

# Urban Arterial Road Flooding: A Bibliometric Review of Causes and Research Trends (2000–2024)

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**ABSTRACT:** Flooding on urban arterial roads has become an increasingly frequent problem, particularly in rapidly urbanizing cities experiencing higher rainfall intensity. Flooding on major roads, which are crucial for city transportation and the economy, often causes traffic jams, makes it harder to get around, and creates safety risks. This research seeks to investigate prevailing research trends and pinpoint significant factors associated with flooding on urban arterial roads, employing a bibliometric methodology. A systematic literature review was undertaken, utilizing publications indexed in Scopus and Google Scholar spanning the years 2000 to 2024. A total of 928 pertinent articles were retrieved through the application of the keywords "flood," "urban road," and "drainage." Subsequently, bibliometric analysis was conducted using Publish or Perish, VOSviewer, and Microsoft Excel to evaluate publication trends, citation patterns, author collaboration networks, keyword co-occurrence, and journal distribution. The data reveal a significant increase in academic publications over the past decade, indicating a growing scholarly interest in the effects of flooding on transportation systems. An analysis of keywords shows that the main research areas include urban drainage performance, changes in land use, flood risk assessment, and simulation-based modeling. The most frequently cited studies consistently identify inadequate drainage infrastructure, rapid urban development, and increasing rainfall intensity as the key drivers of flooding events on urban arterial roads. Flooding events that impact urban thoroughfares constitute a multifaceted challenge. The interplay of water flow, existing infrastructure conditions, and urban planning methodologies underpins this particular challenge. This study provides a thorough analysis of the existing scholarly literature, identifying shortcomings in the functional performance of critical transportation routes. Consequently, it presents insights designed to guide future research initiatives and the improvement of urban infrastructure.

**KEYWORDS:** Flooding; urban roads; urbanization; drainage system; mobility.

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## 1. Introduction

Flooding is one of the most frequent and destructive natural disasters affecting many regions worldwide. Flood events have surged in both frequency and intensity over the past several decades, making them a major global concern [1]. Densely populated coastal and urban areas stand out as particularly vulnerable, owing to explosive population increases and rampant land

conversion [2]. Moreover, the interplay between climate change and accelerated urbanization has intensified flooding frequency and extent across numerous global locations [3]. Consequently, floodwaters inundate typically dry lands, inflicting harm on agricultural fields, impairing critical infrastructure, displacing residents, and triggering substantial economic losses [4].

Indonesia often finds itself in the crosshairs of disaster, facing a range of threats, both natural and man-made. Indonesia's location at the crossroads of three major tectonic plates—the Eurasian, Indo-Australian, and Pacific—leaves it highly exposed to earthquakes, volcanic activity, and tsunamis. Adding to this, roughly 13% of the globe's active volcanoes dot the Indonesian archipelago, presenting ongoing hazards to local populations [5]. Beyond geological hazards, flooding constitutes one of the most frequent disasters in Indonesia. Recent studies from diverse Asian settings highlight a clear association between urban expansion, shifts in land use, and an increasing frequency of flood occurrences [6]. Road infrastructure forms a central component of urban systems, designed to sustain economic activities and facilitate the movement of people and goods. Within burgeoning urban centers, road networks are indispensable for sustaining urban functionality and accessibility [7]. Nevertheless, urban road transportation systems are increasingly vulnerable to pluvial flooding, or surface flooding, which transpires when rainfall-induced runoff surpasses drainage capacity, a consequence of extensive impervious surfaces and deficient drainage systems [8]. Flooding events significantly impair the functionality of transportation networks, often compromising road safety, causing travel delays, mandating route modifications, and sometimes leading to trip cancellations [9]. Globally, urban flooding causes about 39% of the yearly damage to transportation networks, underscoring its heavy toll on city movement and economic activity [8].

