non-fatal injuries, many resulting in disability (He *et al.*, 2022; Setyowati *et al.*, 2024b) The impact is especially severe in low- and middle-income countries (LMICs), where the mortality rate stands at 27.5 per 100,000 population, compared to 8.3 per 100,000 in high-income nations (Hizkel *et al.*, 2021; Setyowati *et al.*, 2025) This disparity not only endangers public health but also hampers socio-economic progress, as traffic accidents inflict considerable direct and indirect costs on healthcare systems. Notably, they have overtaken infectious diseases like HIV/AIDS and tuberculosis to rank eighth among global causes of death and are the principal cause of death for individuals aged 5–29 in LMICs (Andarini, Camelia and Ibrahim, 2021; Pervez, 2024; Setyowati *et al.*, 2024a).

Although setting quantifiable road safety goals has contributed to declining fatality rates, many LMICs continue to face bureaucratic

Cite this as: *Setyowati, D. L. et al. (2025) 'Global Disparities in Road Safety: Trends, Knowledge Gaps, And Strategic Interventions', The Indonesian Journal of Occupational Safety and Health, 14(1), pp. 119-132.*

 doi:10.20473/ijosh.v14i1.2025.119-132. Received January 23, 2025; 1st revision March 27, 2025; 2nd revision April 28, 2025; Accepted April 30, 2025; Published: April 2025. Published by Universitas Airlangga.

barriers, limited political will, and challenges in implementing sustainable road safety systems (He *et al.*, 2022). These limitations necessitate the adoption of multidimensional strategies that integrate technological innovation, behavioral science, and infrastructure planning. Public awareness campaigns not only shape the perceptions and behaviors of road users but can also yield substantial safety benefits across various demographics (Aghdam *et al.*, 2020). Innovative efforts that include interactive elements, such as augmented reality, effectively engage parents and children, fostering meaningful dialogue about road safety (Zamani, 2024). Furthermore, initiatives focusing on specific groups like schoolchildren have successfully instilled safer road behaviors from a young age (Tiwari *et al.*, 2021; Kourmousi *et al.*, 2024).

Driver education plays a pivotal role in reducing accidents by improving compliance with traffic regulations and safe driving practices. A systematic review revealed that comprehensive driver education programs significantly decrease the risk of accidents, underscoring the importance of ongoing instruction (Faus *et al.*, 2022). Technological integration, including virtual reality simulations, creates immersive learning experiences that reinforce the retention of safety measures (Khan *et al.*, 2021a; Kirytopoulos *et al.*, 2024).

Enhanced road infrastructure also contributes to safer driving environments. Research confirms that well-designed roadways can mitigate crash risks, especially in regions with diverse vehicle use and insufficient driver training (Agarwala and Vasudevan, 2023). Pedestrian crossings, traffic signals, and protected lanes for vulnerable road users reduce potential hazards (Regmi, 2021; Sari, Malkhamah and Budi, 2024). Coupling infrastructure upgrades with robust enforcement of traffic laws further maximizes safety benefits (Gasana *et al.*, 2022; Möller *et al.*, 2022).

Recent findings highlight the vital role of data-driven safety management in strengthening road safety outcomes. By systematically collecting, analyzing, and applying accident data, stakeholders can develop evidence-based solutions that address specific risks (Yan *et al.*, 2021; Goel *et al.*, 2024). This approach clarifies driver behavior and risk perception, allowing tailored educational programs (Champahom *et al.*, 2022). Furthermore, ongoing assessment of interventions enables immediate enhancements informed by feedback (Faus *et al.*, 2022).

Recent road safety research has discovered several global trends, including the growing utilization of digital tools like virtual reality (VR), machine learning (ML), and educational simulations to enhance mobility safety. Conceptual advancements also indicate an increasing integration of behavioral science, especially in comprehending impulsivity, distraction, and risk perception across various categories of road users. Moreover, the focus on equitable infrastructure safeguarding vulnerable groups, including cyclists and pedestrians, has intensified.

Nonetheless, significant knowledge deficiencies persist. The majority of research is focused in high-income countries, resulting in the underrepresentation of LMICs in research investigations and policy frameworks. There is a deficiency of validation for numerous technological interventions in practical or resource-constrained environments.

This study undertakes a bibliometric analysis of road safety research from 2014 to 2025 to tackle these challenges. It attempts to recognize and synthesize global trends, conceptual advancements, and knowledge gaps, focusing specifically on the disparities between high-income countries and low- and middle-income countries (LMICs). This study aims to guide future research goals and policy actions that are inclusive, evidence-based, and context-sensitive by assessing publication volumes, researcher collaborations, and geographic distribution.

METHODS

Bibliometric Approach

Bibliometric analysis is a quantitative method that employs bibliographic databases, such as Web of Science and Scopus, to assess publication volume, impact, and trends (Amin *et al.*, 2024; Virani and Rautela, 2025). Utilizing citation, co-citation, and keyword analyses, tools such as VOSviewer delineate structures, pinpoint research hotspots, and evaluate influence (Liu *et al.*, 2024; Wang *et al.*, 2024).

This approach accommodates substantial quantities of publications, providing an impartial and comprehensive overview in contrast to meta-analysis or systematic literature reviews. Bibliometric analysis mitigates subjectivity bias by eliminating

the necessity to exclude articles during screening (Fauzi, 2023).

Science mapping, a bibliometric methodology, elucidates research frameworks, dynamics, and progression (Corsi *et al.*, 2022; Zhong *et al.*, 2024). Visualizing relationships informs decisions regarding future research directions. This research utilizes two principal bibliometric analyses: Bibliographic Coupling: Employed to examine emerging and current trends (Donthu *et al.*, 2021). The principle asserts that two documents with shared references exhibit thematic similarities, termed (Rojas-Lamorena, Del Barrio-García and Alcántara-Pilar, 2022); (2) Co-word analysis: This method emphasizes the co-occurrence of keywords to delineate research structures and trends. This method elucidates essential topics, knowledge domains, and their temporal evolution by visualizing conceptual relationships (Mokhtarpour and Khasseh, 2021; Krithika, Shanmugam and Kiruba, 2023). It assists researchers in pinpointing pertinent research gaps and prospective avenues.

Research Design and Data Collection Procedure

A specialized query string (Table 1) was applied to retrieve articles on virtual reality, traffic safety education, road safety education, and related topics. Searches for titles, abstracts, and keywords were confined to the Scopus database, chosen for its extensive coverage of over 22,800 titles from more than 5,000 international publishers across diverse disciplines (Zainuldin and Lui, 2021). Only peer-reviewed journal articles were included to ensure higher-quality research, while books, book chapters, conference proceedings, and editorials were excluded. Data were analyzed using VOS viewer 1.6.18 to generate a network visualization for science mapping.

Table 1. Search string in the Scopus Database

Keywords	Justification
(“road safety education” OR “Traffic safety education”) AND (“technology” OR “virtual reality” OR “mobile applications” OR “simulation”) AND (“methods” OR “training” OR “approaches”)	Identify literature related to road safety education and technology.

