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Abstract: About 1.3 million deaths occur every year due to road traffic crashes, making road safety a growing concern in many cities. This study considers the extent to which road safety challenges contribute to the built environment. In this paper, we applied the visualization technology of Bibliometrics supported by VOSviewer software and CitesSpace to develop a systematic review to understand the research status and identify gaps in road safety related to built environmental issues. This method has advantages in comprehensive quantitative statistics, visual information display, accurate description, and evaluation. Data was gathered from Scopus databases between 2000 to 2021, and a final number of 437 publications were retrieved. Road safety and land use were the primary keywords to locate relevant publications and identify their relationship. The analysis included the number of publications, research areas, and keywords for an in-depth evaluation. The result was visualized and bibliographically analyzed by demonstrating the existing occurrences between crucial terms, keywords and research areas. The findings revealed that road safety plays a vital role in significant issues, among others, that relate to land use and urban planning in the particular area associated with road safety. Therefore, it is essential to deliberately consider road safety in the very beginning to ensure that proper future solutions can be implemented through appropriate planning and design that is consistent with the surrounding city.

Keywords: bibliometrics; built environment; road accidents; urban factors; urban planning

1. Introduction

The global urban population has been steadily on the rise, with approximately 56 percent living in urban areas as of 2021 [1]. Historically, progress in the developed world is often seen to have resulted from urbanization. Urbanization also influences transportation and road safety [2,3]. In general, transport plays a vital role in supporting access to education and health facilities, electricity, internet and other technologies. Access to jobs and other economic opportunities is better in cities than in rural areas. For this reason, a significant proportion of the land area in cities is allocated to support access to opportunities and various urban activities, which include housing, roads, etc. [4–6].

Transportation is a component of the overall urban infrastructure that supports better interactions between people and their mobility. Urban transportation is essential as it facilitates the movement of people within the city, especially their everyday commuting from homes to workplaces and vice versa [7]. Transportation and land use no doubt influence each other, and their interactions help reshape the current urban transportation systems, better supporting future urban mobility as well as the sustainable development of our society, economy, and environment [8]. Yet the ever-increasing incidences of traffic-related problems leading to road crashes and fatalities are considered one of the leading causes of mortality among road users worldwide [9,10]. More than 90 percent of road accident deaths occur in low-income and middle-income countries, especially those who travel by motorcycle, bicycle...
or walking. While road accidents are a significant cause of death among all age groups, the impact becomes very significant amongst more vulnerable age groups, such as children and adults between the ages of 5 and 29 years [11–13]. For instance, 2016 WHO figures reported that there were 22,491 road fatalities recorded in Thailand, with a rate of 32.7 fatalities per 100,000 population. This is more than 10 times higher than the best-performing countries, which have a rate of 2–3 fatalities per 100,000 population (World Health Organization, 2018). Furthermore, the problem has become severe that there is an urgent need to improve urban road safety [14,15]. However, research investigation on road safety shows that this problem has multiple significant driving forces coming from different factors. These are vehicle-related factors, road environment factors, and most importantly, humanmade factors [16–21]. However, focusing on solving problems based on human behavior is more complicated since human behavior is the result of the influence of both internal and external factors such as attitude, perception, etc. The “Forgiving Roads” concept is fundamental to the Safe System Approach to road safety [22]. A key principle of the concept is the shift of responsibility from the road user as being the responsible agent of their road behavior to a greater emphasis on building safeguards into the system to limit injury-causing crashes, to ensure that the damage is only minor and there is a high chance of recovering from injuries [23]. That is to say, road system designers and managers have a greater responsibility to ensure that the roadside environment design focuses on reducing the severity of human error that leads to road-related fatalities. This means that the design of roads and roadside environments are important factors to consider when building safer urban road network projects. Therefore, considering land use in conjunction with road safety becomes vital because land use plays an important role in defining area-based activities. Land use characteristics (such as diversity and density) and land use patterns can reveal areas that accommodate potentially vulnerable road users, such as schools with children, that should be prioritized in terms of the Safe Systems approach. There are several studies that already provide significant evidence that land-use planning is related to fatalities and injuries [24–26].

Improvements in the most hazardous locations where fatalities occur range from specific plans to different planning strategies (e.g., blackspots, intersection improvements, street renovations, safe cycle, and pedestrian networks) and implementation at multiple scales or levels (route action plans, area-wide programs and intelligent traffic management systems, among others). Furthermore, urban road safety studies utilizing different approaches lead to different road safety policy recommendations. Therefore, a review of research in urban road safety can provide robust evidence on the state of research and identify existing research gaps [27]. However, most literature reviews in this domain were performed based on a summary of the literature, which required a long-term accumulation, summarization and extraction of research activities. This paper proposes an innovative approach by applying bibliometric methods to quantitatively analyze the collection of literature to explore the state of research of urban and road safety research. Moreover, understanding the state of research on urban and road safety and identifying the research gaps potentially opens alternative ways to alleviate road fatalities in urban areas to emerge from this bibliometric search. In order to meet this objective, several factors can be powerfully identified by determining the existing association with road fatalities.

