

Energy, Environment, and Sustainability
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Transportation Systems Technology and Integrated Management



 Springer

Energy, Environment, and Sustainability

Series Editor

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Transportation Systems Technology and Integrated Management

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ISSN 2522-8366

ISSN 2522-8374 (electronic)

Energy, Environment, and Sustainability

ISBN 978-981-99-1516-3

ISBN 978-981-99-1517-0 (eBook)

<https://doi.org/10.1007/978-981-99-1517-0>

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Preface

Transportation systems technology deals with the practical uses of innovative transportation approach that combines with the latest state-of-the-art technology and policy changes. Without the implementation of both, modern mode of transportation is impossible. For an effective transport system, the changes that have been implemented in the past and the direction for future uses must be communicated effectively to impart the changes for better infrastructure, including transport system design and supply chain management. The integrated transport management system implies the way forward for a better methodology that needs to be employed for a better society cost-effectively.

The International Society for Energy, Environment, and Sustainability (ISEES) was founded at the Indian Institute of Technology Kanpur (IIT Kanpur), India, in January 2014 to spread knowledge/ awareness and catalyse research activities in the fields of energy, environment, sustainability, and combustion. Society's goal is to contribute to the development of clean, affordable, and secure energy resources and a sustainable environment for society and spread knowledge in the areas mentioned above, and create awareness about the environmental challenges the world is facing today. The unique way adopted by ISEES was to break the conventional silos of specialisations (engineering, science, environment, agriculture, biotechnology, materials, fuels, etc.) to tackle the problems related to energy, environment, and sustainability in a holistic manner. This is quite evident in the participation of experts from all fields to resolve these issues. The ISEES is involved in various activities, such as conducting workshops, seminars, and conferences, in the domains of its interests. The society also recognises the outstanding works of young scientists, professionals, and engineers for their contributions in these fields by conferring them awards under various categories.

Sixth International Conference on 'Sustainable Energy and Environmental Challenges' (VI-SEEC) was organised under the auspices of ISEES from 27–29 December 2021, in hybrid mode due to restrictions on travel because of the ongoing COVID-19 pandemic situation. This conference provided a platform for discussions between eminent scientists and engineers from various countries, including India, Spain, Austria, Australia, South Korea, Brazil, Mexico, USA, Malaysia, Japan, Hong Kong,

China, the UK, Netherlands, Poland, Finland, Italy, Israel, Kenya, Turkey, and Saudi Arabia. At this conference, eminent international speakers presented their views on energy, combustion, emissions, and alternative energy resources for sustainable development and a cleaner environment. The conference presented two high-voltage plenary talks by Prof. Ashutosh Sharma, Secretary, DST and Dr. VK Saraswat, Honourable Member, NITI Ayog.

The conference included twelve technical panel discussions on energy and environmental sustainability topics. Each session had 6–7 eminent scientists who shared their opinion and discussed the trends for the future. The technical sessions at the conference included Fuels for Sustainable Transport, Challenges for Desalination and Wastewater Treatment and Possible Solutions, Engine Combustion Modelling, Simulation and Sprays, Bioenergy/biofuels, Coal Biomass Combustion for Power Generation, Microbial Processes and Products, Future of IC Engine Technology and Roadmap, Air Pollution and Climate Change: Sustainable Approaches, Sustainable Energy from Carbon Neutral Sources, Biological Waste Treatment, Combustion: Emerging Paradigm and Thermochemical Processes for Biomass. 500+ participants and speakers from around the world attended this three days conference.

This conference laid out the roadmap for technology development, opportunities, and challenges in energy, environment, and sustainability domains. All these topics are very relevant for the country and the world in the present context. We acknowledge the support from various agencies and organisations for conducting the Sixth ISEES conference (VI-SEEC), where these books germinated. We want to acknowledge our publishing partner Springer (Special thanks to Ms. Swati Mehershi).

The editors would like to express their sincere gratitude to many authors worldwide for submitting their high-quality work on time and revising it appropriately at short notice. We want to express our special gratitude to our prolific set of reviewers, Dr. Hari Krishna Gaddam, Dr. Santosh Kumar Mishra, Dr. Bipin Kumar Singh, Dr. Ravi Shankar Sinha, Dr. Abhilasha Saksena, Dr. Pradeep, Dr. Vikram Kumar, Dr. Sunil Kumar Sharma, Mr. Surya Pratap Singh, Mr. Abhay, Mr. Hardikk Valera, Mr. Utkarsha, who reviewed various chapters of this monograph and provided their valuable suggestions to improve the manuscripts.

The book aims to understand transportation ecosystems and management with its underlying technologies for futuristic freight and passenger movement. Chapters include recent results and focus on current trends in the transportation sector. The topics covered in this book range from current advances in transportation to essential technological aspects, including environment and energy, design of mobile aerial ropeways based on autonomous self-propelled chassis, highway soil performance, and repositioning of the rail system for competitiveness. In this book, different survey data from the large community have been gathered and illustrated to show the public's choices and preferences to understand the use case transportation policy. Further, these choices are integrated with management to generate a framework of the new policy that can serve the purpose of many in an economical way to design new facilities. The deep insight provided in the book, including design aspects, policy-making, describing the energy-efficient system, and the role of private trains on the effect of middle-income groups, is the backbone of this book, which is being highlighted

by the working professionals in the consultation with transportation commodities including both public and private players. We hope the book will greatly interest the professionals and postgraduate students involved in policy-making, planning, infrastructure development, and managerial aspects in transport and environmental research.

