

Scientometric and Bibliographic Analysis of Pedestrian Safety Research

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Abstract

The vulnerability of pedestrians means that pedestrian and vehicle crashes often have severe consequences. Pedestrian safety related research has attracted researchers' attention since the 1970s and has become increasingly popular in recent years. There were about 250 papers published in 2021 alone on this research domain. However, scientometric studies on a specific safety area are rarely conducted. Scientometric and bibliographic analyses provide researchers with a thorough understanding of research topics and historical knowledge on authorship, publishers, keywords (thematic topics), and collaborations that occurred in the research community on the specific research domain. This study bridges this gap by collecting 2,689 pedestrian safety-related papers from the Web of Science (WoS) Core Collection database and conducting a scientometric and bibliographic analysis. The results show the increasing popularity of pedestrian safety-related studies, and the number of papers has increased significantly each year since 2000. This study also investigated the changes in the research interests in pedestrian safety-related studies temporally. The results show research interests changed from investigating the built environment, theoretical modeling, behavioral studies, and advanced modeling techniques over time. Moreover, the findings suggest that child pedestrian safety interests started to gain popularity in 2008, soon after the Safe Routes to School (SRTS) program was initiated in 2005, which shows the positive interactions between this research domain and policy-making progress.

Keywords

pedestrians, human factors, safety, bibliographic analysis, research trends

Pedestrian safety has attracted many researchers in recent years. In 2021 alone, about 250 papers were published in this small research domain. Although systematic literature reviews on safety-related issues have been widely conducted, bibliometric studies on a specific safety topic are rarely conducted. This study aims to explore this research domain from a bibliometric perspective. The findings of this bibliometric study have many benefits. First, they can provide a thorough understanding of the development of this research domain. Second, they not only can show the country, publication source, organization, or individual researchers who have contributed to this research domain the most, but also the co-authorship and co-citations among organizations, publication sources, and various authors. Third, this study could also expose some concerns about this research domain. For example, some organizations may heavily collaborate with researchers from inside their own organization and

lack connections with other organizations, which is not the best scenario for the evolution of a research domain.

Pedestrian safety is a popular research domain for researchers from different fields. This research domain has become increasingly popular in recent years, especially since pedestrian exposure and associated crash counts have spiked. Many pedestrian safety-related articles are published every year in various transportation, public health, and medical journals. However, as numerous researchers have been addressing pedestrian safety-related issues from many different angles, the history of these studies and the evolution of this special research

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domain remain less explored. This study conducted a thorough bibliometric analysis of published pedestrian crashes, risk, and safety-related articles from 1970 to 2021. All available published articles were retrieved from the Web of Science (WoS) core collection database. In this paper, the focus is on a specialized bibliometric overview to (i) identify the temporal trends of the number of published articles and citations in this research domain; (ii) recognize the more prominent and productive countries, organizations, publication sources, and individual researchers; (iii) explore the co-authorship, top cited papers, co-citations among organizations, and individuals across the world; and (iv) discover patterns inside the keywords of these studies.

Bibliometric and scientometric analysis can contribute to the transportation research community in many ways. First, scientometric analysis of pedestrian safety had not been conducted before this paper was first developed in 2020. Second, the temporal trend could inform transportation researchers about the popularity of topics over time and inspire researchers to explore trends and insights associated with different temporal clusters. Third, the spatial distribution of these published research articles can demonstrate the locations with the most active pedestrian research communities. Fourth, this research could provide insightful information about the prominent authors, universities, and organizations in this domain. These findings may show the leading power of these individuals and organizations and encourage diversity and collaboration. Fifth, the results could also identify the journals that are best suited for pedestrian safety research. This may provide helpful information for future researchers about potential journals for their relevant research publication. Additionally, it can also encourage other journals to expand their diversity of research domains.

Methodology: Data Source and Processing

Data Description

The Core Collection Database of Web of Science (WoS) (<http://www.webofknowledge.com/>) was the primary resource for this study. We also collected relevant literature from the TRID server (<https://trid.trb.org/>). Scopus was not explored because of limited access issues. Publications from 1970 to 2021 were collected from WoS. The keywords used for searching include “pedestrian safety,” “pedestrian crashes,” “pedestrian crash,” “pedestrian accident,” “pedestrian accidents,” “pedestrian collision,” “pedestrian collisions,” “safe walking,” “pedestrian safer,” “complete streets,” and other relevant word groups. Table 1 presents the number of publications and the different types in this period. A manual check was conducted to discard the non-relevant papers,

Table I. Types of Publications

Type	Count
Article	1,881
Article; Book chapter	25
Article; Early access	23
Article; Proceedings paper	57
Book	1
Book review	16
Correction	11
Correction, addition	2
Editorial material	28
Editorial material; Book chapter	2
Editorial material; Early access	1
Letter	13
Meeting abstract	139
News item	12
Note	11
Proceedings paper	415
Reprint	2
Retraction	2
Retraction; Early access	1
Review	46
Review; Early access	1

resulting in 1,881 articles, 415 conference papers, and 139 meeting abstracts. The number of publications in each of the rest of the categories was less than 100.

Analysis Methods

Performing bibliometric and scientometric analysis can provide a quick overview of overall trends and directions, which aids in understanding a particular domain's research trends. This study used collected references associated with pedestrian safety research and applied bibliometric and scientometric analysis. In recent years, many renowned journals have published a wide range of bibliometric studies (1–9). Bibliometrics was developed by Pritchard (10) as a way to apply statistical methods and mathematics to publications. The different metrics in the bibliographic method can provide quantitative measures of publications, co-authorships, citations, and other associated parameters. It provides a wide range of quantitative measures, making it a very efficient method to determine the research trends of a certain research domain.

The history and development of knowledge in a particular domain were revealed by the analysis associated with the mapping knowledge domain. It presents correlational research in the form of link-based knowledge maps to determine structural associations, and it allows the reader to use key literature, key scholars, research trends, and future directions to analyze a particular research domain's potential for evolution. Two major bibliometric methods (bibliographic coupling and

Table 2. Publications by Country

Country	Frequency	Single country publications	Multiple country publications
USA	695	611	84
China	306	215	91
Australia	137	112	25
Canada	130	102	28
United Kingdom	123	102	21
Germany	86	70	16
Japan	82	72	10
South Korea	78	69	9
India	75	64	11
France	58	45	13
Sweden	54	37	17
Iran	52	41	11
Italy	49	42	7
Spain	46	31	15
Poland	39	38	1
New Zealand	29	24	5
Israel	23	21	2
Ireland	20	13	7
Switzerland	20	13	7
Malaysia	19	18	1

co-authorship) available in the VOSviewer software, a visualization and analytical package in the field of bibliometrics, were used in this paper for ease of result interpretation and analysis construction. The VOSviewer tool was used in this study to conduct the analysis. The core algorithms embedded in VOSviewer include the unified approach of VOS mapping and clustering of bibliometric networks (11–13), the construction of similarity matrices (11), and the principle of density graphing (12). This tool is also capable of handling large amounts of data because of its excellent graphical-presentation capability. This tool is suitable for three specific visualizations: overlay visualization, network visualization, and density visualization. Overlay visualization provides a glance of advancement over time. Network visualizations explain the network connections among authors, the countries of origin of authors, and the collaboration between institutes. Density visualization is mainly used to reveal the relationship between co-cited articles.

