J Euro Eco His.
ISSN : 0391-5115
Volume 7, Issue 2 (2026)
THE JOURNAL OF EUROPEAN ECONOMIC HISTORY

Innovative finance for sustainable infrastructure: A hybrid review using bibliometric and content analysis

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Abstract
Sustainable infrastructure investing is one of the important factors while achieving sustainable development goals. While traditional sources of finance are insufficient, innovative investing for sustainable infrastructure has emerged to be a viable option. To understand the changing landscape of sustainable infrastructure financing, this study synthesised the academic literature on sustainable investing and financing using bibliometric analysis followed by content analysis. High quality articles from the year 2011 to mid-2025 were retrieved from the Scopus database using PRISMA framework and content analysis was performed on selected 25 articles. The intellectual and conceptual structures in the bibliometric analysis highlighted the research themes and progression in the field so far. Through bibliometrics, a quantitative review of extant literature was done along with in-depth content analysis which provides novel insights. Three themes emerged out of the content analysis: sustainable development, finance & investment and PPPs & green infrastructure which forms the basis of future research. The study also summarises the research using the theories-context-characteristics methods (TCCM) framework. The findings will help future researchers to focus on further theory development in the areas of sustainable investing and financing. The study also offers practical implications for investors, issuers, and regulators involved in sustainable investing.
Keywords: Sustainable infrastructure, sustainable development, sustainable finance, infrastructure investment, green bonds

1. Introduction

"Sustainable infrastructure refers to infrastructure projects that are planned, designed, constructed, operated, and decommissioned in a manner that ensures economic and financial, social, environmental (including climate resilience), and institutional sustainability over the entire life cycle of the project" (IDB, 2018; Bhattacharaya, et al., 2019). It has been viewed as the relationship between social, environmental, and economic components of development and integrates the principles of green and resilient design. The development of sustainable infrastructures aims to promote the access of marginalized populations to renewable energy, clean water, mobility, education and health, lay the foundations for inclusive prosperity, reduce the impact of global warming by providing clean and decarbonized architecture and directing the economy toward slow carbon growth (Studart & Gallagher, 2018; Ding et al.,

2024). Table 1 presents the most cited definitions of sustainable infrastructure by different authors.

Table 1: Definitions of Sustainable infrastructure

Author & Year	Journal	Citations	Publisher	Definition of Sustainable infrastructure
Choi et al., (2021)	Journal of environmental management	219	Elsevier	"Sustainable infrastructure or green infrastructure is generally defined as a hybrid network of natural, semi-natural, and engineered features within, around and beyond urban areas at all scales, which is planned and managed to provide multiple ecosystem services and benefits".
Hendricks et al., (2018)	Sustainable cities and society	143	Elsevier	"Sustainable infrastructure is defined as the systems that have the capacity to endure over a long period of time; enabling the human-built environment to thrive and providing an opportunity for human society to improve its quality of life, without compromising the integrity and availability of natural, economic, and social assets for future generations".
Ray and Kamal (2019)	Development and Change	34	Wiley	They defined sustainable infrastructure as "projects aimed at climate mitigation and/or adaptation".
Gonzalez-Ruiz et al., (2019)	Engineering, Construction and Architectural Management	32	Emerald	"Sustainable infrastructure is defined as an infrastructure that integrates environmental, social and governance aspects into a project's planning, building and operating stages".

**Source: Compiled by author from different literature sources*

However, shifting to sustainable infrastructure is a complex task that requires advanced techniques and adequate funds. Financing mechanisms which include sustainability criteria for creating new infrastructure are required to achieve both investment and climate change goals. Thus, the infrastructure financing landscape is experiencing fundamental changes.

Over the years, the demand for infrastructure financing has increased across countries, which led to the need for diversification of funding sources and innovative solutions. Also, Sustainable infrastructure financing and the achievement of Sustainable Development Goals (SDGs) would require additional investment. OECD estimates that the average annual investment in climate-friendly infrastructure will be $6.9 trillion to meet global development needs by 2030 (OECD, 2017). While global financial solutions are being anticipated, infrastructure project financing gaps have greatly expanded (Dash, 2018). Although traditional sources of infrastructure funding, such as bank loans, syndicated loans, and multilateral development banks, still play a significant role, private investors are increasingly becoming involved in recent years. Innovative financing mechanisms such as green bonds, Public Private

Partnerships (PPPs or P3) has emerged as a viable option for infrastructure development especially in the context of developing countries. These mechanisms seek to align financial incentives with the SDGs and attract investment from a variety of stakeholders, including institutional investors, development banks, and charitable groups.

Despite advances, there are still considerable gaps and challenges in financing sustainable infrastructure and industry (Shrivastava et al., 2023). The world needs to ramp up investments in sustainable infrastructure to cope up with the infrastructure deficits especially in emerging economies and attainment of sustainable development goals (SDGs). Sustainable investments is a viable method to support the development of sustainable infrastructure. It enables the allocation of financial resources towards actions supporting SDG attainment. However, despite recent momentum for sustainable investments and financing, many countries need to meet their 2030 Sustainable Development Goals, and it is crucial to increase sustainable investment substantially above current levels (United Nations, 2022). Sustainable investment and financing require investors' objectives to match sustainable projects with measurable results. It is essential to understand the facilitators and barriers to sustainable finance, and theoretical development and empirical validation are also required to reconcile these contradictory conclusions (Joshipura et al., 2024).

Sustainable investing and financing research is proliferating, necessitating to be systematically explored in the context of sustainable infrastructure. Therefore, a quali-quantitative approach that combines both a bibliometric analysis method and a content analysis process is applied in the study. To bridge the gap, this paper reviews the literature on sustainable finance to understand the knowledge progression of research on sustainable infrastructure investing and financing and aimed to answer the following research questions:

i. Which are the most influential authors, institutions, journals, and articles in the domain of innovative finance for sustainable infrastructure.
ii. What are the intellectual foundations and conceptual structures that shape the research on innovative financial mechanisms for sustainable infrastructure.
iii. What dominant theories, geographic contexts, research characteristics, and methodological approaches (TCCM) have been used in studies on innovative finance for sustainable infrastructure.
iv. What is the current state of research on innovative finance for sustainable infrastructure and future areas of investigation.

The contributions of this paper are threefold. Firstly, through an extensive bibliometric review of 374 high-quality articles, it reveals the intellectual and conceptual structure of the field. Secondly, a content analysis of 25 most influential articles provides new insights into sustainable investment and financing, contributing to the development of theory in this area. Lastly, this paper develops a
comprehensive theories-context-characteristics-methods (TCCM) framework to summarise theories, contexts, characteristics, and methods. Future research directions are also suggested in the area of sustainable infrastructure development.

The aim of our systematic review of literature is to synthesize existing evidence of investments and sources of funding for sustainable infrastructure. It will contribute holistically towards the understanding of the field and identify the research hotspots and trends which will help

academic researchers in advancing further in the field. This knowledge can help integrate sustainable transition into infrastructure sectors and coordinate policies and investments for climate-resilient pathways for sustainable development.
Figure 1 summarises the study graphically.

