Original Research

Trends and Evolution of Road User behaviour Research: A Bibliometric Review

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Abstract

Every single person is entitled to equal space on the roads or sidewalks, so they rely on each other's empathy and compassion and not be self-centered. Therefore, it is essential to promote the ethics of road safety and road users' exemplary behavior upmost. This review analyzed the publication trends and thematic evolution of road user behaviour over 47 years from 1973 to 2020. The assessment uses the Scopus database and various bibliometric indicators, such as output growth trends, eminent countries, research hotspots, and author keywords. Also, this study presented a graphical visualization of bibliometric indicators using a VOSviewer. Another bibliometric software tool, known as SciMAT, was used to inspect road user behaviour research's thematic evolution. The verdicts revealed that the number of publications increased exponentially, starting in 2005 with a hike in publications in 2020. Road user behaviour researches were diverse by examining the various research hotspots. This review also focuses on several themes and dimensions of road user behaviour research. The essential motor theme during the first period (2005-2012) was "schools". Other motor themes, such as "cross-sectional studies," "car", and "space-temporal-analysis", became the most significant number of publications in the second period (2013-2020). These four themes may be beneficial as a benchmark for researchers focusing on the art of road user behaviour. This bibliometric study provides a comprehensive and in-depth view of road users' behaviour that may help future researchers advance potential knowledge in this field.

Introduction

Behavioural research receives increased attention from psychologists to learn about human factors and unified this subject with other research themes (Reis, Collins & Berscheid, 2000), such as road safety (Babić et al., 2020). Individuals' action reflects behaviour; thus, it is vital to interpret their thoughts to some degree that needs to be realised (Abdullah & Abd Aziz, 2020; Dolan, Hallsworth, Halpern, King, Metcalfe & Vlaev, 2012). In a social context, primarily related to road safety, the behaviour is the mainstay of encouraging road users who are ethical and respectful, whether they use motor vehicles or pedestrians. The reason is individuals have the same space to move from one destination to another. This scenario illustrates essential interaction between people on the road, who should rely on each other's empathy and compassion and not be self-centred. Human interactions are a wide-ranging scholarly effort covering a broad spectrum of academic fields to comprehend road users' behaviours (Crawford, Watling & Connors, 2018; Markkula et al., 2020).

Road crashes result from a complex interplay between human, technical, and environmental factors that became a fundamental reason for advocating road safety (Petridou & Moustaki, 2000; Pino, Baldari, Pelosi & Giucastro, 2014). Nevertheless, human driving behaviour was the main factor leading to crashes with a statistic of 90%, whereas the remaining 10% is due to technical and environmental factors (Haghi, Ketabi, Ghanbari & Rajabi, 2014; Intini, Colonna & Ryeng, 2019). Although driving is a daily activity, various unsafe driving activities such as driving under the influence of alcohol and drug, speeding, not wearing a seat belt, or texting while driving has resulted in road crashes. Ghadban, Abdella, Alhajyaseen and Al-Khalifa (2017) agreed that a person's nature and abilities are often different, and these relationships have influenced their behaviour while driving. Hence, currently, global communities and organizations have invested in improving road safety by scrutinizing unsafe driving behaviour among road users (Ghadban, Abdella, Al-Khalifa, Hamouda & Abdur-Rouf, 2018).

Above and beyond, driving is a complex task, which requires both motor and cognitive processes to be performed simultaneously (Artifice, Rajaonah, Sarraipa, Mourad & Jardim-Goncalves, 2018). Drivers must interact with pedestrians and other drivers and deal with environmental challenges, for instance, various weather conditions, varying road surfaces, and limited lighting. For these reasons, it should not be surprising that something can go wrong and that it is indeed relatively costly. Each year, around 1.25 million people were killed in collisions, and another 20-50 million are injured, which negatively impacts the victims, families, employers, and the country (Hulse, Xie & Galea, 2018). Numerous studies are available that assess driving behaviour on the road. Howbeit, much of the research remains undocumented or relies on indirect measures (Kaye, Lewis & Freeman, 2018). Even though self-report measures have some limitations, they provide a good driving behaviour measure (Taubman-Ben-Ari, Eherenfreund-Hager & Prato, 2016).

The number of deaths due to road crashes increased over the years, even as road safety measures continue to grow (ITF, 2017). This has led to personal and public financial strain because of road crashes. Many families fall into poverty because long-term medical expenses put pecuniary pressure on the family or because the family has to take care of a disabled relative (Mohan, Khayesi, Tiwari & Nafukho, 2006). In road safety research, it plays a vital role in reducing road crashes' frequency and severity. Researchers in road safety have been exploring using driving behaviour data to understand the factors that cause crashes (Singh & Kathuria, 2021). The simple scenarios that have contributed to road crashes can also be depicted in a

vehicle movement conflict. Vehicle movement conflict occurred when drivers attempting to turn left or right force their vehicles into an intersection (Ramlan, Irawan & Munawar, 2020). The highest risk is associated with a left-turn or right-turn conflict type, turning right (in right-handed drive countries) while facing red light (Prasetijo et al., 2020).

According to Rolison, Regev, Moutari and Feeney (2018), numerous factors such as inexperience, lack of skill, risky driving behaviours, visual impairment and cognitive difficulty are all associated with road crashes. A detailed analysis of most road crashes' causes reveals that driver behaviour is the primary factor in most accidents (Antin, 2011; Grace, Hashmi, Nawi, Fung & Abdibin, 2020; Rowe, Roman, McKenna, Barker & Poulter, 2015). Singh (2015) reported that driving offences and traffic violations are the leading causes in 74% of fatal and injury road crashes. Studies show that drivers' risky driving behaviour increases the accident risk (Fruhen & Flin, 2015; Moan, 2013). Therefore, understanding the driver's driving behaviour is vital in reducing accidents. A study conducted by Bärgman (2016) found that driving behaviour is conceptualized differently. Mahudin and Sakiman (2020) emphasize the importance of hours worked to unsafe driving behaviour and safety climate perception in ride-hailing services. They also added that, in particular, it appears to be true that long hours spent at work relate to more unsafe driving behaviour, irrespective of the types of drivers. In a nutshell, the above discussion exhibited that road user behaviour is fundamental in promoting a road safety culture and improving road safety behaviour.

A wide-ranging bibliometric analysis was performed in various subdomains of road crashes and related issues. The subdomains were; motorcycle accidents (Ospina-Mateus, Jiménez, LLopez-Valdes & Salas-Navarro, 2019), road traffic injuries (Butt, Ashiq, Rehman, Minhas & Khan, 2020; Jing, Shan & Zhang, 2021; Sharma, Bairwa, Gowthamghosh, Gupta & Mangal, 2018), simulated driving (Guo, Lv, Liu, Wang & Duffy, 2019), traffic medicine (Sweileh, Jabi & Zyoud, 2019), and reviewing the transport domain (Najmi, Rashidi, Abbasi & Waller, 2017). Since road crashes have increasingly become a global concern related to road user behaviour; thus, refining the evolution of road user behaviour research trends is imperative. This article summarises and explains road user behaviour based on research trends and thematic development over four decades from 1973 to 2020.

