Contents lists available at http://qu.edu.iq

Al-Qadisiyah Journal for Engineering Sciences

Journal homepage: https://qjes.qu.edu.iq/

A review into studies related to the effect of the pavement surface condition on traffic safety: A scientometric analysis

Manal Ghadban Al-Zubaidi* , Hamsa Zubaidi and Bassim H. Al-Humeidawi

Roads and Transport Engineering Department, College of Engineering, University of Al-Qadisiyah, Iraq

ARTICLE INFO

Article history:
Received 15 December 2022
Received in revised form 21 February 2023
Accepted 18 August 2023

Keywords:
Traffic Safety
Pavement Surface Condition
Pavement Distress
Injury Severity
Rutting
Roughness
Skid Resistance

ABSTRACT

Traffic crashes are one of the main reasons for the deaths of many people and the loss of property. Therefore, it is important to conduct research and studies to reduce the risk of accidents and identify the causes that lead to their occurrence. The condition of the pavement is one of the main factors that lead to accidents, as several studies have been presented that show the impact of pavement defects such as rutting, roughness, and skid resistance on traffic safety. The purpose of this study was to identify and compile the most important research papers using the Web of Science (WOS), and then analyze the data using the VOSviewer program, as well as learn about most countries and journals that have published the related pavement condition of road crashes, as well as the authors and their collaboration. In addition to knowing the keywords that help researchers research this topic, to benefit from these studies, we must know the causes of accidents, analyze and treat them, and improve the performance of roads using modern analysis and maintenance methods that ensure traffic safety.

1. introduction

With the development of transportation systems, traffic safety has become a widespread problem around the world, and with the increase in the number of vehicles, crashes have increased significantly. Any crash involving a collision between two cars or more or a car crash with others, such as pedestrians, walls, animals, or any objects on the road, will result in death, injury, or property damage [1].

According to the World Health Organization [2], approximately 1.35 million people are killed annually in traffic accidents. A further 50 million people sustain non-fatal injuries, with many becoming disabled as a result. Traffic injuries cause great economic losses to individuals, their families, and entire countries. the statistics of the World Health Organization. Researchers have conducted many studies to reduce traffic crashes and preserve the safety of people and property.

Many factors affect accident rates, including the road, the driving environment, and the driver. Pavement condition is one of the main reasons that lead to an increase in crash rates. [3, 4].

In most U.S. states, injury severity is quantified based on the KABCO scale, which consists of five injury levels: (K) death, (A) incapacitating injury, (B) non-incapacitating injury, (C) potential injury, and (O) no injury. The fatal category receives special attention; if an injured individual dies within 30 days of the incident, the crash report is revised to reflect this occurrence [5].

Many researchers used A scientometric overview as a review of previous research, for example [6-14].

* *Corresponding author.*
E-mail address: manal22aa33@gmail.com (Manal Ghadban)

https://doi.org/10.30772/qjes.2023.178990

2. Literature review

Researchers have conducted many studies that show the relationship between crashes and pavement conditions. In a study conducted on some streets in Bauchi City in 2012, Bauchi-Jos, Bauchi-Yobe, and Bauchi-Gombe, the influence of pavement surface conditions on accident rates was investigated using road condition scores for these three roads. There are significant relationships between surface conditions and the severity of crashes [15]. In Northern Virginia's Fairfax District, researchers investigated the effect of pavement defects on the rate of crashes. The purpose of this research is to investigate accidents and street features associated with each collision to determine the impact of those factors on the accident rate and, subsequently, to construct models for forecasting the accident rate on each section of the road. According to the findings, the surface state has a considerable effect on the crash rate [16-25]. According to the researchers [26] bad pavement conditions reduce the severity of crashes for single-vehicle accident rates on low-speed highways and increase high-speed loads. When there are multiple collisions, the severity of the accidents increases when the pavement is in poor condition. Another study about cities with harsh temperatures should consider ongoing pavement care to avoid accidents. It has been demonstrated in China that two significant elements that contribute to deadly accidents are traffic flow and pavement conditions [27] It was also mentioned [20] that the characteristics of the pavement are one of the factors that affect the accident rate [22, 28,29].

2.1. Pavement Defects

The state of the pavement can be negatively impacted by some factors affecting pavement failures, such as poor construction conditions, a harsh climate, moisture, temperature, bad drainage, improper maintenance, and excessive traffic. In this section, we discuss some pavement defects that significantly impact accident rates and severity[26, 30-35].

2.1.1. Rutting

Rutting is a permanent deformation, which is a depression that occurs in the wheel path on the road surface. Pavement elevation may rise along the rut's sides. The rut is often only visible after a downpour. When water fills a rut, the vehicle will pull into the rut paths, causing hydroplaning [36]. [37] indicated that several factors influence rutting, such as increased binder content, which increases rut depth. When the binder is used more than is required, aggregate particles lubricate and move. In addition, when layer thickness increases, so does rut depth; when the layer thickness is too thick, the aggregate has the potential to move. Also, rut depths decrease as the performance grade PG (binder grade) increases. Binders are polymer-modified to improve performance, which can result in less rutting susceptibility. Moreover, rut depth increases as void mineral aggregate (VMA) increases. [38] found that mixes with stiff binders and large particles of aggregates are generally more rut-resistant than those with finer aggregates and higher binder contents. In a study by [39] the authors classified rutting into three levels: If the depth of rutting is under 6 mm, it is considered minor severity. It's doubtful that there will be any hydroplaning issues or wet weather mishaps. When the depth of rutting is between (7 and 12 mm), the severity of the accident is moderate because rainy weather accidents and hydroplaning might result from an insufficient cross slope. when the depth of rutting is greater than (13 mm) high severity, which greatly increases the danger of wet weather accidents and hydroplaning. [40] discovered that the accident rate increases as the rut depth exceeds (7.6 mm) (0.3 in). Another study in Indiana used accident data for nine years to show the effect of pavement defects on traffic accidents. It was found that increasing the rutting depth in paving increases the crash rate by 94.27 percent while reducing the crash rate by 5.73 percent [41,42].

2.1.2. Roughness

Roughness is defined as irregularities on the pavement surface; it refers to pavement ride quality and leads to an increase in the vibration of vehicles, which reduces vehicle speed. It causes harm to the vehicle's tire and raises the vehicle's operating costs. The International Roughness Index (IRI) produced from measured roadway segments can be used to measure the roughness of pavement [36]. A study conducted to explore the relationship between the roughness of the road and traffic safety found that the parts of the road that have the highest accident rate have a higher rate of road roughness than the parts of the road that have the lowest accident rate [43]. Other researchers found that when the roughness of the road is high, the crash rate will be higher [44]. IRI values are different based on the roadway classification. Under common traffic speeds on dry roads, the new pavement may range from 1.5 m/km to 3.5 m/km and older pavement may range from 2.5 m/km to 6 m/km [3], [45-47]. The Federal Highway Administration (FHWA) proposes ride quality criteria of 170 in/mile (2.7 m/km). A study in Indiana State investigated the impact of the pavement surface condition on crash severity on a rural highway. The data was collected for 1524 road segments over three years. This study used a negative binomial model to analyze the data. It is noted that in poorer pavement conditions that have higher roughness, accidents will be more frequent due to the difficulty of controlling the vehicle by the drivers, The other part of the study indicates that under the same conditions, the increase in the roughness reduces the frequency of accidents because the drivers will be more careful when driving [48]. A study at Ohio State investigated the influence of pavement roughness on accident rates. The results showed that pavement with a roughness index of 1.5 m/km has a low accident rate, while pavement with a roughness index of 2.25 m/km and greater has higher accident rates. The researchers also suggested that the study's findings could be used as a reference to assist local and governmental transportation agencies with road maintenance operations[3]. A one standard deviation increase in road roughness (IRI) can result in an 11% decrease in average speed and an increase in vehicle crashes large enough to move a safe road segment with no crashes in an average month to about 0.5 standard deviations above the sample period's average crash rate, resulting in a significant decrease in traffic safety [41]. Another study examined the effect of changes in roadway roughness on vehicle speed by using a linear regression model. The data was collected from the freeway network in California from 2000 to 2011. The results indicated that roadway roughness has a small influence on free-flow speed; a one-meter-per-kilometer change in IRI results in a 0.48-0.64-kilometer-per-hour change in average free-flow speed [49-51].