RESULT

Descriptive Analysis

The first 718 documents were found through the Scopus database search. Only journal articles and periods from 2014 to 2025 were filtered out, leaving 402 publications in the final total of the documents. Figure 1 illustrates a consistent upward trend in publication volume, increasing from fewer than 10 articles in 2015 to nearly 90 in 2023, indicating a strong global research interest in road safety topics.

Bibliographic Analysis

Among the 402 analyzed documents, 29 had at least 43 citations and were used to generate a bibliographic coupling map. These documents were grouped into five clusters, revealing different

Table 2. Top 10 Documents in Bibliographic Coupling Analysis

Rank	Publication	Citation	Total link strength
1	Sovacool B.K. (2017)	113	14
2	Sovacool B.K.; Abrahamse W.; Zhang L.; Ren J. (2019)	111	12
3	Useche S.A.; Alonso F.; Montoro L.; Esteban C. (2019)	58	10
4	Sovacool B.K.; Axsen J. (2018)	100	10
5	Wang C.; Zhang W.; Feng Z.; Wang K.; Gao Y. (2020)	34	9
6	Useche S.A.; Alonso F.; Montoro L.; Esteban C. (2018)	51	9
7	Zahid M.; Chen Y.; Khan S.; Jamal A.; Ijaz M.; Ahmed T. (2020)	67	7
8	Meir A.; Oron-Gilad T.; Parmet Y. (2015a)	75	7
9	Meir A.; Oron-Gilad T.; Parmet Y. (2015b)	51	7
10	Useche S.A.; O'hern S.; Gonzalez-Marin A.; Gene-Morales J.; Alonso F.; Stephens A.N. (2022)	30	6

conceptual domains within the road safety literature. Sovacool (2017) (14 TLS), Sovacool *et al.* (2019) (12 TLS), and Useche *et al.* (2019) (10 TLS) showed the highest Total Link Strength (TLS), highlighting their centrality in the scholarly network.

The network visualization of bibliographic coupling is shown in Figure 2. The five clusters are unrelated to one another. The current and forthcoming advancements in road safety are addressed below. The clusters are labeled through inductive interpretation by revisiting representative articles and synthesizing them according to common themes and research streams.

Cluster 1 (red): "Enhancing road safety by Gamification and Technology". This cluster signifies a worldwide trend towards a combination of virtual and digital technologies to encourage safe driving practices. Research conducted by Gounaridou and Dimoulas (2021) developed a training computer game utilizing the Unreal Engine, merging first-person narrative with experiential learning to improve traffic attention and responsibility for society (Gounaridou, Siamtanidou and Dimoulas, 2021). Zahid *et al.* (2020) employed GIS and machine learning (ML) in a related study to identify over-speeding as the predominant violation, with a stack model providing enhanced accuracy for specific actions (Zahid *et al.*, 2020). Nguyen-Phuoc *et al.* (2019) reported a 30% accident rate among non-student riders of app-based taxi motorcycles, advocating for daily travel restrictions and extensive traffic safety education (Nguyen-Phuoc *et al.*, 2019). Faus *et al.* (2021) illustrated that traffic campaigns are considerably more effective when integrated with legislation and education, underscoring the necessity of comprehensive behavior-modification techniques (Faus *et al.*, 2021). Finally, Khan *et al.* (2021) developed a 3D VR and Kinect-based training system for children, demonstrating significant enhancements in road-crossing behaviors and increased safety awareness (Khan *et al.*, 2021). This reflects both a conceptual development and an emerging research frontier in applying technology to reduce violations and increase awareness.

Cluster 2 (green): "Understanding and Addressing Behavioral Factors in Road Safety". This cluster focuses on risk perception, impulsivity, and attentional distractions, particularly among youth and cyclists. Meir *et al.* (2015) revealed that children aged 7–9 struggled to detect hazards hidden by parked vehicles, whereas older children more effectively identified curvature-based threats (Meir, Oron-Gilad and Parmet, 2015a). Ameir *et al.* (2015) confirmed that training programs significantly enhanced children's ability to recognize obstructed-view conditions and approach materialized hazards and junctions more cautiously (Meir, Oron-Gilad and Parmet, 2015b). In exploring risky cycling behaviors, Wang *et al.* (2020) identified five critical factors traffic violations, impulsive tendencies, ordinary violations, distractions, and errors and found higher risk-taking among males and younger cyclists, whereas greater risk perception and better cycling skills correlated with fewer unsafe actions (Wang *et al.*, 2020). Stelling-Konczak *et al.* (2017) discovered that portable device use reduced auditory awareness among teenage cyclists, although many offset this by compensatory strategies; the study warns against overreliance on such adaptations (Stelling-Konczak *et al.*, 2017). Schneider and Bengler (2019) highlighted methodological gaps in pedestrian research, proposing improvements to bolster pedestrian safety and mobility (Schneider and Bengler, 2020). The cluster shows a shift in safety paradigms from infrastructure-only solutions to human-centered approaches highlighting a conceptual shift in behavioral safety research.