The remainder of the paper is structured as follows. First, a quantitative analysis of the publication data collected from the WoS is undertaken using a bibliometric approach. Next, publication influence measures and publication matrices are described with a list of the top 40 most cited papers on pedestrian safety. After that, dominance measures and several publication indices are explored. Finally, knowledge maps that reveal main topics, knowledge bases, research frontiers, and future trends were created using VOSViewer to perform document co-citation analysis and keyword co-occurrence analysis.

Results and Discussion

Publication Matrices

Table 2 lists the top 20 countries where researchers have published the most pedestrian safety articles. The United States is at the top of the list. Researchers from the United States have published 695 pedestrian safety-related articles since 1970. China had the second highest number of articles on this topic with 306 articles, followed by Australia (137 publications), Canada (130 publications), and the United Kingdom (123 publications). The rest of the countries have less than 100 publications on this issue. Switzerland and Malaysia were at the end of the top 20 list with 20 and 19 publications, respectively. Single country publications (SCP) are indicators that describe the number of publications produced through intra-country collaboration. Multiple country publications (MCP) indicate the publication was produced by the collaboration of researchers from more than one country. Out of 695 publications, the United States has 611 SCP, which is the highest count of SCP of any of the countries. China has the second most SCP at 215, followed by Australia at 112, and Canada and the United Kingdom at 102. All other countries have an SCP under 100. For MCP, China has the highest count of 91 publications, which were co-authored by researchers from China and other countries. The United States has the second highest MCP at 84, and all the other countries have an MCP under 30. Interestingly, Malaysia and Poland both only have one publication which was an MCP.

Table 3. Publications by Journal

Ranking	Journal	Count
1	<i>Accident Analysis & Prevention</i>	339
2	<i>Injury Prevention</i>	116
3	<i>Traffic Injury Prevention</i>	111
4	<i>Transportation Research Record</i>	95
5	<i>International Journal of Crashworthiness</i>	68
6	<i>Transportation Research Part F-Traffic Psychology and Behaviour</i>	54
7	<i>Safety Science</i>	52
8	<i>Journal of Safety Research</i>	35
9	<i>Journal of Transport & Health</i>	35
10	<i>International Journal of Injury Control and Safety Promotion</i>	34
11	<i>Ite Journal-Institute of Transportation Engineers</i>	31
12	<i>Journal of Transportation Safety & Security</i>	26
13	<i>Sustainability</i>	24
14	<i>Forensic Science International</i>	23
15	<i>International Journal of Environmental Research and Public Health</i>	22
16	<i>Pediatrics</i>	22
17	<i>Journal of Trauma-Injury Infection and Critical Care</i>	21
18	<i>Journal of the Australasian College of Road Safety</i>	19
19	<i>International Journal of Automotive Technology</i>	17
20	<i>American Journal of Public Health</i>	16

Table 3 lists the number of pedestrian safety-related publications across different journals. The results show that the journal *Accident Analysis & Prevention* has the most pedestrian safety-related publications, with 339 articles in total. The number of pedestrian safety-related articles published by AAP is about three times the amount published by the second journal—*Injury Prevention* (116 articles). *Traffic Injury Prevention* is in third place with 111 publications, followed by *Transportation Research Record* with 95 publications, the *International Journal of Crashworthiness* with 68 publications, *Transportation Research Part F-Traffic Psychology and Behaviour* with 54 publications, *Safety Science* with 52 publications, the *Journal of Safety Research* with 35 publications, the *Journal of Transport & Health* with 35 publications, and the *International Journal of Injury Control and Safety Promotion* with 34 publications. The *American Journal of Public Health* (16 publications) and the *International Journal of Automotive Technology* (17 publications) had the fewest pedestrian safety-related publications. Compared with the *American Journal of Public Health*, *Accident Analysis & Prevention* (the top journal) had about 21 times the number of publications.

Publication Influence Measures

Figure 1 illustrates the number of pedestrian safety-related publications and the number of citations each year over a period of time from 1970 to 2021. Figure 1a shows the trend of each year's publication number on the topic of pedestrian safety. As shown in Figure 1, between 1970 and 2021 the growth trend of the

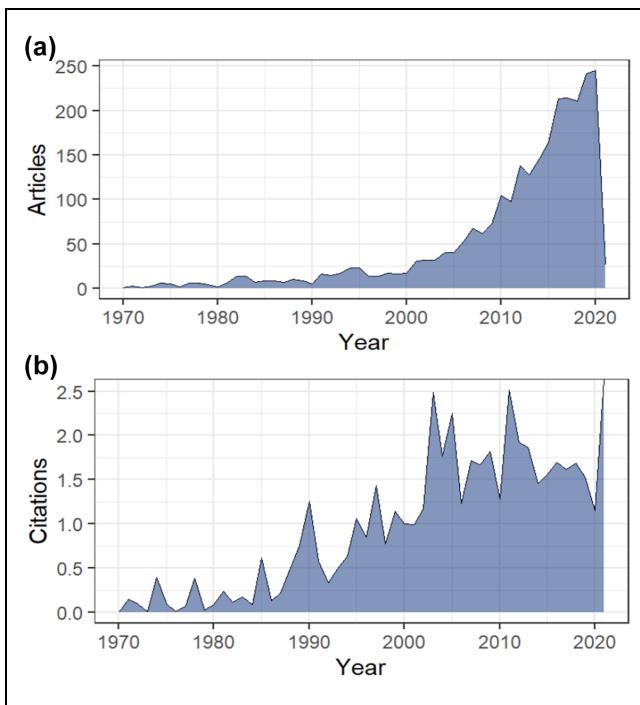


Figure 1. Scientific production and citation measures: (a) number of publications by year and (b) number of citations by year.

publication number was relatively steady. The number of publications was below 25 in 2000. However, this number started to grow rapidly after 2000. It took 10 years for this number to increase to 100 publications each year, and then it took another 10 years for this number to double. There were around 250 pedestrian safety-related

publications in 2021. The average number of article citations per year is presented in Figure 1b. The overall trend of the average number of citations per year increased between 1970 and 2021. The average number of citations between 1970 and 1985 was around 0.4, after which it increased to around 1.25 until 2000. From 2000 to 2020, the average number of citations had several peaks and changes, with the minimum number of citations being 1.0 (2000) and the maximum being around 2.75 (2020). Within this time frame, there were several significant peaks in the average number of citations per year in 1990, 2003, 2011, and 2020.