Urban areas now face more frequent and severe rainfall-induced flooding, particularly where drainage infrastructure lags behind rapid city expansion [4]. Swelling populations and intensified development—spanning housing, industry, and commerce—sharpen these problems, worsening floods and water stagnation [10]. In metropolitan regions like Jakarta, alterations in land use have diminished the natural capacity for water infiltration and modified surface runoff dynamics, thereby overburdening existing drainage systems. As a result, cities downstream struggle to handle increased runoff because their drainage systems are already at capacity, which leads to repeated flooding [11].

Road flooding, often a consequence of deficient drainage systems or poor engineering, frequently leads to traffic congestion, accelerated pavement deterioration, and reduced road usability [12]. These impacts are intensified by heavy rainfall, thus positioning flood-related incidents as the primary weather-related factor in transport network disruption [13]. Consequently, in addition to the direct physical destruction, flooding precipitates indirect repercussions, encompassing prolonged traffic disruptions, interruptions to manufacturing and distribution networks, and broader economic inefficiencies, all of which substantially increase the total costs linked to flood occurrences [14]. Moreover, climate change has exacerbated hydrological extremes, resulting in more frequent and intense precipitation events, thereby heightening the likelihood of severe flooding within urban environments [15]. The onset and severity of urban flooding are shaped by a complex set of interacting factors, including environmental, infrastructural, and governance-related elements.

Drainage infrastructure plays a vital role in controlling surface runoff and preventing water ponding in urban areas. Sustainable Urban Drainage Systems (SUDS) have been widely

advocated as an integrated strategy that combines green spaces and engineered elements—such as green roofs, rain gardens, and permeable pavements—to mimic natural hydrological processes and improve urban resilience to extreme rainfall [16]. Nevertheless, poorly designed or inadequately maintained drainage systems significantly increase the likelihood of urban flooding, particularly along major road corridors [10, 12].

Rainfall characteristics are a crucial factor in determining the occurrence of floods. Unusual weather patterns, like La Niña, are strongly linked to increased rainfall in Indonesia, which often leads to widespread flooding [17]. Furthermore, climate change is projected to intensify both the intensity and frequency of rainfall, consequently heightening flood risks in areas experiencing rapid urbanization [18]. Considering the inherent variability of rainfall, sophisticated data processing methodologies, encompassing data mining and machine learning, have gained prominence in the analysis of extensive datasets, the identification of concealed patterns, and the enhancement of flood prediction and early warning systems [19–21].

Topography significantly influences flood vulnerability, as the slope and elevation of land affect how surface water moves. Areas that are flat and at low elevations often collect water because they lack natural drainage, which makes them more susceptible to flooding. In contrast, steep areas can experience quick runoff and flash floods downstream [22]. Indonesia's geography, characterized by lowlands, river basins, and coastal plains, increases flood risks, particularly in downstream areas that receive large amounts of runoff from upstream [23]. Therefore, thorough flood control studies highlight the importance of considering topography, rainfall patterns, river characteristics, land use, and urban infrastructure when developing effective flood mitigation strategies [24, 25]. However, data-driven flood mapping approaches may overlook traditional hydrological requirements and inherit limitations from historical datasets, which must be carefully addressed in flood risk assessments [26].

Despite extensive research on urban flooding, the effects on urban arterial roads, crucial for both urban mobility and economic activities, have not been adequately examined. Most recent research centers on broad urban flooding patterns, drainage networks, or hydrologic simulations, often neglecting how drainage shortfalls, land-use shifts, heavy rainfall, and terrain features interplay to impair arterial road performance. This research distinguishes itself by specifically highlighting urban arterial roads as critical infrastructure susceptible to flooding, thus incorporating hydrological, infrastructural, and spatial components within a cohesive analytical framework.

This research thus aims to pinpoint major factors driving floods on urban arterial roads and assess their fallout on public mobility and everyday routines. Its findings should equip better drainage designs and flood defenses, especially amid fast-expanding cities. Based on current research, urban road flooding is caused by a combination of how water moves, how well infrastructure can handle it, and how land is used. These factors together affect how vulnerable the transportation system is, which then leads to roads being flooded and travel being disrupted. The conceptual relationships among these variables are illustrated in Figure 1, which provides the analytical framework used to guide this study.