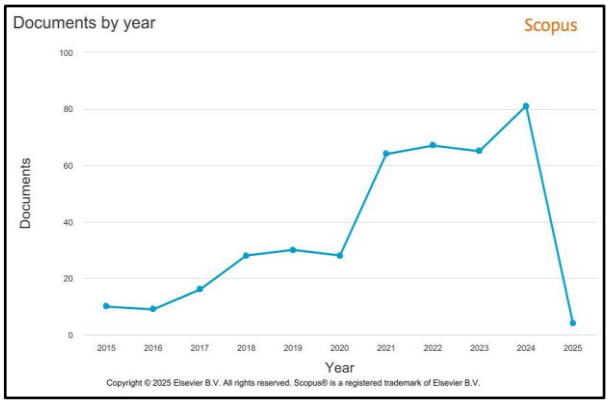

Figure 1. Documents by Year from Scopus Database

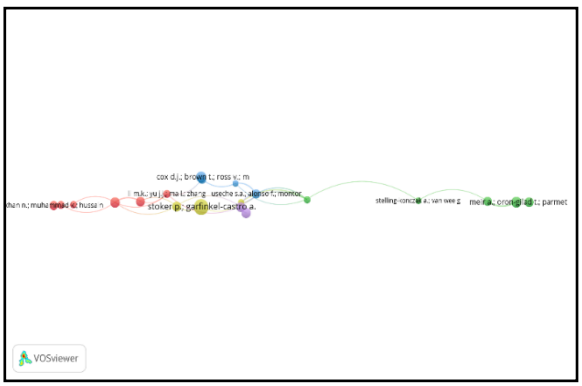

Figure 2. Bibliographic Coupling Analysis

Cluster 3 (blue): "Advancing Risk Perception and Training for Safer Driving". This cluster emphasizes tailored interventions for novice drivers and vulnerable groups. Cox *et al.* (2017) observed that beginner drivers with spectrum disorder exhibited lower executive function (EF) and driving skills. Yet, after undergoing Virtual Reality Driver Skills Training (VRDST), these drivers experienced notable gains in EF and tactical driving abilities, underscoring VRDST's promise (Cox *et al.*, 2017). Useche *et al.* (2018) noted that frequent distractions ranging from other road users and weather conditions to phone calls predominantly contribute to cyclist crashes, with age-based risk perception also playing a role (Useche *et al.*, 2018). Alonso *et al.* (2017) found that drivers generally perceive regulations and police vigilance as beneficial, although sanctions are often seen as educational or revenue-oriented, pointing to trust-building as a fundamental element of a robust safety culture (Alonso *et al.*, 2017). Additionally, Cassarino and Murphy (2018) highlighted incomplete cognitive development and social pressures in young novice drivers, advocating for comprehensive, multi-level solutions that integrate individual, social, and environmental components (Cassarino and Murphy, 2018). These studies reflect a blend of behavioral and technological developments aimed at enhancing safety culture.

Cluster 4 (yellow): "Promoting Equity and Safety through Infrastructure and Behavioral Insights". This cluster identifies disparities in research focus and infrastructure design, especially in LMICs. Stoker *et al.* (2015) stressed that land use and road design can either diminish or amplify pedestrian injuries, underscoring the need for layouts that minimize hazards (Stoker *et al.*, 2015). Haghani *et al.* (2022) highlighted a global imbalance in scholarly attention, with low- and middle-income countries where most road deaths occur receiving comparatively less focus. They call for bolstered cross-border cooperation and expanded support for LMIC researchers to address prevalent socio-psychological challenges and improve statistical modeling (Haghani *et al.*, 2022). Meanwhile, Useche *et al.* (2022) examined public perceptions of two-wheeled riders, including e-scooter users, often deemed riskier partly due to limited traffic rule familiarity. The authors advocate better infrastructure, clearer regulations, and education to correct misperceptions and enhance interactions among diverse road users (Useche *et al.*, 2022). This directly addresses the critical knowledge gaps noted in LMICs and represents a call for equitable development in road safety research.

Cluster 5 (purple): "Understanding and Mitigating Cyclist Crash Risks through Behavioral and Environmental Analysis". This cluster

Table 3. Bibliographic Coupling Analysis on Road Safety Research Domains

Cluster No and Color	Cluster Label	Number of Publications	Representative Publication
1 (red)	Advancing road safety through Gamification and Technology	5	Gounaridou and Dimoulas (2021) (Gounaridou, Siamtanidou and Dimoulas, 2021); Zahid et al. (2020) (Zahid et al., 2020); Nguyen-Phuoc et al. (2019) (Nguyen-Phuoc et al., 2019); Faus et al (2021) (Faus et al., 2021); Khan et al. (2021) (Khan et al., 2021b)
2 (green)	Understanding and Addressing Behavioral Factors in Road Safety	5	Meir et al. (2015) (Meir, Oron-Gilad and Parmet, 2015a); Meir et al. (2015) (Meir, Oron-Gilad and Parmet, 2015b); Cheng Wang et al. (2020) (Wang et al., 2020); Stelling-Konczak et al. (2017) [18]; Schneider and Bengler (2019)
3 (blue)	Advancing Risk Perception and Training for Safer Driving	4	Cox et al. (2017) (Cox et al., 2017); Useche et al. (2018) (S. A. Useche et al., 2018); Alonso et al. (2017) (Alonso et al., 2017); Cassarino and Murphy (2018) (Cassarino and Murphy, 2018)
4 (yellow)	Promoting Equity and Safety through Infrastructure and Behavioral Insights	3	Philip Stoker et al. (2015) (Stoker et al., 2015); Haghani et al. (2022) (Haghani et al., 2022); Useche et al. (2022)(Useche et al., 2022)
5 (purple)	Understanding and Mitigating Cyclist Crash Risks Through Behavioral and Environmental Analysis	2	Useche et al. (2019)(Useche et al., 2019); Useche et al. (2018)(S. Useche et al., 2018)

integrates modeling of risks and behavioral understanding to elucidate factors contributing to cyclist crashes. Useche *et al.* (2019) utilized Structural Equation Models to investigate crash risks, demonstrating that unsafe behaviors, risk perception, knowledge of traffic norms, and cycling activity were significant predictors. Multi-group path analysis revealed that cycling intensity has a more pronounced effect on crash rates among younger cyclists (≤25 years) (Useche *et al.*, 2019). In a separate investigation, Useche *et al.* (2018) identified that age, riding intensity, risky behaviors, and insufficient facilities significantly contributed to cycling accidents, underscoring the necessity for comprehensive strategies to tackle both behavioral and environmental aspects (Useche *et al.*, 2018). It underscores the necessity for cohesive safety solutions that amalgamate education, policy, and environment, emphasizing both trends and current research gaps.

Table 3 presents a summary of the bibliographic coupling analysis, detailing the cluster number and color, labels, publication count, and representative publications.

Co-Word Analysis

Applying the same database, The Co-Word Analysis applied in this study reveals significant insights into road safety research by examining 60 out of 3,042 keywords that meet a threshold of 13 occurrences. The analysis categorizes the data into three distinct clusters, each representing key themes in the field of road safety: (1) Emerging Technologies for Road Safety, (2) Behavioral Insights and Risk Factors, and (3) Enhancing Risk Awareness and Training. The results provide a comprehensive understanding of current research trends, highlighting intersections between technology, human behavior, and training in addressing road safety issues.

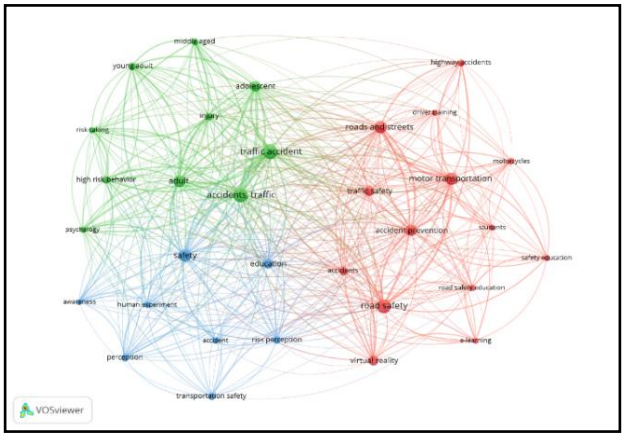

Figure 3. Co-Word analysis on Integrated Approaches to Enhance Road Safety through Behavior and Technology

The structure of the network of the co-word analysis is shown in Figure 3. Three distinct themes are represented by the three visible clusters. The three clusters are given the proper labels based on the author's inductive interpretation.