2. Methodology

This paper adopts a systematic literature review (SLR) to synthesize the existing body of knowledge and empirical studies on road safety. As a methodological approach, the SLR adopts a methodical process that is transparent and reproducible [28]. It is a process of finding extant research and critically appraising its relevance to the subject being studied. It is a useful technique when collecting and analyzing data for the purpose of identifying empirical evidence, which is based on a specified set of inclusion criteria, and systematically reviewing the literature, reducing potential bias and increasing the reliability of findings underpinning the discussions, and then drawing conclusions to respond to the stated research question [29]. In this study, we define the state of research on urban road safety and built environments.
2.1. Literature Review

Unplanned urban development can lead to several problems, including road accidents that create hazardous conditions for all motorized and non-motorized transport users [30]. Land use planning and policy might influence the transportation dimension, especially in mobility and road safety [24]. The spatial organization of land use activities within urban areas can generate mobility patterns in different modes of choice, e.g., automobile, motorcycle, bus, bicycle, pedestrian, etc. Notably, land use planning determines the volume of traffic on the road networks, which is unsuitable urban and transportation planning that unquestionably impacts road safety [31]. Research on the direct relationship between land use and traffic crashes began in the nineties [25]. In addition, several studies provide a significant role that land-use planning related to fatalities and injuries resulting from road accidents among road users. Kim and Yamashita (2002) considered their research on motor vehicle crashes and land use [32], and Ziakopoulos and Yannis (2020) also reviewed spatial approaches to road safety and pointed out that the built environment needs to be more strictly defined [26]. Kim et al. (2006) and Kaygisiz, Senbil, and Yildiz (2017) also studied the influence of land use and other factors on road traffic injuries and fatalities [33,34], as did Musa and Moses’ (2014) analysis of the effect of land use on road traffic injuries and fatalities [35]. Cai et al. (2019) applied a deep learning approach for transportation safety planning with transportation and land use data [36]. Elias and Shiftan (2011) pointed out that changes in land use from bypass road constructions affect road safety levels [37]. Mukherjee and Mitra (2019) found that factors such as land use type affect pedestrian safety [38]. Mukoko and Pulugurtha (2020) examined the influence of land use and other factors on bicycle-vehicle crashes [39]. Effati and Saheli (2022) investigated the influence of rural land uses and accessibility-related factors to estimate pedestrian safety. Some studies pointed to the effect of specific types of land use on crashes [40]. For example, one study pinpointed that the causal effect of a work zone on crash occurrence is significantly positive [41]. By including Chung et al. (2023), the results revealed the different effects of points of interest or POI-based land use on traffic accidents [42]. The results also pointed to some significant land use types, which are residential, commercial, governmental, and institutional land uses which provide the significant role of land-use planning in fatalities and injuries resulting from road accidents. However, reducing fatalities and injuries resulting from road accidents should be analyzed based on an integrated approach. For instance, Goniewicz et al. (2015) showed that the number of fatal accidents and severe injuries from road accidents can be reduced by applying an integrated approach to road safety [43]. It requires co-operation among politicians, experts and professionals from research centers and universities dealing with road traffic safety, road traffic administration, rescue services, police and the media [44]. Marshall (2018) summarized the international road safety disparities by comparing Australia and the United States, arguing that Australia also enacted its version of vision zero on the basis of the safe system approach more than a decade before similar policies began cropping up in US cities [45]. While it is difficult to attribute recent road safety successes to any specific policy, Australia continues to expand its role in leading safety outcomes and has become a road safety example worthy of consideration. Crocco et al. (2010) pointed to an integrated approach for studying the safety of road networks by identifying the relationship between traffic accident occurrence among behavioral, environmental and infrastructure parameters [46]. The research results indicated that drivers could take advantage of a heightened level of safety by avoiding unnecessary risks. Safarpour, Khorasani-Zavareh, and Mohammadi (2020) studied the common road safety approach by scoping review of the paradigm shifts from traditional road safety policies to an integrated perspective which must be considered in road safety as a system [47]. Goniewicz and Lasota (2021) explained that an integrated approach to road safety should be carried out within all facets of a road safety system, including transport, health care, supervision, law, and spatial planning [48]. Several research studies in many developed countries confirmed that the number of fatalities and serious injuries resulting from road accidents could be reduced by applying an integrated approach to road safety.
studies. Several research studies in many developed countries confirmed that the number of fatalities and serious injuries resulting from road accidents could be reduced by applying an integrated approach to road safety studies. The earlier discussion found that no single factor could be highlighted in relation to road safety incidents. The cause of road accidents has involved many contributing factors, with land use planning as one of the causes of road accidents. Land use planning is also related to several other dimensions, i.e., physical activity. Thus, the transition of land use and road safety studies can help classify categories or issues of past research to fulfill the gap in the research, which is part of the provision of safe and sustainable planning for all road users.