Materials and Methods

A bibliometric review became a popular research endeavour because of the multitude of studies being published in virtually all knowledge areas. A macroscopic overview of vast numbers of scientific literature through bibliometric analyses is crucial to scholars' decisions (De Oliveira, da Silva, Juliani & Barbosa, 2019). Campbell (1896) was the first researcher who conducted a bibliometric review using statistical analysis of subject-based publications. Another early study was conducted by Cole and Eales (1917), who considered publication trends on comparative anatomy from 1550 to 1860.

Pritchard (1969) argued that bibliometric review was a convenient statistical and mathematical technique for analyzing books and other communication media. With the advent of technology and publishing software tools, bibliometric studies become valuable and exciting for obtaining information on publication trends, evaluating the quantity and quality of publications, and exploring information related to the authors, specific keywords, and citations (Abdullah & Abd Aziz, 2020). Also, bibliometric analysis is extensively used to evaluate articles, publishing countries, institution performance, and other factors that influence

researchers' interests.

Bibliometrics is a handy research tool and impressive for researchers to provide a comprehensive review of relevant knowledge. It is because scientific literature relies on three primary forms (Cheng, Li, Petrick & O'Leary, 2011). According to Cheng et al. (2011), the first aspect is academic works generate, disseminate, and share vital information. Second, scholarly work had helped funding organizations to disperse study funds. And third, inform appointment and promotion decisions and define authors, agencies, and organizations' relative positions.

The number of publications on a specific theme and the range of research topics provide bibliometrics to indicate the field's current direction and scope (Wang, Pan, Ke,., Wang & Wei, 2014). Reviewing processes do not include new models or methodologies, but the bibliometric analysis still helps support the development of research (Amin, Khan & Amyotte, 2019). For these reasons, bibliometric analysis is considered an acceptable method for assessing and applying research skills to gain insight into safer road user behaviour. The bibliometric review in this study is based on three critical steps defined by Sharifi, Simangan and Kaneko (2020) below:
  i. Ascertain the database.
  ii. Refine publication trends.
  iii. Explore thematic evolution.

Ascertain the database

Road user behaviour is used as an entrance criterion to pick out studies that might be relevant in this review. To this end, the Scopus database is carefully chosen to explore a reliable, appropriate, and recent publications list. There are two reasons for selecting the Scopus database. The first reason is that the reliability and quality of research conducted by individual researchers are reviewed to ensure high-quality standards (Montoya, Alcayde, Baños & Manzano-Agugliaro, 2018). The second reason is that the Scopus database included more articles than the Pubmed and Web of Science (Sweileh, 2020). The index of publications on road user behaviour was retrieved from the Scopus database on January 7, 2021. The term "road user behaviour" was searched within TITLE-ABS-KEY along with the quotation mark. The retrieved data were then exported to Microsoft Excel, Publish or Perish, VOSviewer, and Science Mapping Analysis Tool (SCiMAT) for further examination. The total number of publications returned from the given query was 270. Out of the 270 publications, 183 were articles from various journal sources, 57 were conference papers, 20 were book series, and less than ten other publications, including books and reports. Out of 270 publications, there were 265 publications printed in English, two in Swedish, and one publication in French, German, and Spanish.

Refine publication trends

Numerous software tools for aggregating scientific articles and related information have recently been established, such as VOSviewer, SciMAT, and Publish or Perish (PoP). This study mapped visual elements using VOSviewer software, which converts the retrieved data to clusters in the Comma Separated Values (CSV) format (Van Eck & Waltman, 2019). Co-occurrence analysis is used to identify the author's keyword. And, the co-citation analysis was used to group publication outlets based on citations. The nodes and links shown in the mapping

diagrams were the two main outputs of the refined publication trends on road user behaviour. The node represents the publication frequency, while the connection's width refers to the relationship's strength (Van Eck & Waltman, 2019). Besides, reference lists from scholarly publications were also reviewed using PoP software to figure out the top ten cited articles.

Explore thematic evolution

Thematic analysis in this study is scrutinized using SciMAT software to discover the thematic and conceptual development of road user behaviour research. The focus of this study was to examine the evolution of road user behaviour from 2005 to 2020. The timeframe was selected since there is exponential growth during the periods. The study was divided into two-time spans; the first period (2005-2012) and the second period (2013 -2020). The evolution description derives from four different themes based on research conducted by Cobo, López-Herrera, Herrera-Viedma and Herrera (2011), as shown in Table 1.

Table 1
The Simplified of Four Themes in the Strategic Diagram (Cobo et al., 2011)

Themes	Position	Explanation
Motor themes	Upper-right quadrant	• Well established and essential for the organization of a field of research • Centrality and density are very high • These themes are related to each other in a similarly broad scope
Highly developed and isolated themes	Upper-left quadrant	• Well-developed internal ties but inconsequential external ties • Only marginal importance for the field • These themes emphasize the necessary specialist and peripheral role.
Emerging or declining themes	Lower-left quadrant	• Weakly developed and marginal • Being low density and low centrality • These themes represent either emerging or disappearing
Basic and transversal themes	Lower-right	• Essential for a research field but is not developed • These themes depict transversal, general and basic

Thematic networks in Figure 1 offer the evolution of research themes, whereas, in Figure 2, thematic development represented the connection of different themes through the periods observed. Figure 1 shows that the strategic diagram uses a horizontal axis to measure centrality and a vertical axis to display network density. According to Cobo et al. (2011), centrality refers to the metric that measures the relationship between networks, which means that higher centrality correlates with other network themes and plays a critical role in developing study fields. In contrast, the measurement of intra-network relationships with an evident and robust internal relationship to a subject is called a density (Moral-Munoz et al., 2018).
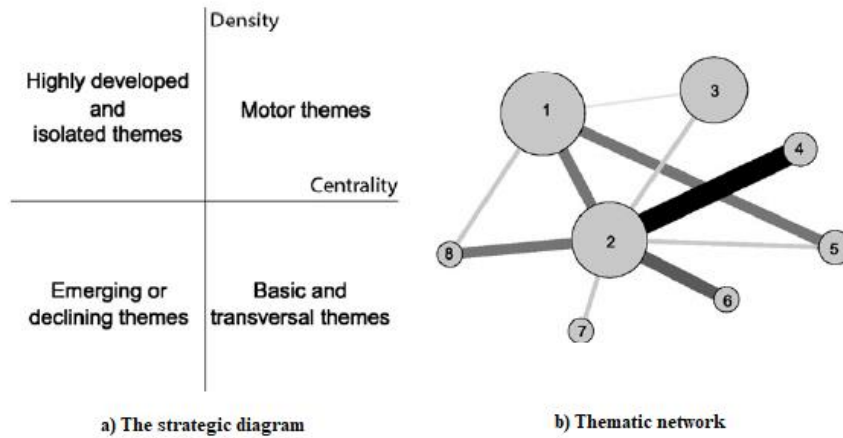
a) The strategic diagram   b) Thematic network

Figure 1: The strategic diagram and thematic network (Cobo et al. , 2011)