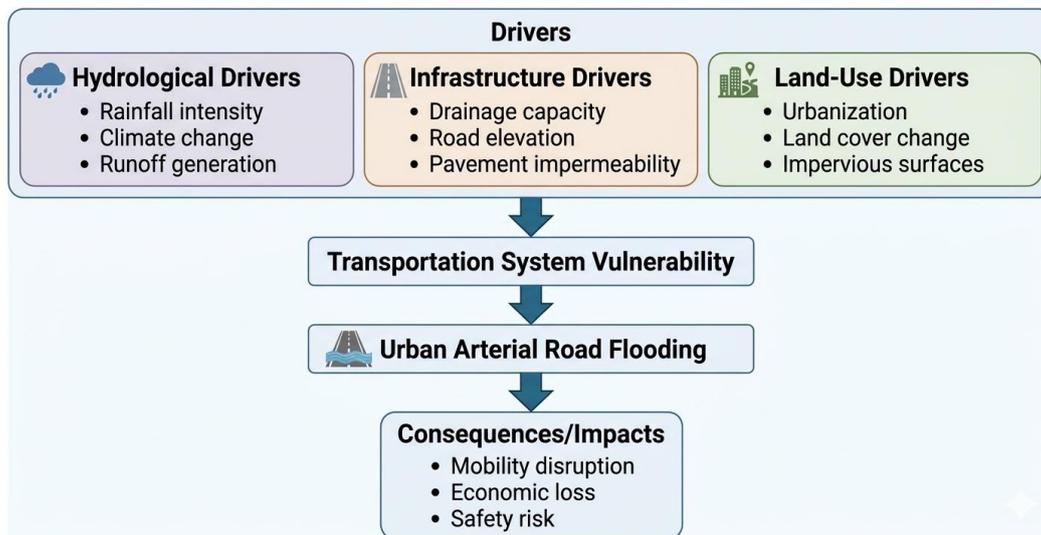


Figure 1. Conceptual framework of flooding on urban arterial roads.

## 2. Materials and Methods

This study employs a bibliometric analysis combined with systematic literature mapping to examine the scientific development of research related to flooding on urban arterial roads. Bibliometric analysis was selected because it allows the quantitative exploration of publication patterns, knowledge structures, author collaborations, and thematic evolution within a research field. The literature dataset was retrieved from two internationally recognized academic databases: Scopus and Google Scholar. On 15 January 2025, we gathered data via Publish or Perish software (version 8.9.4512). This software allows for integrated retrieval and citation analysis across several academic databases.

To find relevant publications for this study, a structured Boolean search was performed. The database query employed the following search string: TITLE-ABS-KEY ("flood" OR "urban flood" OR "pluvial flood\*") AND ("urban road\*" OR "arterial road\*" OR "transport\* network\*" OR "road infrastructure") AND ("drainage" OR "stormwater" OR "urban drainage system") The field tag TITLE-ABS-KEY was utilized to limit the search to article titles, abstracts, and keywords within the Scopus database, thereby ensuring topical relevance.

To account for variations in keyword forms, wildcard symbols, such as the asterisk (\*), were employed (e.g., flood, floods, flooding). The search parameters were restricted to publications spanning from January 2000 to December 2024, thereby facilitating the identification of both enduring research trajectories and contemporary advancements. The initial search returned 928 records. The dataset was subsequently subjected to a screening procedure designed to enhance its quality and uniformity. Duplicate entries present within the two databases were eliminated, leading to the removal of two records. During the title and abstract screening phase, publications failing to satisfy the inclusion criteria—including non-English articles, editorial notes, incomplete metadata, and documents irrelevant to transportation infrastructure or urban flooding—were excluded. After this filtering process, a total of 924 publications were retained for bibliometric analysis.

The inclusion criteria consisted of peer-reviewed journal articles and conference proceedings written in English and related to urban flooding, drainage systems, road infrastructure, or transportation vulnerability. To ensure consistency in the citation analysis, we excluded books, book chapters, theses, editorials, and non-scientific documents. The

bibliographic records were exported in RIS format from Publish or Perish and subsequently processed using Microsoft Excel for data cleaning, duplicate verification, and preliminary statistical analysis. Excel was used to calculate annual publication trends, citation counts, and document distributions.