2.2. Data Source and Research Process

This paper applies bibliometric analysis, which is a document analysis method or quantitative method [49,50]. This technique takes advantage of bibliometric theory by using secondary data, which can be acquired from databases [51,52]. Bibliometric analysis has become a tool for identifying research trends and classifying issues based on various sets of publications [53,54]. In addition, there are advantages to using quantitative statistics through mathematical and statistical approaches [55], complementing qualitative information. This technique helps researchers in evaluating academic studies in a specific field. The databases source could be extracted from different databases, e.g., Google Scholar, Research Gate, Web of Science (WoS), and Scopus [56]. The processes of data source and research can be depicted in Figure 1. First, it begins with defining keywords through a literature review of the broad topic of road safety and urban planning. Second, consider the main keywords obtain from the literature review and then source keywords from the critical topic in TITLE-ABS-KEY (T/A/K) on the Scopus database. The Scopus database is an appropriate online database resource for data collection. It contains a comprehensive range and an extremely large number of abstracts and citations database of peer-reviewed literature, consisting of papers from leading journals, guaranteeing the quality of the data source [57,58]. The sources of input data can be extracted in the form of “.csv” (Microsoft Excel) format [59].

The time span of the analysis was articles published between 2000 to 2021 that focus on “land use” and “road safety”. At this stage, the number of publications that are related to the keywords of “land use” and “road safety” is substantial: land use is equal to 155,727 publications, and road safety is equal to 106,394 publications.

Third, in the screening process, it considered a combination of all keywords, including “land use” AND “road safety” OR “road accident” OR “road crash” OR “traffic safety” OR “traffic accidents” OR “traffic crash” OR “casualty” OR “traffic injuries”, which counted for approximately 752 publications. Finally, the final screening process was performed for 752 data units based on five sub-criteria. These are open access (all), document type (all), source type (all), publication stage (final), and keyword screening by screening text in the publication. A total number of 437 publications were retrieved and analyzed. This data extraction and research process resulted in the final number of articles that were taken into the data analysis process.

2.3. Analytical Tool and Visual Examination

This paper utilizes a set of essential publications by focusing on scientific articles on road safety related to land use that analyzed, visualized, and displayed the relationships among the publications to identify their interrelationships. This study used VOSviewer (Visualization of Similarities Viewer) and CitesSpace (6. 1. R6, Chaomei Chen, Philadelphia, PA, USA). VOSviewer was applied as a tool for cluster analysis and visualizing bibliometric networks or maps [60,61]. CiteSpace is widely used for literature analysis and diverse visualization, which is suitable for evolutionary assessment based on the co-occurrence of keywords [62–64]. These networks include a variety of publications comprising of journals, researchers, or individual publications [65] and constructed based on citation, co-authorship, co-occurrence, bibliographic coupling, and co-citation analysis [60,66–68]. Consequently, it was displayed for bibliometric graphic maps [69,70], in which both VOSviewer and CitesSpace visualization enabled the node of the dense network to display interactions.
This tool can analyze large volumes of literature by applying two types of analysis which are co-occurrence and co-authorship [71]. Co-occurrence analysis contributes by constructing a term map, where the frequency of occurrence can be used to identify a keyword term’s potential [72]. At the same time, co-authorship analysis contributes to building an interaction or relationship among scholars in the same research field [73,74]. Visualization contributes to establishing network visualization, overlay visualization, and density visualization. Based on this application, the research can demonstrate the overview of road safety issues’ research status and identify the gaps, particularly related to the land use system.

Figure 1. Research framework (Source: Authors).