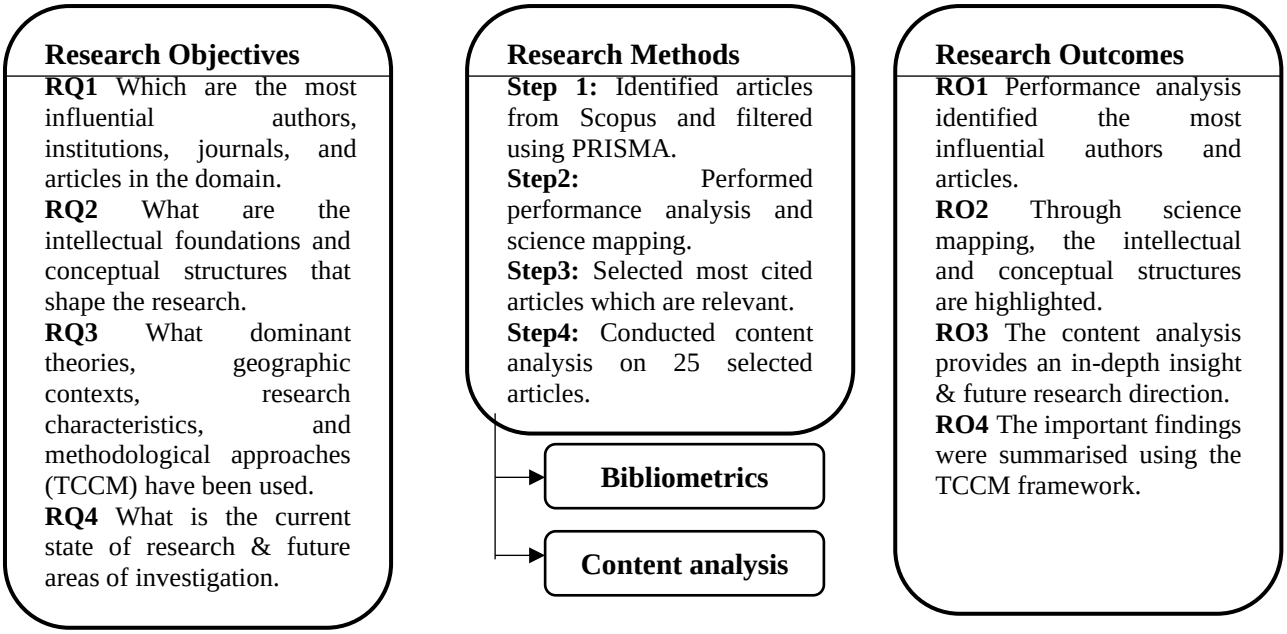

Fig.1 Summary of research design

2. Research Methodology

This study uses a three-phase design integrating systematic literature identification and screening (PRISMA), quantitative bibliometric analysis and qualitative content analysis using TCCM framework. The bibliometric analysis used performance analysis which identified the most influential authors, documents, journals and institutions in the field of sustainable investments. Science mapping allows both intellectual and conceptual structures through visualisation. The co-citation network of documents reveals the intellectual structure while the conceptual structure comprises of the thematic mapping (centrality-density map), three field plot, keyword analysis and co-occurrence network.

Bibliometric data was retrieved from the database of Scopus. The title-abstract-keywords (TIT-ABS-KEY) search query was used using the search string "Sustainable infrastructure" OR “green infrastructure” OR “infrastructure sustainability” OR "infrastructure financing" OR "infrastructure investment" AND "innovative finance" OR "green finance" OR "public private partnership" OR "green bonds" OR "climate finance". This resulted into 485 documents, the search results were confined to the language of English only (469 documents). The time period was taken from the year 2011 to mid-2025 (15 years) which resulted into 431 documents. Further the search results were confined to the areas of Social Sciences, Business, Management and Accounting, Economics, Econometrics and Finance, Environmental Science, Energy and Decision Sciences. Using the PRISMA framework, screening of articles was performed, some

duplicates and irrelevant articles were removed using manual screening. The final analysis was conducted on 374 documents including articles (228), book chapters (68), conference papers (38), review articles (22) and books (12).

Content analysis was performed on 25 top-ranked relevant articles which have significant impact in the field to identify the themes. Themes emerging from content analysis were triangulated with the results from the thematic map. A comprehensive hybrid approach which allows for enhancing existing literature and provides future research directions. To further structure the review findings, the TCCM framework (Theory, Context, Characteristics, Methodology) was applied. Figure 2 summarises the selection strategy using PRISMA.

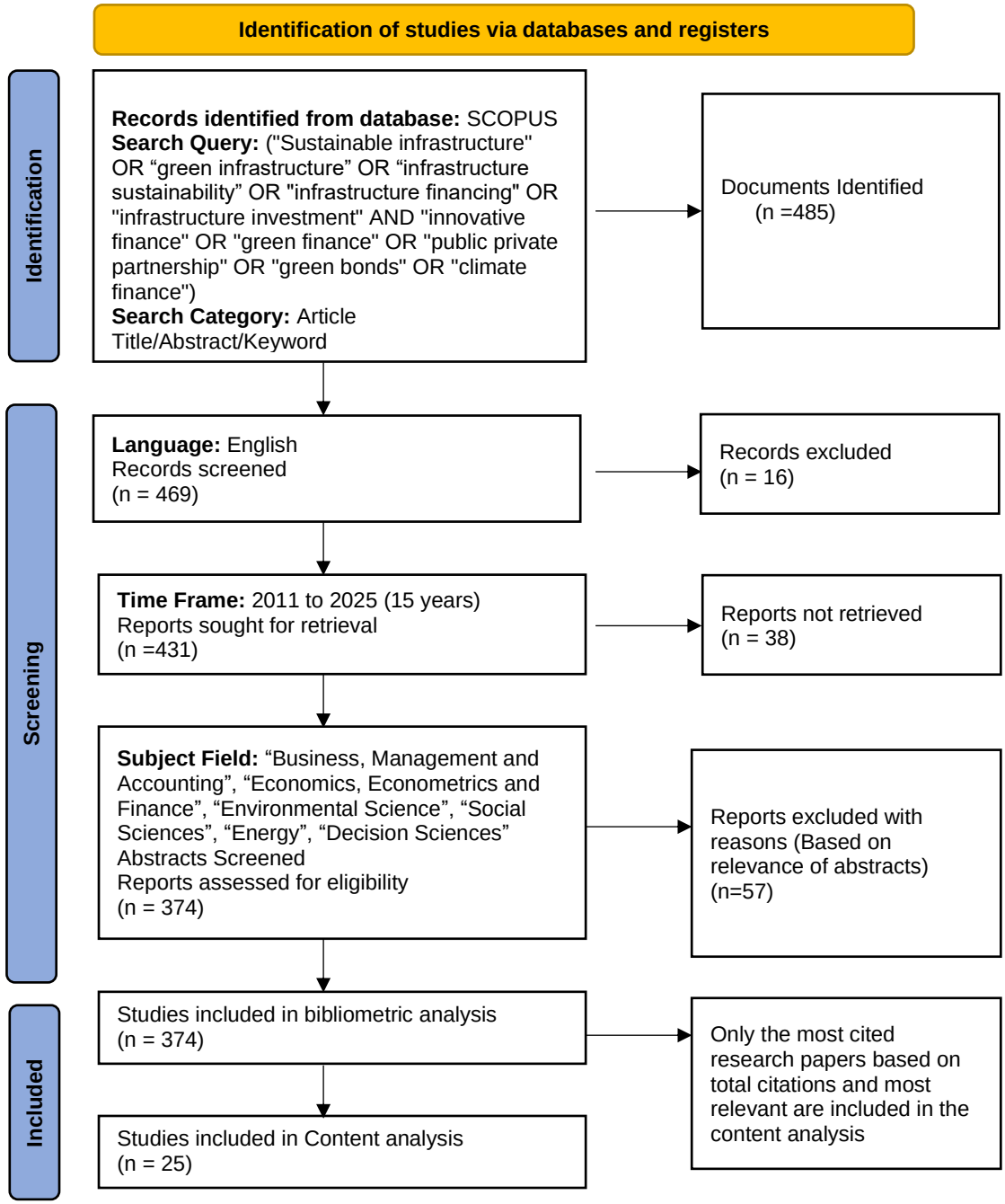

Fig. 2. Article screening process for bibliometric and content analysis using PRISMA
(Source: Page MJ, et al. BMJ 2021;372: n71. doi: 10.1136/bmj. n71)