2.1.3. Skid resistance

Skid resistance refers to the friction force between the surface of the road and the tire of the vehicle. It is considered one of the most important

characteristics of the road, the loss of which affects traffic safety. A study in Spain measured skid resistance with Sideway-force Coefficient Routine Investigation Machine (SCRIM) for a two-lane rural roadway. Crash data was collected for 1750 km to find the effect of road surface conditions on crash rate and to evaluate the impact of improved friction on pavement safety. The results showed that when skidding resistance values increased, both dry and wet pavement accident rates decreased. Pavement friction schemes had a significant decrease in wet pavement accident rates of 68% [52]. Another study in Virginia analyzed data from 1.6 km of road with wet accidents to examine the relationships between accident rate and skid resistance and found that when the skid numbers decrease, the wet accident rate increases [53-55].

A study in Iowa state examined the effect of pavement conditions on the risk of highway departure accidents. The information was collected between 2006 and 2016. According to the study, having a high skid resistance reduces the severity of an accident regardless of whether the road is dry or [44], [56,57]

3. Data collection

Web of Science (WoS) is a platform consisting of many research databases described in previous literature and designed to support scientific and academic research. It provides access to many databases that refer to research sources for specialized research. Users can now conduct in-depth searches in specialized subfields of scientific and academic research. It has more than 148 million documents, including books, journals, and proceedings that date back to the turn of the 20th century. WOS was used to search for studies and research on accidents and traffic safety that relate to pavement conditions, and the keywords were used in the search (i.e., pavement vehicle crashes). Documents for the years 1990-2022 were retrieved from WOS using applicable research criteria and after filtering unrelated research publications. WOS shows some figures that illustrate the relationship between citations and publication numbers (Figure 1), where (4.183 transportation is above 180), followed by (7.3 asphalt with 20 citations). (Figure 2) shows the relationship between citations and publication types for the related studies. it includes transportation with 140 citations, followed by civil engineering with approximately 90 citations.

Many researchers have used a Web of Science (WoS) site, and the VOSviewer program, especially in the field of traffic accidents[58-60]. Many studies have discussed the risk of accidents and made a scientometric overview[61-64].

4. Analytical method

Bibliometrics is the research and analysis of the format components of texts, papers, articles, and data. It is widely used and approved in many different disciplines, particularly for quantitative assessments by researchers, institutions, and publications based on academic outputs. Many application programs have been developed to carry out the bibliometric method, including Bib Excel, Vos Viewer, Pajek, Gephi, CiteSpace, and Histcite. In this study, VOSviewer was used to create bibliometric and visual maps. VOSviewer is a software application that enables you to construct maps using network data and then visualize and explore those maps. There are three types of visualizations in VOSviewer network visualizations, overlay visualizations, and density visualizations[65]. Several researchers presented a scientometric Overview of several important studies using the VOSviewer program such as [6,12]. Many researchers have used the VOS viewer program to create charts and graphics that show the most prominent researchers, journals, and countries interested in the topic of research, accidents, and the work of A scientometric overview[66-69].

4.1. Top contributions

Table 1 shows the 10 contributions by authors, countries, and institutes. In terms of total link strength, the top three authors are Abdel-aty, Mohamed, with 35 publications, Yan Xuedong, with 24 publications, and Li, Zongzhi, with 20 publications. A highly contributing country with 64 publications is the United States (USA), followed by China with 34 publications, and Canada with 14 publications. The top three terms of the total link strength for universities are Purdue University with 28 publications, Penn State University with 16 publications, and Changan University with 14 publications[70-81].

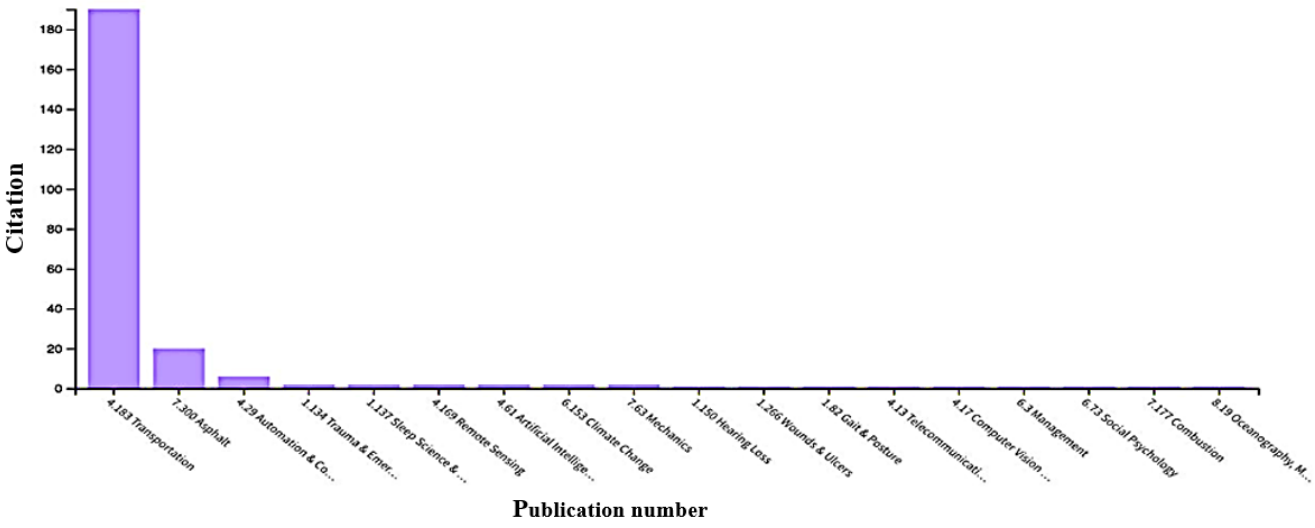

Figure 1. Relationship between citation and publication number

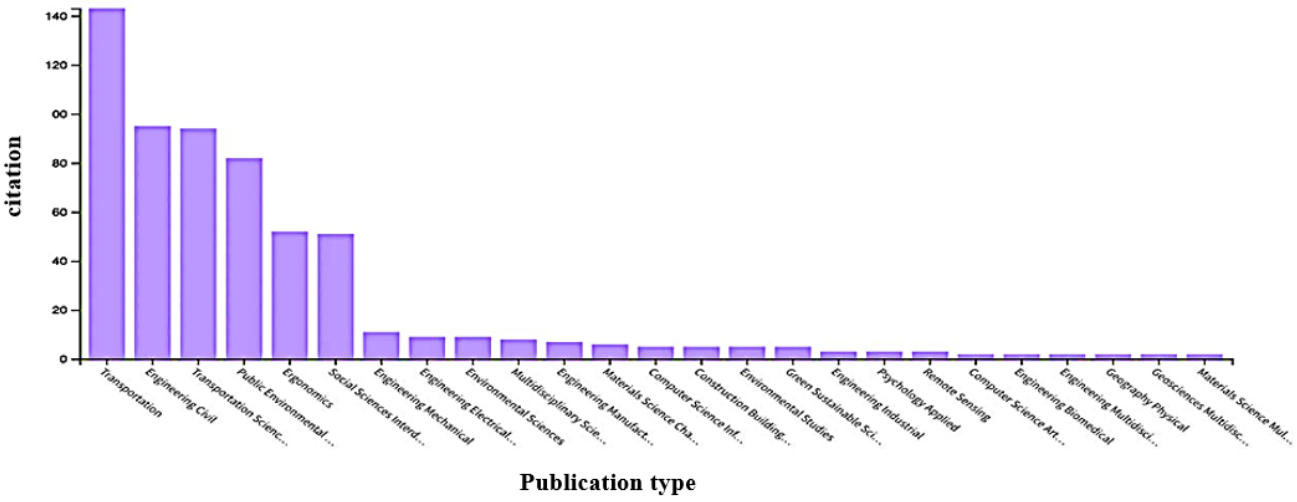

Figure 2. Relationship between citation and publication type

Co-authorship Measures

Figure 3 shows a map of the most prominent authors discussing accidents due to the condition of the pavement and the joint research and cooperation among them. The elements are represented and classified by circles of different sizes and colors, and the elements are connected by lines representing the relationships between the elements.