Vadodara, India

Vadodara, India

Kanpur, India

Kanpur, India

Ram Krishna Upadhyay

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About the Editors



Dr. Ram Krishna Upadhyay is currently working as Assistant Professor at the National Rail and Transportation Institute, Vadodara, established by the Ministry of Railway, Government of India. He received his Ph.D. and M.Tech. from the Indian Institute of Technology (ISM) Dhanbad in Mechanical & Mining Machinery Engineering with a broad specialization in Surface Engineering and Tribology. Before joining NRTI Vadodara, Dr. Upadhyay has worked as Postdoctoral Fellow at the Indian Institute of Technology (IIT) Kanpur for over three years. His research interests include lubrication and materials wear for industrial application, tribology of additive manufactured parts, and nanocomposites. He is a recipient of the SERB-ACS NPDP Best Poster Competition Award by the Science and Engineering Research Board, New Delhi, and the American Chemical Society, USA. He published several journal papers, book chapters, edited a book, and completed a project funded by the Science and Engineering Research Board, New Delhi.



Dr. Sunil Kumar Sharma is an Assistant Professor and the Assistant Program Director of the Engineering and Applied Science Department at the National Rail and Transportation Institute Vadodara, established by the Ministry of Railway, Government of India. He received his Ph.D. from the Indian Institute of Technology, Roorkee. He worked at the Non-destructive Evaluation and Structural Health Monitoring Laboratory at C. N. University, South Korea. His research interests are vehicle dynamics, contact mechanics, mechatronics, and real-time software-enabled control systems for high-speed rail vehicles. He published several research articles in national and international journals. Dr. Sharma is also among the top 2% of scientists in a global list compiled by Stanford University, USA.



Dr. Vikram Kumar is currently at Indian Institute of Technology (IIT) Kanpur where he also received his Ph.D. in Mechanical Engineering. His areas of research include polymer and composite coating, wear, friction and lubrication, IC engine tribology, alternative fuels, advanced low-temperature combustion, engine emissions measurement, and particulate characterization. Dr. Kumar has edited 1 book and authored 7 book chapters and 16 research articles in international journals and conferences. He has been awarded with ‘ISEES Best Ph.D. Thesis Award’ (2018) and ‘Senior Research Associateship’ under ‘SCIR-POOL Scientist’ (2018–2021). He is Lifetime Member of ISEES.



Mr. Hardikk Valera is pursuing Ph.D. from Indian Institute of Technology (IIT) Kanpur. He completed his M.Tech. and B.Tech. from NIT Jalandhar (India) and Ganpat University, respectively. His research interests include methanol-fueled SI engines, methanol-fueled CI engines, optical diagnostics, fuel spray characterization, and emission control from engines.

Chapter 1

Introduction to Transportation Systems Technology and Integrated Management



**Ram Krishna Upadhyay, Sunil Kumar Sharma, Vikram Kumar,
and Hardikk Valera**

Abstract Transportation is considered a key element in the development of a city. Urbanisation will not be possible without proper mobility and well-integrated transportation. Effective and dependable mass transportation networks are critical for the world to maintain its rapid economic development. Services and industrial sectors, in particular, are concentrated around large metropolitan centres, necessitating robust and dependable urban transportation networks to transfer jobs and link from the manufacturing plants to the supply chain. The importance of urban and rural transportation stems from its role in poverty reduction by enhancing access to labour markets and raising wages in disadvantaged communities. Availability and urbanisation sustainability are essential for fostering the long-term economic development of a city's growth in the world. Therefore, they are inextricably linked in spatial distribution, urban stock, flow growth, and built structure unification. However, due to car-centric strategies implemented by subsequent city plans and initiatives, urban mobility has not led to optimal outcomes. In terms of policy and organisational consequences, urban migration is multifaceted. As a result, coherence in policy initiatives and linkages between systems is critical. Improved connectivity is not accomplished by constructing additional bridges, rail lines, or cars, nor by implementing impromptu spatial measures such as traffic control strategies to achieve delocalisation and decongestion in isolation. Countries like India and cities with dense populations and inadequate infrastructure have always struggled to provide congestion-free urban transportation. Part of the reason for this is the weak public transportation systems of such cities. Such inefficient public transportation systems have reduced people's trust in these services. These problems should be tackled by providing a sustainable transport system. This book aims to deliver an effective

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R. K. Upadhyay et al. (eds.), *Transportation Systems Technology
and Integrated Management*, Energy, Environment, and Sustainability,
https://doi.org/10.1007/978-981-99-1517-0_1

way of providing a sustainable transport system by reducing all the inefficiencies pertaining to the different modes of transport and by giving better policymaking strategies.

Keywords Transportation · Railways · Management aspect · Corrosion · Public parking · Road infrastructure

The rhythm of mobility has emerged as a dynamic accelerated central in developing countries, those becoming more urbanised with urban transportation networks serving as the urban form's skeleton. Even though cities and towns have elevated levels of public transport, getting to locations, events, and facilities are becoming impossible concerning convenience, expense, and time. In reality, current rates of metropolitan transportation are causing disasters characterised by solid concentrations of traffic, atmosphere emissions, traffic deaths, and asymmetry, inevitably contributing to an unfavourable connectivity crisis. The resolution of the problem lies in the development of transport technologies with reliable solutions that can be accommodated in the existing facilities. Transportation technology includes the latest automated transportation systems, such as integrated transport information systems, advanced public transportation systems, adaptive cruise control systems, automatic collision systems, adaptive cruise control, advanced traffic management system, and other intelligent transportation systems, including sensors and wireless technologies, helps to improve road safety, comfort, and fuel efficiency, as well as reduce the number of accidents, traffic congestion, and commuter waiting time by providing green extension. Integrating management in the transportation sector has immensely paved the way for futuristic modifications with better-applied technologies and cost-effective productions in the public transportation sector. All the issues and developing technologies related to the country's transportation system are addressed in the book for insightful information to the policymakers willing to address the challenges and help develop better infrastructure for a reliable and safe transport network.