For network visualization and scientometric mapping, the dataset was analyzed using VOSviewer (version 1.6.20). This software enables the construction of bibliometric networks including co-authorship networks, citation networks, and keyword co-occurrence structures. The analysis included mapping how authors worked together, assessing the impact of citations, examining how keywords appeared together, and grouping related themes. Figure 2 presents a PRISMA-style flow diagram, which summarizes the stages of literature identification, screening, eligibility assessment, and final inclusion employed in this investigation. A comparative analysis of the bibliographic outcomes derived from Scopus and Google Scholar was undertaken to evaluate potential database bias and ascertain the dataset's robustness. This comparison encompassed the number of records retrieved, citation counts, and bibliometric indicators, including the h-index. The results of this comparison are presented in Table 1.

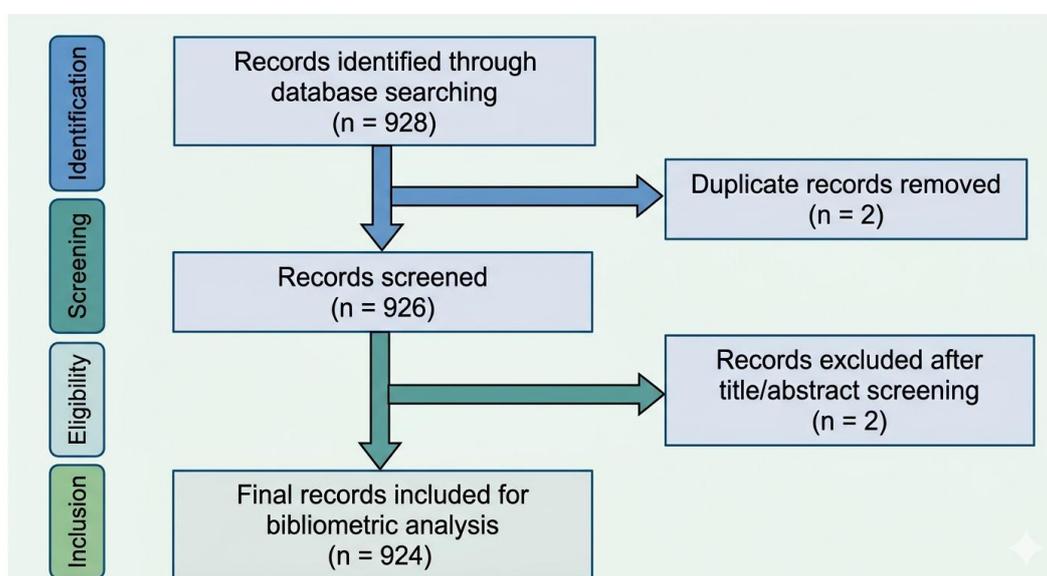


Figure 2. PRISMA flow diagram of the literature screening process

Table 1. Comparison of bibliographic results from Scopus and Google Scholar.

Database	Records Retrieved	Total Citations	Average Citations per Paper	H-index
Scopus	512	10,843	21.2	46
Google Scholar	416	15,927	38.3	58
Combined Dataset	928	26,770	28.8	52

A comparative analysis of Scopus and Google Scholar reveals notable differences in citation metrics between the two databases. Google Scholar generally exhibits elevated citation counts and h-index values, a consequence of its broader indexing scope, which encompasses theses, reports, and non-peer-reviewed documents. This expansive coverage potentially contributes to citation inflation when contrasted with databases like Scopus, which are more selective. Nevertheless, the thematic structure, as determined by keyword co-occurrence analysis, demonstrates considerable consistency across both datasets, suggesting that the inclusion of Google Scholar does not significantly disrupt the core intellectual framework of the discipline.