Below is a detailed analysis and review of the results. Cluster 1 (red): "Advancing Road Safety through Emerging Technologies". This cluster highlights how digital innovations AI, IoT, and VR can significantly enhance road safety by analyzing driver behavior and environmental conditions. Keywords: virtual reality, driver training, road safety education. Torbaghan *et al.* (2022) stress the potential of these tools in reducing human error but note the limited real-world usage thus far (Torbaghan *et al.*, 2022). Kwon *et al.* (2022) demonstrate how visibility barriers and pavement markings affect pedestrian risk perception, underlining VR's effectiveness in simulating environmental hazards (Kwon *et al.*, 2022). While Krasniuk *et al.* (2024) find that driving simulator training across 15 studies leads to immediate improvements in lane-keeping and speed control, the influence on actual driving safety remains inconclusive, likely due to bias in

Table 4. Top 15 Keywords in the Co-occurrence of Keywords Analysis

Rank	Keyword	Occurrences	Total Link Strength
1	Traffic accident	77	384
2	Accidents, traffic	71	370
3	Adult	50	289
4	Motor transportation	55	257
5	Road safety	73	253
6	Roads and streets	56	250
7	Safety	54	246
8	Adolescent	40	231
9	Accident prevention	47	223
10	Education	33	156
11	Young adult	21	153
12	High-risk behavior	21	144
13	Traffic safety	37	119
14	Psychology	17	113
15	Middle-aged	18	112

study designs (Krasniuk *et al.*, 2024). Nonetheless, simulators can still serve as valuable adjuncts to conventional driver education. Further, Sabeti *et al.* (2024) and Khan *et al.* (2021) illustrate how AR and VR can benefit specialized contexts like work zones and child training thereby advocating for broader integration of digital tools into road safety initiatives (Khan *et al.*, 2021b; Sabeti, Ardecani and Shoghli, 2024). This trend reflects the growing conceptual reliance on digital tools to enhance learning, awareness, and accident prevention.

Cluster 2 (green): "Behavioral Insights and Risk Factors in Road Safety". Focusing on psychosocial influences, this cluster examines high-risk groups such as young drivers. Keywords: adolescent, high-risk behavior, impulsivity. Beesten and Breges (2022) emphasize that targeted follow-up education addressing knowledge gaps substantially shapes reactive behaviors in safety campaigns (von Beesten and Bresges, 2022). Smith *et al.* (2024) identify sleep deficits as a crucial modifiable factor to curb crash risks among young motorists (Smith *et al.*, 2024). Stress and childhood adversities further complicate this relationship, affecting mental health and driving behaviors (Varghese *et al.*, 2023). Meanwhile, Bohdidi *et al.* (2024) stress culturally informed strategies for youth engagement (Bohdidi *et al.*, 2024), and studies by Koloushani *et al.* (2022) and Hossain *et al.* (2022) highlight the need to address cellphone use and seatbelt non-compliance two prevalent high-risk behaviors (Hossain *et al.*, 2022; Koloushani *et al.*, 2022). This area highlights behavioral dimensions, especially in young or distracted drivers, showing a strong link to accident causality and the need for behavior-targeted interventions.

Cluster 3 (blue): "Enhancing Risk Perception and Road Safety Training". Keywords: education, risk perception, awareness. This cluster reveals an emphasis on perception-based learning models and their role in shaping proactive safety habits. Chou *et al.* (2022) show how structured training enhances awareness and attitudinal shifts (Chou *et al.*, 2022). However, McIlroy *et al.* (2022) note that fatalistic mindsets and risk-taking attitudes impede progress, especially among younger male drivers (McIlroy *et al.*, 2022). Lijarcio *et al.* (2022) and Faus *et al.* (2023) recommend gender-focused, decision-making-oriented training rather than purely skills-based approaches (Faus, Alonso, Esteban, *et al.*, 2022; Lijarcio *et al.*, 2022). Incorporating psychosocial considerations, Chen *et al.* (2022) and Sayed and Said (2022) advocate tools like the DBQ and behavior-based frameworks to combat overconfidence and low-risk awareness (Chen *et al.*, 2022; Sayed, Abdelgawad and Said, 2022).

Table 5, which includes cluster number and color, cluster labels, number of keywords, and representative keywords, provides an overview of the co-word analysis.

Synthesis:

The combined analyses from bibliographic coupling and co-word mapping highlight clear global research trends in applying technology and behavioral science, conceptual shifts toward

Table 5. Summary of co-word analysis on Integrated Approaches to Enhance Road Safety through Behavior and Technology

Cluster No and Color	Cluster Label	Number of Keywords	Representative Keywords
1 (red)	Advancing road safety through Gamification and Technology	5	Gounaridou and Dimoulas (2021) (Gounaridou, Siamtanidou and Dimoulas, 2021); Zahid et al. (2020) (Zahid 1 (red) Empowering Safe Driving in the Digital Age 14 Road safety, motor transportation, road and streets, virtual reality, road safety education, safety education, driver training et al., 2020); Nguyen-Phuoc et al. (2019) (Nguyen-Phuoc et al., 2019); Faus et al (2021) (Faus et al., 2021); Khan et al. (2021) (Khan et al., 2021b)
2 (green)	Tackling High-Risk Behaviors to Prevent Traffic Accidents in Adolescents and Young Adults	10	Traffic accident, accidents, traffic, adult, adolescent, high-risk behavior, risk-taking, young adult, injury
3 (blue)	Elevating Safety and Risk Awareness in Transportation	8	Safety, education, risk perception, perception, awareness, transportation safety, accident, human experiment

multidimensional approaches, and critical gaps, especially in representation and validation within LMICs. These findings directly fulfill the study's objectives and provide a systematic comprehension of existing trends and shortcomings in the road safety sector.

DISCUSSION

Implications

Challenging Global Trends

The study confirms the increasing focus on incorporating advanced technologies, including virtual reality (VR), simulators, and machine learning, into traffic safety investigation and intervention development. These technologies provide innovative opportunities for proactive, personalized, and context-aware road safety strategies. Khan *et al.* (2021) illustrated that VR-based training can markedly improve children's comprehension of road safety (Khan *et al.*, 2021). Kirytopoulos *et al.* (2024) emphasized the efficacy of VR tools in enhancing driver awareness in road tunnels (Kirytopoulos *et al.*, 2024). Zahid *et al.* (2020) employed machine learning to detect overspeeding patterns in taxi drivers, proposing data-driven interventions (Zahid *et al.*, 2020). Nguyen-Phuoc *et al.* (2019) identified a significant incidence of crashes among app-based riders, emphasizing the critical necessity for technology-enhanced education (Nguyen-Phuoc *et al.*, 2019). Sovacool (2017) underscored the significance of impactful technological studies in influencing global road safety discussions (Sovacool, 2017).