The book chapter is a collection of integrated technologies of the transport system. Firstly, flooding events on the climate change strategies for road infrastructure are addressed for better adaption involving hard and soft adaptations due to the criticality of the flooding event for guiding land-use decisions and evaluating adaptation strategies. It helps in decision-making for required strategies, including public policy guidelines, to make road infrastructure more resilient against the impacts of flood events caused by climate threats such as heavy precipitation, sea-level rise, and storm surges. This could undoubtedly make the road infrastructure resilient. In another work, the issue of private trains for the middle-income group is covered through public opinion. Safety and security remain the most prioritised dimensions for people, customer service, and service efficiency, followed by onboard technological facilities. Vehicle automation is regarded as one of the most promising technologies in transportation networks. Adaptive cruise control (ACC) systems are the most reliable speed monitoring/adjusting technology. The energy demand and fuel consumption for human-driven and ACC-engaged vehicles in experiment-like

running conditions with various vehicle specifications are included. It is found that the system is less energy-efficient, revealing a tendency for upstream energy propagation inside the platoon and abrupt speed, resilient acceleration may negatively affect the energy impact. Another important issue is greenhouse gas emissions. New clean forms of energy production using renewable sources are the best practical way to stop climate change. This can be accomplished by renewable hydrogen uses, which can be utilised in hydrogen-powered vehicles. Hydrogen is available in excess, which can be easily obtained and stored for further use by many different processes. However, its production process should be controlled better so the energy requirement should be minimised. Also, the requirement of transportation hurdles can be controlled due to its gaseous nature compared to the other liquid resources. The integration of management in the transportation sector is also discussed, including the companies' strategic goals that facilitate the users at a high level of contentment with their performance and the challenges associated with public, logistics, and goods transportation. The planning, procurement, and lifecycle management stages are important factors in optimising the supply chain system. The application of business processes in the sphere of transportation services is made possible by the modification of transport and logistics systems. It's a good idea to embrace innovations that can improve supply chain efficiencies, such as robotic process automation, artificial intelligence, drones, autonomous cars, and the Internet of things. These technologies are essential as vehicle growth in recent times is increasing exponentially, leading to high road congestion. The reason for this is the increase in the city's overall population of private vehicles/middle-range vehicles. This could be controlled by the changing in the rules. Policymakers should keep proper guidance and information system for parking prices in mind and shift towards a multilevel parking system to increase the supply. It may be helpful to increase the parking fees that may discourage people from using private vehicles and shifting to public transport. A design procedure is discussed based on the mathematical modelling of an autonomous self-propelled wheeled chassis of high-load capacity mobile transport and overloading equipment. It can be used to rapidly create logistics infrastructure for the sustainable development of hard-to-reach areas with complex natural terrain and rapid deployment during transport operations in man-made disasters. A transit network design problem (TNDP), which deals with finding efficient network routes among a set of alternatives that best satisfies the conflicting objectives of different network stakeholders, including passengers and operators, is studied to improve a network's operational efficiency using simulation-based techniques. The simulation models are helpful in the transit network design and thus evaluate the stochastic behaviour of different stakeholders on a network. A transit network design using a support tool helps policymakers develop effective policy decisions relevant to the transportation realities for sustainable development. The electric vehicle purchase policy is also discussed to adopt an innovative alternative fuel technology. The study uses a survey to investigate the factors influencing the purchase of traditional two-wheeler and factors that will prompt a younger generation to purchase a two-wheeler electric vehicle in the near future. Factor analysis is conducted on the Likert scale data obtained through a questionnaire survey to club the various variables into a few

factors for easier interpretation. The study attempted to understand the growing and ever-changing landscape of electric vehicle adoption in India and its various government programmes. The factors influencing the purchase of traditional two-wheelers were price, characteristics, and the vehicle's economic value. The factors influencing the adoption of electric two-wheelers were pricing, vehicle characteristics, and social contribution. In addition, the economic comparison between electric vehicles (EVs) and internal combustion engine vehicles (ICEVs) based on the total cost of ownership is reviewed based on economic sustainability. It is suggested that the cost of electric vehicles should be reduced significantly to make an environment-friendly sustainable transport system using electrification without letting an economic burden on the government.

The book contains various aspects of transportation, management, and policy-making to provide a better perspective towards a sustainable transportation system that can overcome present challenging issues. Particular topics covered in this book are as follows:

- Introduction to transportation technology and integrated management
- Climate change adaptation strategies for road transportation infrastructure: a systematic review on flooding events
- Examining effects of the introduction of private trains on middle-income groups
- Energy-based assessment of commercial adaptive cruise control systems
- Optimum production-ordering policy for a vendor buyer co-ordinated system subject to production disruption
- Opportunities and challenges for the new hydrogen economy: advances in renewable hydrogen
- Corrosion protection practices and integrity management challenges in oil and gas pipeline
- Role of technology in the management of transportation
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- Sustainability and safety challenges in mining transportation by railway in India
- Performance of ribs in double pass jet solar air heater: a review
- Optimising transit networks using simulation-based techniques
- A survey of various 2,5-furandicarboxylic acid-based renewable polyesters
- Recycling of platinum group metals and alternative catalysts for catalytic converters
- Two-wheeler electric vehicles purchase policy
- The adaptability of management in transportation systems
- Comparison of economic viability of electric and internal combustion engine vehicles based on total cost of ownership analysis.