Beyond identifying the most highly cited individual studies, the top-cited literature was further categorized into thematic research domains in order to better understand the intellectual structure of the field. The classification groups the most influential publications into major themes such as climate-driven floods, urban drainage systems, GIS-based flood modeling, resilience strategies, and governance approaches. Table 2 summarizes the thematic distribution of these frequently cited studies. In the VOSviewer analysis, a minimum keyword occurrence threshold of 5 was applied. The association strength normalization method was used for network construction, and the clustering resolution parameter was set to the default value to identify thematic clusters.

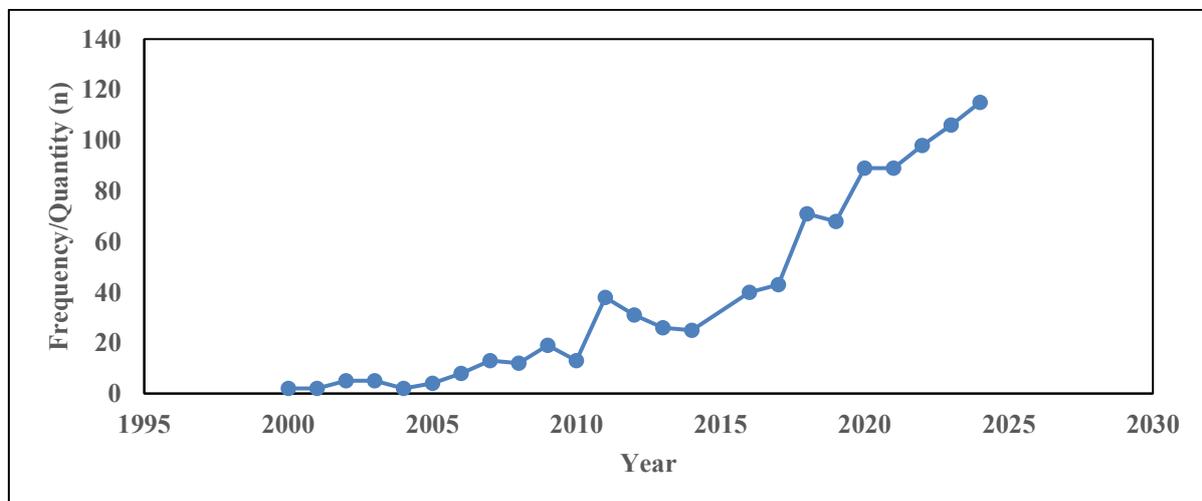
**Table 2.** Thematic classification of the top-cited literature.

Theme	Example Topics	Number of Papers
Climate-driven floods	climate change impacts, rainfall intensity	14
Urban drainage systems	stormwater infrastructure, drainage design	11
GIS and flood modelling	flood mapping, hazard zoning	10
Urban resilience	flood adaptation strategies	8
Governance and planning	urban policy and flood management	7

### 3. Results and Discussion

#### 3.1. Number of articles published per year.

The annual distribution of publications related to flooding on urban arterial roads provides an overview of how research interest in this topic has evolved over time. As shown in Figure 3, although the search period was set from 2000 to 2024, the retrieved publications extend from 2000 to 2025, yielding a total of 924 scientific articles. Publication output follows a clear upward trend, especially after 2010, and continues to rise until reaching 115 articles in 2024. This pattern indicates a growing global interest in urban flooding and its effects on transportation infrastructure. In addition to temporal trends, publication activity is distributed across various academic journals. The ten journals with the highest number of publications on this topic are summarized in Table 2. The publication growth pattern suggests a substantial increase in scholarly interest in urban flooding and transportation infrastructure research. To further evaluate this trend, a regression analysis was performed using annual publication counts. The results show an exponential growth trend, with a coefficient of determination ( $R^2$ ) of about 0.87, which supports the view that research activity in this field has expanded rapidly.



**Figure 3.** Annual number of publications related to flooding on urban arterial roads (2000–2024).

### 3.2. Bibliometric citation analysis.

Citation analysis was used to identify the most influential studies in the field. Using data obtained from Publish or Perish and processed in Microsoft Excel, the ten most highly cited documents were identified from the total dataset of 924 publications. The results of this analysis are presented in Table 3.