The thicker lines represent the strongest communication between the elements, as the space between the items, shows their degree of connectedness.

Table 1. Top 10 contributions of institutes, countries, and authors.

No	Authors	F	Country	F	Institute	F
01	Abdel-aty, Mohamed	35	USA	64	Purdue U.	28
02	Yan, Xuedong	24	Peoples China	34	Penn State U.	16
03	Li, Zongzhi	20	Canada	14	Changan U.	14
04	Flintsch, Gerardo w.	19	Qatar	05	Texas A&M Transportatio n	14
05	Labi, Samuel	19	Australia	04	Southeast U.	13
06	Hunag, Bashan	18	Belgium	04	Virginia Tech	13
07	Lin, Pei-sung	18	England	04	Ryerson U.	10
08	Noyce, David a.	17	Iraq	04	Texas A&M U.	10
09	Brijs, tom	16	South Korea	03	U. of Tennessee	10
10	Pirdavani, Ali	16	Bangladesh	03	U. of waterloo	10

Note: F= Frequency, U= University

The overall strength of co-authorship connections with other writers is computed. The writers with the most overall link strength are chosen. As a result, there are 67 items and 11 cluster networks, and the circles are colored based on the clusters. Among the most important writers are Abdel-aty Mohamed, and Yan. Xuedong; Anastaspoulos, Panagiotis ch.; Mannering, Fred; Ahmed.Mohamed, and Sarwar. MD Tawfiq. Abdel-Aty, Mohamed conducted many types of research on traffic safety. Some of his research with other researchers shows that road resurfacing projects reduce collision frequency[82]. Another study on ride quality (roughness) found that higher IRI led to the deteriorated pavement as a result of more accidents[83]. Researchers Baoshan Huang and Xuedong Yan have been involved in many research projects. One of their studies illustrated that there is a significant relationship between pavement conditions and the type and severity of accident frequencies[84]. Whenever researchers are within one group or close to the other group, this indicates the degree of cooperation and participation between researchers.

4.1.2. Institutes map

Figure 4 shows the joint organizations resulting in a total of 66 items in 12 cluster networks. It can be noticed that the University of Central Florida, Virginia Technology, Pennsylvania State University, Changan University, and Texas A&M University Syst have the highest contribution to work related to crashes related to pavement conditions[85-96].

4.1.3 Country map

The network map shows the countries that publish the most research related to accidents, resulting in 30 items (12 clusters) where the United States is followed by China and Canada. These countries have presented a lot of research that contributes to the development of transportation systems to reduce their danger and link the relationship between the condition of pavement and traffic accidents.