Table 4 lists the 50 top cited publications on pedestrian safety between 1970 and 2021. The number of citations of each article was collected from the WoS database, which reflects the articles on the subject with the most attention. The top five most cited articles are Eluru et al. (14), Lee and Abdel-Aty (15), Retting et al. (16), LaScala et al. (17), and Wier et al. (18). All 50 listed papers were cited about 100 or more times through 2021. The publication with the highest citations, over 300, was written by Eluru et al. (14). For the total citations per year (TC/Y), there are variations across all listed publications. A large portion of the top cited papers came from the journal *Accident Analysis & Prevention*, which was previously noted to be the journal with the most pedestrian safety-related articles (Table 3).

It is interesting that the top cited paper (14) is not limited to pedestrians only. Eluru et al. (14) applied an econometric structure in a model called the mixed generalized ordered response logit (MGORL) model. The MGORL model was applied to analyze non-motorist (both pedestrians and cyclists) accident severity. The results demonstrated that age, speed limit, location, and time of day are the most important factors affecting non-motorist accident severity. Crash severity analysis is one of the dominant research areas in transportation safety engineering. In the top cited papers, several other papers also explored injury severity: Sze and Wong (25), Kim et al. (29), Kim et al. (36), Jajac and Ivan (64), Mohamed et al. (43), and Demetriades et al. (56).

Lee and Abdel-Aty (15) studied intersection vehicle-pedestrian crashes. Log-linear models were applied to identify factors that are closely related to high rates of pedestrian crashes. Moreover, an ordered probit model was applied to predict the likelihood of pedestrian injury severity. The final results showed that demographic, road geometric, traffic, and environmental condition factors are closely related to pedestrian injury severity and frequency.

Retting et al. (16) developed a review paper about built environment engineering modifications that can help to decrease vehicle-pedestrian crash risks. The authors categorized all countermeasures into three broad groups: speed control, pedestrian and vehicle separation, and measures to increase pedestrians' visibility and

conspicuousness. This review paper shows that countermeasures to the built environment can substantially decrease vehicle-pedestrian crash risks.

LaScala et al. (17) applied spatial analysis to extensively study the geometry correlation of pedestrian crash injury by using a spatial autocorrelation corrected regression model. As the results indicated, traffic flow, age distribution, unemployment rate, education level, and population density are related to pedestrian injury rates. Moreover, the availability of bars in local areas is also related to pedestrian-involved crash frequency.

Wier et al. (18) developed a model to estimate area-level vehicle-pedestrian injury crash changes related to transportation and land use planning development. The model used in this study is called the simple bivariate model. The models can interpret around 72% of the systematic changes in vehicle-pedestrian injury crashes. Several important measures are included in the model, such as land area, the proportion of land area for commercial and residential uses, poverty rate, and proportion of elderly residents.

Co-Authorship Analysis

Organization Level. Figure 2 illustrates the co-authorship by organizations (some of the names are stemmed or shortened due to the better display protocols used in VOSviewer). The plot is generated through the VOSviewer application based on the connections in the collected database. The node size depicts the number of authorships. The higher the number, the larger the node size. Curved lines between nodes indicate co-authorship relations; the greater the number, the thicker the line. The major institutes with the most authorships include the University of North Carolina, Hunan University, Monash University, the University of Alabama at Birmingham, and the University of Washington. The analysis identified four potential clusters, as shown with different colors in Figure 2. Institutes in the same cluster more frequently collaborate with each other. Hunan University is at the center of the blue cluster, and it has frequently collaborated with Tsinghua University, the University of Virginia, the University of Adelaide, and Hanyang University. The University of North Carolina is at the center of the blue cluster. Purdue University, the University of Central Florida, and the University of South Florida are in a separate cluster. The University of Washington and the University of Alabama at Birmingham are two major institutes in the red cluster. They have frequently closely collaborated with Columbia University, the University of British Columbia, and the University of Idaho. In the yellow cluster, Monash University has the most authorships, and the Indian Institute of Technology is also in the

Table 4. Top Cited References

First author	Title	Journal	Year	Total citations	Total citations per year	Reference
Eluru N	A mixed generalized ordered response model for examining pedestrian and bicyclist injury severity level in traffic crashes	<i>Accident Analysis & Prevention</i>	2008	302	21.57	Eluru et al. (14)
Lee C	Comprehensive analysis of vehicle–pedestrian crashes, at intersections in Florida	<i>Accident Analysis & Prevention</i>	2005	285	16.76	Lee and Abdel-Aty (15)
Retting R	Review of evidence-based traffic engineering measures designed to reduce pedestrian–motor vehicle crashes	<i>American Journal of Public Health</i>	2003	212	11.16	Retting et al. (16)
LaScala E	Demographic and environmental correlates of pedestrian injury collisions: a spatial analysis	<i>Accident Analysis & Prevention</i>	2000	211	9.59	LaScala et al. (17)
Wier M	An area-level model of vehicle-pedestrian injury collisions with implications for land use and transportation planning	<i>Accident Analysis & Prevention</i>	2009	196	15.08	Wier et al. (18)
Nasar J	Mobile telephones, distracted attention, and pedestrian safety	<i>Accident Analysis & Prevention</i>	2008	190	13.57	Nasar et al. (19)
Oxley J	Crossing roads safely: an experimental study of age differences in gap selection by pedestrians	<i>Accident Analysis & Prevention</i>	2005	178	10.47	Oxley et al. (20)
Ewing R	Urban sprawl as a risk factor in motor vehicle occupant and pedestrian fatalities	<i>American Journal of Public Health</i>	2003	173	9.11	Ewing et al. (21)
Schwebel D	Distraction and pedestrian safety: how talking on the phone, texting, and listening to music impact crossing the street	<i>Accident Analysis & Prevention</i>	2012	167	16.70	Schwebel et al. (22)
Rosén E	Pedestrian fatality risk as a function of car impact speed	<i>Accident Analysis & Prevention</i>	2009	164	12.62	Rosén and Sander (23)
Nasar J	Pedestrian injuries because of mobile phone use in public places	<i>Accident Analysis & Prevention</i>	2013	163	18.11	Nasar and Troyer (24)
Sze N	Diagnostic analysis of the logistic model for pedestrian injury severity in traffic crashes	<i>Accident Analysis & Prevention</i>	2007	159	10.60	Sze and Wong (25)
Siddiqui C	Macroscopic spatial analysis of pedestrian and bicycle crashes	<i>Accident Analysis & Prevention</i>	2012	156	15.60	Siddiqui et al. (26)