**Table 3.** Most impactful documents based on citation analysis

No	Ref	Cites	Title	Year	Source	Publisher
1	[27]	1544	Flood risk and climate change: Global perspectives	2014	Hydrological Sciences Journal	Taylor & Francis
2	[28]	1350	Cities and Flooding	2012	World Bank Publication	World Bank
3	[29]	744	Urban flood hazard zoning using GIS	2010	Engineering Geology	Elsevier
4	[4]	737	A review of the current status of flood modelling for urban flood risk management in developing countries	2020	Scientific African	Elsevier
5	[15]	719	Flood resilience: A systematic review	2020	Journal of Environmental Planning and Management	Taylor & Francis
6	[6]	702	Urbanization and increasing flood risk in the northern coast of Central Java, Indonesia	2020	Land	MDPI
7	[18]	601	Urban flood impact on traffic disruption	2020	Water	MDPI
8	[9]	575	Effects of extreme flash floods on transportation infrastructure	2020	International Journal of Disaster Risk Reduction	Elsevier
9	[14]	570	Flood impacts on urban road connectivity in China	2022	Scientific Reports	Springer Nature
10	[19]	564	Urban flood numerical simulation: Methods and perspectives	2022	Environmental Modelling & Software	Elsevier

Among the studies reviewed, the three most cited publications recorded 1,544, 1,350, and 744 citations, respectively. The substantial number of citations indicates that these works have significantly shaped the development of flood-related research, particularly in urban and transportation settings. One of the most influential studies offers a comprehensive global and regional evaluation of flood risk under a range of climate change scenarios [25]. The statement argues that more intense rainfall events, changing climate conditions, and the inherent fragility of urban infrastructure—especially arterial road systems—interact in ways that increase the probability of flood exposure in cities [14]. Another often-cited study emphasizes the importance of integrated urban flood risk management, identifying rapid urban expansion, unplanned shifts in land-use patterns, and poor drainage capacity as central factors behind the growing incidence of urban flooding. In arterial road networks, these conditions commonly turn streets into surface flow routes during heavy rainfall episodes, leading to recurring interruptions in transportation activities [7, 30].

From a methodological standpoint, several influential works show that combining Geographic Information Systems (GIS) with multi-criteria decision analysis can improve the identification of flood-prone areas. This type of framework supports the assessment of key physical, hydrological, and infrastructural factors—such as road elevation, the degree of surface impermeability, and closeness to drainage networks—that strongly influence the occurrence and severity of flooding on urban arterial roads.





**Table 5.** Leading journals publishing research on flooding in urban arterial roads (2000–2024).

No	Journal	Cite Score	Percentile	Quartile	Subject Area (Scopus Category)
1	Science of the Total Environment	16.4	94%	Q1	Environmental Engineering
2	Journal of Hydrology	11.1	95%	Q1	Water Science and Technology
3	Journal of Environmental Management	14.4	94%	Q1	Environmental Management
4	Water (Switzerland)	6	87%	Q2	Aquatic Science
5	Urban Water Journal	3.6	68%	Q2	Geography, Planning and Development
6	International Journal of Disaster Risk Reduction	8.5	95%	Q1	Safety Research
7	Sustainability (Switzerland)	7.7	90%	Q1	Geography, Planning and Development
8	Journal of Traffic and Transportation Engineering (English Edition)	13.9	96%	Q1	Civil and Structural Engineering
9	European Journal of Transport and Infrastructure Research	4.8	81%	Q1	Urban Studies
10	Smart Cities	14.7	98%	Q1	Urban Studies

The way publications are distributed across journals indicates that studies on flooding and transportation infrastructure are predominantly published in high-impact, interdisciplinary outlets in environmental science, hydrology, and urban studies. A large share of the main journals belongs to the Q1 quartile in Scopus, reflecting the increasing academic importance of this research area. The findings as a whole suggest that waterlogging on urban arterial roads emerges from an interaction of restricted drainage capacity, shifts in land use, and episodes of intense rainfall. The bibliometric review brings out key reference works, evolving patterns of co-authorship, and recurring subject areas, highlighting the importance of combining flood management strategies with more robust infrastructure planning to reduce the effects of flooding on urban transport systems. Although substantial progress has been made in understanding urban flooding, important gaps in the existing literature still persist. Bringing together the bibliometric data shows that research attention is unevenly distributed across thematic areas, geographic contexts, and methodological frameworks. The primary research gaps uncovered in this study are compiled in Table 6, which marks out specific domains that warrant deeper exploration in subsequent research.