Chapter 2

Climate Change Adaptation Strategies for Road Transportation Infrastructure: A Systematic Review on Flooding Events



Victor Hugo Souza de Abreu, Thaís Guedes Máximo Monteiro, Adriano de Oliveira Vasconcelos, and Andrea Souza Santos

Abstract During the last decades, the number of flooding events has increased significantly, due to the global trend of urbanization and climate change, becoming a recurring biophysical impact, resulting in major physical disruption to water and wastewater systems, life and economic losses, and damage to the critical infrastructure. For the road transportation sector, this reality is indisputable, as severe flooding events tend to severely damage the transportation infrastructure and reduce the network connectivity, increasing repair, maintenance, and construction costs. Thus, through a systematic literature review, with direct database searches and application of inclusion and qualification (quality and applicability) filters, a repository of 213 publications on adaptation strategies applied to reduce the impacts of flooding on road infrastructure is developed. Most of these studies have been published since 2014, due to the publication of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. It should also be noted that, of the overall total, only 47% of studies deal specifically with the road transportation sector (the remaining 53% cite the sector only as an example), thus demonstrating the urgency of further studies on the topic. It should also be noted that the climate risk assessment, involving the creation of current and future flood risk maps, is essential for determining the best climate change adaptation strategies for road transportation infrastructure. As flood damages and costs are largely and strictly site-specific, analyses are critical for guiding land use decisions and evaluating adaptation strategies that can be divided into hard adaptation (optimization or redesign of hydraulic components, installation of protective structures and optimization of environmental conditions) and soft adaptation (creation

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of transportation-focused master plans and development of quantitative models and systems).

Keywords Climate change · Impact · Flooding · Road infrastructure · Adaptation

2.1 Introduction

Flooding events have become a frequent biophysical impact in recent years, constituting one of the most severe and potentially devastating natural disasters, especially in the urban context due to impervious surfaces [1–7]. This biophysical impact ends up by causing not only major physical disruption to water, but also significant life and economic losses [8–10], and thus, well-planned decision making is necessary to reduce damages to infrastructure [11], such as electric, road and rail and sewage networks [12]. It is estimated that the larger the area affected by flooding, the greater the damage to the infrastructure and the disruption of its services, resulting in increased operational and maintenance costs [7, 13–15]. Impacts range from completely destroyed bridges and sewage systems to severely damaged schools and hospitals [16].

Specifically in relation to the transportation sector and its infrastructure, which underpins economic activities by enabling the movement of goods and people [17], depending on severity, floods can cause lane closures and reduced system capacity, leading to bottlenecks and congestion [14, 15]. Severe flooding events can damage transportation infrastructure—loss of its useful life—and reduce network connectivity, as well as increase repair, maintenance, and construction costs [18]. The cost of disruption due to flooding has been estimated at £100,000 at peak times for each major road affected in the UK—tangible effects [19], not to mention the incalculable cost of flood-related deaths as a result of vehicles being driven over flooded roads—intangible effects [20].

To make this situation worse, the number and severity of flood damage in urban areas will continue to increase in the coming decades due to the global trend of urbanization and climate change [7, 10, 21]. To have an idea, the expected annual damage from surface water flooding in UK, for example, may increase by 135% by 2080 under the future climate scenario [22]. The limited and in some cases insufficient adaptive capacity of the road infrastructure to withstand extreme hydrological events may to some extent be due to knowledge and methodological gaps regarding adequate adaptation to climate change [23].

Thus, implementing adaptation measures while considering climate risk analysis under a variety of future scenarios is crucial for establishing a long-term sustainable urban drainage system [24]. Thus, this paper conducts a relevant and current systematic investigation with a bibliometric approach with a focus on studies published in the last decade. Comprehensively, a review is performed to conduct this state-of-the-art research with emphasis on the impacts of flooding events resulting from climate change on the road infrastructure and climate risk assessment, as well as the

corresponding climate change adaptation strategies and planning issues, with a focus on increasing awareness and knowledge as a basis for effective actions. Following this introduction section, Sect. 2.2 indicates the methodological procedure used to conduct this state-of-the-art research. Section 2.3 presents the research results with respect to biometric analyses and Sect. 2.4 with respect to systematic analyses—critically analyzing the selected studies. Finally, Sect. 2.5 concludes this paper and presents some suggestions for next research directions.

2.2 Methodological Procedure

With the growing increase in climate threats and biophysical impacts resulting from climate change, the need for studies on the subject has become even more urgent [14, 15]]. Thus, systematic reviews provide a range of extremely relevant results, preventing the limitation of conclusions with the reading of insufficient content or few studies. The reason is that, unlike simpler and more traditional reviews, systematic reviews aim to avoid biases that may appear in each phase from a rigorous method of (i) search and selection; (ii) evaluation of the relevance and validation of results; (iii) collection; (iv) synthesis; and (v) data interpretation [25]. In turn, bibliometric analysis, which is one of the main strategies used for the compilation and development of knowledge about scientific productions [26], is a quantitative–qualitative research method used in the analysis of sets of graphical descriptions of documents [27], offering convenient analysis methods due to the reference to codified knowledge, use of measurable data, and data availability [28] and providing information that assists researchers in identifying gaps to be explored in future research [29].

Thus, to obtain information about the impacts of climate change on the road transport infrastructure, with a focus on the biophysical impact of flooding, a systematic review with a bibliometric approach was developed to identify and analyze relevant studies (quality and applicability). It is worth noting that this research is based on the work of Abreu et al. [30], who sought to identify adaptation measures for various climate threats and their corresponding biophysical impacts. This review, which includes relevant studies preferably published in the last decade, allows researchers to identify emerging issues and associated themes, understand how these concerns and themes have evolved over time, and identify the challenges to be faced in the future. This paper also conducts a comprehensive review of state-of-the-art data on climate adaptation in the road transportation sector, with a focus on minimizing the impacts of flooding events. To this end, the systematic literature review consists of three phases, namely (i) systematic review protocol; (ii) direct and documentary searches; (iii) data processing; and (iv) developing the research repository and obtaining results.