3. Bibliometric Analysis

Bibliometric analysis compares existing literature and analyzes research progress from various perspectives across different disciplines. This method uses keyword co-occurrence analysis to uncover prominent academic publications and emerging topics. It evaluates relationships between articles using both backward-looking (e.g., co-citation) and forward-looking (e.g., bibliographic coupling) viewpoints. (Donthu et al., 2021)

3.1 Performance Analysis

Performance analysis examines the contributions of research constituents to a given field (Cobo et al., 2011). This study examines 485 articles for a period of 15 years from January 2011 to mid-2025 (June). Figure 3 shows the annual research publications in the field. It is evident from the figure that publications in this field have increased at a slower pace from 2011 to 2021. However, research interest in the field spiked since 2021 and number of publications rose to 49 in 2022, 42 in 2023, 57 in 2024 and 34 in the first half (till June) of 2025. Thereby, indicating exponential growth in sustainable investing and innovative infrastructure financing over the past 5 years. This shift in academic interest towards this field may be attributed to the stakeholder's increased recognition of incorporating sustainability practices into business. Figure 4 presents the country-wise publications in the field of sustainable infrastructure investing. United States (75), China (46) and India (42) are the top three countries in terms of the volume of research contributions, reflecting a growing interest in this area.

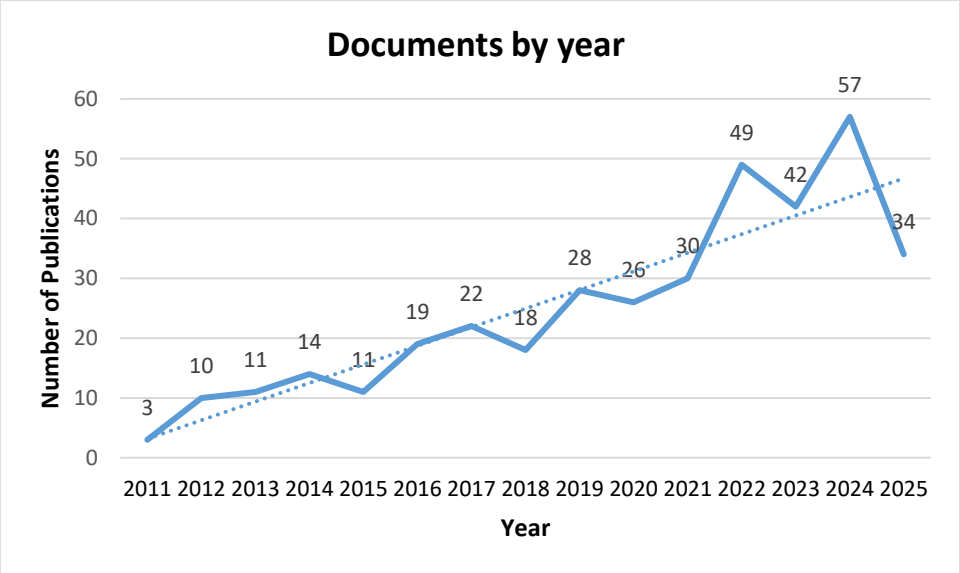

Fig. 3 Number of publications annually (2011-mid-2025)

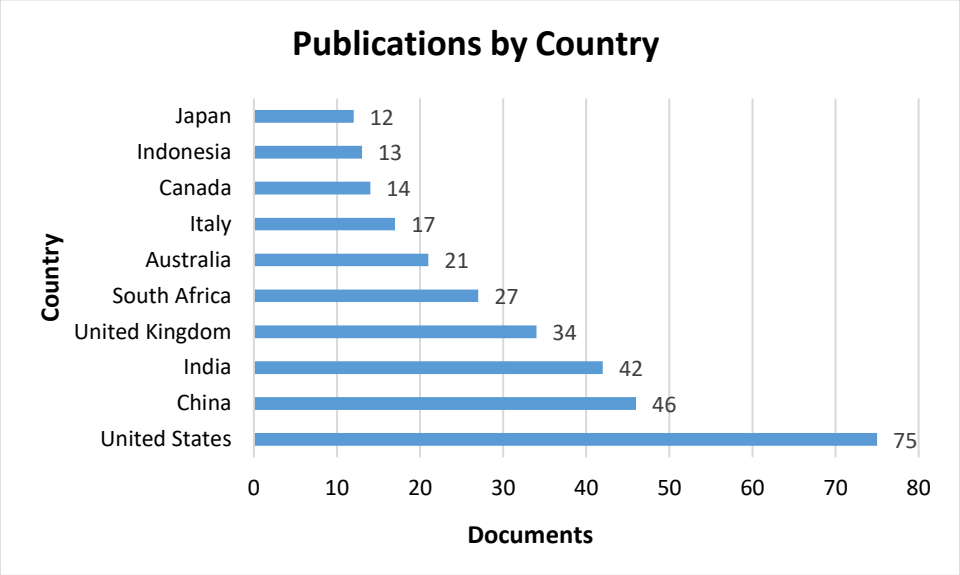

Fig. 4 Country-wise publications

3.1.1 Most influential authors and affiliations

Table 2 presents the most influential authors, affiliations and sources in the field of sustainable investing. Part A illustrates the most cited authors along with their h-index and institutions with the most publications. Laishram B and Yoshino N are the most cited authors with their h-index 3 and 4 respectively. Their research focused upon infrastructure development through PPP and enhancing private infrastructure & utilising green finance for sustainability. Patil NA is third in citations with 75 citations and his most cited paper is "Infrastructure development through PPPs in India: criteria for sustainability assessment" co-authored with Laishram B with 66 citations published in the Journal of Environmental Planning and Management. Other authors in the top 10 most cited have also contributed to the field with their influential research. Abraham D explored the public perceptions of innovative financing for infrastructure systems in the U.S. Whereas Botero S focused on financial eco-innovation as a mechanism for fostering the development of sustainable infrastructure systems.

The University of Johannesburg and University of South Africa had the most publications among others. Both are from South Africa indicating concern about sustainability. Universities from Japan, Indonesia, China and India also contributed to the list of publications in the field of sustainable infrastructure investing.

3.1.2 Most relevant sources

Part B in table 2 presents the list of most relevant sources by publications and citations. The top journals with the most publications include Sustainability (Switzerland), Journal of Infrastructure Policy and Development & Competitive Government Public Private Partnerships. Yoshino N, the second most cited author with 143 citations has published many articles in the Journal of Infrastructure Policy and Development and Sustainability (Switzerland) making them in the list of top 10 publications and citations. Science of the Total Environment topped the list of maximum number of citations due to the most influential article. The paper "Advances and challenges in sustainable tourism toward a green economy" with 451 global citations was published in this journal.