**Table 6.** Research gap matrix.

Category	Dominant Themes	Underexplored Themes
Hydrology	rainfall modelling	urban road drainage interaction
Infrastructure	drainage performance	arterial road resilience
Geography	China, Europe	Southeast Asia
Methods	GIS modelling	integrated transport flood modelling
Policy	flood mitigation	transport policy integration

#### 4. Conclusions

This study provides a broad bibliometric overview of research into the causes of flooding on urban arterial roads between 2000 and 2024. Interest in this topic has grown progressively, especially after 2010, as urban flooding becomes an increasingly pressing issue in fast-growing cities. Flooding on urban arterial roads appears to result from the combined effect of several key drivers: poorly designed or overloaded drainage systems, land-use changes that lower natural infiltration, higher rainfall intensity, and limited coordination between infrastructure development and spatial planning. Well-cited studies suggest that arterial roads frequently serve as unplanned flow routes during extreme rainfall, leading to traffic blockages, structural damage to infrastructure, and declining urban mobility. Bibliometric citation analysis reveals

a relatively small group of core publications that continue to influence present-day research on flood risk. These studies highlight the importance of integrated flood risk management, which brings together hydrological analysis, land-use regulation, and infrastructure planning to lessen the impacts of flooding on transportation networks. The author collaboration network further indicates that the domain is primarily influenced by a limited cadre of highly interconnected researchers, thereby signifying both a concentration of specialized knowledge and the potential for broader interdisciplinary and international partnerships. Keyword co-occurrence patterns in recent studies show a growing focus on flood management, simulation modeling, urban drainage performance, and risk assessment. This trend indicates a transition from reactive flood response strategies to more proactive, resilience-oriented planning approaches. The growing prominence of themes linked to urban road infrastructure networks and infrastructure resilience underscores the important role of arterial roads in urban systems. Despite its contributions, this study has several limitations. The analysis is based on publications indexed in Scopus and Google Scholar, which may overlook relevant local or non-English works. In addition, bibliometric methods capture research trends and relationships among studies but do not directly evaluate the technical performance of individual flood mitigation measures. Future research should integrate bibliometric results with empirical case studies, hydraulic modeling, and field observations to more thoroughly assess flood mitigation strategies on urban arterial roads. Better coordination between drainage planning, land-use regulation, and transportation infrastructure design is essential to strengthen urban resilience and support sustainable mobility in flood-prone cities.

### **Author Contribution**

Ade Jaya Saputra was responsible for conceptualizing the research topic and defining the scope of the bibliometric review. He carried out the initial literature search and data collection using Publish or Perish and also assisted with data preprocessing and preliminary analysis. Teguh Syaputra served as the corresponding author and supervised the overall research process. He was responsible for developing the research methodology, steering the bibliometric analysis using VOSviewer, and validating the results. He also undertook a critical revision of the manuscript, ensuring it met scientific standards and was logically sound. Furthermore, he contributed to interpreting the findings and provided final approval of the manuscript. Jody Martin Ginting contributed to data analysis and visualization, including the interpretation of bibliometric maps, collaboration networks, and keyword co-occurrence outputs. He assisted in drafting the Results and Discussion sections and provided critical feedback to enhance the clarity and overall structure of the manuscript.

### **Competing Interest**

The authors declare that they have no competing interests, financial or non-financial, that could be perceived as influencing the work reported in this manuscript. The research was conducted independently, and no external organization influenced the study design, data analysis, interpretation of results, or the preparation of the manuscript.

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