In the first step, there is the definition of the most relevant keywords for the efficient conduction of the research, as well as the definition of the inclusion and qualification criteria, as summarized in Table 2.1. It is noteworthy that it was considered relevant to use combinations between some keywords directly related to climate change and

Table 2.1 Description of the research strategies

Criterion	Description
Database	Web of Science and Scopus
Topics	<p>Web of Science - TS = ('climate change' AND 'road infrastructure' AND 'adaptation' AND 'flood*') OR TS = ('climate change' AND 'highway infrastructure' AND 'adaptation' AND 'flood*') OR TS = ('climate change' AND 'pavement' AND 'adaptation' AND 'flood*') OR TS = ('climate change' AND 'road infrastructure' AND 'adaptation' AND 'inundation') OR TS = ('climate change' AND 'highway infrastructure' AND 'adaptation' AND 'inundation') OR TS = ('climate change' AND 'pavement' AND 'adaptation' AND 'inundation')</p> <p>Scopus - (TITLE-ABS- KEY ('climate AND change' AND 'road AND infrastructure' AND 'adaptation' AND 'flood*') OR TITLE-ABS-KEY ('climate AND change' AND 'highway AND infrastructure' AND 'adaptation' AND 'flood*') OR TITLE-ABS-KEY ('climate AND change' AND 'pavement' AND 'adaptation' AND 'flood*') OR TITLE-ABS- KEY ('climate AND change' AND 'road AND infrastructure' AND 'adaptation' AND 'inundation') OR TITLE-ABS- KEY ('climate AND change' AND 'highway AND infrastructure' AND 'adaptation' AND 'inundation') OR TITLE-ABS- KEY ('climate AND change' AND 'pavement' AND 'adaptation' AND 'inundation'))</p>
Search Method	Direct Search
Inclusion	I1: Time of coverage: all years in the database (1945–2021), although special focus was given to the most current studies—last ten years (2011–2022); I2: Source Relevance
Qualification	Q1: Are the study objectives clearly identified? Q2: Does the research present a well-reasoned literature review? Q3: Do the research methods support the study objectives? Q4: Does the study present technical innovation? Q5: Are the contributions discussed? Q6: Are limitations explicitly stated? and Q7: Are the results and conclusions consistent with pre-established objectives?
Search Date	January 02, 2022, at 7:00 pm

other keywords directly related to road transport. The choice of keywords and their combinations considered a brainstorming process to choose the most relevant terms and, subsequently, a team composed of academicians and professionals in the transportation area refined these keywords to provide a solid validation, according to the same as that established by Wang et al. [31]. It should be noted that both TS and TITLE-ABS-KEY indicate the keywords that will be searched in the title, abstract, and keywords of included studies, respectively, in the Web of Science and Scopus databases.

In the second step, searches are conducted in two main databases: (i) Scopus and (ii) Web of Science. In addition, documentary searches were carried out in important databases of scientific bodies and initiatives that deal with climate change such as the IPCC—Intergovernmental Panel on Climate Change, the National Research Council and the World Bank Group. This type of research was considered more adequate to the context of the development of lists of adaptation measures (Hard adaptation and Soft adaptation) applied to floods. At this stage, the initial research repository consisted of 514 studies.

Step 3 consisted of data processing, which consists of consolidating and organizing data to produce technical information necessary for the efficient conduct of the research. Since different databases can provide the same studies, the EndNote bibliographic management software was used to organize data and remove duplicate content. This step provided the necessary research repository for subsequent bibliometric and systematic analyses, finally considering the biophysical impacts of flooding. In it, 188 duplicate studies and 113 studies that did not meet the inclusion and qualification criteria (quality and applicability) were excluded, so the final research repository consisted of 213 studies.

Finally, Step 4 consisted of the development of the research report and the obtaining of results, expressed here as an article containing the knowledge produced from the research analyses. It is noteworthy that, to perform bibliographic and systematic analyses, several other computer programs were used, such as Excel for the creation of simpler graphs like the evolution of publications and citations per year, VOSviewer for the generation of interconnection maps between keywords, Tableau for the creation of maps of publications per country under investigation, among others.

2.3 Bibliometric Analysis

With the creation of the research repository, it was possible to conduct several bibliographic analyses, as exposed throughout this section and, that way, we sought to evaluate studies according to their year of publication. Thus, according to Fig. 2.1, after the publication of the Fifth Assessment Report [32], the number of publications grew steeply, peaking in 2020. To have an idea, the sum of studies until 2013 corresponds to approximately 14% of all publications, and the years 2020 and 2021 alone accounted for 13% and 12% of publications, respectively. All this indicates that

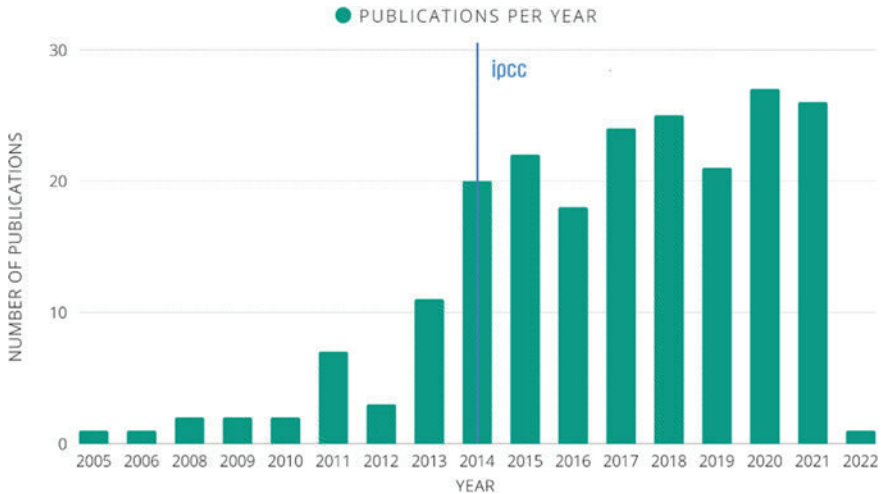


Fig. 2.1 Evolution of publications by year

the topic has become more popular in recent years and is likely of growing further with new IPCC publications, forecast for the year 2022. It is noteworthy that similar results were also found by Abreu et al. [30], who conducted a more comprehensive systematic review, considering impacts not only from flooding events but also from soil and rock slides, erosion, fires, and direct impacts from high temperatures.