Highlighting Conceptual Developments

Recent literature indicates a substantial transformation in the conceptual frameworks guiding road safety research, expanding from infrastructure to encompass psychosocial and behavioral aspects. Useche *et al.* (2018) emphasized that cyclist accidents frequently result from distractions and impaired risk assessment, underscoring the necessity for behavioral interventions (Useche *et al.*, 2018). Wang *et al.* (2020) determined that teenage male cyclists are particularly susceptible due to aggressiveness and distractions (Wang *et al.*, 2020). Meir *et al.* (2015a) established that younger children have difficulty identifying road hazards, thereby necessitating age-related educational interventions (Meir, Oron-Gilad and Parmet, 2015a). Stelling-Konczak *et al.* (2017) cautioned against the use of mobile devices by adolescent cyclists due to reduced auditory awareness (Stelling-Konczak *et al.*, 2017). Faus *et al.* (2022) demonstrated that effectively organized driver education can reduce crash risks among adults, thereby justifying continued investment in educational programs (Faus, Alonso, Estéban, *et al.*, 2022).

Furthermore, the clustering analysis elucidates significant conceptual advancements in the domain. Research on road safety is now integrating principles of behavioral science, including aggression, distraction, and risk perception, to develop improved strategies (Useche *et al.*, 2018). Moreover, there is a discernible transition towards inclusive urban planning, wherein infrastructure design is guided by principles of equity and user diversity, especially for marginalized groups such as bikers and pedestrians (Hughes, Anund and Falkmer, 2016). These advancements enhance current frameworks for comprehending and tackling road safety issues, indicating that an integration of human-centered education and equity-focused design is crucial for mitigating crash risks among varied populations.

Exposing Critical Knowledge Gaps

Notwithstanding technological advancements and conceptual development, low- and middle-income countries (LMICs) continue to be inadequately represented in road safety research. He *et al.* (2022) and Setyowati *et al.* (2024b) observed the significant global burden of road accidents, particularly in low- and middle-income countries (He *et al.*, 2022; Setyowati *et al.*, 2024b). Hizkel *et al.* (2021) indicated that low- and middle-income countries experience fatality rates exceeding three times those of high-income countries (Hizkel *et al.*, 2021). Setyowati *et al.* (2025) discovered that young motorcyclists in these areas face disproportionate risks (Setyowati *et al.*, 2025). Andarini *et al.* (2021) observed that traffic injuries have overtaken infectious diseases as leading causes of death (Andarini, Camelia and Ibrahim, 2021). Pervez (2024) pointed out that fatalities among youth (aged 5–29) are highest in LMICs (Pervez, 2024). As emphasized in the bibliographic and co-word analyses, research from high-income countries continues to dominate the field, leaving LMIC-specific challenges underexplored (Haghani *et al.*, 2022). Moreover, many interventions based on

advanced technologies such as VR and AI have yet to be validated in real-world, low-resource contexts, limiting their practical relevance and scalability. Addressing these disparities is critical for developing equitable, globally relevant road safety strategies that reflect local needs and realities.

Managerial Implications

The findings offer critical guidance for policymakers, practitioners, and educators aiming to improve road safety outcomes. Faus *et al.* (2021) illustrated that the integration of traffic campaigns with law enforcement efforts markedly enhances behavior (Faus *et al.*, 2021). Aghdam *et al.* (2020) proposed national awareness initiatives aimed at shaping societal norms and behaviors (Aghdam *et al.*, 2020). Zamani (2024) demonstrated that augmented reality promotes parent-child interaction, thereby expanding the scope of safety training (Zamani, 2024). Tiwari *et al.* (2021) and Kourmousi *et al.* (2024) validated the efficacy of school-based safety programs in fostering enduring safe practices (Tiwari *et al.*, 2021; Kourmousi *et al.*, 2024). Moreover, infrastructural enhancements advocated by Agarwala and Vasudevan (2023), Regmi (2021), and Sari *et al.* (2024) emphasized that deliberate design, such as pedestrian crossings and protected lanes, can mitigate crash risk (Regmi, 2021; Agarwala and Vasudevan, 2023; Sari, Malkhamah and Budi, 2024).

The thematic clusters determined by this study offer a practical framework for multi-stakeholder collaboration. Initially, digital technologies like AI, IoT, and VR can be utilized to develop economical, accessible training platforms that enhance conventional compliance (Khan *et al.*, 2021b). Culturally tailored educational campaigns are essential, especially for youth and at-risk groups, including bikers and walkers (Meir, Oron-Gilad and Parmet, 2015b, 2015a; Smith *et al.*, 2024). Third, urban policy makers and planners are urged to employ data-driven methodologies to identify and address high-risk areas, in accordance with empirical findings such as those presented by Stoker *et al.* (2015) (Stoker *et al.*, 2015). Finally, cross-sector and worldwide collaboration is essential for converting research into practical policies, particularly in low- and middle-income countries where inequalities are most evident (Haghani *et al.*, 2022). Collectively, these strategies contribute to more equitable and effective road safety systems.

Limitations and Future Research Avenues

Future studies must address persistent gaps by incorporating diverse geographies and validating technological tools in real-life LMIC settings. Yan *et al.* (2021) and Goel *et al.* (2024) emphasized the value of data systems in tailoring interventions and monitoring their impact (Yan *et al.*, 2021; Goel *et al.*, 2024). Champahom *et al.* (2022) highlighted the compounding effects of weather, age, and distractions on accident severity, suggesting the need for multilayered data analytics (Champahom *et al.*, 2022). Möller *et al.* (2022) demonstrated that novice drivers with past offenses are more prone to crashes, reinforcing predictive profiling and early intervention (Möller *et al.*, 2022). Gasana *et al.* (2022) pointed out socio-demographic disparities in road outcomes, especially among migrants (Gasana *et al.*, 2022).

However, it is important to acknowledge several limitations in the current analytical approach. First, the reliance on highly cited articles within bibliographic coupling and co-word analysis might inadvertently exclude emerging yet under-cited research themes. Second, the predominance of English-language publications in Scopus may result in geographic and linguistic bias, potentially underrepresenting vital insights from non-English speaking regions. Third, while the thematic clusters offer valuable conceptual organization, their overlaps may obscure clearer domain-specific conclusions.

Future research should therefore embrace greater inclusivity by integrating lesser-known, under-cited, and non-English sources, especially those originating from LMICs. Cross-cultural and longitudinal studies are essential to capture dynamic changes in road safety paradigms. Moreover, field validation of cutting-edge tools such as wearable safety devices and immersive training technologies should be prioritized to assess real-world feasibility and effectiveness. Building global consortia for data sharing, collaborative funding, and international policymaking could significantly strengthen the reach and impact of road safety interventions.

CONCLUSION

This study concludes that road safety research has evolved into a multidimensional domain that integrates technological innovations, behavioral science, and infrastructure-based strategies. Through bibliographic coupling and co-word analyses, the five clusters were identified ranging

from gamification and VR to psychosocial factors, targeted training, infrastructure design, and cyclist-focused interventions highlighting the breadth of current work. Influential works by Sovacool and Useche indicate a strong focus on both technological and human-centered approaches. However, significant challenges remain, including limited real-world validations and the overrepresentation of high-income countries in current research. To bridge these gaps, active collaboration with low- and middle-income countries is essential for developing inclusive, context-relevant, and evidence-based road safety solutions.