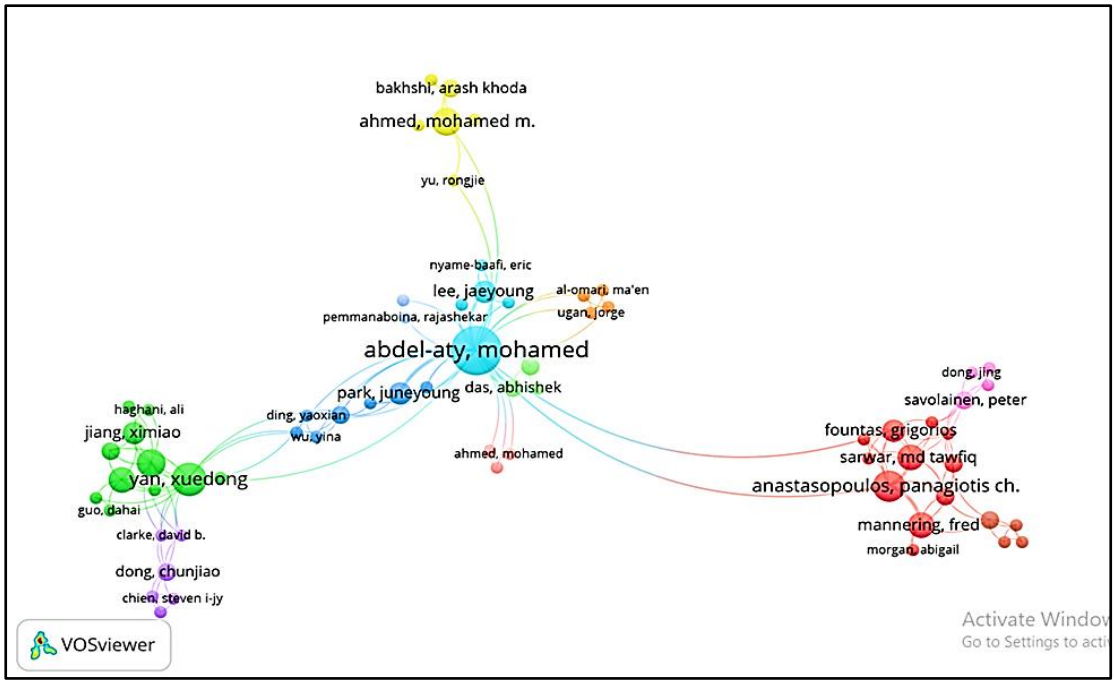

Figure 3. Network visualization map of the author

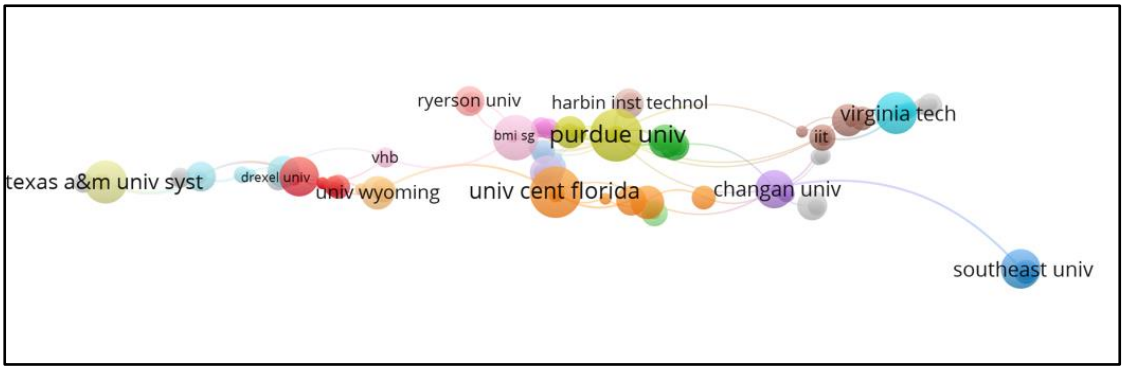

Figure 4. Network visualization map of the Institute

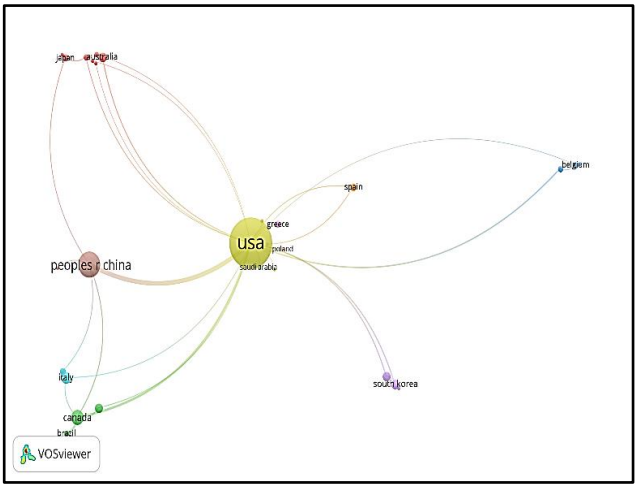

Figure 5. Network visualization map of the Country

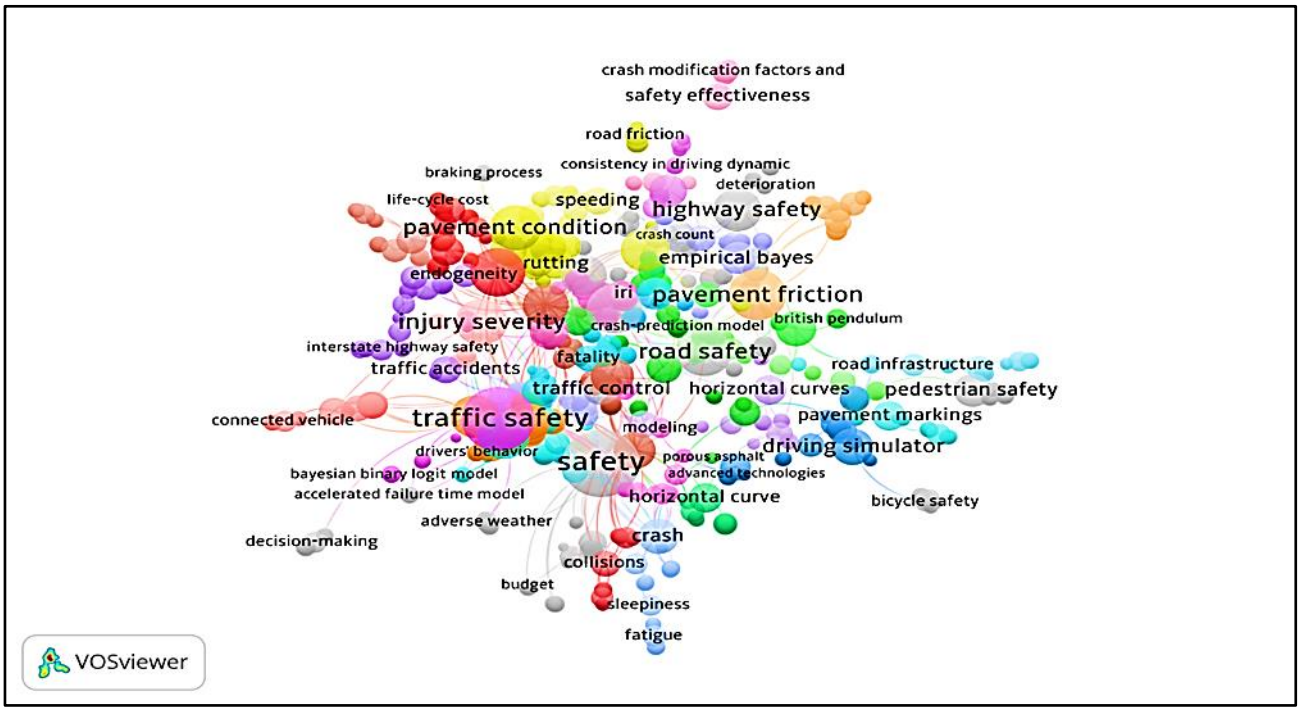

Figure 6. Network visualization map of keywords

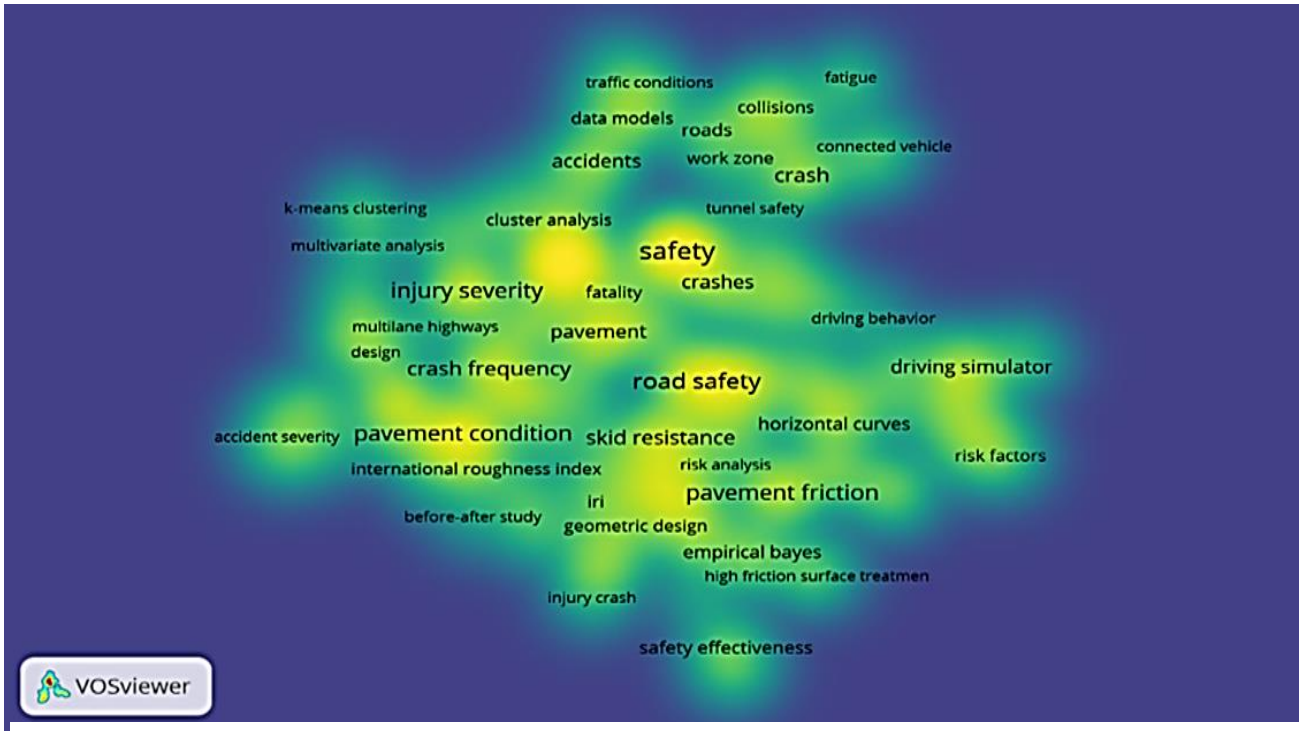

Figure 7. Density visualization map of keywords

4.1.1. Co-occurrence Measures

Figure 6 illustrates the joint author keywords, resulting in a total of 786 items in 45 cluster networks. Many nodes appear, each with its color and size, representing the impact of keywords and the degree to which they are used in the search engine, where we notice many keywords that can be used to find the most prominent research that links the relationship between pavement conditions, traffic safety, and the severity and frequency of accidents. The yellow color in Figure 7 shows the density visualization map of the co-occurrences. Road safety, pavement condition, pavement friction, highway safety, traffic safety, and injury severity are some of the high-density and closely related keywords. Each of these keywords helps the researcher find many types of published research. The large nodes show the most used keywords, and the line represents the degree of proximity between these words, as many keywords share one search. Many types of research have focused on the condition of pavement and its relationship to traffic safety [97-113].