Table 2: Most influential authors, affiliations and sources

Part A: Most influential authors and affiliations					
Top 10 authors with the highest citations				**Most relevant affiliations**	
Order	**Author**	**h-index**	**Total Citation**	**Affiliations**	**Total Publications**
1	Laishram B	3	155	University of Johannesburg	8
2	Yoshino N	4	143	University of South Africa	6
3	Patil NA	3	75	Keio University	5
4	Abraham D	2	71	Moscow State Institute of International Relations MGIMO	5
5	Chen S	2	49	Universidad Nacional de Colombia Medellin	5
6	Botero S	2	45	Universitas Indonesia	5
7	Edwards DJ	2	36	Birla Institute of Technology and Science, Pilani	4
8	Chen B	3	28	Zhejiang University	4
9	Mishra S	3	24	University College London	4
10	Button K	2	11	Erasmus Universiteit Rotterdam	4
Part B: Most influential sources					
Most relevant sources				**Most cited sources**	
Order	**Source**	**Publications**		**Source**	**Citations**
1	Sustainability (Switzerland)	16		Science of the Total Environment	451
2	Journal of Infrastructure Policy and Development	10		Water (Switzerland)	291
3	Competitive Government Public Private Partnerships	7		Ecological Economics	234
4	Climate Policy	5		Journal of Urban Technology	190
5	Engineering Construction and Architectural Management	4		Economic Change and Restructuring	160
6	Journal of Financial Management of Property and Construction	4		Sustainability (Switzerland)	117
7	Transport Policy	4		Public Administration Review	101
8	Frontiers in Sustainable Cities	3		Cities	90
9	Journal of Construction Engineering and Management	3		Journal of Sustainable Finance and Investment	85
10	Journal of Sustainable Finance and Investment	3		Transportation Research Part A: Policy and Practice	83

3.1.3 Most cited documents

The most cited documents are presented in table 3. Pan et al., (2018) and Li et al., (2017) were the most cited authors with global citations 451 & 291 focusing on green infrastructure and Public–Private Partnerships (PPPs). Shwayri S.T. with 190 citations stressed upon the concept of eco-city in South Korea and Sartzetakis E.S. with 160 citations highlighted the concept of green bonds. After thorough examination, green bonds were found to be an emerging source of sustainable infrastructure investment as mentioned by many authors. Schumacher et al., (2020) examined the role of sustainable finance and investment in Japan along with including environmental, social, and governance (ESG) criteria in financial decision-making. The global citations and journal rankings illustrate the influence of articles in the field of sustainable investment.

Table 3: Most influential documents

S. N	Authors*	Year	Source	Title	Global Citations	Journal Ranking	Author Keywords
1	Pan S.-Y.; Gao M.; Kim H.; Shah K.J.; Pei S.-L.; Chiang P.-C.	2018	Science of the Total Environment	Advances and challenges in sustainable tourism toward a green economy	451	Q1	Green building; Green infrastructure; Renewable energy; Smart technology; Sustainable transport; Water-energy-food nexus
2	Li H.; Ding L.; Ren M.; Li C.; Wang H.	2017	Water (Switzerland)	Sponge city construction in China: A survey of the challenges and opportunities	291	Q1	Green infrastructure; Low impact development; Public–private-partnership; Urban flood; Urban stormwater management
3	O'Hara S.; Toussaint E.C.	2021	Ecological Economics	Food access in crisis: Food security and COVID-19	234	Q1, A	COVID-19; Food access; Food justice; Food policy; Food security; Structural disparities;

							Structural racism; The commons; Urban agriculture; Urban food system
4	Shwayri S.T.	2013	Journal of Urban Technology	A Model Korean Ubiquitous Eco-City? The Politics of Making Songdo	190	Q1	Development ; Eco-City; Free Economic Zone; Incheon; Public-Private Partnership; Songdo; South Korea; Ubiquitous
5	Sartzetakis E.S.	2021	Economic Change and Restructuring	Green bonds as an instrument to finance low carbon transition	160	Q2, B	Climate change; Green bonds; Low carbon transition
6	Taghizadeh-Hesary F.; Yoshino N.; Phoumin H.	2021	Sustainability (Switzerland)	Analyzing the characteristics of green bond markets to facilitate green finance in the post-covid-19 world	117	Q1	Asia and the Pacific; Green bonds; Green finance; post-COVID-19 era; Sustainable development
7	Tan J.; Zhao J.Z.	2019	Public Administration Review	The Rise of Public–Private Partnerships in China: An Effective Financing Approach for Infrastructure Investment?	101	Q1, A	NA

8	Toxopeus H.; Kotsila P.; Conde M.; Katona A.; van der Jagt A.P.N.; Polzin F.	2020	Cities	How 'just' is hybrid governance of urban nature-based solutions?	90	Q1	Environmental justice; Hybrid governance; Public-private partnerships; Urban greening; Urban nature-based solutions
9	Schumacher K.; Chenet H.; Volz U.	2020	Journal of Sustainable Finance and Investment	Sustainable finance in Japan	85	Q1	climate-related risks; ESG; Japan; Sustainable finance and investment; TCFD; TOPIX
10	Percoco M.	2014	Transportation Research Part A: Policy and Practice	Quality of institutions and private participation in transport infrastructure investment: Evidence from developing countries	83	Q1, A*	Infrastructure investment; Institutions; Public-Private Partnerships

**Note: The authors name has been written in full as they have been cited in the references at the end.*

3.2 Science mapping through visualisation

Science mapping displays the structural and dynamic aspects of scientific research (Borner et al., 2003; Morris et al., 2008). It examines the intellectual and conceptual structures of sustainable financing and investing. Intellectual structure shows how the work of an author influences a given scientific community whereas the conceptual structure talks about the main themes and trends. The co-citation network of documents reveals the intellectual structure, and the thematic map, three field plot, co-occurrence network uncovers the conceptual structure.

3.2.1 Intellectual structure

Fig. 5 shows the co-citation network between references i.e., how frequently pairs of documents are cited together using Vosviewer. Keeping the minimum number of citations 3,

116 meet the threshold and six clusters emerged: 1. Green bonds, climate finance & investment mechanisms, 2. Public-private partnerships and infrastructure finance, 3. Sustainable infrastructure planning and investment strategies, 4. Urban infrastructure and governance, 5. Assessment for sustainability of infrastructure, 6. Development banks, policy instruments & macroeconomic investment.

Cluster 1 (red) has 23 documents and Flammer (2021) and Woetzel et al., (2016) were the significant contributors which focusses upon sustainable & green finance instruments such as green bonds, climate finance policy. Cluster 2 (green) also has 23 items. Aschauer (1989), Graham & Marvin (2002) highlighted the importance of Public-Private Partnerships and Infrastructure Finance. They examined urban infrastructure as a socio-political construct. Cluster 3 (dark blue) has 21 items focusing upon sustainable infrastructure planning and investment strategies. Cui et al., (2018) and Hodge & Greve (2007) were the major contributors the research field investigating PPP governance frameworks, risk-sharing arrangements, and long-term financial sustainability. Cluster 4 (yellow) has 17 items focusing on urban infrastructure and governance. Cluster 5 (purple) highlights the need of assessment for sustainability of infrastructure and governance of PFI/PPP projects (Clifton & Duffield, 2006). Cluster 6 (light blue) includes 12 items concentrating on development banks, policy instruments & macroeconomic investments in driving sustainable infrastructure investments.