Subsequently, it was possible to verify which are the main sources of publication of studies, as identified in Fig. 2.2, which shows that a large part of the studies—approximately 70%—consists of articles (many of them published in large journals with blind peer-review process, which gives greater relevance to the process), followed by reviews and conference proceedings, with global reach. This indicates a wide range of scientific exploration in the area under investigation.

Another interesting analysis is to find out which journals publish most studies on the theme, as well as their impact factor, according to Table 2.2. This analysis allows directing submission efforts to journals aligned with the scope of studies, so that researchers do not waste unnecessary time submitting their studies to journals that are not interested in the subject being investigated.

Table 2.2 shows that the journals that most stand out in terms of number of publications are Journal of Infrastructure Systems, Sustainability (Switzerland) and Climatic Change. In addition, when ordering them by Impact Factor, Science of the Total Environment, Transportation Research Part D: Transport and Environment, and Climatic Change stand out, all with IF greater than 4.7, demonstrating that the subject is covered in important journals.

Special emphasis can also be given to studies most cited in the Research Repository, as presented in Table 2.3. Sometimes, many citations of a scientific publication may prove to be an indicator of innovation (a new idea, method, discovery, etc.), which should be further investigated by those interested in working on the subject

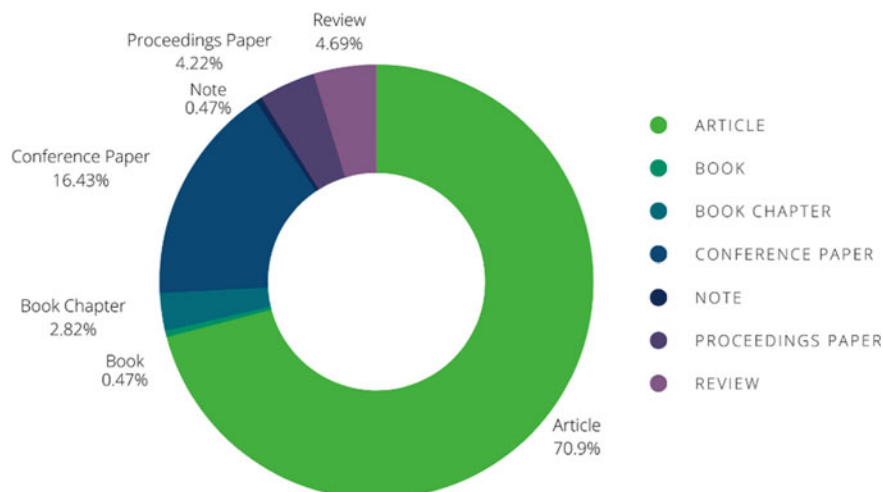


Fig. 2.2 Publications by type of document

Table 2.2 Publications by journal

Journal	Publications (%)	Impact factor (2020)
Journal of Infrastructure Systems	4.4	2.411
Sustainability (Switzerland)	4.4	3.251
Climatic Change	3.4	4.743
International Journal of Disaster Risk Reduction	3.0	4.320
Transportation Research Record	3.0	1.560
Transport Policy	2.0	4.674
Regional Environmental Change	1.5	3.678
Science of the Total Environment	1.5	7.963
Transportation Research Part D: Transport and Environment	1.5	5.495
Water (Switzerland)	1.5	3.103

[33]. In this regard, based on citations from the Web of Science database, it is identified that the most cited studies are Zahmatkesh et al. [34], Dong et al. [24] and Mei et al. [35], all with more than 95 citations. In addition, it was also possible to identify the average number of citations per year (CpY), where top ranked studies are Mei et al. [35], Dong et al. [24] and Argyroudis et al. [36], respectively.

The possibility of creating a network of interconnection between keywords, according to Fig. 2.3, is also worth mentioning. In this figure, it is possible to highlight very recurrent and even intuitive keywords, due to the search topics considered (see Table 2.1) such as “Climate Change,” “Sustainability,” and “Climate change adaptation” and “Roads and Streets.”

Table 2.3 Most cited studies

Reference	Title	Biophysical Impact	Journal	Total citation	CpY
Zahmatkesh et al. [34]	Low-impact development practices to mitigate climate change effects on urban storm water runoff: Case study of New York City	Flood, mostly	Journal of Irrigation and Drainage Engineering	117	16.7
Dong et al. [24]	Enhancing future resilience in urban drainage system: Green versus gray infrastructure	Flood, mostly	Water Research	97	19.4
Mei et al. [35]	Integrated assessments of green infrastructure for flood mitigation to support robust decision making for sponge city construction in an urbanized watershed	Flood	Science Of The Total Environment	96	24.0
Selva et al. [37]	Roadless and low-traffic areas as conservation targets in Europe	Flood/soil and rock displacement/forest fires	Environmental Management	94	8.5
Charlesworth [38]	A review of the adaptation and mitigation of global climate change using sustainable drainage in cities	Flood/high temperatures	Journal of Water and Climate Change	82	6.8
Sterr [39]	Assessment Of Vulnerability And Adaptation To Sea-Level Rise For The Coastal Zone Of Germany	Flood/erosion	Journal Of Coastal Research	81	5.8

(continued)

Table 2.3 (continued)

Reference	Title	Biophysical Impact	Journal	Total citation	CpY
Neumann et al. [42]	Climate change risks to US infrastructure: impacts on roads, bridges, coastal development, and urban drainage	Flood/erosion	Climatic Change	79	11.3
Chinowsky et al. [40]	Assessment of climate change adaptation costs for the US Road network	Flood/erosion	Global Environmental Change	57	6.3
Argyroudis et al. [36]	Fragility of transport assets exposed to multiple hazards: State-of-the-art review toward infrastructural resilience	Flood/earthquake/soil and rock movement/erosion	Reliability Engineering & System Safety	51	17.0
Pregolato et al. [8]	Impact of climate change on disruption to Urban transport networks from pluvial flooding	Flood	Journal of Infrastructure Systems	51	10.2

The presence of other interesting keywords such as “Risk Assessment,” “Vulnerability Assessment,” “Deterioration,” and “Cost-effectiveness” should also be highlighted. It is also noteworthy that this network presents 1,606 items, 36 clusters, 28,943 links with total size of 32,764. In addition, it is also possible to rank the main keywords, as shown in Table 2.4.