CONFLICT OF INTEREST

The authors affirm that the performance could not have been impacted by any substantial conflicting financial, professional, or personal interests.

AUTHORS' CONTRIBUTION

DLS: Conceptualization, Methodology, Software, Data curation, Writing- Original draft preparation. YS, CS: Data curation, Writing-Original draft preparation. DL, BK: Visualization, Investigation. HMD: Software, Validation, Writing-Original draft preparation. MAF, MAS: Writing-Reviewing and Editing.

ACKNOWLEDGEMENTS

We would like to thank of Library of Diponegoro University which provides full access to SCOPUS.

REFERENCES

Agarwala, R. and Vasudevan, V. (2023) 'Role of High-Speed Roads and Vehicle Ownership on Traffic Fatalities in India', *Transportation Research Record: Journal of the Transportation Research Board*, 2677(1), pp. 1461–1472. Available at: https://doi.org/10.1177/03611981221104803.

Aghdam, F.B. *et al.* (2020) 'Developing a National Road Traffic Safety Education Program in Iran', *BMC Public Health*, 20(1). Available at: https://doi.org/10.1186/s12889-020-09142-1.

Alonso, F. *et al.* (2017) 'Knowledge, Perceived Effectiveness and Qualification of Traffic Rules, Police Supervision, Sanctions and Justice', *Cogent Social Sciences*, 3(1). Available at: https://doi.org/10.1080/23311886.2017.1393855.

Amin, M.A.M. *et al.* (2024) 'Bibliometric Analysis of the Use of Electrospun Chitosan Nanofibers in Biomedical Applications', *Journal of Sustainable Materials Processing and Management*, 4(1). Available at: https://doi.org/10.30880/jsmpm.2024.04.01.001.

Andarini, D., Camelia, A. and Ibrahim, M.M. (2021) 'Factors Related to Road Accidents in Palembang, South Sumatera, Indonesia', *International Journal of Public Health Science (IJPHS)*, 10(3), p. 638. Available at: https://doi.org/10.11591/ijphs.v10i3.20768.

von Beesten, S. and Bresges, A. (2022) 'Effectiveness of Road Safety Prevention in Schools', *Frontiers in Psychology*, 13. Available at: https://doi.org/10.3389/fpsyg.2022.1046403.

Bohdidi, Z. *et al.* (2024) 'Enhancing Road Safety Decision-Making through Analysis of Youth Survey Data: A Descriptive Statistical Approach', *Safety*, 10(2), p. 45. Available at: https://doi.org/10.3390/safety10020045.

Cassarino, M. and Murphy, G. (2018) 'Reducing Young Drivers' Crash Risk: Are We there Yet? An Ecological Systems-based Review of the Last Decade of Research', *Transportation Research Part F: Traffic Psychology and Behaviour*, 56, pp. 54–73. Available at: https://doi.org/10.1016/j.trf.2018.04.003.

Champahom, T. *et al.* (2022) 'Factors Affecting Severity of Motorcycle Accidents on Thailand's Arterial Roads: Multiple Correspondence Analysis and Ordered Logistics Regression Approaches', *IATSS Research*, 46(1), pp. 101–111. Available at: https://doi.org/10.1016/j.iatssr.2021.10.006.

Chen, Y. *et al.* (2022) 'Underestimated Risk Perception Characteristics of Drivers Based on Extended Theory of Planned Behavior', *International Journal of Environmental Research and Public Health*, 19(5), p. 2744. Available at: https://doi.org/10.3390/ijerph19052744.

Chou, C.-C. *et al.* (2022) 'Effectiveness Evaluation on Cross-sector Collaborative Education Programs for Traffic Safety toward Sustainable Motorcycle Culture in Vietnam', *IATSS Research*, 46(2), pp. 258–268. Available at: https://doi.org/10.1016/j.iatssr.2022.01.001.

Corsi, S. *et al.* (2022) 'A Bibliometric Analysis of the Scientific Literature on Biostimulants', *Agronomy*, 12(6), p. 1257. Available at: https://doi.org/10.3390/agronomy12061257.

Cox, D.J. *et al.* (2017) 'Can Youth with Autism Spectrum Disorder Use Virtual Reality Driving Simulation Training to Evaluate and Improve Driving Performance? An Exploratory Study', *Journal of Autism and Developmental Disorders*, 47(8), pp. 2544–2555. Available at: https://doi.org/10.1007/s10803-017-3164-7.

Donthu, N. *et al.* (2021) 'How to Conduct a Bibliometric Analysis: An Overview and Guidelines', *Journal of Business Research*, 133, pp. 285–296. Available at: https://doi.org/10.1016/j.jbusres.2021.04.070.

Faus, M. *et al.* (2021) 'Are Traffic Announcements Really Effective? A Systematic Review of Evaluations of Crash-Prevention Communication Campaigns', *Safety*, 7(4), p. 66. Available at: https://doi.org/10.3390/safety7040066.

Faus, M. *et al.* (2022) 'Are Adult Driver Education Programs Effective? A Systematic Review of Evaluations of Accident Prevention Training Courses', *International Journal of Educational Psychology*, 12(1), pp. 62–91. Available at: https://doi.org/10.17583/ijep.8805.

Fauzi, M.A. (2023) 'Knowledge Sharing in Health Community of Practice (CoP) and Online Health Communities (OHCs): A Bibliometric Analysis', *Journal of Information & Knowledge Management*, 22(03). Available at: https://doi.org/10.1142/S0219649223500065.

Gasana, J. *et al.* (2022) 'Risky Roads in Kuwait: An Uneven Toll on Migrant Workers', *International Journal of Environmental Research and Public Healt*h, 19(15), p. 9726. Available at: https://doi.org/10.3390/ijerph19159726.

Goel, R. *et al.* (2024) 'Effectiveness of Road Safety Interventions: An Evidence and Gap Map', Campbell Systematic Reviews, 20(1). Available at: https://doi.org/10.1002/cl2.1367.

Gounaridou, A., Siamtanidou, E. and Dimoulas, C. (2021) 'A Serious Game for Mediated Education on Traffic behavior and Safety Awareness', *Education Sciences*, 11(3). Available at: https://doi.org/10.3390/educsci11030127.

Haghani, M. *et al.* (2022) 'Road Safety Research in the Context of Low- and Middle-income Countries: Macro-scale Literature Analyses, Trends, Knowledge Gaps and Challenges', *Safety Science*, 146(October 2021), p. 105513. Available at: https://doi.org/10.1016/j.ssci.2021.105513.

He, Y. *et al.* (2022) 'Visualization and Analysis of Global Vision Zero Studies and Policy Orientation in China', *International Journal of Environmental Research and Public Health*, 19(22), p. 14841. Available at: https://doi.org/10.3390/ijerph192214841.