A thematic network complemented the strategic diagram by showing the relationships between themes. The nodes are sized by frequency or the number of documents, and the thickness of the link is proportional to the equivalence index of documents (Cobo et al., 2011). As shown in Figure 2, the evolution map indicated the thematic field evolution is linked over the study period. The nodes' size is reflected in the number of documents within a given theme, and links between nodes are proportional to the similarity in a topic. The themes that shared identical labels are allied by a solid line and themes that share similar keywords but have separate tags attached by a dotted line (Cobo et al., 2011; Moral-Munoz et al., 2018). Thru overlapping maps, the data's stability over time can easily be determined by the researchers (Cobo et al., 2011). Cobo et al. (2011) specified that the horizontal line provides a measure of equivalency. It is mean that the forward-pointing arrow shows the number of words missing during the first period, and the inward-pointing arrow indicates the number of recent entries that would be found (Moral-Munoz et al., 2018).
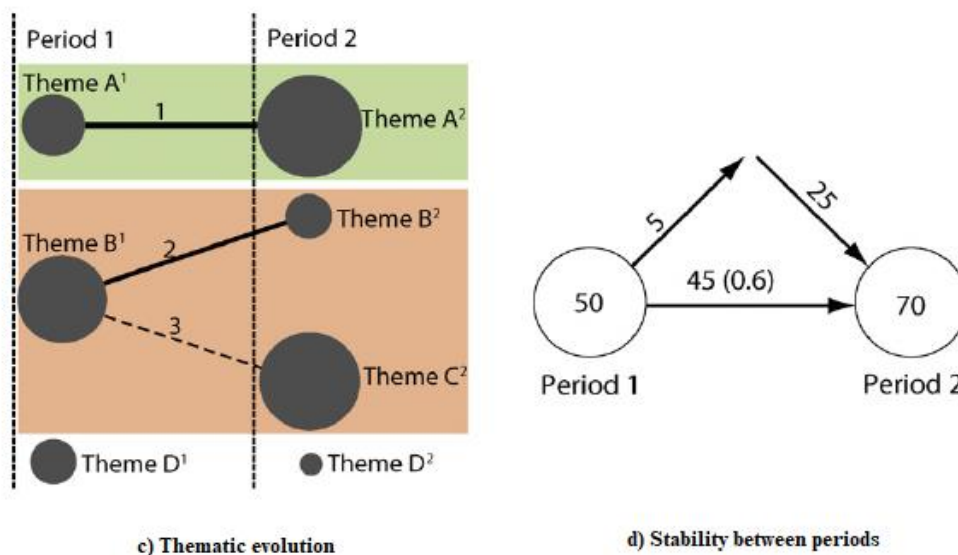

c) Thematic evolution   d) Stability between periods

Figure 2. The evolution map and stability between periods (Cobo et al., 2011)

Results

Year-wise distribution of articles

The number of publications indicates the quality of work done in studies and developed

over the decades. Figure 3 shows the number of road user behaviour research conducted between 1973 and 2020. In two decades, from 1973 to 1995, the number of publications was sluggish, with an average of fewer than five articles annually. The academic works were then increased by five in 1996 but decreased slightly to four in 1997 and were found only one publication in 1998. Preliminary in 2005, the number of publications increased exponentially with at least five publications, but then it was decreased in 2010 with three publications. The number of publications increased significantly in 2011 with ten publications; afterwards, the number of publications undergoing a fluctuating cycle from 2013 to 2015. There were a steadily increased number of publications from 2016 to 2020, with the highest publication of 36 in 2020. It is indicated that the increase in publications is mainly due to an increasing interest in road user behaviour research between 2016 and 2020. It brings increased focus to the study and offers information on the needs and understanding the patterns and variability in road user behaviour (Crawford et al., 2018). Also, extensive user behaviour research was performed recently, concentrating on the realisation, modelling and prediction of user behaviour in the past, present and future (Martín, Fernández-Isabel, de Diego & Beltrán, 2021).
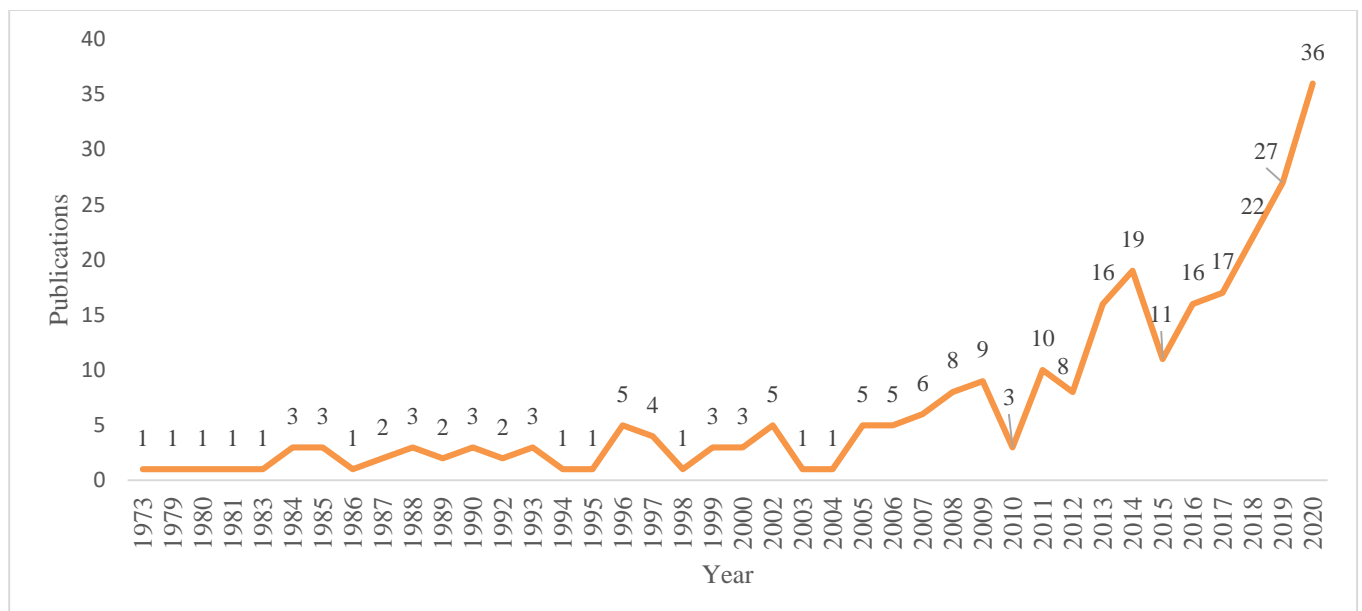

Figure 3: Year-wise distribution of articles on road user behaviour

Geographical-wise and institutions distribution of articles

A bibliometric review is used to determine the geographical location of scientific advances, which indicates the quality and concentration of scientific research in countries. The most prolific countries in terms of knowledge sharing in road user behaviour (see Figure 4) are mainly geographically concentrated in the United Kingdom (38 publications), Australia (30 publications), the United States (25 publications), and Netherlands (24 publications). These countries had published more than 20 publications over four decades. The results showed that developed countries had dominated the publication of road user behaviour for over four decades. This phenomenon has occurred in these countries, which are affected continuously by increased travel and population. Therefore, there have been more interventions in those countries to reduce road crashes (Bhalla & Gleason, 2020). Also, economically developed countries tend to invest more in road safety versus other less developed countries (Zou, Yue &
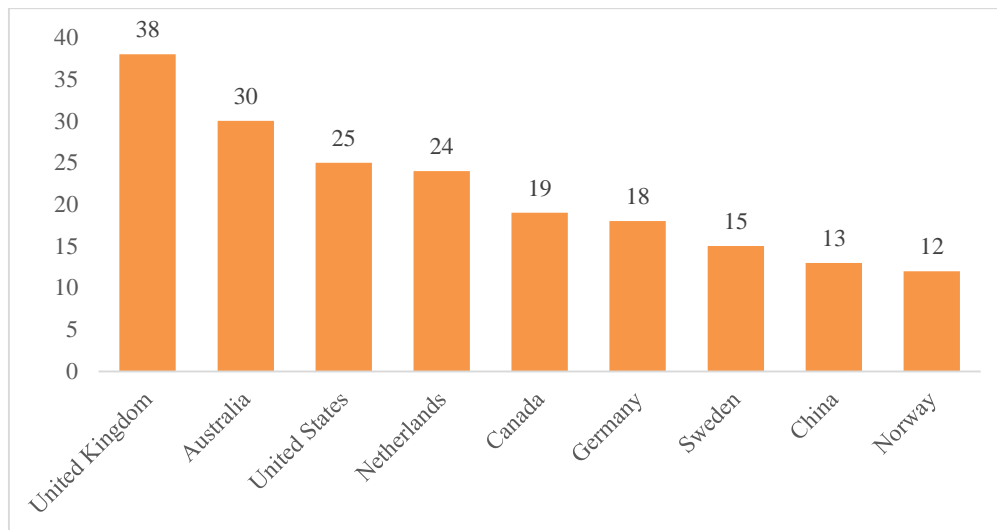
Le Vu, 2018).