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3. Results

Road traffic crashes have been treated as a problem from the early days and are considered the eighth leading cause of death globally [75]. More than half of all road traffic deaths and injuries involve vulnerable road users such as pedestrians, cyclists, motorcyclists, and their passengers, a problem that must be effectively solved almost immediately [76]. UN General Assembly adopted a resolution of “Improving global road safety”, proclaiming the Decade of Action for Road Safety 2021–2030, with the target of preventing at least 50 percent of road traffic deaths and injuries by 2030 [77]. Road safety and land use are related, and the extent of their relationship is determined through thoughtful planning processes to prevent unsafe road conditions [30]. Land use planning addresses activities permitted in different areas (e.g., residential, commercial, industry, recreation, etc.). Some areas permitted more than one activity, referred to as mixed-use, where each type of activity is effective in the growth of automobiles, particularly the volume of traffic. In addition, urban development is exposing countries with lower safety system standards to more safety risks. Though the research about the relationship between land use and road safety has shown to be significant, not so much safety research has focused on this linkage. With an in-depth understanding of this linkage, guidelines for improving safe traveling within the city can be provided. This paper focuses on identifying the research status and research gaps of past research until exploring the relationship between road safety and land use by using visualization technology in bibliometrics with the support of the VOSviewer software and CitesSpace. When road safety issues were considered, the analysis demonstrated that most keywords adopted in several studies are related to human factors, followed by the issue of road and streets, traffic accidents, motor transportation, gender, adult, vehicles, accident prevention, car/automobile driving, risk assessment, pedestrian safety, risk factor, behavioral research, traffic control, public health, intelligent systems, etc. These findings reveal that the trending ideas of safety publications are around the main issues related to three major causes of crashes: (1) humans and roads (streets), (2) environment, and (3) vehicle factors were the main clusters contributing to road crashes. However, when the land use keyword was further employed, as depicted in Figure 2 on road safety publications, it showed that an association exists between road safety and land use.

Figure 2. Network visualization on keywords with road safety research.
3.1. Annual Publication Trend and Country of Study (Co-Authorship)

The authors also analyzed the annual publication trend, the issues of publication of bibliometric papers and the country of study. The number of literature publications for the scope of the research based on Scopus data was initially examined through performance analysis and retrieval topics related to the specific keyword of “land use” and “road safety” between 2000 and 2021. Year-wise publication of bibliometric papers is a vital indicator of the development trend in this particular research area and a reflection of a change in the extent of the subject knowledge related to both keywords of “land use” and “road safety” (see Figure 3). It was found that publications on land use and road safety present an exciting trend, increasing over a number of years. When the initial stage of 2000–2010 was considered, 94 publications with an average annual growth of 8.55 were discovered. Between 2011 and 2021, 343 publications with an average annual growth of 31.18 were found. This publishing trend was doubled with the adoption of more understanding of the contributions of built environmental factors on road safety. Between 2000 and 2021, it was found that the number of publications showed a continually increasing trend, with increasing considerations for environmental factors, in relation to urban land use. However, an increase and decrease in specific years were also discovered since 2000, as illustrated in Figure 3. It was revealed that the co-authorship map among 68 countries (areas) could also be visualized by using network visualization. A data mapping for each node representing the countries of the current study was displayed. The greater node size shows the number of publications, while the links between the nodes represent the collaborations. The greater width of the link shows closer collaborations. This analytical approach could help to present indices to demonstrate the potential collaboration among several countries in this research.

According to the retrieved results, further analysis of road safety and land use studies was conducted in 68 countries. Table 1 illustrates the lists of the top 10 countries where the research was conducted based on the total number of documents. This data demonstrated that most publications originated from developed countries based in America, Europe, and Asia. The United States of America is the most active country in integrating road safety and land use research topics, with a dominant output of 163 publications (accounting for 26.46%). This is followed by China, with 63 publications (accounting for 10.23%), 47 publications in Canada (accounting for 7.63%), 38 publications in Australia (accounting for 6.17%), and 34 publications in the United Kingdom (accounting for 5.52%). When countries in the Asian region were considered, China was the most active country with an output of 63 articles, followed by India, Hong Kong, and Japan, respectively. As expected,
the United States, China, Canada, Australia, United Kingdom took the issues concerning road safety and land use as a higher priority, as depicted in Figure 4.

Table 1. The top ten most active countries of the research on integrating road safety and land use.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>Documents (Quantity)</th>
<th>Percentage</th>
<th>Total Link Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>United States</td>
<td>163</td>
<td>26.46</td>
<td>126</td>
</tr>
<tr>
<td>2</td>
<td>China</td>
<td>63</td>
<td>10.23</td>
<td>43</td>
</tr>
<tr>
<td>3</td>
<td>Canada</td>
<td>47</td>
<td>7.63</td>
<td>37</td>
</tr>
<tr>
<td>4</td>
<td>Australia</td>
<td>38</td>
<td>6.17</td>
<td>78</td>
</tr>
<tr>
<td>5</td>
<td>United Kingdom</td>
<td>34</td>
<td>5.52</td>
<td>27</td>
</tr>
<tr>
<td>6</td>
<td>India</td>
<td>18</td>
<td>2.92</td>
<td>23</td>
</tr>
<tr>
<td>7</td>
<td>Hong Kong</td>
<td>17</td>
<td>2.76</td>
<td>61</td>
</tr>
<tr>
<td>8</td>
<td>Germany</td>
<td>12</td>
<td>1.95</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>Japan</td>
<td>11</td>
<td>1.79</td>
<td>55</td>
</tr>
<tr>
<td>10</td>
<td>Netherlands</td>
<td>11</td>
<td>1.79</td>
<td>19</td>
</tr>
</tbody>
</table>

Note(s): maximum 25 countries per document.