5. Conclusion

The condition of the pavement and its deterioration is one of the main factors that increase the risk of accidents, as several studies have been presented that show the impact of pavement defects such as rutting, roughness, and skid resistance on traffic safety. The VOS program was used to meet the most important researchers who published about pavement defects and their relationship to accidents, and the degree of cooperation among them, including Abdel-aty. Mohamed; Yan. Xuedong; Anastaspoulos, Panagiotis Ch; Mannering, Fred; Ahmed.Mohamed m.; and Sarwar. MD Tawfiq. It also identified the most prominent countries interested in this topic of research, which is more influential than other countries in the dissemination of research, which is the United States, China, and Canada. Active collaborating universities on the subject of traffic safety and its relationship to accidents are the University of Central Florida, Virginia technology system, Pennsylvania State University, Changan University, and Texas A&M University System. Therefore, this research provides a map to guide researchers and the basics of research related to the relationship between pavement conditions and vehicle crashes.

6. Recommendation

Given the importance of pavement condition, which is considered one of the main contribution factors, especially after studies have proven its impact on traffic safety, it is recommended conducting extensive and comprehensive studies on the pavement in Iraq. Furthermore, studying all other factors contributing to pavement failure, especially since there are not enough local studies on this subject and there is no evidence of the possibility of applying the results of previous studies in Iraq because Iraq has a unique economic, and social environment that may not be applicable to the results of previous studies. Also, Iraq's infrastructure and access to resources may be different than in other countries where the studies were conducted, making it difficult to apply the same results. In addition, the data used in previous studies may not be applicable or available in Iraq, making it difficult to draw meaningful conclusions from them.

For that, when conducting research about pavement condition related traffic safety, it is important to consider the following:

1. Identify the types of pavement conditions that may have an impact on traffic safety. This includes factors such as surface texture, surface roughness, and potholes.
2. Collect data on the pavement conditions in different areas and analyze it to determine if there is a correlation between pavement condition and traffic safety.
3. Develop a survey to collect information from drivers about their experiences with different types of pavement conditions and how they affect their driving behavior.
4. Analyze the survey results to identify any patterns or trends in how different types of pavement conditions affect driver behavior and traffic safety.
5. Use the data collected from the survey and analysis to develop recommendations for improving pavement conditions to improve traffic safety.

Finally, it is crucial that periodic maintenance be performed and that the pavement condition be continuously evaluated to control pavement defects and treat them before the pavement condition deteriorates and fails.

Authors' contribution

All authors contributed equally to the preparation of this article.

Declaration of competing interest

The authors declare no conflicts of interest.

Funding source

This study didn't receive any specific funds.

REFERENCES

[1] Garber, N. J., & Hoel, L. A. (2009). Traffic and highway engineering. Cengage Learning.

[2] World Health Organization. (2018). Global status report on road safety 2018.

[3] Elghriany, A., Yi, P., Liu, P., & Yu, Q. (2016). Investigation of the effect of pavement roughness on crash rates for rigid pavement. *Journal of Transportation Safety and Security*, *8*(2), 164–176. https://doi.org/10.1080/19439962.2015.1025458

[4] Zubaidi, H., Alnedawi, A., Obaid, I. and Abadi, M.G., 2022. Injury severities from heavy vehicle accidents: An exploratory empirical analysis. Journal of traffic and transportation engineering (English edition), 9(6), pp.991-1002. https://doi.org/10.1016/j.jtte.2021.02.009

[5] Tarko, A. P., Bar-Gera, H., Thomaz, J., & Issariyanukula, A. (2010). Model-based application of abbreviated injury scale to police-reported crash injuries. *Transportation Research Record*, *2148*, 59–68. https://doi.org/10.3141/2148-07

[6] Alnedawi, A., Ullah, S., Azam, A., Mousa, E., Obaid, I., & Yosri, A. (2022). Integrated and holistic knowledge map of resilient modulus studies for pavement materials: A scientometric analysis and bibliometric review of research frontiers and prospects. In Transportation Geotechnics (Vol. 33). Elsevier Ltd. https://doi.org/10.1016/j.trgeo.2021.100711

[7] Caffò, A. O., Tinella, L., Lopez, A., Spano, G., Massaro, Y., Lisi, A., Stasolla, F., Catanesi, R., Nardulli, F., Grattagliano, I., & Bosco, A. (2020). The drives for driving simulation: A scientometric analysis and a selective review of reviews on simulated driving research. In *Frontiers in Psychology* (Vol. 11). Frontiers Media S.A. https://doi.org/10.3389/fpsyg.2020.00917

[8] Kim, M. C., & Chen, C. (2015). A scientometric review of emerging trends and new developments in recommendation systems. Scientometrics, 104(1), 239–263. https://doi.org/10.1007/s11192-015-1595-5

[9] Olawumi, T. O., & Chan, D. W. M. (2018). A scientometric review of global research on sustainability and sustainable development. In Journal of Cleaner Production (Vol. 183, pp. 231–250). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2018.02.162

[10] Ospina-Mateus, H., Quintana Jiménez, L. A., Lopez-Valdes, F. J., & Salas-Navarro, K. (2019). Bibliometric analysis in motorcycle accident research: a global overview. Scientometrics, 121(2), 793–815. https://doi.org/10.1007/s11192-019-03234-5

[11] Zou, X., Yue, W. L., & Vu, H. le. (2018). Visualization and analysis of mapping knowledge domain of road safety studies. Accident Analysis and Prevention, 118, 131–145. https://doi.org/10.1016/j.aap.2018.06.010

[12] Das, S., & Al-Zubaidi, H. (2021). Last Forty Years of ITE Journal Articles: A Scientometric Overview Transportation Safety Planning (TSP) Noteworthy Practices View project Coauthor Network Project View project. https://www.ite.org/publications/ite-journal/last-forty-years-of-ite-journal-articles-a-scientometric-overview/

[13] Hughes, B. P., Newstead, S., Anund, A., Shu, C. C., & Falkmer, T. (2015). A review of models relevant to road safety. Accident Analysis and Prevention, 74, 250–270. https://doi.org/10.1016/j.aap.2014.06.003

[14] Vigneshkumar, & Salve, U. R. (2020). A scientometric analysis and review of fall from height research in construction. 1–19.

[15] Mohammed, A., Umar, S. Y., Samson, D., & Ahmad, T. Y. (2016). The Effect of Pavement Condition on Traffic Safety: A Case Study of Some Federal Roads in Bauchi State. IOSR Journal of Mechanical and Civil Engineering, 12(03), 139–146.https://doi.org/10.9790/1684-120301139146

[16] Mohagheghi, A., 2020. Effect of Pavement Condition on Traffic Crash Frequency and Severity in Virginia (Doctoral dissertation, Virginia Tech).

[17] Christoforou, Z., Cohen, S., & Karlaftis, M. G. (2010). Vehicle occupant injury severity on highways: An empirical investigation. Accident Analysis and Prevention, 42(6), 1606–1620. https://doi.org/10.1016/j.aap.2010.03.019

[18] Abdel-Aty, M., Devarasetty, P. C., & Pande, A. (2009). Safety evaluation of multilane arterials in Florida. *Accident Analysis and Prevention*, *41*(4), 777–788. https://doi.org/10.1016/j.aap.2009.03.015

[19] Hughes, B.P., Newstead, S., Anund, A., Shu, C.C. and Falkmer, T., 2015. A review of models relevant to road safety. Accident Analysis & Prevention, 74, pp.250-270.