Figure 4: Geographical-wise distribution of articles on road user behaviour

The institutions that researched road user behaviour were also considered in this analysis based on at least ten publications. Figure 5 displayed Monash University had led as the most prominent institution with 14 academic works on road user behaviour. The second ranks go to the Queensland University of Technology (11 publications), and the third place was the SWOV Institute for Road Safety Research (9 publications). In this review, the Australian-based institution dominated the top three institutions' rank. The analysis of prominent institutions also indicated that academics and professional experts have been actively involved in road user behaviour for 47 years and have played a significant role in publications. Road user behaviour is a crucial factor in increasing the number of road crashes worldwide; thus, academics and professional experts consider road users' behaviour to be the main risk factor for road fatalities that need to be further scrutinized (Jameel & Evdorides, 2021).
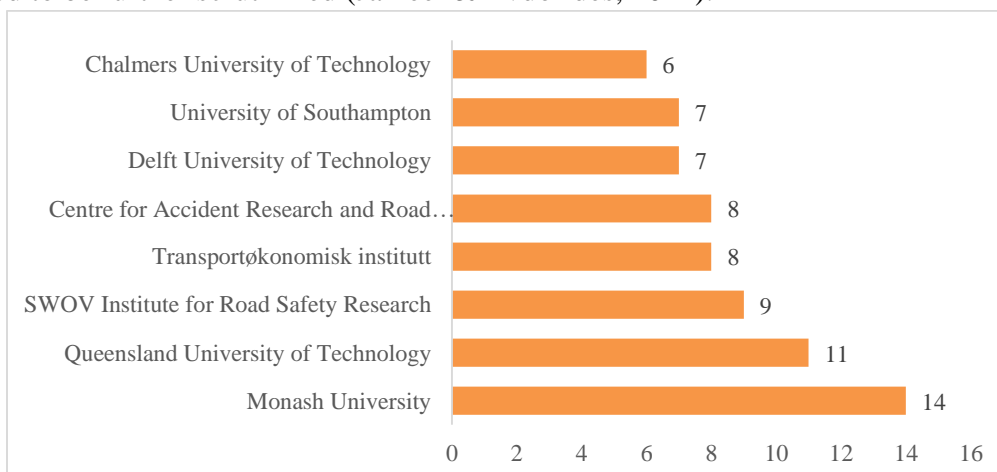

Figure 5: Institutions distribution of articles on road user behaviour

Analysis of sources and research Hotspot

Figure 6 depicted 11 sources with more than four publications on road user behaviour out of 146 publication sources. The Accident Analysis and Prevention was the most potent source

with 32 publications. The core reason is that this United Kingdom-based journal had reached more readers and was classified as a high-impact publisher by Scopus with the First Quartile (Q1) in 2019. The ranked second goes to the Transportation Research Part F Traffic Psychology and Behaviour with 19 publications (SCImago, 2020). Transportation Research Record is established in third place. Based on this finding, it is proposed that these sources have contributed valuable information that will allow prospective researchers to draw on them and will be helpful in their future research on road user behaviour. It also conveys a message that the sources make it easier for readers to locate and exploit the information they need.
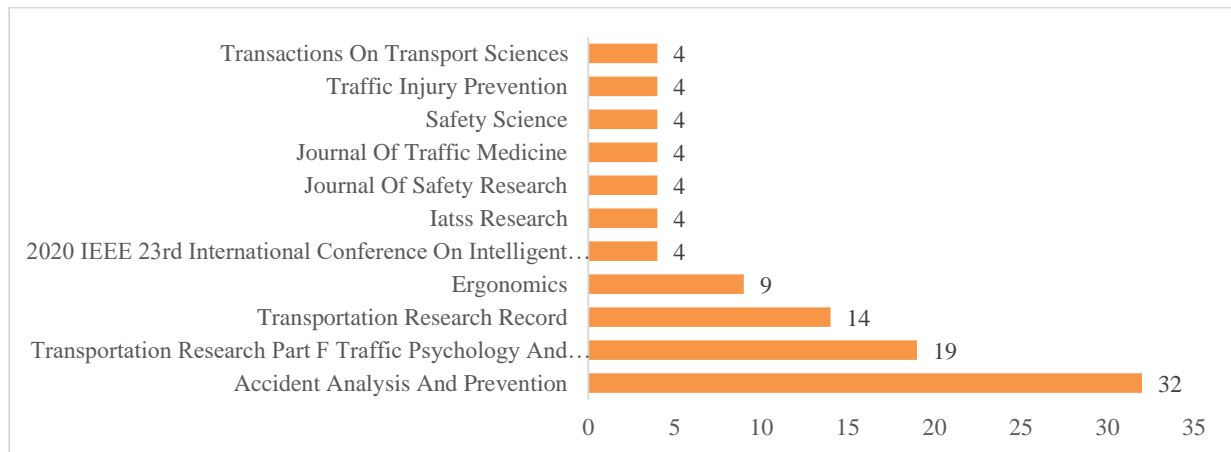

Figure 6: Analysis of sources

The contribution of the research hotspots showed an empirical range of research categories. The analysis of the research hotspots in 270 publications was separate into 25 categories. As shown in Figure 7, the top five research areas are Engineering (170 publications), Social Science (145 publications), Medicine (65 publications), Computer Science (44 publications) and Psychology (35 publications). Engineering has become a top-notch research hotspot because strategies developed to overcome road crashes and injuries have been mainly fixated on four-M approached: man, machine, motorway and money (Short & Pinet-Peralta, 2010; Vaezipour, Rakotonirainy, Haworth & Delhomme, 2017). In general, these four-M approaches were closely linked to the engineering field
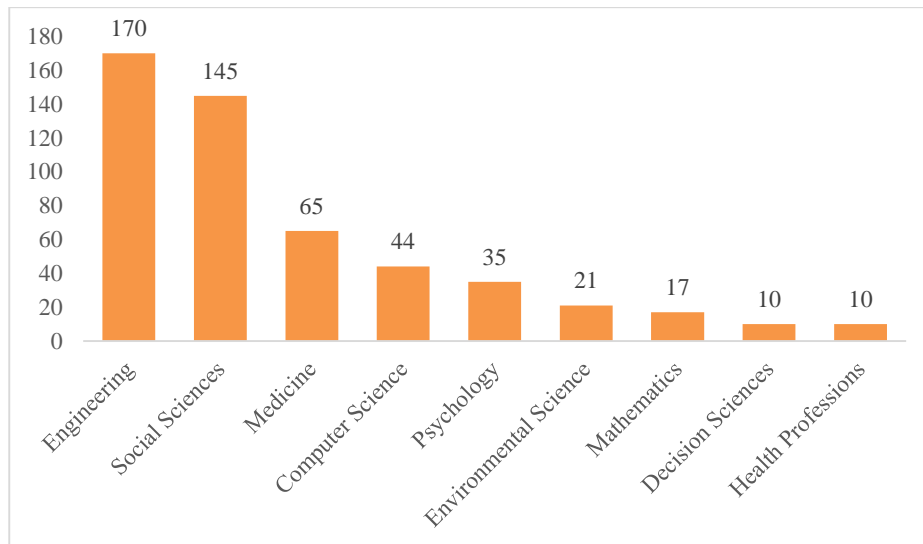
Figure 7: Analysis of research hotspot