Figure 4. The co-authorship map of the country/region by using network visualization.

3.2. Term Co-Occurrence Map Based on Text Data (Abstract Field)

Road safety and land use studies are highly multidisciplinary research topics. Thus, the research field originates from different domains (e.g., transportation planning, urban planning, road safety, land use planning, law, built environment, infrastructure planning, medicine, health, traffic engineering, etc.). Analyzing the term co-occurrence map based on text data can provide most of the research status. Figure 5a,b demonstrate visualizations where each node displayed represents the abstract keyword through the time phase, while links between nodes represent the connection. The data revealed that “traffic safety” is the most frequent term, followed by “neighborhood environment”, “land use characteristics”, “walkability”, “urban environment”, “transportation safety planning”, and “fatal pedestrian crashes”. Furthermore, the data indicated that the keywords in the abstract are more related to road aspects (e.g., crash, casualty, traffic safety, accident, crashes, road safety, etc.) than land use aspects (such as environment, neighborhood, land use). In addition, the
critical term also relates to “method” or “technique of analysis” in terms of assessment, review, traffic analysis zone, geographic information system, etc. These results further reinforce the highly multidisciplinary characteristics of the scope of this research area.

Figure 5. Term co-occurrence map based on text data (abstract field) of integrating research between road safety and land use. (a) Network visualization of keywords within integrating road safety and land use research. (b) Time phase of abstract keywords.

We consider the first top 10 most frequently cited reviews in our research, as listed by the number of citations illustrated in Table 2. Most citations found were “Residents’ perceptions of walkability” attributes in objectively different neighborhoods, which was followed by “a pilot study” (number of citations is 307), followed by “a land use, transport, and population health: estimating the health benefits of compact cities” (number of citations is 295), and “an area-level model of vehicle-pedestrian injury collisions with implications for land use and transportation planning” (number of citations is 259), respectively. Overall, most of the keywords adopted in several publications on the “land use and road safety” relationship to spatial analysis or area-level model were analyzed in terms of the implications for land use, built environment, and transportation planning.
Table 2. The first 10 most frequently cited reviews in our sample are listed by the number of citations.

<table>
<thead>
<tr>
<th>Citations</th>
<th>Title</th>
<th>Authors</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>221</td>
<td>The urban built environment and mobility in older adults: A comprehensive review</td>
<td>Rosso A.L., Auchincloss A.H., Michael Y.L.</td>
<td>2011</td>
</tr>
<tr>
<td>199</td>
<td>The link between the built environment, pedestrian activity and pedestrian-vehicle collision occurrence at signalized intersections</td>
<td>Miranda- Moreno L.F., Morency P., El-Geneidy A.M.</td>
<td>2011</td>
</tr>
<tr>
<td>198</td>
<td>A spatially disaggregate analysis of road casualties in England</td>
<td>Noland R.B., Quddus M.A.</td>
<td>2004</td>
</tr>
<tr>
<td>177</td>
<td>GIS measured environmental correlates of active school transport: A systematic review of 14 studies</td>
<td>Wong B.Y.-M., Faulkner G., Buiuung R.</td>
<td>2011</td>
</tr>
<tr>
<td>177</td>
<td>Walkability and safety around elementary schools: Economic and ethnic disparities</td>
<td>Zhu X., Lee C.</td>
<td>2008</td>
</tr>
</tbody>
</table>


3.3. Publication Performance Analysis with the Keyword Co-Occurrence

The keyword co-occurrence analysis output obtained from the analysis can be categorized into two types of keywords: index keyword and author keyword. An analysis of the keywords co-occurrence map based on the author keyword indicated in the publications showed 1156 keywords in the selected publications. Only those that appeared at least five times were considered for analysis (Figure 6).

The top 10 high-frequency keywords are “built environment” (14.55% occurrences), “land use” (10.22% occurrences), “road safety” (8.98% occurrences), “traffic safety” (7.43% occurrences), “physical activity” (5.57% occurrences), “GIS”, “safety”, walkability (4.64% occurrences), “pedestrian safety” (3.72% occurrences), “spatial analysis” and “traffic accidents” (3.41% occurrences), respectively. The correlation analysis between the keywords revealed five clusters, as shown in Figure 7. Cluster 1 represents “physical analysis”, which relates to the built environment, GIS, physical activity, walkability, etc. Cluster 2 represents “vulnerability related to pedestrian safety”, which is especially important for road safety planning. Cluster 3 represents “land use and road safety”, which relates to land use planning, urban planning, etc. Cluster 4 represents “children”. Finally, cluster 5 represents “accident”, which relates to accidents, crashes, and safety. The analysis indicated that road safety and land use were performed by applying several road users, travel modes, approaches and techniques.