(continued)

Table 4. (continued)

First author	Title	Journal	Year	Total citations	Total citations per year	Reference
Roberts I	Effect of environmental factors on risk of injury of child pedestrians by motor vehicles - a case-control study	<i>British Medical Journal</i>	1995	154	5.70	Roberts et al. (27)
Hatfield J	The effects of mobile phone use on pedestrian crossing behaviour at signalised and unsignalised intersections	<i>Accident Analysis & Prevention</i>	2007	152	10.13	Hatfield and Murphy (28)
Kim J	A note on modeling pedestrian-injury severity in motor-vehicle crashes with the mixed logit model	<i>Accident Analysis & Prevention</i>	2010	148	12.33	Kim et al. (29)
Oxley J	Differences in traffic judgements between young and old adult pedestrians	<i>Accident Analysis & Prevention</i>	1997	148	5.92	Oxley et al. (30)
Rivara F	Demographic analysis of childhood pedestrian injuries	<i>Pediatrics</i>	1985	147	3.97	Rivara and Barber (31)
Zajac S	Factors influencing injury severity of motor vehicle-crossing pedestrian crashes in rural Connecticut	<i>Accident Analysis & Prevention</i>	2003	145	7.63	Zajac and Ivan (32)
Holland C	The effect of age, gender and driver status on pedestrians' intentions to cross the road in risky situations	<i>Accident Analysis & Prevention</i>	2007	144	9.60	Holland and Hill (33)
Gårder P	The impact of speed and other variables on pedestrian safety in Maine	<i>Accident Analysis & Prevention</i>	2004	137	7.61	Gårder (34)
Zegeer C	Pedestrian crash trends and potential countermeasures from around the world	<i>Accident Analysis & Prevention</i>	2012	131	13.10	Zegeer and Bushell (35)
Kim J	Age and pedestrian injury severity in motor-vehicle crashes: a heteroskedastic logit analysis	<i>Accident Analysis & Prevention</i>	2008	128	9.14	Kim et al. (36)
Rosén E	Literature review of pedestrian fatality risk as a function of car impact speed	<i>Accident Analysis & Prevention</i>	2011	127	11.55	Rosén et al. (37)
Hulse L	Perceptions of autonomous vehicles: relationships with road users, risk, gender and age	<i>Safety Science</i>	2018	124	31.00	Hulse et al. (38)
Committee on Environmental Health	The built environment: designing communities to promote physical activity in children	<i>Pediatrics</i>	2009	121	9.31	Committee on Environmental Health (39)

(continued)

Table 4. (continued)

First author	Title	Journal	Year	Total citations	Total citations per year	Reference
Tiwari G	Survival analysis: pedestrian risk exposure at signalized intersections	<i>Transportation Research Part F - Traffic Psychology and Behaviour</i>	2007	119	7.93	Tiwari et al. (40)
Stavrinos D	Distracted walking: cell phones increase injury risk for college pedestrians	<i>Journal of Safety Research</i>	2011	115	10.45	Stavrinos et al. (41)
Duperrex O	Safety education of pedestrians for injury prevention: a systematic review of randomised controlled trials	<i>British Medical Journal</i>	2002	115	5.75	Duperrex et al. (42)
Mohamed M	A clustering regression approach: a comprehensive injury severity analysis of pedestrian–vehicle crashes in New York, US and Montreal, Canada	<i>Safety Science</i>	2013	113	12.56	Mohamed et al. (43)
Durkin M	Epidemiology and prevention of traffic injuries to urban children and adolescents	<i>Pediatrics</i>	1999	112	4.87	Durkin et al. (44)
Keller C	Will the pedestrian cross? a study on pedestrian path prediction	<i>IEEE Transactions on Intelligent Transportation Systems</i>	2014	111	13.88	Keller and Gavrila (45)
Keller C	Active pedestrian safety by automatic braking and evasive steering	<i>IEEE Transactions on Intelligent Transportation Systems</i>	2011	111	10.09	Keller et al. (46)
Sullivan J	The role of ambient light level in fatal crashes: inferences from daylight saving time transitions	<i>Accident Analysis & Prevention</i>	2002	111	5.55	Sullivan and Flannagan (47)
Wang Y	A Poisson-lognormal conditional-autoregressive model for multivariate spatial analysis of pedestrian crash counts across neighborhoods	<i>Accident Analysis & Prevention</i>	2013	108	12.00	Wang and Kockelman (48)
Barton B	The roles of age, gender, inhibitory control, and parental supervision in children's pedestrian safety	<i>Journal of Pediatric Psychology</i>	2007	107	7.13	Barton and Schwebel (49)
Ballesteros M	Pedestrian injuries and vehicle type in Maryland, 1995-1999	<i>Accident Analysis & Prevention</i>	2004	107	5.94	Ballesteros et al. (50)
Moudon A	The risk of pedestrian injury and fatality in collisions with motor vehicles, a social ecological study of state routes and city streets in King County, Washington	<i>Accident Analysis & Prevention</i>	2011	104	9.45	Moudon et al. (51)

(continued)

Table 4. (continued)

First author	Title	Journal	Year	Total citations	Total citations per year	Reference
Clifton K	Severity of injury resulting from pedestrian–vehicle crashes: what can we learn from examining the built environment?	<i>Transportation Research Part D- Transport and Environment</i>	2009	104	8.00	Clifton et al. (52)
Neider M	Pedestrians, vehicles, and cell phones	<i>Accident Analysis & Prevention</i>	2010	103	8.58	Neider et al. (53)
Schwebel D	Validation of virtual reality as a tool to understand and prevent child pedestrian injury	<i>Accident Analysis & Prevention</i>	2008	103	7.36	Schwebel et al. (54)
Anderson R	Vehicle travel speeds and the incidence of fatal pedestrian crashes	<i>Accident Analysis & Prevention</i>	1997	101	4.04	Anderson et al. (55)
Demetriades D	Pedestrians injured by automobiles: relationship of age to injury type and severity	<i>Journal of the American College of Surgeons</i>	2004	100	5.56	Demetriades et al. (56)
Rivara F	Child pedestrian injuries in the United States - current status of the problem, potential interventions, and future research needs	<i>American Journal of Diseases of Children</i>	1990	98	3.06	Rivara (57)
Ukkusuri S	The role of built environment on pedestrian crash frequency	<i>Safety Science</i>	2012	97	9.70	Ukkusuri et al. (58)
Boarnet M	California's Safe Routes to School program - impacts on walking, bicycling, and pedestrian safety	<i>Journal of the American Planning Association</i>	2005	97	5.71	Boarnet et al. (59)
Lefler D	The fatality and injury risk of light truck impacts with pedestrians in the United States	<i>Accident Analysis & Prevention</i>	2004	97	5.39	Lefler and Gabler (60)
Clifton K J	An examination of the environmental attributes associated with pedestrian–vehicular crashes near public schools	<i>Accident Analysis & Prevention</i>	2007	96	6.40	Clifton and Kreamer-Fults (61)
Aziz H	Exploring the determinants of pedestrian–vehicle crash severity in New York City	<i>Accident Analysis & Prevention</i>	2013	94	10.44	Aziz et al. (62)
Tefft B	Impact speed and a pedestrian's risk of severe injury or death	<i>Accident Analysis & Prevention</i>	2013	93	10.33	Tefft (63)