[20] Lozano, R., Naghavi, M., Foreman, K., Lim, S., Shibuya, K., Aboyans, V., Abraham, J., Adair, T., Aggarwal, R., Ahn, S. Y., AlMazroa, M. A., Alvarado, M., Anderson, H. R., Anderson, L. M., Andrews, K. G., Atkinson, C., Baddour, L. M., Barker-Collo, S., Bartels, D. H., … Murray, C. J. L. (2012). Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: A systematic analysis for the Global Burden of Disease Study 2010. The Lancet, 380(9859), 2095–2128. https://doi.org/10.1016/S0140-6736(12)61728-0

[21] Obaid, I., Alnedawi, A., Aboud, G. M., Tamakloe, R., Zuabidi, H., & Das, S. (2022). Factors associated with driver injury severity of motor vehicle crashes on sealed and unsealed pavements: Random parameter model with heterogeneity in means and variances. International Journal of Transportation Science and Technology. https://doi.org/10.1016/j.ijtst.2022.04.002

[22] Washington, S., Karlaftis, M., Mannering, F., & Anastasopoulos, P. (2020). Statistical and Econometric Methods for Transportation Data Analysis. https://www.crcpress.com/go/ids

[23] Zubaidi, H. A., Anderson, J. C., & Hernandez, S. (2020). Understanding roundabout safety through the application of advanced econometric techniques. International Journal of Transportation Science and Technology, 9(4), 309–321. https://doi.org/10.1016/j.ijtst.2020.03.001

[24] Aldhalemi, A., & Abidi, F. (2022, March 3). Evaluation of the Iraqi Road Safety System in Light of Crash Severity Indicators. https://doi.org/10.4108/eai.7-9-2021.2314895

[25] Leidman, E., Maliniak, M., Sultan, A. S. S., Hassan, A., Hussain, S. J., & Bilukha, O. O. (2016). Road traffic fatalities in selected governorates of Iraq from 2010 to 2013: Prospective surveillance. Conflict and Health, 10(1). https://doi.org/10.1186/s13031-016-0070-0

[25] Darma, Y., Karim, M. R., & Abdullah, S. (2017). An analysis of Malaysia road traffic death distribution by road environment. Sadhana - Academy Proceedings in Engineering Sciences, 42(9), 1605–1615. https://doi.org/10.1007/s12046-017-0694-9

[26] Lee, J., Nam, B. H., & Abdel-Aty, M. (2015). Effects of pavement surface conditions on traffic crash severity. Journal of Transportation Engineering, 141(10). https://doi.org/10.1061/(ASCE)TE.1943-5436.0000785

[27] Han, X., Xiang, Q., & Leng, H. (2011). Evaluating the Effect of Freeway Pavement Conditions on Traffic Flow Stability

[28] Zubaidi, H. A., Obaid, I. A., Alnedawi, A., & Das, S. (2021). Motor vehicle driver injury severity analysis utilizing a random parameter binary probit model considering different types of driving licenses in 4-legs roundabouts in South Australia. Safety Science, 134. https://doi.org/10.1016/j.ssci.2020.105083

[29] Das, S., Datta, S., Zubaidi, H. A., & Obaid, I. A. (2021). Applying interpretable machine learning to classify tree and utility pole related crash injury types. IATSS Research, 45(3), 310–316. https://doi.org/10.1016/j.iatssr.2021.01.001

[30]Abdel-Aty, M., Devarasetty, P. C., & Pande, A. (2009). Safety evaluation of multilane arterials in Florida. Accident Analysis and Prevention, 41(4), pp.777–788. https://doi.org/10.1016/j.aap.2009.03.015

[31] Cenek, P. D., Henderson, R. J. (Robert J., Forbes, M. C., Davies, R. B., Tait, A., & NZ Transport Agency. (2014). The relationship between crash rates and rutting.

[32] Chandra, S., Sekhar, C. R., Bharti, A. K., & Kangadurai, B. (2013). Relationship between pavement roughness and distress parameters for indian highways. Journal of Transportation Engineering, 139(5), 467–475. https://doi.org/10.1061/(ASCE)TE.1943-5436.0000512

[33] Pinatt, J. M., Chicati, M. L., Ildefonso, J. S., & Filetti, C. R. G. D. arce. (2020). Evaluation of pavement condition index by different methods: Case study of Maringá, Brazil. Transportation Research Interdisciplinary Perspectives, 4. https://doi.org/10.1016/j.trip.2020.100100

[34] Solla, M., Lagüela, S., González-Jorge, H., & Arias, P. (2014). Approach to identify cracking in asphalt pavement using GPR and infrared thermographic methods: Preliminary findings. NDT and E International, 62, 55–65. https://doi.org/10.1016/j.ndteint.2013.11.006

[35] Takallou, M. (2010). Safety Handbook for Oregon's Local Roads and Streets. www.up.edu/highwaysafety

[36] Huang, Y.H., 2004. Pavement analysis and design (Vol. 2, pp. 401-409). Upper Saddle River, NJ: Pearson Prentice Hall.

[37] Williams, S.G., 2003. The effects of HMA mixture characteristics on rutting susceptibility.TransportationResearchBoard.https://www.researchgate.net/publication/266487664

[38] Kandhal, P.S. and Mallick, R.B., 2001. Effect of mix gradation on rutting potential of dense-graded asphalt mixtures. Transportation Research Record, 1767(1), pp.146-151. https://doi.org/10.3141/1767-18

[39] Hicks, R. G., Seeds, S. B., & Peshkin, D. G. (2000). Selecting a preventive maintenance treatment for flexible pavements (Issue 202). http://fp2.org

[40] Start, M.R., Kim, J. and Berg, W.D., 1998. Potential safety cost-

effectiveness of treating rutted pavements. Transportation research record, 1629(1), pp.208-213.

[41] Anastasopoulos, P. C., & Mannering, F. L. (2009). A note on modeling vehicle accident frequencies with random-parameters count models. Accident Analysis and Prevention, 41(1), 153–159. https://doi.org/10.1016/j.aap.2008.10.005

[42] Al-Humeidawi, B. H. (2016). Experimental Characterization of Rutting Performance of HMA Designed with Aggregate Gradations According to Superpave and Marshall Methods. World Journal of Engineering and Technology, 04(03), 477–487. https://doi.org/10.4236/wjet.2016.43048

[43] King, B.A., 2014. The effect of road roughness on traffic speed and road safety.

[44] Alhasan, A., Nlenanya, I., Smadi, O., & MacKenzie, C. A. (2018). Impact of pavement surface condition on roadway departure crash risk in Iowa. Infrastructures, 3(2). https://doi.org/10.3390/infrastructures3020014

[45] Yu, B., & Lu, Q. (2014). Empirical model of roughness effect on vehicle speed. International Journal of Pavement Engineering, 15(4), 345–351. https://doi.org/10.1080/10298436.2013.792931

[46] Chandra, S. (2004). Effect of Road Roughness on Capacity of Two-Lane Roads. https://doi.org/10.1061/ASCE0733-947X2004130:3360

[47] Arhin, S.A., Williams, L.N., Ribbiso, A. and Anderson, M.F., 2015. Pavement condition index, international roughness index, ride quality, prediction, urban areas; pavement condition index, international roughness index, ride quality, prediction, urban areas. J. Civ. Eng. Res, 2015(1), pp.10-17. https://doi.org/10.5923/j.jce.20150501.02

[48] Chen, S., Saeed, T.U. and Labi, S., 2017. Impact of road-surface condition on rural highway safety: A multivariate random parameters negative binomial approach. Analytic methods in accident research, 16, pp.75-89.

[49] Wang, T., Harvey, J., Lea, J. and Kim, C., 2014. Impact of pavement roughness on vehicle free-flow speed. Journal of transportation engineering, 140(9), p.04014039. https://doi.org/10.1061/(ASCE)TE.1943-5436.0000689

[50] Al-Humeidawi, B. H., Chafat, O. H., Dheyaa, E., & Al-Zubaidi, A. (2021). Evaluation for the effect of pavement type on the total life cost and environmental aspects of roads. 9(3), 266–276.

[51] Nguyen, X., Nguyen, T., & Hoa Tran, P. (2020). The Effect of Road Surface Roughness to Recommended Speed of Vehicles. IOP Conference Series: Materials Science and Engineering, 886(1). https://doi.org/10.1088/1757-899X/886/1/012014

[52] Mayora, J. M. P., & Piña, R. J. (2009). An assessment of the skid resistance effect on traffic safety under wet-pavement conditions. Accident Analysis and Prevention, 41(4), 881–886. https://doi.org/10.1016/j.aap.2009.05.004

[53]Kuttesch, J. S., Trani, A., Kevin, M., & Mcghee, K. (2004). Quantifying the Relationship between Skid Resistance and Wet Weather Accidents for Virginia Data.