Hizkel, A. *et al.* (2021) 'Outcome and Associated Factors Among Road Traffic Accident Victims at Wolaita Soddo Christian Hospital, Wolaita Soddo, South Ethiopia 2020, Institution-Based Cross-Sectional Study'. Available at: https://doi.org/10.1101/2021.09.16.21262878.

Hossain, M.M. *et al.* (2022) 'Cellphone-distracted Crashes of Novice Teen Drivers: Understanding Associations of Contributing Factors for Crash Severity Levels and Cellphone usage Types', *Traffic Injury Prevention*, 23(7), pp. 390–397. Available at: https://doi.org/10.1080/15389588.2022.2097667.

Hughes, B.P., Anund, A. and Falkmer, T. (2016) 'A Comprehensive Conceptual Framework for Road Safety Strategies', *Accident Analysis & Prevention*, 90, pp. 13–28. Available at: https://doi.org/10.1016/j.aap.2016.01.017.

Khan, N. *et al.* (2021a) 'An Adaptive Game-Based Learning Strategy for Children Road Safety Education and Practice in Virtual Space', *Sensors*, 21(11), p. 3661. Available at: https://doi.org/10.3390/s21113661.

Kirytopoulos, K. *et al.* (2024) 'A Virtual Reality Instrument to Raise Drivers' Awareness on Safer Driving through Road Tunnels', *Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability*, 238(3), pp. 451–463. Available at: https://doi.org/10.1177/1748006X231175719.

Koloushani, M. *et al.* (2022) 'The Analysis of Spatial Patterns and Significant Factors Associated with Young-Driver-Involved Crashes in Florida', *Sustainability*, 14(2), p. 696. Available at: https://doi.org/10.3390/su14020696.

Kourmousi, N. *et al.* (2024) 'Evaluation of the Road Safety Education "E-drive Academy" Interactive Program in Greek Elementary Schools: A Study of 834 Fourth Grade Students', *Journal of Road Safety*, 35(1), pp. 27–39. Available at: https://doi.org/10.33492/JRS-D-24-1-2117050.

Krasniuk, S. *et al.* (2024) 'The Effectiveness of Driving Simulator Training on Driving Skills and Safety in Young Novice Drivers: A Systematic Review of Interventions', *Journal of Safety Research*, 91(March), pp. 20–37. Available at: https://doi.org/10.1016/j.jsr.2024.08.002.

Krithika P., Shanmugam V. and Kiruba, A.S. (2023) 'Emerging Patterns of E-Commerce Apparel

Attributes: A Bibliometric Analysis', *Quality - Access to Success*, 24(194). Available at: https://doi.org/10.47750/QAS/24.194.46.

Kwon, J.-H. *et al.* (2022) 'Pedestrians Safety Perception and Crossing Behaviors in Narrow Urban Streets: An Experimental Study using Immersive Virtual Reality Technology', *Accident Analysis & Prevention*, 174(April), p. 106757. Available at: https://doi.org/10.1016/j.aap.2022.106757.

Lijarcio, I. *et al.* (2022) 'Assessing Risk Perception over Recidivist Traffic Offenders from a Multi-group Approach: How Gendered Could It Be?', *The European Journal of Psychology Applied to Legal Context*, 14(1), pp. 33–41. Available at: https://doi.org/10.5093/ejpalc2022a4.

Liu, Mingyue *et al.* (2024) 'Global Research Hotspots and Trends of Theta Burst Stimulation from 2004 to 2023: A Bibliometric Analysis', *Frontiers in Neurology*, 15. Available at: https://doi.org/10.3389/fneur.2024.1469877.

McIlroy, R.C. *et al.* (2022) 'The Influence of Fatalistic Beliefs and Risk Perceptions on Road Safety Attitudes in Latin America; A Two-Country Study', *Transportation Research Part F: Traffic Psychology and Behaviour*, 90(July), pp. 84–99. Available at: https://doi.org/10.1016/j.trf.2022.08.003.

Meir, A., Oron-Gilad, T. and Parmet, Y. (2015a) 'Are Child-Pedestrians Able to Identify Hazardous Traffic Situations? Measuring Their Abilities in A Virtual Reality Environment', *Safety Science*, 80, pp. 33–40. Available at: https://doi.org/10.1016/j.ssci.2015.07.007.

Meir, A., Oron-Gilad, T. and Parmet, Y. (2015b) 'Can Child-Pedestrians' Hazard Perception Skills be Enhanced?', *Accident Analysis and Prevention*, 83, pp. 101–110. Available at: https://doi.org/10.1016/j.aap.2015.07.006.

Mokhtarpour, R. and Khasseh, A.A. (2021) 'Twenty-Six Years of LIS Research Focus and Hot Spots, 1990–2016: A co-word analysis', *Journal of Information Science*, 47(6), pp. 794–808. Available at: https://doi.org/10.1177/0165551520932119.

Möller, H. *et al.* (2022) 'Driving Offences and Risk of Subsequent Crash in Novice Drivers: the Drive Cohort Study 12-Year Follow-up', I*njury Prevention*, 28(5), pp. 396–404. Available at: https://doi.org/10.1136/injuryprev-2021-044482.

Nguyen-Phuoc, D.Q. *et al.* (2019) 'Exploring the Prevalence and Factors Associated with Self-reported Traffic Crashes among App-based Motorcycle Taxis in Vietnam', *Transport Policy,* 81, pp. 68–74. Available at: https://doi.org/10.1016/j.tranpol.2019.06.006.

Pervez, A. (2024) 'Navigating the Road to Safer Travel in Pakistan: A Multi-Perspective Analysis of Road Safety Challenges and Solutions', *Research Journal of Engineering & Technology*, 13(2). Available at: https://doi.org/10.33317/ssurj.591.

Regmi, M. (2021) 'What does it Take to Improve Road Safety in Asia?', *Journal of Road Safety,* 32(4), pp. 29–39. Available at: https://doi.org/10.33492/JRS-D-21-00040.

Rojas-Lamorena, Á.J., Del Barrio-García, S. and Alcántara-Pilar, J.M. (2022) 'A Review of Three Decades of Academic Research on Brand Equity: A Bibliometric Approach using Co-word Analysis and Bibliographic Coupling', *Journal of Business Research*, 139, pp. 1067–1083. Available at: https://doi.org/10.1016/j.jbusres.2021.10.025.

Sabeti, S., Ardecani, F.B. and Shoghli, O. (2024) 'Augmented Reality Warnings in Roadway Work Zones: Evaluating the Effect of Modality on Worker Reaction Times', *Computer science*, pp. 1–16. Available at: https://doi.org/https://doi.org/10.48550/arXiv.2403.15571.

Sari, N., Malkhamah, S. and Budi, S. (2024) 'Road Traffic Accidents Factor on Rural Arterial Roads', *Journal of Applied Engineering Science*, 22(2), pp. 470–482. Available at: https://doi.org/10.5937/jaes0-49183.