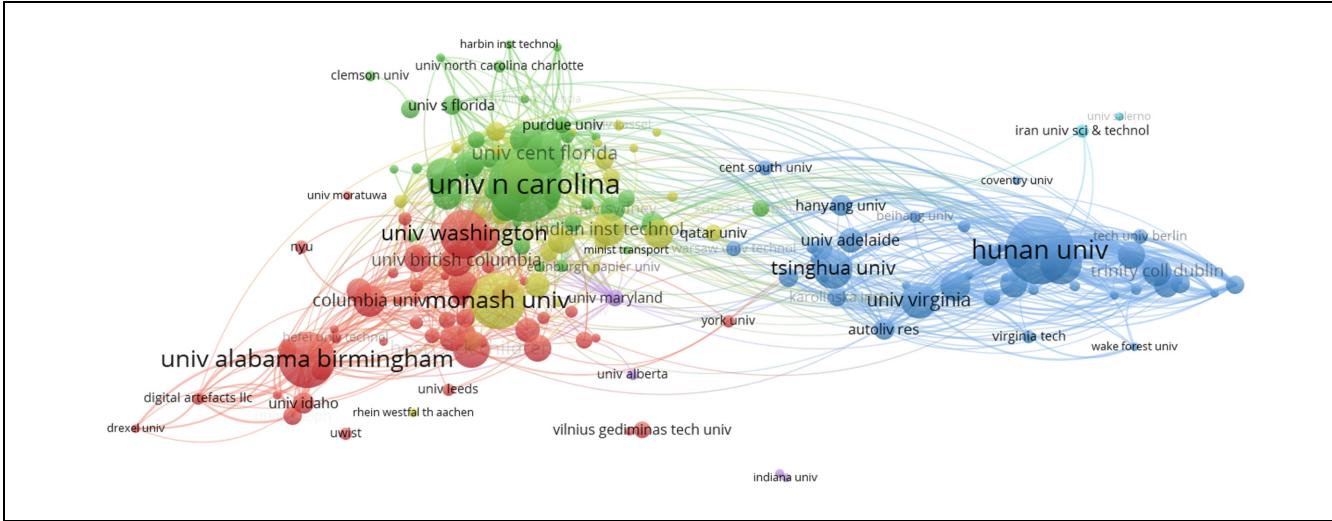


Figure 2. Co-authorships by organization.

same cluster. In the green cluster, the University of North Carolina, the University of Central Florida, and Purdue University were major institutes. They had frequent collaborations with the University of South Florida and the University of North Carolina Charlotte. It is interesting to note that the red, green, and yellow clusters seem to have closer collaborations with one another compared with the blue cluster. On the contrary, there are several isolated nodes without any links to other nodes, such as Indiana University and the University of Salerno. This suggests that the publications were produced by the organizations' members without any external contribution. In other words, some research institutes have very limited collaboration efforts. Some organizations did have some collaboration efforts, but still had a very limited number of co-authorships, such as York University, Iran University of Science and Technology, and Clemson University. In this study, out of 2,012 institutions, five have more than 184 co-authorships.

The research gap is the absence of a scientometric study on pedestrian crash safety analysis. The current study is designed to use scientometric and text mining tools to identify patterns. The current study is not a systematic literature review. Readers can consult our systematic review of pedestrian safety studies, which is out of the scope of the current study. This paper explores the research publication trends over the years on this topic and links the general findings.

Author Level. Figure 3 introduces the co-authorships at the author level (some of the display names are shortened due to the better display protocols used in VOSviewer). The size of the node indicates the number of publications published by that author, and the thickness of the lines represents the number of co-authorships. To better visualize

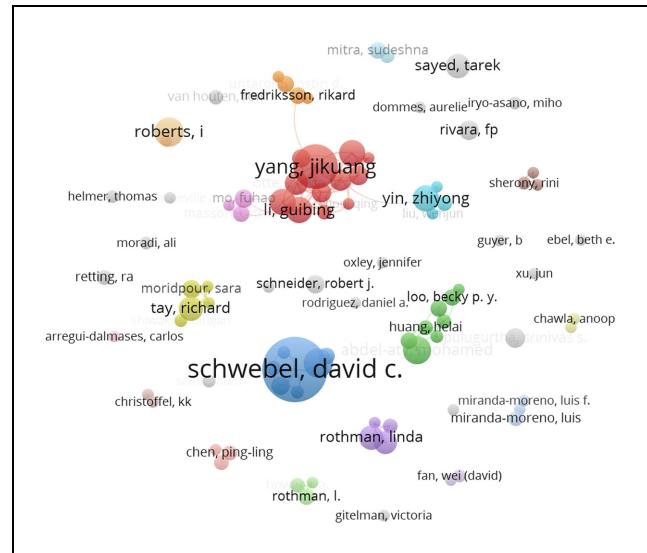


Figure 3. Co-authorships.

the results, Figure 3 only displays authors with more than six publications in the pedestrian safety research area. Ninety authors are included in Figure 3. D. Schwebel, within the blue nodes cluster, is the author with the most publications in this area, and there are no obvious lines indicating major co-authorships. That does not suggest this author heavily published papers as a single author, rather the lack of co-authorship indication could suggest that this author's co-authors were diverse instead of frequently co-authoring with the same authors. Another author, J. Yang in the red nodes cluster, has multiple visible co-authorship links. This author appears to have the second most publications in this area. This author often co-authors with Z. Yin, G. Li, and R. Fredriksson on pedestrian safety-related research. The green node cluster

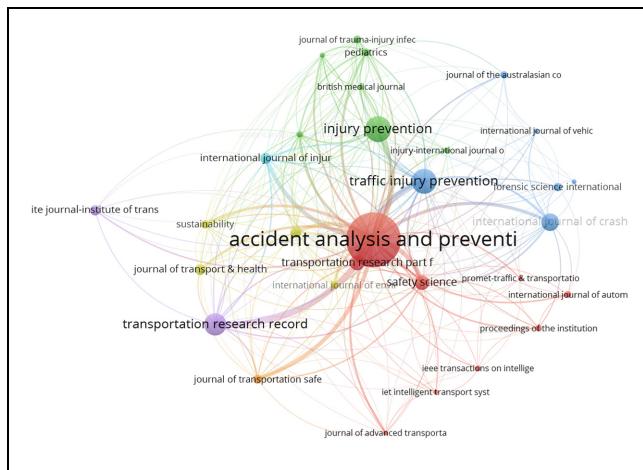


Figure 4. Citations by publication sources.

shows a strong co-authorship between H. Huang and B. Loo in this research area. In the yellow node cluster, it appears that R. Tay and S. Moridpour frequently co-author articles together.