[54] Andriejauskas, T., Vorobjovas, V., & Mielonas, V. (2014). Evaluation of skid resistance characteristics and measurement methods. 9th International Conference on Environmental Engineering, ICEE 2014. https://doi.org/10.3846/enviro.2014.141

[55] Tyfour, W. R. (2009). Tire Skid Resistance on Contaminated Wet Pavements. In Jordan Journal of Mechanical and Industrial Engineering (Vol. 3, Issue 2).

[56] Hossain, Z., Chowdhury, N. H., & Braham, A. (2018). Forensic Evaluation of Premature Pavement Failures in Arkansas. Journal of Performance of Constructed Facilities, 32(3). https://doi.org/10.1061/(asce)cf.1943-5509.0001141

[57] Jitsangiam, P., Nusit, K., & Nikraz, H. (2019). An Evaluation of Moisture Damage Resistance of Asphalt Concrete based on Dynamic Creep Characteristics. KSCE Journal of Civil Engineering, 23(4), 1610–1616. https://doi.org/10.1007/s12205-019-1369-3

[58] Mongeon, P., & Paul-Hus, A. (2016). The journal coverage of Web of Science and Scopus: a comparative analysis. Scientometrics, 106(1), 213–228. https://doi.org/10.1007/s11192-015-1765-5

[59] Pranckutė, R. (2021). Web of science (Wos) and scopus: The titans of bibliographic information in today's academic world. In Publications (Vol. 9, Issue 1). MDPI AG. https://doi.org/10.3390/publications9010012

[60] Soosaraei, M., Khasseh, A. A., Fakhar, M., & Hezarjaribi, H. Z. (2018). A decade bibliometric analysis of global research on leishmaniasis in Web of Science database. In Annals of Medicine and Surgery (Vol. 26, pp. 30–37). Elsevier Ltd. https://doi.org/10.1016/j.amsu.2017.12.014

[61] He, Y., Feng, Q., Yan, L., & Lu, X. Y. (2022). Visualization and Analysis of Mapping Knowledge Domain of Heterogeneous Traffic Flow. Computational Intelligence and Neuroscience, 2022. https://doi.org/10.1155/2022/7754961

[62] Li, J., Guo, X., Shen, S., & Aleksandar, J. (2014). Bibliometric mapping of "International Symposium on Safety Science and Technology (1998-2012)." Procedia Engineering, 84, 70–79. https://doi.org/10.1016/j.proeng.2014.10.411

[63] Li, W. H., Hadizadeh, M., Yusof, A., & Naharudin, M. N. (2022). Analysis of Research Trends on Elbow Pain in Overhead Sports: A Bibliometric Study Based on Web of Science Database and VOSviewer. Healthcare, 10(11), 2242. https://doi.org/10.3390/healthcare10112242

[64] Zou, X., Vu, H. L., & Huang, H. (2020). Fifty Years of Accident Analysis & Prevention: A Bibliometric and Scientometric Overview. Accident Analysis and Prevention, 144. https://doi.org/10.1016/j.aap.2020.105568

[65] Jan van Eck, N., & Waltman, L. (2022). VOSviewer Manual.

[66] Gautam, P. (2021). A Web of Science based bibliometric reconnaissance of the Himalaya-Karakoram-Hindukush-Tibet region with focus on field sciences. Journal of Nepal Geological Society, 62, 18–33. https://doi.org/10.3126/jngs.v62i0.38690

[67] Kolesnykova, T., Matveyeva, O., Manashkin, L., & Mìshchenko, M. (2019). Railway transportation of dangerous goods: a bibliometric aspect. MATEC Web of Conferences, 294, 03014. https://doi.org/10.1051/matecconf/201929403014

[68] Musa, H. H., El-Sharief, M., Musa, I. H., Musa, T. H., & Akintunde, T. Y. (2021). Global scientific research output on sickle cell disease: A comprehensive bibliometric analysis of web of science publication. In Scientific African (Vol. 12). Elsevier B.V. https://doi.org/10.1016/j.sciaf.2021.e00774

[69] Xue, J., Reniers, G., Li, J., Yang, M., Wu, C., & van Gelder, P. H. A. J. M. (2021). A bibliometric and visualized overview for the evolution of process safety and environmental protection. International Journal of Environmental Research and Public Health, 18(11). https://doi.org/10.3390/ijerph18115985

[70] Başhan, V., Demirel, H., & Gul, M. (2020). An FMEA-based TOPSIS approach under single valued neutrosophic sets for maritime risk evaluation: the case of ship navigation safety. Soft Computing, 24(24), 18749–18764. https://doi.org/10.1007/s00500-020-05108-y

[71] Bhat, C. R. (2003). Simulation estimation of mixed discrete choice models using randomized and scrambled Halton sequences. Transportation Research Part B: Methodological, 37(9), 837–855. https://doi.org/10.1016/S0191-2615(02)00090-5

[72] Chen, S., Saeed, T. U., Alqadhi, S. D., & Labi, S. (2019). Safety impacts of pavement surface roughness at two-lane and multi-lane highways: accounting for heterogeneity and seemingly unrelated correlation across crash severities. Transportmetrica A: Transport Science, 15(1), 18–33.

https://doi.org/10.1080/23249935.2017.1378281

[73] Dey, G., Banerjee, P., Sharma, R. K., Maity, J. P., Etesami, H., Shaw, A. K., Huang, Y. H., Huang, H. bin, & Chen, C. Y. (2021). Management of phosphorus in salinity-stressed agriculture for sustainable crop production by salt-tolerant phosphate-solubilizing bacteria—a review. In Agronomy (Vol. 11, Issue 8). MDPI AG. https://doi.org/10.3390/agronomy11081552

[74] Flintsch, G. W., Ferne, B., Diefenderfer, B., Katicha, S., Bryce, J., & Nell, S. (2012). Evaluation of traffic-speed deflectometers. Transportation Research Record, 2304, 37–46. https://doi.org/10.3141/2304-05

[75] Garrido, R., Bastos, A., de Almeida, A., & Elvas, J. P. (2014). Prediction of road accident severity using the ordered probit model. Transportation Research Procedia, 3, 214–223. https://doi.org/10.1016/j.trpro.2014.10.107

[76] Hermans, E., Brijs, T., Wets, G., & Vanhoof, K. (2009). Benchmarking road safety: Lessons to learn from a data envelopment analysis. Accident Analysis and Prevention, 41(1), 174–182. https://doi.org/10.1016/j.aap.2008.10.010

[77] Li, W., Han, Y., Wang, P., & Guan, H. (2019). Invulnerability analysis of traffic network in tourist attraction under unexpected emergency events based on cascading failure. IEEE Access, 7, 147383–147398. https://doi.org/10.1109/ACCESS.2019.2946737

[78] Li, Y., & Huang, J. (2014). Safety impact of pavement conditions. In Transportation Research Record (Vol. 2455, pp. 77–88). National Research Council. https://doi.org/10.3141/2455-09

[79] Shah, S. A. R., Ahmad, N., Shen, Y., Pirdavani, A., Basheer, M. A., & Brijs, T. (2018). Road safety risk assessment: An analysis of transport policy and management for low-, middle-, and high-income Asian countries. Sustainability (Switzerland), 10(2). https://doi.org/10.3390/su10020389

[80] Zhang, H., Wang, Q., He, S., Wu, K., Ren, M., Dong, H., Di, J., Yu, Z., & Huang, C. (2020). Ambient air pollution and gestational diabetes mellitus: A review of evidence from biological mechanisms to population epidemiology. In Science of the Total Environment (Vol. 719). Elsevier B.V. https://doi.org/10.1016/j.scitotenv.2020.137349