Analysis of prominent authors and references

Reference analysis is one of the primary bibliometric indicators to review the selected documents. The number of times a publication has been cited is often used to measure the impact and visibility. Table 2 summarises the top-10 cited articles (based on the text's citation number) as per the Scopus database. R. Fuller published an article with the highest number of citations (484 citations), equivalent to 30.25 citations per year. The article entitled "Towards a general theory of driver behaviour". Accident Analysis and Prevention published this article. The number of citations can be described as actual data, which means that the article's citation will increase. This guide will serve as an excellent resource for novice researchers to explore road user behaviour by securitizing relevant information from the article. Table 2 also showed that C. Hydén was the most highly successful author in this field of study, with his name appearing in many publications on the list.

Table 2

The top-10 cited articles

Cites	Cites Per Year	Authors	Year	Title	Source
484	30.25	R. Fuller	2005	Towards a general theory of driver behaviour	Accident Analysis and Prevention
219	11.53	H. Iversen, T. Rundmo	2002	Personality, risky driving and accident involvement among Norwegian drivers	Personality and Individual Differences
183	16.64	A. Laureshyn, Ã…. Svensson, C. Hydén	2010	Evaluation of traffic safety, based on micro-level behavioural data: Theoretical framework and first implementation	Accident Analysis and Prevention
151	4.58	G.J.S. Wilde	1988	Risk homeostasis theory and traffic accidents: Propositions, deductions and discussion of dissension in recent reactions	Ergonomics
108	7.2	A. Svensson, C. Hydén	2006	Estimating the severity of safety related behaviour	Accident Analysis and Prevention

Cites	Cites Per Year	Authors	Year	Title	Source
107	9.73	N. Saunier, T. Sayed, K. Ismail	2010	Large-scale automated analysis of vehicle interactions and collisions	Transportation Research Record
97	8.08	L. Jackson, P. Chapman, D. Crundall	2009	What happens next? Predicting other road users' behaviour as a function of driving experience and processing time	Ergonomics
83	13.83	R.L. Sanders	2015	Perceived traffic risk for cyclists: The impact of near miss and collision experiences	Accident Analysis and Prevention
73	3.48	C. Hydén, A. Várhelyi	2000	The effects on safety, time consumption and environment of large-scale use of roundabouts in an urban area: A case study	Accident Analysis and Prevention
71	5.46	F. Wegman, L. Aarts, C. Bax	2008	Advancing sustainable safety. National road safety outlook for The Netherlands for 2005-2020	Safety Science

Mapping of road user behaviour research thru VOS viewer

This sub-topic provides a visual description to deepen the conclusions of the previous sub-topics. The VOSviewer software is used to evaluate co-citation and the authors' keywords co-occurrence. Figure 8 displays the findings of co-citation analysis of publication outlets on road user behaviour research with a threshold of 20 citations and 11 sources. Accident Analysis and Prevention is the most-cited journal with the best network links (red cluster) with a total link strength is 1347 and 256 citations. An Accident Analysis and Prevention is congregated in a similar group with the other seven outlets such as Safety Science, Journal of Safety Research, and Injury Prevention.

VOSviewer also allows for the analysis of the most frequent keywords appearing in a given set of publications. In this analysis, VOSviewer mapped the keywords of the authors. Figure 8 provided a network diagram of the authors' keywords with various colours, node sizes, font sizes, and the thickness of the connecting lines to illustrate the relationship with other keywords.
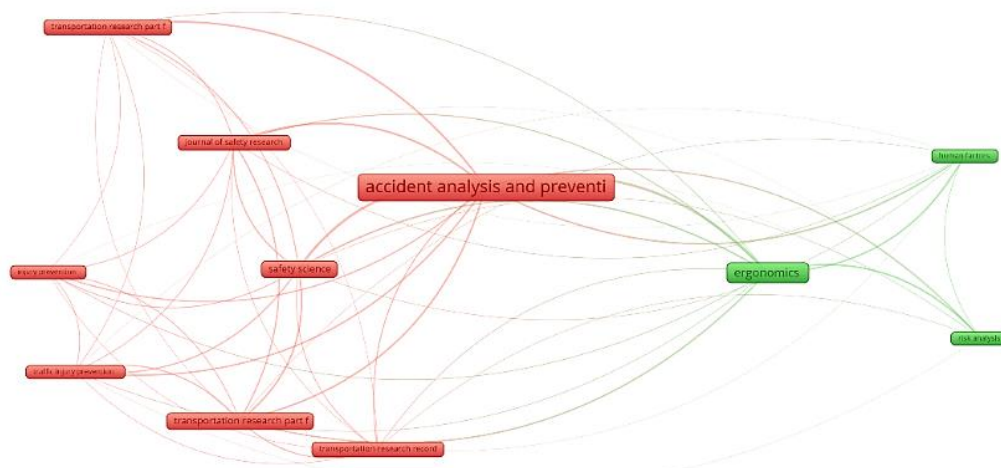
Figure 8: The co-citation analysis of publication outlets

The keyword "road safety" in red colour is the most frequent keyword. Different popular co-occurrence keywords in this review are "road user behaviour", "pedestrians", and "traffic safety". This review confirms that road user behaviour has an interdisciplinary perspective and connects with a wide range of fields, including traffic safety and automated driving. Although many new study areas have emerged in the last four decades, researchers may still be necessary to develop creative concepts, novel subjects, and methods or theories in this field of study. This can be accomplished by designing a road user behaviour model with integrated components derived from the authors' keywords, as shown in Figure 9.
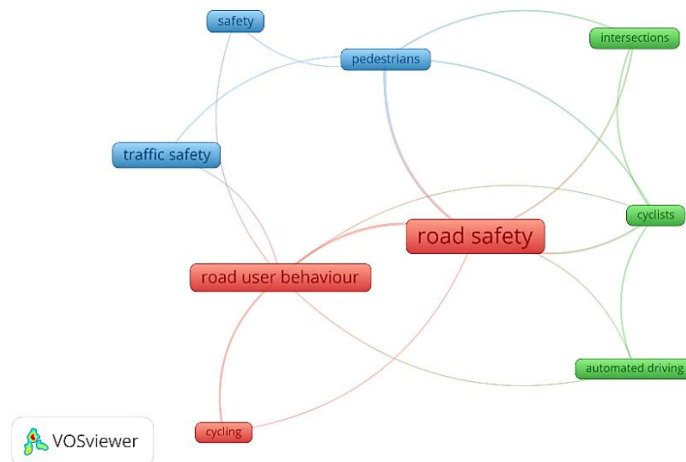