Citation Analysis

Publication Source Level. Figure 4 illustrates the co-authorships by publication sources. Similarly, the node size represents the number of authorships, and the curved lines between nodes indicate co-authorship relations. The thicker the link, the higher the number of co-authorships. The co-occurrences are clustered into five different groups with different colors. *Accident Analysis & Prevention* is at the center of all clusters with the highest number of authorships. *Injury Prevention*, *Traffic Injury Prevention*, *Transportation Research Record*, and the *International Journal of Crash* all have high numbers of authorships as well. Strong relationships have been observed between *Accident Analysis & Prevention* and *Injury Prevention*, *Traffic Injury Prevention*, the *International Journal of Crash*, *Transportation Research Record*, *Injury Prevention*, and the *Journal of Transportation Safety*. In addition, *Traffic Injury Prevention* and *Injury Prevention* seem to have a strong relationship with one another. It can be observed that the journals in the red cluster are mainly focused on the application of advanced methods in transportation, and the journals in the green cluster are mainly focused on injury prevention. In this study, out of 899 journals, 10 have more than 31 co-authorships.

Co-Citation Analysis

Author Level. Figure 5 illustrates the co-citations by authors. A co-citation can be defined as the number of citations where two authors are cited together by a third author. Authors that are close to each other are related.

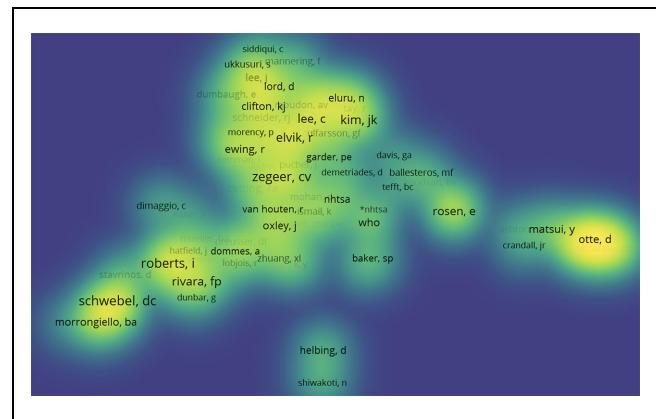


Figure 5. Co-citations by authors.

The larger the number is, the warmer (yellower) the color is, while the smaller the number is, the lighter (greener) the color. Some prominent authors are D. Schwebel, B. Morrone, I. Roberts, F. Rivara, J. Kim, C. Zegeer, R. Elvik, and D. Otte. As mentioned above, the closeness of two authors indicates the co-authorship. The plot suggests the publications co-authored by D. Schwebel and B. Morrone are highly cited by other authors, as well as by I. Roberts and F. Rivara. This can also be seen with D. Otte and Y. Matsui. Interestingly, D. Heibing and N. Shiawakoti along with D. Otte and Y. Matsui are far removed from the other authors, showing a lack of relationship to other authors. In this study, out of 25,193 co-occurrences, the top 50 authors have met 127 co-citations.

Publication Sources Level. Figure 6 shows the co-citation by publication analysis; this is characterized as the recurrence with which two records are cited together by a third record. In other words, the data collected were checks of the number of times two journals' titles were mutually cited after publication. In this study, out of 43,473 co-occurrences, 25 were met by 149 publications. Similarly, in Figure 6, the color of the area centered by an article depends on the number of co-citations. The larger the number is, the warmer (yellower) the color is, while the smaller the number, the lighter (greener) the color. Some major publications with high co-citations are Lee and Abdel-Aty (15), LaScala et al. (17), Retting et al. (16), Wier et al. (18), P. Jacobsen (65), and M. Peden, (66). Three out of six of these top publications came from the *Accident Analysis & Prevention* journal.

Keyword Co-Occurrence Analysis

Paper Titles and Abstract. Figure 7 illustrates the word co-occurrences from paper titles and abstracts across the timeline. This co-occurrence analysis has been divided into four temporal groups: 1970 to 2008, 2008 to 2015,

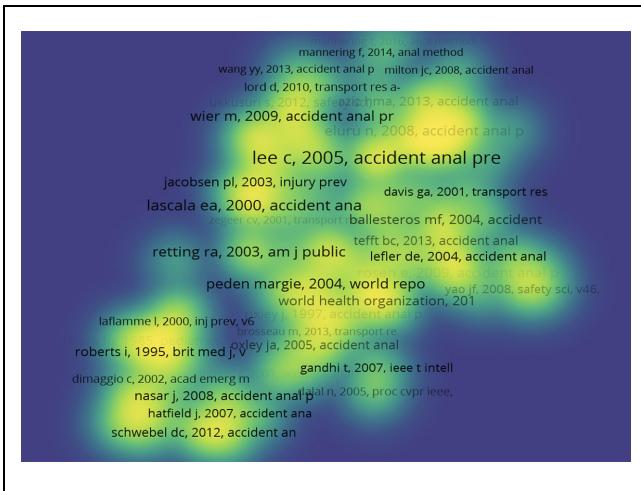


Figure 6. Co-citations by publications.

2016 to 2018, and 2019 to 2021. The temporal clusters were determined roughly based on the similar number of papers in each cluster. This co-occurrence analysis could provide the popularity of words and the co-occurrences among these words in titles and abstracts. The size of the node indicates the frequency of the words. The larger the size, the higher the frequency. The thickness of the lines indicates the co-occurrence between two words. It was not surprising to find out that some words with the largest nodes are “accident,” “pedestrian,” “model,” and “injury.” The colors refer to different clusters. Words in the same network are clustered in the same color. For the pedestrian safety publications, it is reasonable to observe the high frequency of these words. There are several patterns presented in the four sub-plots of Figure 7.

- “Intersection,” “street,” “environment,” and “head injury” are words with relatively high occurrences in the 1970 to 2008 and 2008 to 2015 plots, but these words have less frequency after 2015. The publications before 2015 heavily focused on intersections, streets, and the built environment.
- In the 1970 to 2008 plot, there are visible nodes showing that school and children pedestrian safety is an interest but not the mainstream. However, after 2008, child, school, age, and mortality/death have high occurrences in the rest of the plots. Child pedestrians have been a focus for researchers since then. This may be associated with some government policies to promote children’s safety. For example, the U.S. Congress created the Federal-Aid Safe Routes to School (SRTS) program in 2005, with nearly \$1 billion invested (67). It is possible that the school children’s pedestrian safety-related studies published before 2015 greatly support the successful launch of

the SRTS program. Meanwhile, the SRTS program also funded many school child pedestrian researchers in later years. It is promising to observe the positive interactions between a research domain and policymakers.