2.4 Systematic Analysis

Subsequently, with a thorough reading of studies included in the research repository, systematic analyses can be performed, which allow for the effective and continuous assimilation of this large volume of available information in vast areas of knowledge through a rigorous methodology by searching for results [41]. In the first systematic analysis, it was observed that not all studies included in the database present road transport as the focus of their research, many of them (about 53%) deal with critical

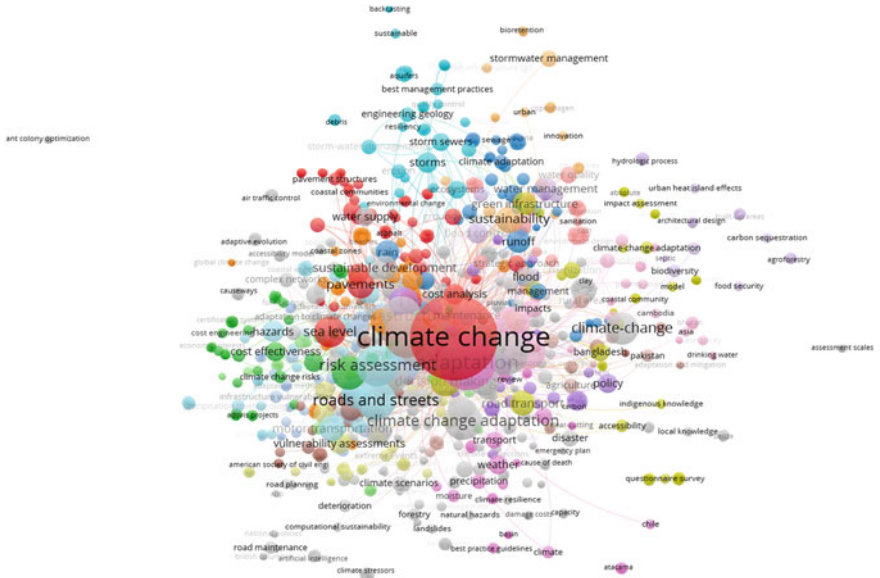
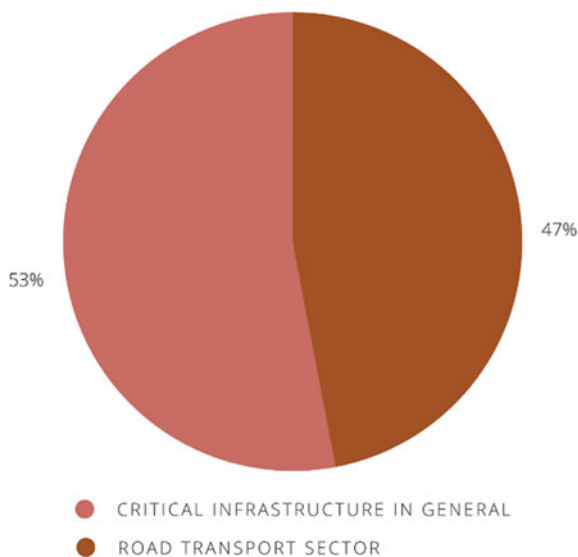


Fig. 2.3 Interlinking network between keywords

Table 2.4 Keyword ranking

Keyword	Number of occurrences
Climate Change	134
Adaptation	58
Floods	36
Flooding	33
Adaptive Management	30
Risk Assessment	32
Roads and Streets	28
Infrastructure	28
Climate change adaptation	26
Vulnerability	26
Transportation	24
Resilience	23
Climate effect	21
Climate models	21
Sea Level	18
Decision Making	16
Adaptation strategies	16

Fig. 2.4 Publications by focus



infrastructure in general and bring some reflections on the road sector, as can be seen in Fig. 2.4, also showing the scarcity of relevant studies on the sector.

Another interesting analysis is to verify which regions have been the focus of studies, especially case studies, on the theme, as expressed in Fig. 2.5. It should be noted that this analysis is different from that, which seeks to investigate the countries of educational institutions in which studies included in the research repository were carried out, because researchers from a given country may investigate a problem present in another country with higher degree of vulnerability and exposure to climate threats. In this regard, there is significant highlight for countries such as the USA (e.g., Chinowsky et al. [40]; Zahmatkesh et al. [34]; Neumann et al. [42]), with 38 publications (18% of the total), Canada (e.g., Denich and Zaghali [43]; Picketts et al. [44]; Abkowitz et al. [45]), with 17 publications (8% of the total), and the UK (e.g., Arkell and Darch [46]), with 15 publications (7% of the total). Together these three countries account for 33% of the publications.