Figure 9: Network visualization map of author keywords

Thematic evolution analysis of road user behaviour research thru SciMAT

The thematic evolution of road user behaviour research is examined using the SciMAT software tool. The evolution map shows that; how thematic field evolution is accompanying the study period. The nodes' size is reflected in the number of documents within a given theme, and links between nodes are proportional to the similarity in a topic. It will be at least one out of all the theme keywords that the theme will contain. The overlapping map allows the researcher to determine how stable the first and second period's data were. The horizontal line is the number of words that are shared. The forward-directed arrow shows how many keywords would be missing during the first period. The inward arrow indicates the number of new keywords, on the other hand. Key outputs of the SciMAT are graphical depictions of the thematic structure across the researcher's selected periods. A strategic diagram has grouped themes into four groups, as discussed in Table 1. The strategic maps in this review are presented in Figures 10 and 11. In these diagrams, the nodes' size is relative to the number of articles allied with each theme.

The first period (2005-2012) as shown in Figure 10, has been inadequate, and only a few major themes have emerged. The topics are "Schools" in the motor themes, "Intersections" in-between motor themes and highly developed, while "human" was in between motor themes and basic and transversal themes. In this study, "Road-users" were found to be the emerging and declining themes. Throughout this period, attention was focused on the "Schools". The reason is between 2005 and 2012, road user behaviour research emerged and was compellingly

necessary for road safety performance and change implementation to overcome road crashes. According to Dragutinovic and Twisk (2006), road safety education has similar health promotion education patterns, so road safety education should start from four to five years of age and continue through primary and secondary education. Schools have been shown to play a significant role in promoting good road behaviour among children at an early age.
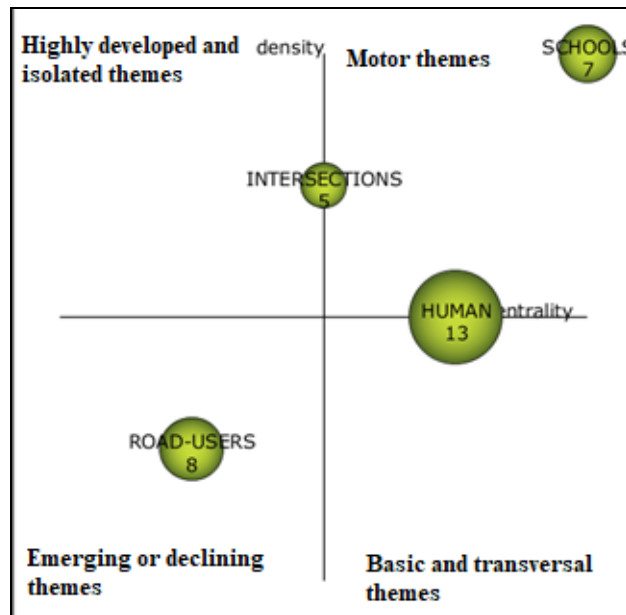

Figure 10: Strategic diagram for the first period (2005-2012)

Three key motor themes identified during the second analysis period (2013-2020) are "cross-sectional-studies," "car", and "spatio-temporal-analysis", as shown in Figure 11. The topic of "cross-sectional-studies" is one of the most common thematic categories related to performance measures. This is because assessing road user behaviour, according to Bergman (2016), is conceptualized differently. Thus, cross-sectional studies are considered an essential research tool for determining the driver's behaviour. The cross-sectional studies used the questionnaire to obtain the related data and could be used to analyze critical factors related to risk prevention and safety behaviour related to road safety. It is also noted that most of the top ten of the cited articles, as shown in Table 2, are quantitative studies that used questionnaires to learn about road user behaviour. This is because the human mind influences behaviour through psychology and the most unsafe behaviour is performed without proper thinking, making it vulnerable to accidents (Ma, Guo & Fang, 2021). Therefore, a questionnaire set through a quantitative study is needed to examine these factors and the relationship with road user behaviour.

During the second period, the cluster network of highly developed and isolated themes collects a thematic network of "road-transport" that is associated with "driving-conditions" and "smart-cities." The themes have well-developed internal ties but little external relations, and thus they are of only marginal importance for the field from 2013 to 2020. It is critical to conduct additional research, as Gambo and Musonda (2021) asserted that poor management practices of road transport assets posed a barrier to the sustainable development of the transport system in developing countries, and previous studies focused primarily on the road construction process' performance. To enliven the themes, identifying the impact of limited parking and

social policies' influence on drivers' jobs on the road transport sector's economy needs to be scrutinized further. This is because the number of vehicles increases, there is inadequate infrastructure to create, and the number of parking spaces required to meet the capacity increases due to the economic impact of insufficient parking spaces on transportation businesses (Poliak, Poliakova, Zhuravleva & Nica, 2021).

Based on this bibliometric review, the terms "behaviour" and "road-user-behavior" were classified as emerging and declining themes from 2013 to 2020. Themes in the lower-left quadrant are both marginal and underdeveloped. The themes in this quadrant are low in density and centrality, and they mostly represent emerging or disappearing themes. It is suggested that the study of road user behaviour should be expanded. Road user behaviour is a significant contributor to the global increase in traffic accidents. Road safety experts and scientists believe that road users' behaviour is the primary risk factor for traffic fatalities (Jameel & Evdorides, 2021). Furthermore, road safety is a critical issue for the entire world, bearing significant weight from both personal safety and an economic and public health standpoint (Abdullah, 2021).

The final three themes are "human", "accidents," and "pedestrian." The themes in the lower-right quadrant are essential for a research field, but they have not been developed. This quadrant contains both transversal and general, fundamental themes. The three linked terms will also be required in the future for more research into road user behaviour. It is critical because pedestrians are among the most vulnerable road users, accounting for approximately 23% of road crash-related fatalities worldwide (Grindle, Pak, Guleyupoglu, Koya, Gayzik, Song & Untaroiu, 2021). Humans are the most common cause of road coincidences; for example, vehicles traveling at high speeds on high-speed highways; as a result, animals and humans are victims of accidents while crossing the roads (Reddy & Gayathri, 2021).
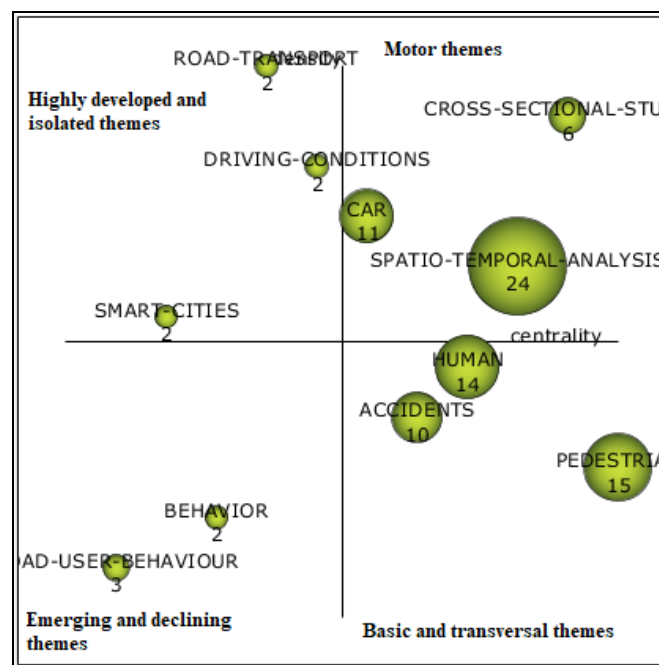