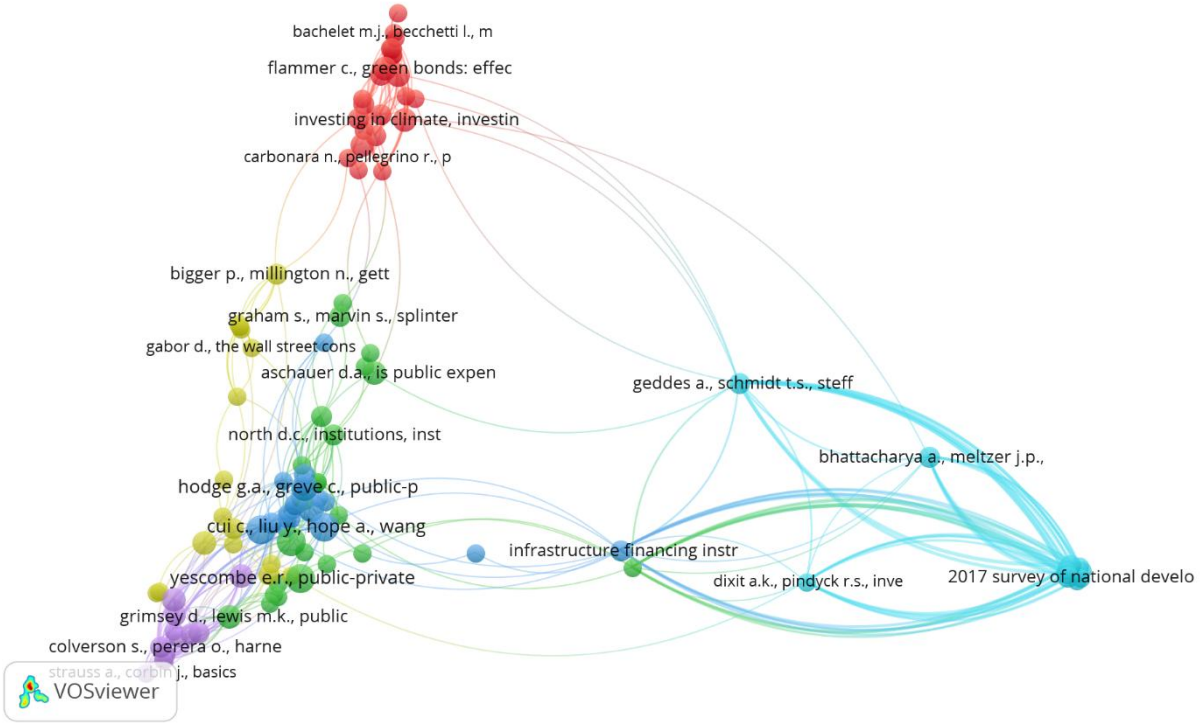

Fig. 5 Co-citation network using Vos viewer

3.2.2 Conceptual structure

The conceptual structure represents the main themes and trends in the field of research. Fig. 6 presents the thematic mapping showcasing the most relevant issues and research work done in the field of sustainable financing and investing. The thematic map highlights the different themes of a given domain into various clusters based upon centrality (relevance to the overall field) and density (development of the theme). (Cobo et al., 2011)

The motor themes are both well-developed and highly relevant, representing the core driving areas of the field. The cluster illustrates that the intersection of sustainability (Kwilinski et al., 2025; Mir et al., 2024; Taneja et al., 2023) with investment strategies and financing models is crucial for sustainable investment (Chethan & Balaji, 2024; Kumar et al., 2025; Canas da Costa & Popović, 2020). Public-private partnerships (PPPs) (Lu & Wilson, 2024; Liu et al., 2024; Ren et al., 2024) are key mechanisms towards green economy and achieving SDGs (Sustainable Development Goals). (Islam et al., 2024; Mahmood et al., 2024).

Basic themes which are the foundational themes for the field but are not deeply explored. This cluster indicates underdeveloped research work on infrastructure investment trends. While central to the field, density remains low, suggesting limited research. (Gupta & Sharma, 2023; Sogut et al., 2025). Niche theme reflects highly developed but isolated research on green solutions for climate resilience. Green finance and cost effectiveness (Kaur et al., 2025; Owojori & Erasmus, 2025; Mir et al., 2025; Aslam et al., 2025) that represents innovative approach and has the potential to transform investment flows.

Emerging themes include studies on Public-Private Partnership (PPP) risk allocation and capital planning (Kasri et al., 2022; Ivanov & Shamanina, 2021; Yurieva et al., 2022; Kouton et al., 2023) which integrates ESG regulations.

3.2.1 Thematic mapping

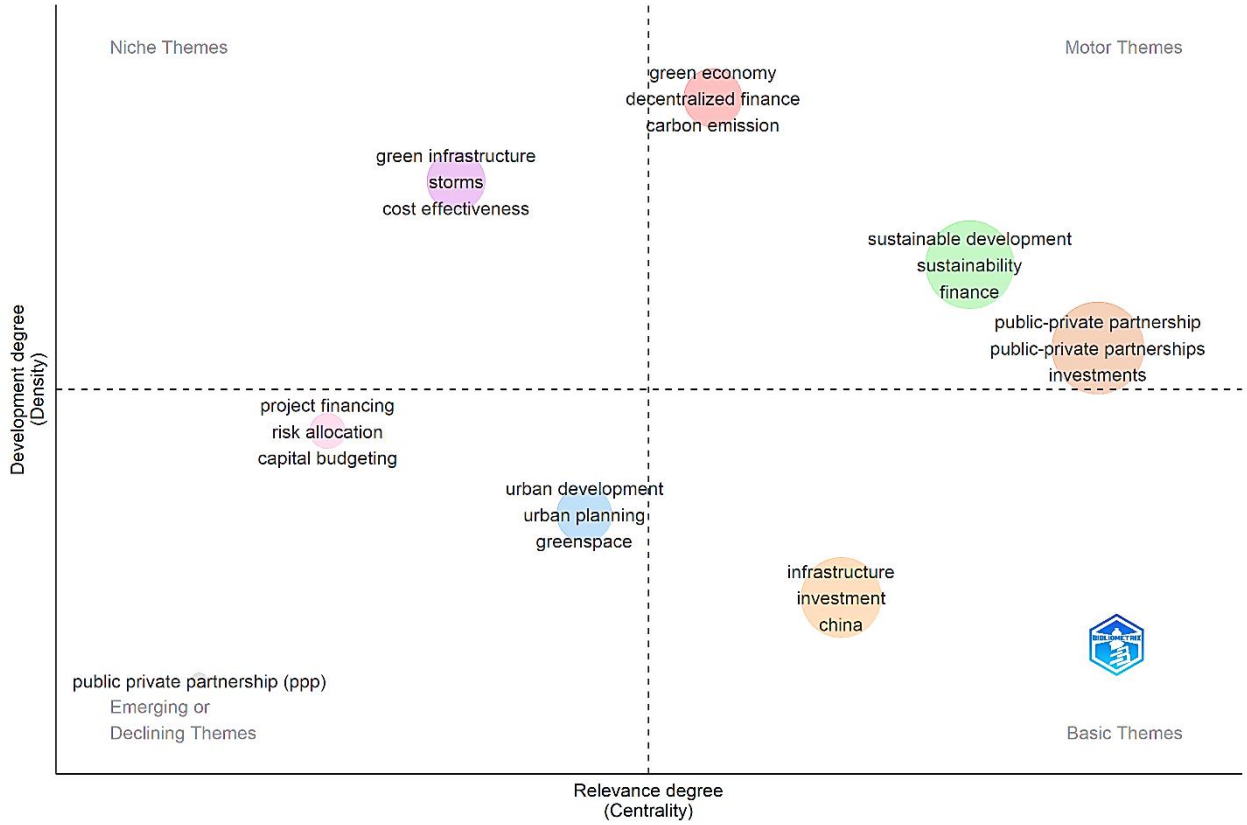

Fig. 6 Thematic map of sustainable financing and investing

3.2.2 Co-occurrence network analysis

Fig. 7 displays the co-occurrence relationship between keywords segregated into different clusters. Based upon interlinkages 3 clusters were formed, red cluster emphasizes the role of investment and infrastructure in achieving sustainable development goals (SDGs), especially in the developing countries. The second cluster (blue) demonstrates the role of public-private partnership in infrastructure financing, whereas green cluster focusses upon the emergence of

green financial instruments, such as green bonds. Public Private Partnership is the central linking term across all clusters, connecting sustainability, infrastructure delivery, and green finance. This visualization not only presents the current landscape but also suggests future research options into sustainable investing integrating ESG frameworks.