Analysis of the keywords co-occurrence map based on the index of keywords indicated in the publications showed 2798 keywords selected from these publications. Only those that appeared at least five times were considered for analysis, as shown in Figure 8. The following details covering a total of 290 network nodes were obtained from the data analysis. The top 10 high-frequency keywords are land use (4.49% occurrences),...
human (3.00% occurrences), traffic accident (2.52% occurrences), motor transportation (1.70% occurrences), roads and streets (1.45% occurrences), environment design and planning (1.43% occurrences), respectively.

The analysis of the correlation between the keywords revealed four clusters, as shown in Figure 9. The details of each cluster are explained as follows:

- Cluster 1 is about “non-human related accidents” and relates to transportation planning such as animal, environmental, wildlife, etc.

![Figure 6. Keyword co-occurrence map based on author keyword and network visualization.](image)

![Figure 7. Keyword co-occurrence map based on author keyword and visualization by network visualization.](image)

**Figure 6.** Keyword co-occurrence map based on author keyword and network visualization.

**Figure 7.** Keyword co-occurrence map based on author keyword and visualization by network visualization.
- Cluster 2 relates to “road and environment dimensions” and is described in terms of road and environment factors such as motor transportation, street traffic control, accessibility, safety engineering, spatial analysis, etc.

- Cluster 3 is about “human and vehicle factors (vulnerable group)” and relates to human factors such as people vulnerable (female, children, elderly), vehicle vulnerable (pedestrians, bicycles, motorcycles), etc.

- Cluster 4 is about “land use and transportation planning and approach” and relates to human factors such as land use, urban and rural area, built environment, cluster analysis, decision tree, forecasting, and intelligent system etc.

Figure 8. Keyword co-occurrence map based on index keyword and network visualization.

Figure 9. Keyword co-occurrence map based on index keyword and density visualization (cluster density).
4. Discussion

The systematic literature review on the integration between land use and road safety research shows that road traffic injuries were a leading cause of death and resulted in serious disabilities for many individuals in cities. However, while transport-related injuries are regarded as a major burden of disease, injury prevention measures (when effectively put in place) can minimize people’s exposure to transport-related harm. Effective injury prevention measures were reviewed to gather important lessons learned as well as increase knowledge and background information. Table 3 presents the top ten of the most active keywords on land use- and road safety-related publications. Based on the list of publications indicated in Table 3, it is clear that there is a need to consider integrating these research fields when considering guidelines for prevention, improvement, and monitoring for mortality and injury alleviation from an accident on the road, among others.

Table 3. The top ten most active keywords of publications.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Index Keyword</th>
<th>Occurrences</th>
<th>Total Link Strength</th>
<th>Author Keyword</th>
<th>Occurrences</th>
<th>Total Link Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Land use</td>
<td>251</td>
<td>3940</td>
<td>Built environment</td>
<td>47</td>
<td>47</td>
</tr>
<tr>
<td>2</td>
<td>Human</td>
<td>168</td>
<td>3755</td>
<td>Land use</td>
<td>33</td>
<td>28</td>
</tr>
<tr>
<td>3</td>
<td>Traffic accident</td>
<td>141</td>
<td>3019</td>
<td>Road safety</td>
<td>29</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>Accidents, traffic</td>
<td>113</td>
<td>2500</td>
<td>Traffic safety</td>
<td>24</td>
<td>18</td>
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<tr>
<td>5</td>
<td>Motor transportation</td>
<td>95</td>
<td>1262</td>
<td>Physical activity</td>
<td>18</td>
<td>22</td>
</tr>
<tr>
<td>6</td>
<td>Roads and streets</td>
<td>81</td>
<td>1127</td>
<td>GIS</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>7</td>
<td>Environment design</td>
<td>80</td>
<td>1953</td>
<td>Safety</td>
<td>15</td>
<td>22</td>
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<tr>
<td>8</td>
<td>Environmental planning</td>
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<td>1888</td>
<td>Walkability</td>
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<td>9</td>
<td>Safety</td>
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<td>Walking</td>
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In this review, we acknowledge that as a limitation, road safety challenges and the scope for solutions may differ owing to contextual differences in terms of the social, political, environmental, and legal/regulatory aspects. However, there are a few points of similarity, specifically regarding the focus on road safety. Moreover, it is strongly encouraged that the prevention of road accidents, which often do not receive equal attention at the global level compared to other causes of fatality, should be a focus for urban governments not only in the Global North (e.g., Australia) but also in the Global South (e.g., Thailand). This becomes urgent as approximately 40–50 percent of road fatalities occur in cities. This large death toll due to traffic-related fatalities and injuries has placed road safety at the core of urban development agenda-making. In this regard, urban analysis methods pose a key area for consideration when thinking about road safety solutions and strategies [2]. There is a strong link and intersections between road safety and land use/urban planning, providing an important next step in terms of conducting research. Therefore, the need for a data-driven planning process to produce robust evidence is necessary. This is because the effect of urban development could be traced down to the very root of the traffic and transport system and, consequently, road safety. Based on the clustering of keyword co-occurrence analysis, several research fields regarding road safety and land use research are directly associated with three major risk factors (i.e., human and non-human, vehicle, road, and environment). Hence, it is recommended that road safety should be combined with urban factors such as land use planning, built environment, urban growth, urban transport, urbanization, land use change, neighborhood, etc. Most keywords relating to road safety reflect the safe systems approach (World Road Association [78,79]). In the early 1990s, the Netherlands and Sweden pioneered a safe systems approach to the road system that considers human fallibility and vulnerability. This system accepts that people make mistakes and are defenseless, and therefore, there is a need to create a road system
where crash forces no longer result in death or severe injury. Furthermore, the necessity to strengthen all parts of the system comprising roads and roadsides, speeds, vehicles and road users was established.