- The word “model” in 2008 to 2015 has a high frequency, along with “performance,” “parameters,” and “simulation.” The publications between 2008 and 2015 emphasized modeling and simulations. These theoretical research interests have been changing quickly.
- The 2016 to 2018 plot shows that words such as “behavior,” “crossing,” “user,” and “situation” have relatively high occurrences. This shows that the interests of research may have started trending more toward behavior, especially actions such as crossing roads. “Injury” also had a high occurrence, showing that research may have been looking more at potential injuries in pedestrian safety analyses. There was also more of a focus on demographics, with words such as “age,” “child,” and “male” having higher occurrences.
- The 2019 to 2021 plot describes the latest trends in pedestrian safety-related studies. Child, age, death/fatality, and behavior are still the focuses of the researchers, along with injuries. Moreover, the words “application” and “crash data” become increasingly important and attract attention.

Keyword Level. Figure 8 shows the keyword co-occurrence. Keywords describe the core elements of a paper. The size of the node indicates the frequency of the keyword shown in all collected pedestrian safety-related articles. The co-occurrence plot associates the most frequent keywords in three colors: red, blue, and green. The association presented in Figure 8 illustrates three types of pedestrian safety-related research. Red nodes indicate the studies that associate pedestrian safety and driver behavior and demographic-related factors. Multiple keywords in red nodes are driver-related, such as “behavior,” “drivers,” “age,” and “speed.” Blue nodes indicate pedestrian safety research on crash severity and the exposure of different types of pedestrians, such as children. These keywords are “severity,” “exposure,” and “children.” Green nodes indicate that the researchers tend to explore the relationship between the built environment and pedestrians. Frequent keywords are “built environment,” “design,” and “model.”

Findings

To summarize the analysis, the key findings of this study are described below:

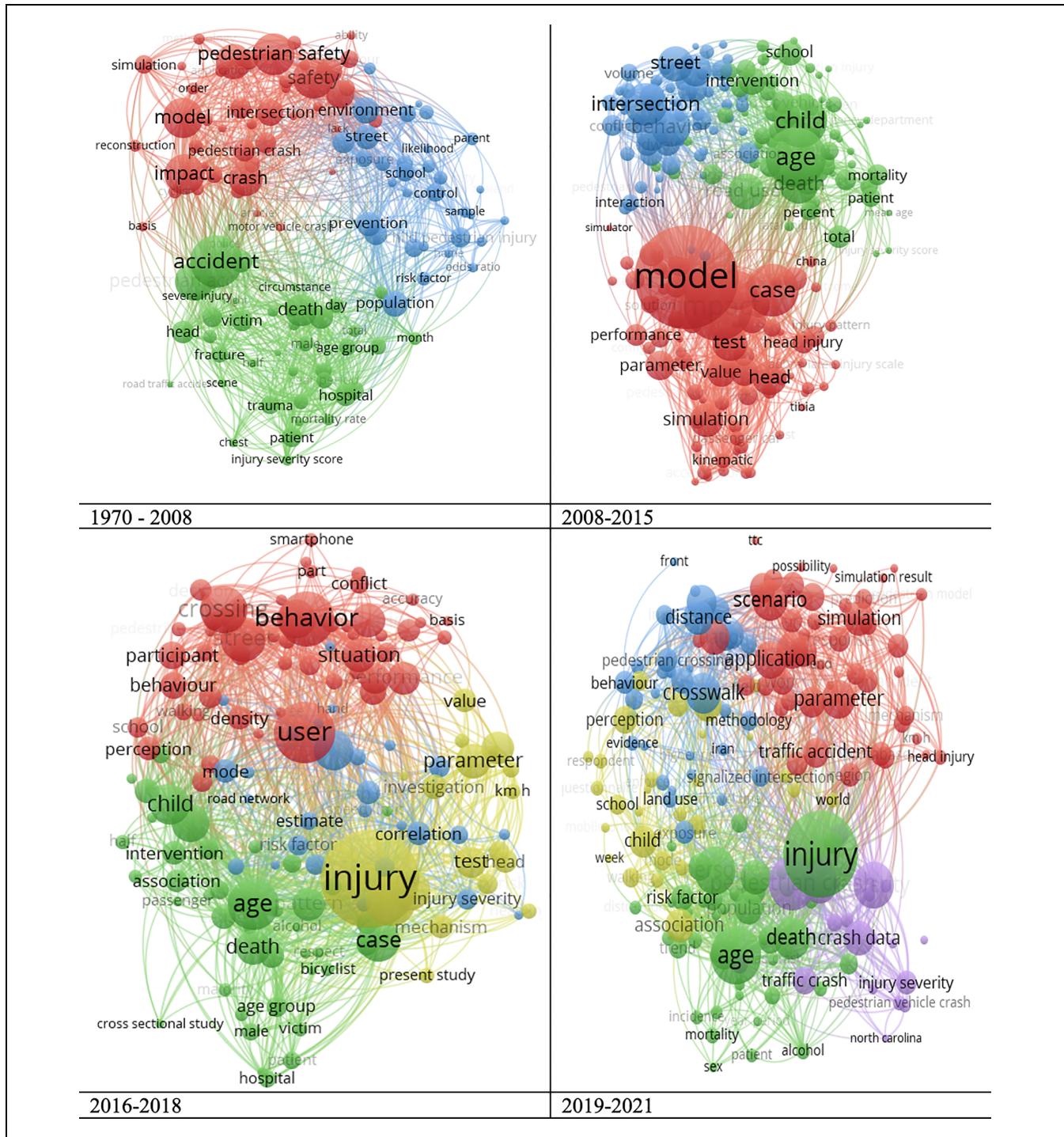


Figure 7. Temporal trends in keyword occurrence from paper titles and abstracts.

- The United States is the country with the most pedestrian safety-related articles published from 1970 to 2021, followed by China and Australia.
- Accident Analysis & Prevention* has published the most pedestrian safety-related articles among all the journals. The second journal is *Injury Prevention*,

and the third is *Traffic Injury Prevention*. It is noteworthy that *Accident Analysis & Prevention* has 339 pedestrian safety-related papers published until 2021. This amount is more than twice the articles that have been published in *Injury Prevention*, which is in second place with 116 articles.