[81] Anastasopoulos, P.C. and Mannering, F.L., 2009. A note on modeling vehicle accident frequencies with random-parameters count models. Accident Analysis & Prevention, 41(1), pp.153-159. https://doi.org/10.1016/j.aap.2008.10.005

[82] Park, J., Abdel-Aty, M., & Wang, J. H. (2017). Time series trends of the safety effects of pavement resurfacing. Accident Analysis and Prevention, 101, 78–86. https://doi.org/10.1016/j.aap.2017.02.006

[83] Lee, J., Abdel-Aty, M., & Nyame-Baafi, E. (2020). Investigating the Effects of Pavement Roughness on Freeway Safety using Data from Five States. Transportation Research Record, 2674(2), 127–134. https://doi.org/10.1177/0361198120905834

[84] Chan, C. Y., Huang, B., Yan, X., & Richards, S. (2009). Relationship between highway pavement condition, crash frequency, and crash type. Journal of Transportation Safety and Security, 1(4), 268–281. https://doi.org/10.1080/19439960903391395

[85] Baskara, S. N., Yaacob, H., Hainin, R., & Hassan, S. A. (2016). Jurnal Teknologi Full Paper accident due to pavement condition-a review (Vol. 78). www.jurnalteknologi.utm.my

[86] Chan, C. Y., Huang, B., Yan, X., & Richards, S. (2010). Investigating effects of asphalt pavement conditions on traffic accidents in Tennessee based on the pavement management system (PMS). Journal of Advanced Transportation, 44(3), 150–161. https://doi.org/10.1002/atr.129

[87] Jrew, B., Abojaradeh, M., Msallam, M., & AL-Kakaie, S. (2015). Management of Traffic Accidents for Principle Urban Streets in Arbil City Iraq.

[88] Mohammed, A., Ambak, K. bin, Mosa, A., & Syamsunur, D. (2018). Traffic Accidents Trends and Characteristics in Iraq. https://www.researchgate.net/publication/312021596

[89] Mkwata, R., & Chong, E. E. M. (2022). Effect of pavement surface conditions on road traffic accident - A Review. E3S Web of Conferences, 347, 01017. https://doi.org/10.1051/e3sconf/202234701017

[90] Isradi, M., Dwiatmoko, H., Subhana, A., Prasetijo, J., & Hartatik, N. (2020). Evaluation Of The Road Pavement Damage With Bina Marga Method And Pavement Condition Index Method.

[91] Dhahad, N. S. (2015). Traffic Accidents in Thi Kar Government Causes and Solutions

[92] Siriphun, S., Horpibulsuk, S., Chotisakul, S., Suddeepong, A., Chinkulkijniwat, A., & Arulrajah, A. (2019). Effect of cumulative traffic and statistical predictive modelling of field skid resistance. Road Materials and Pavement Design, 20(2), 426–439. https://doi.org/10.1080/14680629.2017.1385511

[93] Tsubota, T., Yoshii, T., Shirayanagi, H., & Kurauchi, S. (2018). Effect of Pavement Conditions Accident Risk in Rural Expressways.

[94] Christensen, P. (Writer on transportation), Ragnøy, Arild., & Transport økonomisk institutt (Norway). (2006). Vegdekkets tilstand og trafikksikkerhet : betydningen av spordybde, ujevnhet og endringer i tverrfall for ulykkesrisikoen. Transportøkonomisk institutt.

[95] Joni, H. H., Al-Dahawi, A. M., & Al-Tamimi, O. J. (2019). Analysis of Road Accidents in Baghdad City. Association of Arab Universities Journal of Engineering Sciences, 26(1), 136–144. https://doi.org/10.33261/jaaru.2019.26.1.018

[96] Awad, H. A., & Parry, T. (2018). Investigation the Effect of Pavement Condition Characteristics on Bend Segments Accident Frequency: Application of Fixed and Random Parameters Negative Binomial Models.

[97] Al-Masaeid, H. R. (1997). Impact of pavement condition on rural road accidents. Canadian Journal of Civil Engineering, 24(4), 523–531. https://doi.org/10.1139/cjce-24-4-523

[98] Asad, F. (2017). Road traffic accidents in iraq: a review of evidence-based literature. International journal for traffic and transport engineering, 7(2). https://doi.org/10.7708/ijtte.2017.7(2).09

[99] Olawumi, T. O., & Chan, D. W. M. (2018). A scientometric review of global research on sustainability and sustainable development. In Journal of Cleaner Production (Vol. 183, pp. 231–250). https://doi.org/10.1016/j.jclepro.2018.02.162

[100] Abdulwahab, A. M., Ismael, N. T., & Aboud, G. M. (2021). A Sustainable Framework to Reduce Traffic Accidents in Baghdad City. IOP Conference Series: Earth and Environmental Science, 779(1). https://doi.org/10.1088/1755-1315/779/1/012019

[101]Bock, M., Cardazzi, A., & Humphreys, B. R. (2021). Where the Rubber Meets the Road: Pavement Damage Reduces Traffic Safety and Speed. http://www.nber.org/papers/w2917

[102] Buddhavarapu, P., Banerjee, A., & Prozzi, J. A. (2013). Influence of pavement condition on horizontal curve safety. Accident Analysis and Prevention, 52, 9–18. https://doi.org/10.1016/j.aap.2012.12.010

[103] Hou, Q., Huo, X., & Leng, J. (2020). A correlated random parameters tobit model to analyze the safety effects and temporal instability of factors affecting crash rates. Accident Analysis and Prevention, 134. https://doi.org/10.1016/j.aap.2019.105326

[104] Hussein, N., Hassan, R., & Fahey, M. T. (2021). Effect of pavement condition and geometrics at signalised intersections on casualty crashes. Journal of Safety Research, 76, 276–288. https://doi.org/10.1016/j.jsr.2020.12.021

[105]Ivan, J. N., Ravishanker, N., Jackson, E., Aronov, B., & Guo, S. (2012). A Statistical Analysis of the Effect of Wet-Pavement Friction on Highway

Traffic Safety. Journal of Transportation Safety and Security, 4(2), 116–136. https://doi.org/10.1080/19439962.2011.620218

[106] Li, Y., Liu, C., & Ding, L. (2013). Impact of pavement conditions on crash severity. Accident Analysis and Prevention, 59, 399–406. https://doi.org/10.1016/j.aap.2013.06.028

[107] Naveen, N., Yadav, S. M., & Kumar, A. S. (2018). A Study on Potholes and Its Effects on Vehicular Traffic. In International Journal of Creative Research Thoughts (Vol. 6, Issue 1). www.ijcrt.org

[108] Oyewola, D. O., & Dada, E. G. (2022). Exploring machine learning: a scientometrics approach using bibliometrix and VOSviewer. SN Applied Sciences, 4(5). https://doi.org/10.1007/s42452-022-05027-7

[109] Schrank, D. (2007). THE 2007 URBAN MOBILITY REPORT. http://mobility.tamu.edu

[110] Solla, M., Lagüela, S., González-Jorge, H., & Arias, P. (2014). Approach to identify cracking in asphalt pavement using GPR and infrared thermographic methods: Preliminary findings. NDT and E International, 62, 55–65. https://doi.org/10.1016/j.ndteint.2013.11.006

[111] Stewart, B. T., Lafta, R., al Shatari, S. A. E., Cherewick, M., Flaxman, A., Hagopian, A., Burnham, G., & Kushner, A. L. (2016). Fall injuries in Baghdad from 2003 to 2014: Results of a randomised household cluster survey. Injury, 47(1), 244–249. https://doi.org/10.1016/j.injury.2015.11.006

[112] Tsai, Y.-C. (James), & Chatterjee, A. (2018). Pothole Detection and Classification Using 3D Technology and Watershed Method. Journal of Computing in Civil Engineering, 32(2). https://doi.org/10.1061/(asce)cp.1943-5487.0000726

[113] Vinayakamurthy, M., Mamlouk, M., Underwood, B., & Kaloush, K. (2017). Effect of Pavement Condition on Accident Rate.