In terms of addressing road issues, better street design can encourage more positive road user behavior while also realizing that street use should also include non-movement activities [80]. Cities and transport practitioners have now realized that vehicle-friendly cities are not socially, economically, environmentally, and culturally viable and cause not only the degradation of civic life but also unsafe environments. Planners and designers have acknowledged the importance of streets as ‘places’ to enhance the ‘liveability’ of the city. Hence, many cities are transforming their roads through street redesigning and the provisioning of protected infrastructure, promoting compact city structures. Aside from addressing safety issues, walkable streets would also help reduce private motor vehicle dependency, may subsequently address the increasing levels of non-communicable diseases, and result in positive health outcomes [81,82].

Pedestrians, cyclists, and motorcyclists, who comprise the majority of traffic deaths in cities globally, require these street transformations to eliminate high-risk urban roads. Regarding human factors, drivers with risky behaviors in traveling would often experience accidents due to their risky behavioral patterns [83]. Different sub-factors also affect risky behaviors that must be considered [84,85]. There is a likelihood of accidents occurring if risky behaviors continue since behavior is related to different socioeconomic characteristics, showing negative or positive attitudes in those involved in consuming alcohol and speeding [17,86,87]. It can be seen that risky behaviors are related to individual behaviors or human factors. Human factors are often expressed as human errors and play a significant role in traffic crash involvements [88,89]. However, plans and strategies in addressing this problem should be holistic and comprehensive, aspiring for the elimination of all risks that may also occur in several dimensions.

Vehicle factors were also found to be an important cause of road accidents. Vulnerable road users (VRU) refer to pedestrians, motorcycle riders, cyclists, children seven years and under, the elderly and users of mobility devices [90]. Several publications analyzed vulnerable road users. The concept of vulnerable road users is widely used in transport and road safety discourse. Vulnerable road users are easily injured or killed in a car-dominated road space [91–94]. Issues and deficiencies in the city’s road design, vehicle design and transport policies can be key factors in the increased risk for vulnerable road users [95,96]. However, several studies about urban and street design, including suitable land use characteristics for road users to avoid using a car and promotion of public transportation or active transportation, require further consideration [18].

Technology also offered a crucial keyword for road safety and land use. Several publications attempted to identify the benefits of information and computing technologies (ICT), smart cities, and smart mobility inclusion in intelligent transportation systems [97,98]. Technology can support the improvement of transport outcomes such as road safety, transport productivity, travel reliability, and informed travel choices, among others. There are a great variety of intelligent transportation system technologies based on the idea of the “Haddon Matrix”, with significant improvement in its assistance system used for the improvement of safe driving [27,99]. Type of analysis relating to various research approaches, which can be cluster analysis, spatial analysis, traffic engineering, information management and traffic safety. Consequently, data for road safety and land use analysis can also apply to various approaches. For information management issues, many authorities worldwide acknowledge the importance of a reliable framework for regular collection and reporting of road traffic crash data. Data and information such as putting together a database that includes casualty figures, data on mobility, crashes, behaviors, attitudes, and enforcement facilitates the interpretation of road safety trends and is important to support data-driven analysis [100]. The results of the analysis help shed light on the current state of research around the world for the past several decades, reflecting the extent of urban road safety integration through the study of the relationship between urban planning
and transport systems, with special consideration of the built environment (e.g., land use, road networks, traffic, and levels of urban planning). However, the findings indicate that the empirical research context has mainly been set in developed countries whether it is the United States, China, Canada, Australia, or the United Kingdom. These countries consider concerns about road safety and land use as a higher priority. Moreover, when considering the road safety statistics, it was found that among these countries, the fatality rate was relatively low. Therefore, considering the gap between road safety research and urban planning, the focus should be on applying the research findings in a concrete way, particularly their integration in low- and middle-income countries where a disproportionate amount of traffic-related injuries and fatalities continue to persist. The findings also demonstrate that many urban road safety studies in high-income countries are conducted in breadth and depth, focusing on the study of factors from diverse perspectives of sciences and technological approaches as well as both tangible and non-tangible techniques. These also include issues on the physical dimension as well as motor vehicle-related, behavioral as well as systems, policies and planning, conducted with the use of a variety of analytical processes and techniques, especially in current times where technology-related techniques are being employed, e.g., machine learning and deep learning.