It is also noteworthy that although the three countries above represent the developed North, a continuous effort to investigate the topic in developing countries of the South has been observed, with studies published in African countries (e.g., Arndt et al. [47]; Le Roux et al. [48]; Njogu [13]) and Asian countries (e.g., Chinowsky et al. [49]; Mukesh and Katpatal [7]) being increasingly frequent. This is necessary because many of developing countries react (significant spending in the recovery phase) rather than being proactive in managing the effects of flooding events on the infrastructure, being clearly demonstrated by the inadequate level of preparedness experienced before, during, and after flood events. To make this situation worse, existing literature indicates that the increase in flood events is further constraining

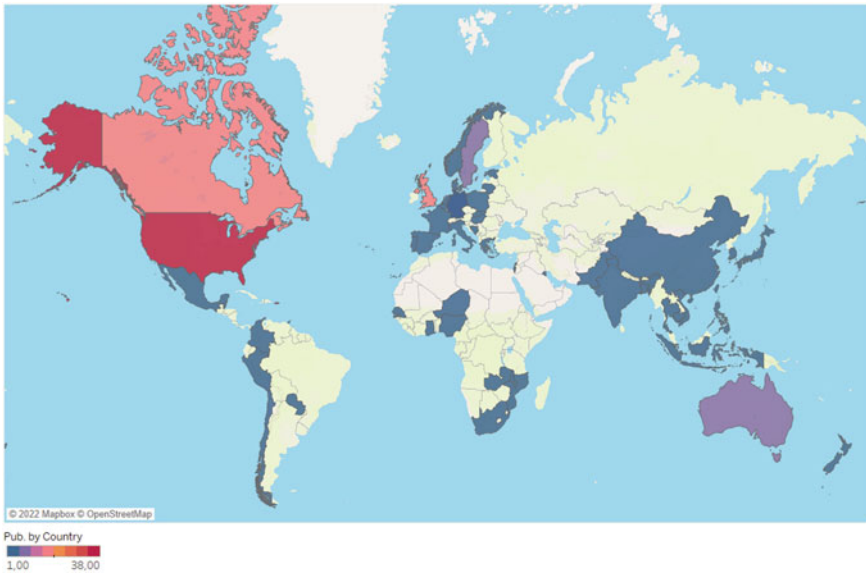


Fig. 2.5 Division of studies by country under analysis

national budgets as countries struggle to allocate more resources in response to natural disasters [13].

It should also be noted that for the construction of the map presented in Fig. 2.5, the federal level (representing which country is being investigated) was considered; i.e., even if the climate risk was specifically assessed for a given city (municipal level), the study was considered as belonging to that country. In this context, Fig. 2.6 seeks to determine which jurisdiction levels (local, municipal, state, federal, regional, or continental), studies were aimed at. It is emphasized that due to the specific and pervasive nature of climate change impacts, adaptation measures need to be taken at all levels, from local to regional to national [32]. Thus, it was observed that, although the federal level presents higher proportion of studies (27%), there is a certain balance among scopes, including strong participation of state, municipal, and local levels. Also on this subject, it is noteworthy that countries with continental dimensions such as the USA and Canada usually conduct analyses in specific cities or even neighborhoods and communities (local analyses) (e.g., Porter et al. [50]). Local communities, especially in developing countries, play a critical role in flood response and recovery (resilience) [13].

Global climate change is believed to induce transformation in the spatiotemporal rainfall distribution and magnitudes [51]. Thus, increased frequencies and patterns of high-intensity precipitation are predicted [6, 21, 52–56], which, as presented in Fig. 2.7, is the most ascertained climate threat in flood studies. Heavy rainfall generally causes surface flows that result in drainage systems that exceed their capacity and thus increase the likelihood of being blocked by Debris [13]. Subsequently, there are

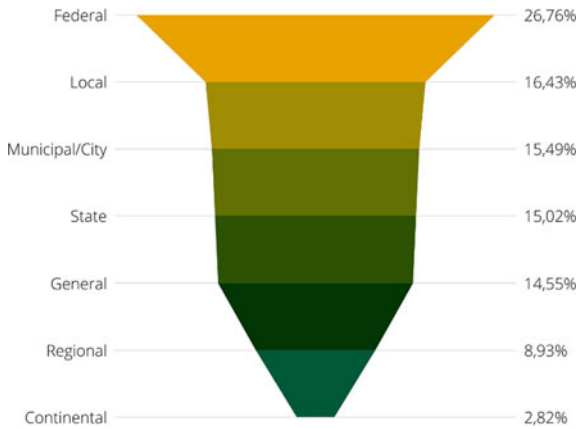


Fig. 2.6 Publications by scope

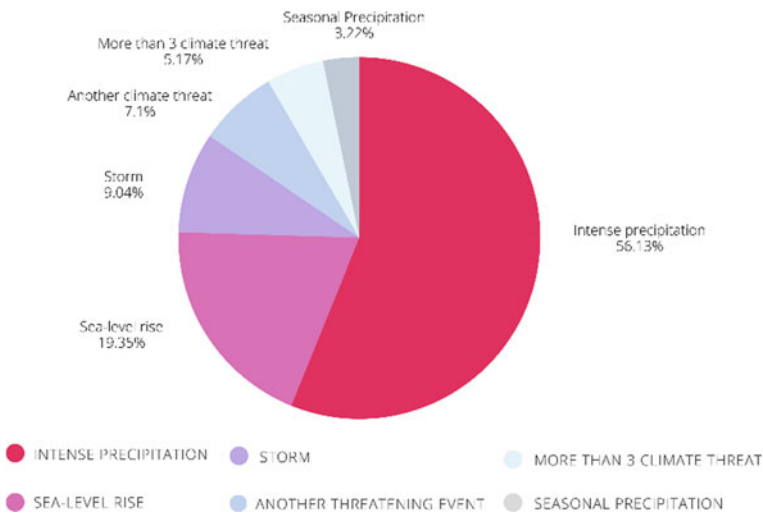


Fig. 2.7 Publications by type of climate threat

sea-level rise in coastal areas (e.g., Dasgupta et al. [57]; Heberger et al. [58]; Sadler et al. [59]), storm surges (e.g., Heberger et al. [58]; Bollinger et al. [60]; Sadler et al. [59]), and seasonal precipitation. It is also noteworthy that climate threats with less recurrence were grouped into another climate threat category, which corresponds to cyclone; freeze/thaw cycles; hurricane; typhoon; and tsunami.

Planning the impact of flooding events on the infrastructure is essential in building resilient road transport infrastructure. An important first step in adapting to increased flood risk is to identify the infrastructure most vulnerable to flooding—through, for example, creating a flood vulnerability map (taking into account aspects related to