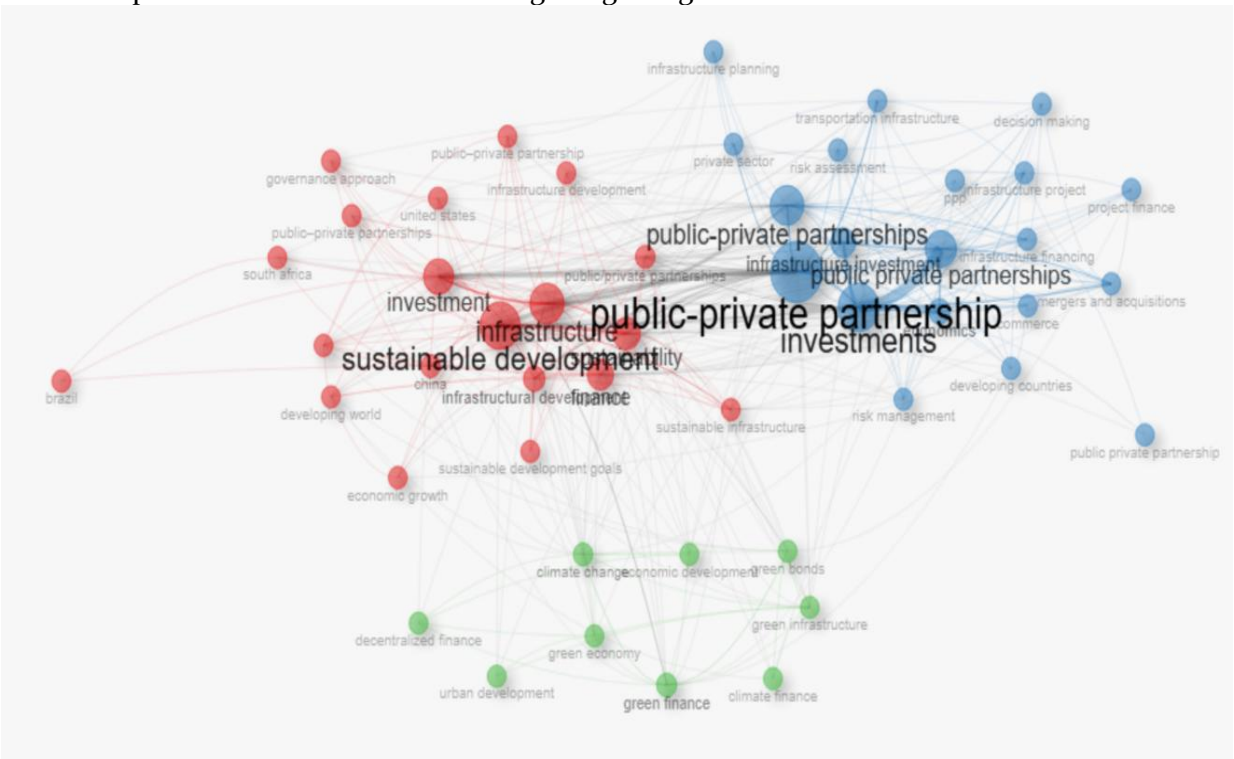

Fig. 7 Co-occurrence Network (All keywords)

3.2.3 Keyword analysis

To comprehend the prevailing themes and trends in the field of sustainable infrastructure investment, keyword analysis is done. Using this approach, popular themes in sustainable infrastructure could be underpinned. Fig. 8 illustrates the word cloud generated using biblioshiny from the keywords extracted from the reviewed studies. By visualising the frequency and co-occurrence of keywords, it is evident that “public-private partnership” (PPP) emerges as a leading area of interest in financing sources for sustainable infrastructure. It is the most frequently mentioned word in the word cloud. Green finance or green bonds also emerges to be a developing concept in the field of sustainable infrastructure. Sustainability or sustainable development is often used in the context of infrastructure investment. Other frequently referenced concepts include “climate change”, “economic development”, “sustainable development goals” indicating a broad and multidisciplinary interest in the field.

J Euro Eco His.
ISSN : 0391-5115
Volume 7, Issue 2 (2026)
THE JOURNAL OF EUROPEAN ECONOMIC HISTORY

Fig. 8 Word cloud of abstract keywords, title keyword & author keywords

3.2.4 Three-Field Plot (Countries -Authors -Keywords)

Fig. 9 connects three key dimensions using a three-field plot created using biblioshiny. It shows how different countries through their key researchers contribute to specific themes and keywords in the field of sustainable infrastructure investing. USA is the most significant contributor, connecting with various authors and thematic areas like green finance, infrastructure financing, and public-private partnerships. India is contributing actively to the areas of sustainability, infrastructural development, and climate change. While Germany, China, and South Africa are also contributing substantially, indicating a global interest in sustainable infrastructure. The prominent authors include Yoshino N which is frequently linked to the areas of infrastructure financing and public-private partnerships. Authors like Wang Y., Mishra S., and González-Ruiz J.D act as knowledge bridges connecting to global themes like green bonds, sustainable infrastructure, and investment. Laishram B. is an active researcher in developing country contexts contributing to infrastructural development and sustainability. The thematic analysis of keywords such as Sustainable development, infrastructure, and Public Private Partnerships indicates common frameworks for investment decisions. While green bonds or green finance emerges as a driving research theme. This visualization highlights the global and collaborative nature of the research in the field of sustainable infrastructure investing.