Figure 11: Strategic diagram for the second period (2013-2020)

Information in Figure 12 indicated the vital fact as follow: The first-period evolution map (2005-2012) for road user behaviour research was based on "schools", "intersections", "human", "managers", and "road-users". These four themes underpin the argument that these

issues have received relatively more attention in the literature. In the second period (2013-2020), the themes of "cross-sectional-studies" are closely related to "schools" in the first period. "car" theme was related to "intersections". The "human" theme is connected with a similar "human" theme in the first period. "Pedestrian" is nexus to "schools", "accidents" linked to "human", "road-transport" is associated with "road-users", and "behavior" is closely linked to "human". In this analysis, "driving-conditions" and "smart-cities" were found to have newly emerged and wide-ranging at successive periods. Future research is also suggested to study these newly emerging themes better to scrutinize road user behaviour more comprehensively and be tangible toward technology and innovation in road safety. The stability between the two periods (overlapping map) also showed that the number of keywords has increased over time (see Figure 12). This represents a continuation of the emphasis on expanding road user behaviour research. The number of emerging road user behaviour research themes is high, suggesting that this research is continually developing and growing due to the study's complexity, dynamic, and uncertain nature.
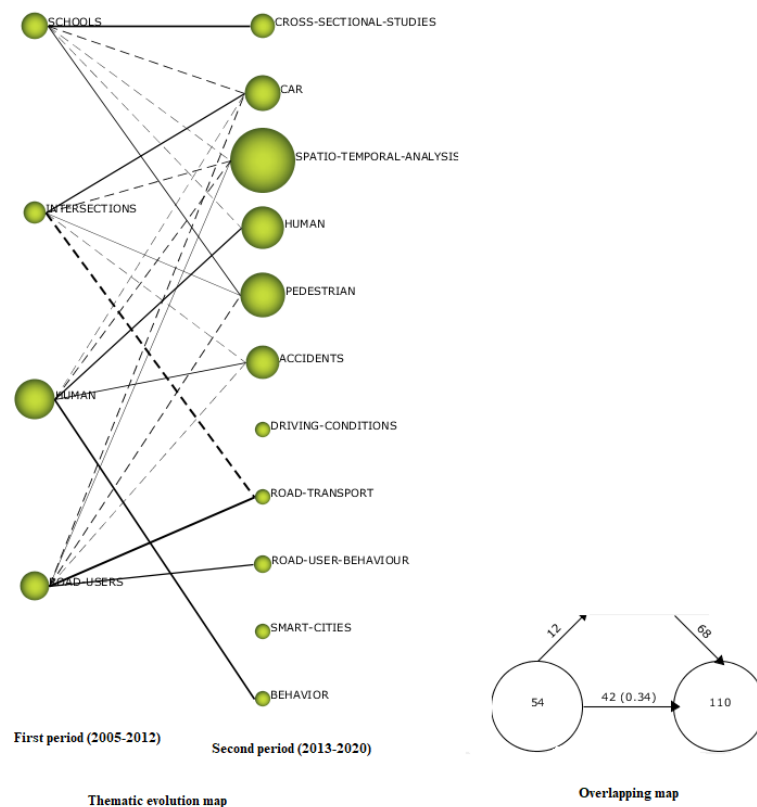

Figure 12: The map of thematic evolution and overlapping (stability between periods)

Discussion

Psychologists are paying more attention to behavioural research to understand human dynamics, and they have merged this field with other research topics such as road safety. Individuals' behaviour reflects their actions; hence, it is essential to interpret their thinking. This study's primary goal is to investigate the publication trends and thematic progression of road user behaviour from 1973 to 2020, spanning 47 years. The evaluation employs the Scopus database and other bibliometric measurements, including output growth trends, renowned

countries, research hotspots, and author keywords.

This study indicated that road user behaviour research publications increased steadily between 2016 and 2020, reaching 36 in 2020. The increase in publications between 2016 and 2020 is attributable primarily to a growing interest in road user behaviour studies. It strengthens the study's focus and gives information on the requirements and differences in road user behaviour patterns (Crawford et al., 2018). Recent studies have concentrated on identifying, modeling, and forecasting past, present, and future user behaviour (Martín et al., 2021). The information gained in this study depicted that the progression of the publication reflects evolutionary nuances, and bibliometric analysis enables us to collect and graphically represent evolutionary nuances across temporal and spatial dimensions. In particular, the objective discovery of knowledge clusters, when subjected to trend analysis, can provide insights into declining, expanding, and developing themes, which is vital for reflecting on the past and gaining an unbiased view of where the area is headed (Mukherjee, Lim, Kumar & Donthu, 2022).

This analysis revealed that developed countries have dominated the publication of road user behaviour research for over four decades. This phenomenon has taken place in several countries, continuously affected by growing travel and population. Therefore, there have been more outstanding efforts to reduce road accidents in these countries (Bhalla & Gleason, 2020). Additionally, economically prosperous countries invest more in road safety than less-developed countries (Zou et al., 2018). Information on institutions conducting an active study on road user behaviour revealed that Monash University was the most distinguished institution. Notably, this assessment revealed that the Australian university dominated the ranking of the top three universities. This information is vital for evaluating relative performance, which could serve as an input for decision-makers and determine the relative potential of prospects in road user behaviour study. Scholars and professionals consider road user behaviour the most critical risk factor for road fatalities that warrant further investigation (Jameel & Evdorides, 2020).

The most influential source was Accident Analysis and Prevention. The primary reason is that Scopus classified this publication as a publisher with a high impact in the First Quartile (Q1) in 2019 (SCImago, 2020). Based on this unearthing, it is argued that the source has supplied valuable information that will be advantageous for future road user behaviour research. It also implies that the sources make it easier for potential readers to locate and utilize the necessary information. Results on prominent authors indicated that R. Fuller obtained the highest number of citations (484 citations), comparable to around 30.25 citations each year for an article entitled "Towards a general theory of driver behaviour", published by Accident Analysis and Prevention. The number of citations can be considered accurate data, implying that the article's source will increase. This guide will be a fantastic resource for newbie researchers investigating road user behaviour, as it secures pertinent material from the article. In terms of research hotspots, this study portrayed that research on road user behaviour attracted scholars from various study areas. Howbeit, Engineering has become a premier research hub. It may be related to the fact that solutions established to prevent road accidents and injuries have centered mainly on a four-M approach: man, machine, motorway, and money; these four-M strategies had close ties to the engineering industry (Short & Pinet-Peralta, 2010; Vaezipour et al., 2017). Based on the analysis of bibliometric characteristics, we discovered that the parameters could describe the sources and research hubs that can assist the intended audience in locating the necessary information on the scrutinized topic. In addition, it is deemed essential

for enhancing research pertinent to road user behaviour and, more importantly, for the theory development and practice improvement in this research area.