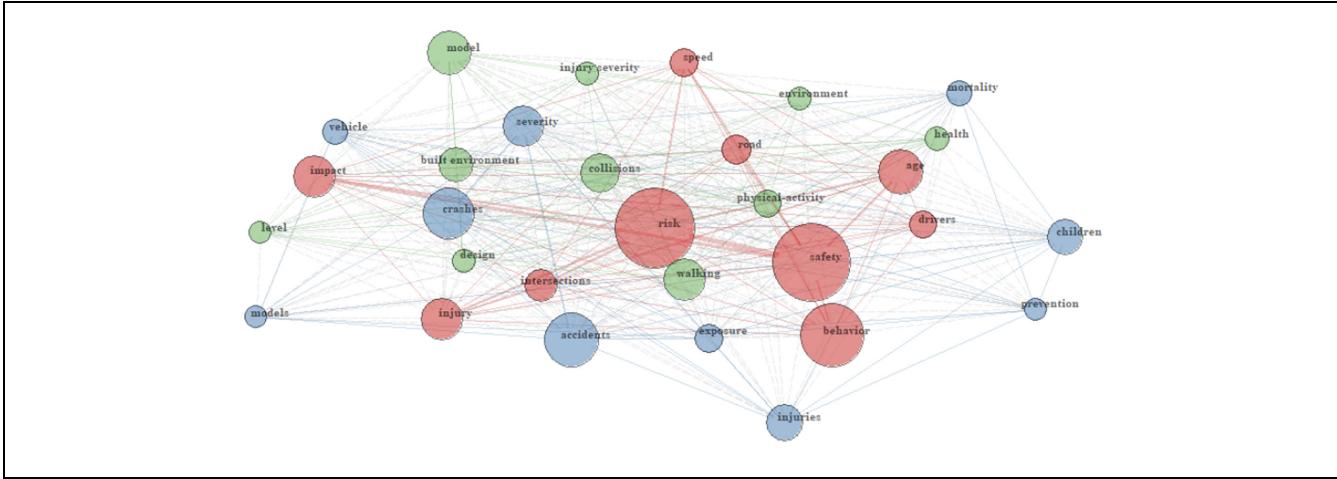


Figure 8. Author keyword co-occurrences.

- From 1970 to 2000, the publications of pedestrian safety-related articles was steadily increasing each year. The total amount of publications was originally less than 25 per year. However, after 2000, the number of publications each year increased significantly. The overall trend of the average article citation each year has kept increasing between 1970 and 2021. However, there are three spikes in the number of average article citations in 1990, 2003, and 2011. The cause behind that requires more in-depth investigation.
- The top five most cited pedestrian safety-related articles are Eluru et al. (14), Lee and Abdel-Aty (15), Retting et al. (16), LaScala et al. (17), and Wier et al. (18). Their total citations until 2021 were 302, 285, 212, 211, 196, respectively.
- The top institutes which have the most co-authorships in pedestrian safety-related publications include the University of North Carolina, Hunan University, the University of Washington, the University of Alabama at Birmingham, and Monash University.
- Strong relationships in co-authorships have been found between articles published in *Accident Analysis & Prevention* and articles published in *Injury Prevention*, *Traffic Injury Prevention*, *International Journal of Crash, Transportation Research Record*, *Injury Prevention*, and *Journal of Transportation Safety*.
- The most productive and prominent researcher in the pedestrian safety area is D. Schwebel, who also has a large variety of co-authorships with other researchers. The results also show that some of the researchers often collaborate with the same authors on pedestrian safety publications.
- The co-occurrence of words in titles and abstracts highlights that research interests have changed temporally from the built environment to theoretical modeling, behavioral, and artificial intelligence applications. Moreover, the analysis of the temporal occurrence of the words found that school child pedestrian safety has become popular since 2008, after the successful launch of the SRTS program. This presents a promising future for the research domain and its ability to change the real world.
- Keyword co-occurrence analysis classifies pedestrian-related studies into three broad categories: the association between pedestrian incidents and involved drivers' driving behavior and demographic factors; crash severity and exposure of various types of pedestrians, such as children; and the relationship between pedestrian accidents and the built environment.

Conclusion

This research presents 2,689 pedestrian safety-related publications from 1970 to 2021 from the WoS Core Collection database and conducts a bibliometric analysis. The analysis results provide a thorough understanding of the evolution of pedestrian safety-related research across time and space. This research is timely and necessary, especially since the analysis results show the great popularity that this research domain gained in recent years. Before 2000, there were fewer than 25 publications each year in this domain. However, since 2021, the number of publications has increased exponentially, and it reached about 250 in 2021. The unique value of this study is to summarize what researchers have done in this research area and visualize the knowledge to help pedestrian

safety researchers to better comprehend the history and explore the future of this research domain.

This study not only presents descriptive statistics about the number of publications and citations from the country level, organization level, and author level from 1970 to 2021, but it also explores the associations among these publications, authors, citations, titles, and keywords. These associations are interpreted from co-authorships, co-citations, and keyword co-occurrence perspectives. Each perspective is explored from the organization level, publication source level, and author level. The results uncover the relationships between authorship, citations, and keywords. The findings present a dynamic understanding of this research domain, its history, and the progress that has been made in recent years. The results show that *Accident Analysis & Prevention* has been the major publication source and has provided a great platform for researchers to share their work on pedestrian safety-related issues. The research also discovers some concerns related to this research domain. For example, the co-authorship analysis found that some prominent institutes have limited collaborations with other external organizations. Greater collaboration across different organizations and various authors could benefit this research domain in the long run.

Another exciting finding is that the research interests in the pedestrian safety-related domain change temporally. More importantly, the word co-occurrences in titles and abstracts suggests positive interactions between the research domain and the policy-making process. The research results could ring alarms and help policymakers to launch certain programs, and these programs could support more related studies and positively shape society. To summarize this bibliographical study, the study results provide a comprehensive understanding of this research domain, its history, and its trends. Moreover, the temporal analysis could show the changes that have been made through the years and demonstrate the promising future of this research domain. Another contribution of this study is the developed framework. Future studies can adopt the process or framework of this study to replicate a scientometric study on any other safety issues.

The current analysis has limitations too. The analysis was based on the data collected from WoS. The usage of other resources such as Scopus could provide additional research studies. However, access to Scopus is not open source and is difficult to acquire. For reasons of space limitation, the analysis was limited to the sub-clusters of certain thresholds. Extension of the filters and thresholds can generate more information and different bibliographic outcomes. Future studies can improve the current limitations of this study. Another review from the thematic perspective is suggested to review the major implications and findings of this type of study.

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Author Contributions

The authors confirm contribution to the paper as follows: study conception and design: S. Das; data collection: S. Das, X. Kong; analysis and interpretation of results: S. Das, X. Kong, Z. Wei, J. Liu; draft manuscript preparation: S. Das, X. Kong, Z. Wei, J. Liu. All authors reviewed the results and approved the final version of the manuscript.

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