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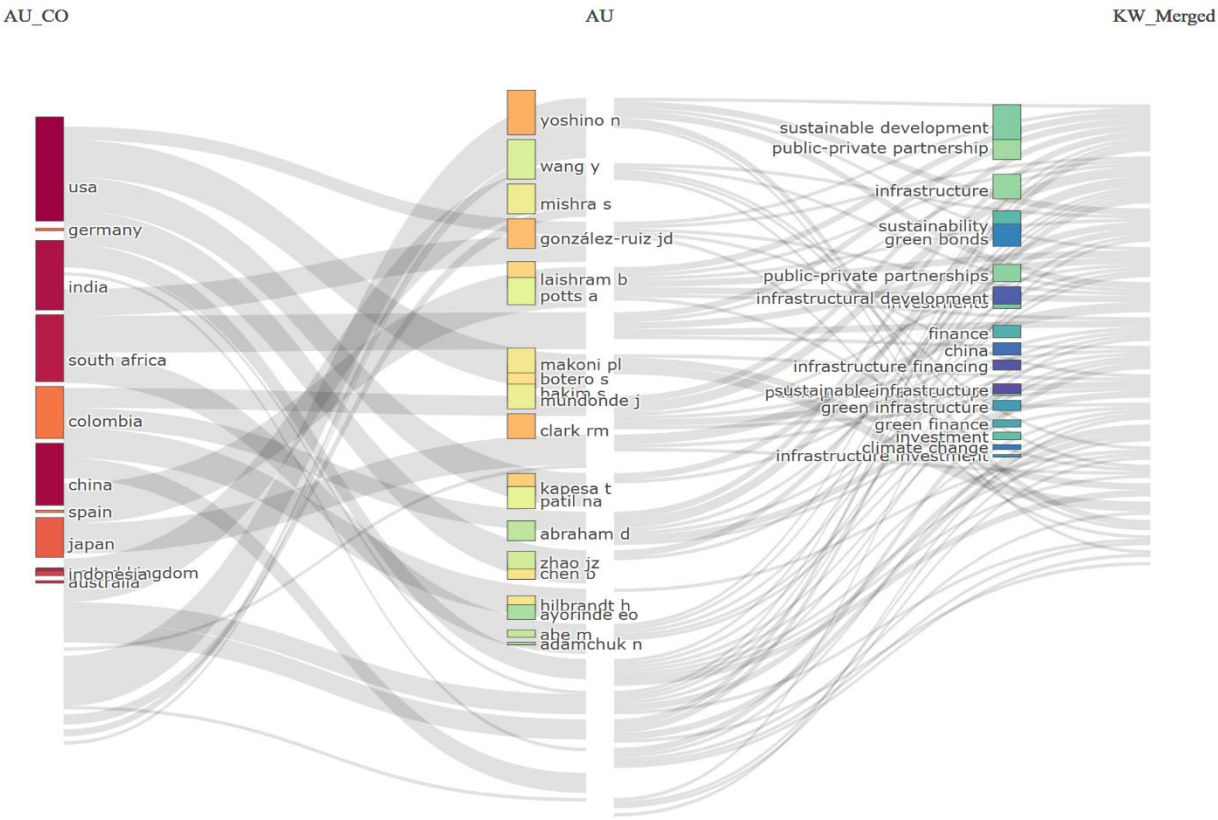

Fig. 9 Three-Field Plot

4. Content Analysis

Content analysis of the 25 most-cited articles revealed the major research streams of sustainable development, finance & investment and PPPs & green infrastructure. Tables 4, 5 and 6 provides a descriptive cluster-wise review of the articles.

4.1 Sustainable Development

Table 4 indicates the major contributions of researchers on the theme of sustainable development. Pan et al. (2018) investigated in green innovation focused on sustainability, regulation, and industry evolution and identified research clusters using bibliometrics. Shwayri (2013) examined challenges include top-down planning, lack of local context sensitivity, dependence on private sector, and insufficient adaptability for future growth. Also highlighted the tension between environmental sustainability and economic development goals. Toxopeus et al. (2020) focused upon the concept of hybrid governance which can both improve and worsen urban justice. Transparency, public control, and inclusive consultation are the key areas. Legal and political conflicts in infrastructure projects are driven by combinations of country context, project design, and local impacts. Involvement of international financial institutions, lack of consultation, high service price increases, and low host-country equity stakes are associated with conflict (Boudet et al., 2011). Cities in developing nations face a climate-finance gap, requiring technical assistance to develop bankable, climate-smart infrastructure. PPFs are instrumental in bridging knowledge and finance, helping with risk mitigation, regulatory navigation, and investor alignment (Gorelick & Walmsley, 2020).

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Table 4: Sustainable Development

S. N	Author & Year	Theories / models used	Geographical area	Time emphasis	Sample size	Ranking	Total Citations	Major insights
1	Pan et al., (2018)	Sustainability assessment frameworks	Global / Asia	2010	Review-based	Q1	837	Tourism sustainability depends on integrative green infrastructure planning.
2	Li et al., (2017)	Urban hydrology models; Resilience theory	China	2010–2017	Multiple Chinese cities	Q1	424	Sponge city concept addresses urban flooding through nature-based solutions.
3	Shwayri (2013)	Smart city paradigm; Political economy	South Korea	2000	Single city case (Songdo)	Q1	350	Critically assesses techno-centric planning in eco-city design.
4	Toxopeus et al., (2020)	Justice theory; Urban governance	EU cities	Contemporary	3 case cities	Q1	144	Highlights equity concerns in public-private urban green space governance.
5	Boudet et al., (2011)	Stakeholder conflict theory	Developing countries	2000–2010	Survey-based	A*	115	Identifies political exclusion as a barrier to sustainable infrastructure.
6	Cooper (2017)	Institutional theory; Global governance	BRICS nations	2010	Conceptual analysis	Q1	112	New Development Bank repositions BRICS in sustainable financing.
7	Gorelick & Walmsley (2020)	Sustainable planning models	Africa	2010–2020	Multiple African cities	-	64	Urgency of climate-adaptive local governance in African cities.
8	Wang & Sun (2016)	Development economics	China	2000–2015	Panel data	Q1, C	75	Infrastructure linked to regional disparity reduction.

4.2 Finance & Investment

Sartzetakis (2021) identified green bonds effective for low-carbon transitions which support intergenerational burden sharing and large-scale investments. Green bonds showed competitive performance, with better risk-adjusted returns and are suggested to fund sustainable urban infrastructure. (Partridge & Medda, 2020). Taghizadeh-Hesary et al., (2021) also support green bonds and green finance systems in backing SDG-linked projects effectively. Granoff et al., (2016) recommended aligning public finance with sustainability, strengthening institutions, mobilizing private finance, and enhancing project pipelines. It provides a roadmap for scaling green infrastructure in developing economies through coordinated policy and finance. Table 5 presents the major contributors in this stream along with their research findings.

Table 5: Finance & Investment

S. N	Author & Year	Theories / models used	Geographical area	Time emphasis	Sample size	Ranking	Total Citations	Major insights
1	Sartzetakis (2021)	Financial instruments theory	Global / EU	2015–2020	Conceptual	Q2, B	326	Green bonds promote clean investments but need standardization.
2	Taghizadeh-Hesary et al., (2021)	Bond market analysis	Asia-Pacific	2010–2020	Secondary data	Q1	155	Rapid growth in green bonds but policy support is uneven.
3	Schumacher et al., (2020)	ESG investment frameworks	Japan	2010	Policy + financial review	Q1	179	Limited ESG uptake despite Japan's economic strength.
4	Granoff et al., (2016)	Institutional economics	Global South	2010	Policy analysis	Q1	114	Policy and financing risks hinder infrastructure investment.
5	Tian et al., (2020)	Blockchain finance theory	Global	2015–2020	Proof-of-concept	-	128	Blockchain improves transparency and efficiency in infra finance.
6	Partridge & Medda (2020)	Yield curve analysis	US / EU	2015–2019	Market data	Q1	145	Green bonds may yield better stability than conventional bonds.
7	Liu (2022)	Financial risk models	China	2016–2021	Econometric	Q1, B	78	Volatility affected by policy shifts and carbon risk.

8	Ng et al., (2021)	Sustainable energy finance	Global	2020–2021	Comparative review	Q1	64	Green finance accelerates renewable energy deployment.
9	Li et al., (2017)	Bond market frameworks	US & EU	2000–2010	Case studies	Q1, A	73	Project bonds can bridge investment gaps in large projects.

4.3 PPPs & green infrastructure

PPPs play a supplementary role rather than replacing traditional public finance. (Tan & Zhao, 2019). Better institutional quality is strongly associated with higher levels of private participation in transport PPPs. Civil freedoms and sound governance frameworks encourage risk transfer to private sector. Corruption and weak institutions limit effective PPP implementation. Institutional reforms can lead to more structured and sustainable PPP contracts in infrastructure (Percoco, 2014). Also, the success of PPPs depends on adaptive governance (Koppenjan, 2015).