According to the results of VOSviewer, the keyword "road safety" is the most prevalent. Other popular keywords in this review include "road user behaviour," "pedestrians," and "traffic safety." This review establishes that road user behaviour has an interdisciplinary perspective and is interconnected with other domains, such as traffic safety and autonomous driving. Although many new fields of study have evolved during the past four decades, researchers may still be required to produce innovative concepts, subjects, techniques, and theories in this field of study. This is possible by building a road user behaviour model with integrated components generated from the authors' keywords.

Information on topic evolution and overlap revealed the following crucial fact: The first-period evolution map for road user behaviour study (2005-2012) was based on "schools", "intersections", "human", "managers", and road users". These four themes support the claim that the literature has paid relatively more attention to these topics. Throughout this period, "Schools" was the topic of discussion. Between 2005 and 2012, road user behaviour research evolved and became crucial for road safety performance and adopting changes to prevent road crashes. According to Dragutinovic and Twisk (2006), road safety education and health promotion education follow similar patterns; hence, road safety education should begin between the ages of four and five and continue throughout primary and secondary school. It has been demonstrated that schools play a vital influence in developing proper road behaviour among young children.

The themes of "cross-sectional-studies" in the second phase (2013-2020) are strongly tied to "schools" in the first period. The "car" theme was associated with "intersections." The "human" theme is related to a similar "human" theme in the first period. "Pedestrian" is connected to "schools," "accidents" to "human," "road-transport" to "road-users," and "behaviour" to "human." In this investigation, it was determined that "driving-conditions" and "smart-cities" arose and expanded in successive times. The themes have well-developed internal linkages but few external relations; hence, they are of marginal importance to the field between 2013 and 2020. Poor management practices of road transport assets provide a barrier to the sustainable growth of the transport system in developing countries, according to Gambo and Musonda (2021), and past study has mostly centered on the performance of the road-building process. To enliven the issues, it is necessary to investigate the economic effects of limited parking and the influence of social policies on drivers' jobs in the road transport sector. This is because the number of vehicles increases, infrastructure creation is inadequate, and the number of parking spaces needed to satisfy capacity increases due to the economic impact of insufficient parking spaces on transportation businesses (Poliak et al., 2021).

Based on this bibliometric analysis, the terms "behaviour" and "road-user-behavior" were categorized as emerging and declining themes from 2013 to 2020. It is suggested that road user behaviour research should be expanded. The behaviour of road users is a significant factor in the global increase in traffic accidents. According to road safety professionals and scientists, motorist conduct is the most significant risk factor for traffic fatalities (Jameel & Evdorides, 2021). Moreover, road safety is a global concern that carries enormous weight from the perspectives of both human safety and economic and public health (Abdullah, 2021). Future research is also recommended to examine these newly emerging issues more thoroughly to scrutinize road user behaviour more positively and be more concrete in terms of technology and

innovation in road safety. The consistency between the two periods (overlapping map) also demonstrated that the number of keywords has grown with time. This is a continuance of the emphasis placed on developing studies into the behaviour of road users. Due to the study's complexity, dynamism, and unpredictability, many new themes in road user behaviour research emerge, indicating that this research is continuously evolving and expanding. Thus, prospective scholars can identify critical knowledge gaps in the literature and locate future contributions concerning established research streams by finding knowledge clusters through science mapping methods. Mukherjee et al. (2022) elucidated that the existence of research gaps and the nature of ties, which reflect relational characteristics among scholarly groups, are essential for developing an understanding of research trends and identifying the social processes that facilitate the co-creation, sharing, and absorption of knowledge within and across different clusters.

Conclusion

This study aims to conduct a bibliometric analysis of academic works published on the subject of road user behaviour research. VOSviewer and SciMAT were used to complete the investigation. The bibliometric review promotes established road user behaviour research directions, assesses emerging trends, and studies research evolution. Based on a bibliometric review of 47 years of road user behaviour research (1973-2020), the findings could provide useful information for researchers and professionals as follows:

i.   The number of publications on road user behaviour had exponentially increased in 2005, and the highest number of publications was 36 in 2020. Nevertheless, it is designated that this research area is still minimal and needs to be further explored in the future, as road behaviour is one of the determining factors that led to road collisions.

ii.   Researchers from nine countries have contributed to road user behaviour research with at least 12 publications. The top three on the list are The United Kingdom (38 publications), Australia (30 publications), and the United States (25 publications). This review shows that developed countries dominate the road user behaviour research field.

iii. The Australian-based institution dominated the top three distribution institutions. The analysis of prominent institutions shows that academics and professional experts have been regularly involved in road user behaviour for 47 years, which has played a significant role in publications about road user behaviour within four decades.

iv.   The most influential sources were Accident Analysis and Prevention, with 32 publications. Engineering has become a top-notch research hotspot due to the strategies developed to overcome road crashes, and injuries have been mainly fixated on four-M approaches related to engineering scopes: man, machine, motorway, and money.

v.   R. Fuller published an article with the highest number of citations (484 citations), equivalent to 30.25 citations per year. The article entitled "Towards a general theory of driver behaviour". Accident Analysis and Prevention published this article. This could drive future researchers to assign relation information from this article to convey eminent ideas on road user behaviour.

vi.   Based on the mapping technique using VOSviewer. The keyword "road safety" in red colour is the most frequent keyword in the publications for 44 years. Other popular co-occurrence keywords in this review are "road user behaviour", "pedestrians", and "traffic safety". This review confirms that research on road user behaviour has an interdisciplinary

perspective and connects with a wide range of fields, including traffic safety and automated driving. Although many new study areas have emerged in the last four decades, researchers may still be necessary to develop creative concepts, novel subjects, and methods or theories in this field of study.

vii.   SciMAT research tools provided relevant information on themes or keywords that split based on two periods: exponential growth after 2005. The first period (2005–2012) depicted that the themes have been inadequate, and only a few major themes have emerged. The themes are "Schools" in the motor themes, and the theme "Intersections" was in-between motor themes and highly developed, while the theme "human" was in between motor themes and basic and transversal themes. This study generated three motor themes in the second analysis period (2013-2020), namely "cross-sectional-studies," "car", and "spatio-temporal-analysis". In this analysis, "driving-conditions" and "smart-cities" were found to have newly emerged and indicated road user behaviour research was diversified and highly vital at successive periods.

Limitations and future research

To determine the state of the art, a bibliometric review might be used. Regrettably, this subject cannot be investigated adequately due to a variety of constraints. This study aimed to determine the primary themes or significant keywords linked with "road user behaviour" research through the usage of the Scopus database. In this regard, future researchers could have used other databases such as Dimensions, Google Scholar, and Microsoft Academic to examine publication trends and the thematic evolution of road user behaviour research. As a result, future studies that wish to expand on the background or address broad concerns to provide the best relevant evidence synthesis are advised to use more traditional review methodologies, such as systematic literature reviews or meta-analyses. This can be accomplished by using key terms such as "road user behaviour" OR "road user behaviour" OR "behaviour of road user" OR "behaviour of road user" OR ("road user" AND (behaviour OR behaviour OR behavioural")).

Finally, this bibliometric review has a finite scope. Only publications meeting the methodology's search refinement criteria ("road user behaviour") have been included. The report's primary shortcoming restricts scientific findings and does not adequately aid many dimensions in comprehending road user behaviour. Consequently, future researchers may be interested in evaluating the pattern of road user behaviour in publications related to demographic factors such as age, gender, income level, race, employment, location, and level of education. They could do so by including demographic factors in the search query. It is more interesting to examine road user behaviour and demographic characteristics to generalize specific groups.

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