While these findings do not have a direct impact on the practice of building safer cities, they identify potential research pathways, pointing towards the need for further investigation on studies that integrate the built environment and road safety. This study has also demonstrated that the use of bibliometric analysis presents a robust analytical technique for evaluating academic studies in a specific field to identify research trends and classify issues based on various sets of research [53,54]. Interestingly, studies of the city’s relationship to transport over the past several decades have pointed to the relationship of the city to urban traffic, which has been discussed as a potential negative impact of accidents, particularly when set within inner city activities [101]. However, the findings also pointed to the dynamics of developmental change in the study, which suggests that studies of the city’s relationship to road safety in relation to the influence of other factors tend to increase with the integration of other factors, influencing potential solutions to road safety problems. More research is needed to examine the influence of urban factors on the promotion of risky behaviors, leading to traffic-related injuries, together with the deployment of modern technology systems to be integrated with urban design to promote road safety for road users within the city. Furthermore, and more importantly, there are research trends that focus on urban design to support the safety of vulnerable road users. With the highlight on the complexity and diversity of contributing factors involved in road safety, the recommendation of integration of interdisciplinary research into planning and urban design, social sciences, innovation, and technology must be addressed. By considering different points of view of countries that publish articles, it can be seen that several developing countries, including Thailand, still have relatively few published articles compared to their more developed country counterparts. This is especially true when dealing with issues related to the integration of technology and large databases. Furthermore, an integrated approach to land use planning and road safety is emerging as an important strategy and advocacy in shaping sustainable development strategies in developing countries.

Moreover, this study also helped highlight the gaps and uncover underrepresented issues, supporting a better comprehension of urban road safety trends associated with built environmental factors. However, this study was limited in terms of the number of articles included in the analysis, with a larger number of articles focused on the Global North. A larger sample will allow a better understanding of the situation and associations. Notably, several recent studies have shown the benefit of understanding through alternative review techniques, even though the number of articles is not high, or less than a thousand [62,74,102].
5. Conclusions

There is a strong association between the location of different types of land uses and transportation, showing their relative connection to essential variables such as the numbers and lengths of trips in any area that guarantees road safety. In this research, the status and trend through bibliometrics analysis were performed by using VOSviewer and Citespace software. The data used for the analysis was collected from the Scopus database from 2000 to 2021, with 437 publications retrieved. ‘Road safety’ and ‘land use’ were the primary keywords used to search for relevant publications. The results were visualized, and bibliographic analysis showed the existing occurrences between critical terms, keywords, and research areas. Furthermore, the results of the analysis show that land use and road safety are highly interdisciplinary, e.g., transportation planning, urban planning, road safety, land use planning, law, built environment, infrastructure planning, medicine, health, and traffic engineering are aligned, having a multidimensional approach in academic research as shown in Figure 10.

![Figure 10. Overview of road safety issues related to transportation and land use planning](Source: Authors)

Road safety has been paid attention to understand the association between urban planning and land use and that the built environment and activity in a particular area are significantly related to the road safety issue of the said context. These findings point to several decisions that defined travel needs, modes, and traffic conditions because of their impact on users’ safety and the functionality of the road network. Nonetheless, decisions made regarding road network planning have a significant impact on land use planning [103]. Notably, the Scopus online database has not included all publications in this study. Furthermore, there is a propensity for dangers in vulnerable groups like pedestrians, bicyclists, and residents alongside or adjacent to the road [77]. Hence, land use and road safety should be prioritized in urban planning. Planners should also deploy new tools capable of demonstrating overall safety benefits rather than just tools to measure the reduction in numbers or rates of crashes. Thus, further studies in this new field are required to significantly reduce mortality and injury from road accidents.
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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved from the Human Research Ethics Committee of Thammasat University Social Sciences (certificate of approval number 064/2022, 18 July 2022).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

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