Patil et al., (2016) identified key challenges facing PPP projects in Indian urban infrastructure, including regulatory hurdles, lack of transparency, financial risks, and inadequate risk-sharing frameworks. It advocates stronger institutional frameworks, clearer contractual arrangements, and capacity-building at the municipal level to improve PPP outcomes. Akomea-Frimpong et al., (2023) explored the transformative role of green finance in achieving energy sustainability beyond Industry 4.0. It highlights that conventional economic growth paradigms are insufficient, calling for integration of AI, green innovation, blockchain, and big data. Emphasis is placed on public-private collaborations, institutional reforms, and green bonds for advancing sustainability. Table 6 highlights the research contributions in context of PPPs & green infrastructure.

Table 6: PPPs & green infrastructure

S. N	Author & Year	Theories / models used	Geographical area	Time emphasis	Sample size	Ranking	Total Citations	Major insights
1	Tan & Zhao (2019)	PPP institutional analysis	China	2000–2018	Policy case review	Q1	175	China's PPP model is hybrid and state-dominated.
2	Percoco (2014)	Institutional theory	Global	2000	Quantitative index	Q1, A*	146	Institutional quality influences infrastructure PPP success.
3	Koppenjan (2015)	Governance theory	EU	2000–2010	Comparative policy	Q1	125	PPP success depends on adaptive governance.
4	Agarchand & Laishram (2017)	Project delivery models	India	Contemporary	Expert interviews	Q1, C	141	Project delivery systems often misalign with sustainability goals.

5	Patil et al., (2016)	PPP risk-sharing models	India	2000–2015	Multiple case studies	Q1, B	96	Risk allocation remains a bottleneck in Indian PPPs.
6	Kumari & Sharma (2017)	PPP project lifecycle	India	2000–2010	Comparative analysis	Q2	110	Private sector involvement linked to cost efficiency.
7	Akomea-Frimpong et al., (2023)	PPP effectiveness model	Ghana	Recent	Survey-based	Q1, C	92	Governance and trust are key for successful PPPs.
8	Liu et al., (2022)	Crisis finance models	China / Global	2020–2022	Econometric	Q1, A	70	COVID disrupted but also accelerated green bond market growth.

5. Conclusion

The study examines the important issues discussed in the literature in the field of sustainable infrastructure investments. The importance of financing and investing in sustainable infrastructure for attaining sustainable growth is becoming more widely acknowledged. There is now general agreement that investments in sustainable infrastructure have the ability to increase productivity (Edemy et al., 2020; Duggal et al., 1999) in addition to generating benefits for the economic development (Frischmann, 2012; Meng et al., 2024). After thoroughly reviewing the research papers from the literature using a systematic PRISMA method, Public-private partnerships (PPP) and green finance or green bonds emerged out to be the important themes in the field of sustainable infrastructure investments. The performance analysis identified the most influential studies and it indicated exponential growth in sustainable investing and innovative infrastructure financing over the past 5 years. United States (75), China (46) and India (42) were the top three countries in terms of the volume of research contributions, reflecting a growing interest in this area. Laishram B and Yoshino N were the most cited authors focusing upon infrastructure development through PPP and enhancing private infrastructure & utilising green finance for sustainability. The top journals with the most publications include Sustainability (Switzerland), Journal of Infrastructure Policy and Development & Competitive Government Public Private Partnerships. Science of the Total Environment topped the list of maximum number of citations due to the most influential article. The paper “Advances and challenges in sustainable tourism toward a green economy” with 451 global citations was published in this journal.

Moreover, science mapping examines the field's conceptual and intellectual frameworks, identifying key themes and subfields. The emerging themes were (i) Green bonds, climate finance & investment mechanisms (ii) Public-private partnerships and infrastructure finance (iii) Sustainable infrastructure planning and investment strategies (iv) Urban infrastructure and governance (v) Assessment for sustainability of infrastructure (vi) Development banks, policy instruments & macroeconomic investment. Whereas, thematic map highlights the different themes of a given domain into various clusters based upon centrality (relevance to the overall field) and density (development of the theme) (Cobo et al., 2011).

The Co-occurrence network analysis highlights Public Private Partnership as the central linking term across all clusters, connecting sustainability, infrastructure delivery, and green finance. Along with this, the three- field plot highlights the global and collaborative nature of

the research in the field of sustainable infrastructure investing. In consensus with bibliometric review, content analysis provided an in-depth insight into the field and contributing to the existing research.

To provide a structured synthesis of the literature on sustainable infrastructure and its financing mechanisms, this study applies the TCCM framework (Theory–Context–Characteristics–Methodology). Fig. 10 synthesize the research findings using. TCCM framework. The framework enabled systematic categorization of key dimensions across the selected studies, ensuring clarity in thematic evolution and knowledge structure.

From a theoretical approach, institutional theory, stakeholder theory, climate finance theory, and PPP theory are frequently used in the literature, each providing unique perspectives on infrastructure investment, governance, and finance innovation. In terms of context, the majority of studies were conducted in urban and policy-focused settings, particularly in emerging economies such as China, India, and Southeast Asia, as well as in developed contexts such as the EU, Japan, and South Korea, highlighting the global relevance and application diversity of green and sustainable infrastructure. Stakeholder collaboration, resilience infrastructure, PPP models, green bonds, and ESG integration were the observed characteristics. And the approaches used in the literature showed a balance between quantitative and qualitative research, ranging from case studies, policy analyses, empirical modeling, bibliometric mapping, and thematic content analysis.

Although there is a growing body of research on sustainable investment and financing, there are still significant gaps that require further investigation. The TCCM framework enhances the strength of the hybrid review and also identifies the research gaps to suggest future areas of research. The field of sustainable infrastructure investment is complex and continually evolving.

Theories	Context	Characteristics	Methods
Theory, Political Economy, Transition Theory			
Stakeholder Theory, Environmental Justice, Urban Governance			
Climate Finance Theory, Public Finance Theory			
Public-Private Partnership (PPP) Theory, Risk Sharing Theory			

Sustainable Development Theory, ESG Frameworks	China (Sponge Cities, PPP in Infrastructure), Japan, Korea, EU, Global	Green infrastructure adoption, policy drivers, governance models, institutional roles	Case studies, Policy analysis, Literature review, Descriptive analysis
Resilience Theory, Nature-based Solutions Framework	Urban regions, Smart cities, Eco-cities (e.g., Songdo, Korea)	Stakeholder collaboration, hybrid governance, inclusivity and justice in green planning	Mixed methods, Thematic analysis, Qualitative content analysis
	Emerging economies, EU policy environment	Role of green bonds, climate-aligned financing tools, financial regulations	Quantitative analysis, Market trend evaluation, Comparative analysis
	Developing countries (esp. China, Southeast Asia, India)	PPP implementation models, risk-return tradeoffs, private sector participation in infrastructure	Bibliometric analysis, Network analysis, Case-based comparison
	Global financial institutions, sustainability reporting systems	ESG integration in infrastructure finance, alignment with SDGs, decarbonization targets	Content analysis, ESG benchmarking, Policy impact assessments
	Coastal cities, flood-prone urban areas	Urban resilience, green infrastructure design, sponge city principles	Empirical surveys, Infrastructure modeling, Landscape simulation

Fig. 10 Theories-context-characteristics-methods (TCCM) framework

The findings of the study are robust in terms of data collection and analysis tools used. However, there are certain limitations which open up the scope for further investigation. The results have been slightly different, if multiple databases were used for selection criteria or a different software was used for bibliometric analysis. Further, the research does not take into account the policy insights that can emerge from considering the contextual aspects. These limitations provide scope for future research and underexplored linkages particularly in integrating innovative financing tools with context-specific sustainability goals.

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