Sayed, I., Abdelgawad, H. and Said, D. (2022) 'Studying Driving Behavior and Risk Perception: A Road Safety Perspective in Egypt', *Journal of Engineering and Applied Science*, 69(1), p. 22. Available at: https://doi.org/10.1186/s44147-021-00059-z.

Schneider, S. and Bengler, K. (2020) 'Virtually the Same? Analysing Pedestrian Behaviour by Means of Virtual Reality', T*ransportation Research Part F: Traffic Psychology and Behaviour*, 68, pp. 231–256. Available at: https://doi.org/10.1016/j.trf.2019.11.005.

Setyowati, D.L. *et al.* (2024a) 'Assessment of Risky Riding Behaviors Using the Motorcycle Rider Behavior Questionnaire (MRBQ) among University Students', *The Open Public Health*

Journal, 17(1), pp. 1–9. Available at: https://doi.org/10.2174/0118749445281252240316204804.

Setyowati, D.L. *et al.* (2024b) 'The Relationship Between Driving Behavior and Road Safety Education Concerning Road Traffic Accidents Among Young Drivers: A Scoping Review', *Malaysian Journal of Medicine and Health Sciences*, 20, pp. 155–162.

Setyowati, D.L. *et al.* (2025) 'Understanding Risk Factors in Road Traffic Accidents among Young Motorcyclists Aged 18-24: A Scoping Review', *Journal of Public Health and Development*, 23(1), pp. 311–328. Available at: https://doi.org/10.55131/jphd/2025/230123.

Smith, S.S. *et al.* (2024) 'Reducing Crash Risk for Young Drivers: Protocol for a Pragmatic Randomised Controlled Trial to Improve Young Driver Sleep', *Heliyon*, 10(5), p. e27066. Available at: https://doi.org/10.1016/j.heliyon.2024.e27066.

Sovacool, B.K. (2017) 'Experts, Theories, and Electric Mobility Transitions: Toward an Integrated Conceptual Framework for the Adoption of Electric Vehicles', *Energy Research and Social Science*, 27, pp. 78–95. Available at: https://doi.org/10.1016/j.erss.2017.02.014.

Stelling-Konczak, A. *et al.* (2017) 'Mobile Phone Conversations, Listening to Music and Quiet (Electric) Cars: Are Traffic Sounds Important for Safe Cycling?', *Accident Analysis and Prevention*, 106(November 2016), pp. 10–22. Available at: https://doi.org/10.1016/j.aap.2017.05.014.

Stoker, P. *et al.* (2015) 'Pedestrian Safety and the Built Environment: A Review of the Risk Factors', *Journal of Planning Literature*, 30(4), pp. 377–392. Available at: https://doi.org/10.1177/0885412215595438.

Tiwari, R.R. *et al.* (2021) 'Road Use Pattern and Street Crossing Habits of Schoolchildren in India', *Frontiers in Public Health*, 9. Available at: https://doi.org/10.3389/fpubh.2021.628147.

Torbaghan, M. E. *et al.* (2022) 'Understanding the Potential of Emerging Digital Technologies for Improving Road Safety', *Accident Analysis & Prevention*, 166(June 2021), p. 106543. Available at: https://doi.org/10.1016/j.aap.2021.106543.

Useche, S. *et al.* (2018) 'Infrastructural and Human Factors Affecting Safety Outcomes of Cyclists', *Sustainability (Switzerland)*, 10(2). Available at: https://doi.org/10.3390/su10020299.

Useche, S.A. *et al.* (2018) 'Distraction of Cyclists: How does it Influence Their Risky Behaviors and Traffic Crashes?', PeerJ, 2018(9), pp. 1-25. Available at: https://doi.org/10.7717/peerj.5616.

Useche, S.A. *et al.* (2019) 'Explaining Self-reported Traffic Crashes of Cyclists: An Empirical Study based on Age and Road Risky Behaviors', *Safety Science*, 113, pp. 105–114. Available at: https://doi.org/https://doi.org/10.1016/j.ssci.2018.11.021.

Useche, S.A. *et al.* (2022) 'Unsafety on Two Wheels, or Social Prejudice? Proxying Behavioral Reports on Bicycle and E-scooter Riding Safety – A mixed-methods Study', *Transportation Research Part F: Traffic Psychology and Behaviour*, 89(October 2021), pp. 168–182. Available at: https://doi.org/10.1016/j.trf.2022.06.015.

Varghese, N. *et al.* (2023) 'Interplay between Stress, Aleep, and BDNF in a High-risk Sample of Young Adults', *Scientific Reports*, 13(1), p. 20524. Available at: https://doi.org/10.1038/s41598-023-47726-0.

Virani, S. and Rautela, S. (2025) 'Metaverse and Education: Identifying Key Themes and Future Research Trajectories', *The International Journal of Information and Learning Technology*, 42(1), pp. 84–106. Available at: https://doi.org/10.1108/IJILT-05-2024-0083.

Wang, C. *et al.* (2020) 'Exploring Factors Influencing the Risky Cycling Behaviors of Young Cyclists Aged 15–24 Years: A Questionnaire-Based Study in China', *Risk Analysis*, 40(8), pp. 1554–1570. Available at: https://doi.org/10.1111/risa.13499.

Wang, R. *et al.* (2024) 'Bibliometric Analysis of the Application of Deep Learning in Cancer from 2015 to 2023', *Cancer Imaging*, 24(1), p. 85. Available at: https://doi.org/10.1186/s40644-024-00737-0.

Yan, M. *et al.* (2021) 'Characteristics and Causes of Particularly Major Road Traffic Accidents Involving Commercial Vehicles in China', *International Journal of Environmental Research and Public Health*, 18(8), p. 3878. Available at: https://doi.org/10.3390/ijerph18083878.

Zahid, M. *et al.* (2020) 'Predicting risky and aggressive driving behavior among taxi drivers: Do spatio-temporal attributes matter?', *International Journal of Environmental Research and Public Health*, 17(11), pp. 1–21. Available at: https://doi.org/10.3390/ijerph17113937.

Zainuldin, M.H. and Lui, T.K. (2021) 'A Bibliometric Analysis of CSR in the Banking Industry: A Decade Study Based on Scopus Scientific Mapping', *The International Journal of Bank Marketing*, 40(1), pp. 1–26. Available at: https://doi.org/10.1108/ijbm-04-2020-0178.

Zamani, N. (2024) 'The Use of Social Media Augmented Reality for Engaging Parents and Educating Children About Road Safety', *Journal of Road Safety*, 35(1), pp. 65–74. Available at: https://doi.org/10.33492/JRS-D-24-1-2123565.

Zhong, S. *et al*. (2024) 'Artificial Intelligence Applications in Bone Fractures: A Bibliometric and Science Mapping Analysis', *Digital Health*, 10. Available at: https://doi.org/10.1177/20552076241279238.