Urban Critical Infrastructure Resilience and the Sustainable Development Goals

Zhiyuan Li [a,b], Scott Thacker [c,d], Ranran Ji [a,b], Yujia Bai [a,b], Yongxin Liu [a,b], Xian Wu [a,b], Guoqin Zhang [a,e,f] , Hong Ye [a,b,e,f] *

[a] Key Lab of Urban Environment and Health, Institute of Urban Environment, Chinese Academy of Sciences, Xiamen 361021, China

[b] University of Chinese Academy of Sciences, Beijing 100049, China

[c] Environmental Change Institute (ECI), University of Oxford, Oxford, UK

[d] Oxford Infrastructure Analytics (OIA), Oxford, UK

[e] CAS Haixi Industrial Technology Innovation Center in Beilun, Ningbo 315800, China

[f] Xiamen Key Laboratory of Smart Management on The Urban Environment, Xiamen 361021, China

Declaration of competing interest

The authors declare no competing interests.

CRediT authorship contribution statement

Zhiyuan Li: Conceptualization, Data curation, Formal analysis, Methodology, Software, Visualization, Writing – original draft. Scott Thacker: Conceptualization, Methodology, Writing – review & editing. Ranran Ji: Writing – review & editing. Yujia Bai: Writing – review & editing. Yongxin Liu: Writing – review & editing. Xian Wu: Writing – review & editing. Guoqin Zhang: Funding acquisition, Software. Hong Ye: Conceptualization, Funding acquisition, Methodology, Supervision, Writing – review & editing.

Acknowledgments

The authors wish to give their sincere gratitude to the Institute of Urban Environment, Chinese Academy of Sciences 'Select the best candidates to undertake key research projects' (grand No. IUE-JBGS-202215), National Natural Science Foundation of China (grand No. 42271299), Ministry of Science and Technology of China (MSTC) with National Key Research and Development Programs (grand No. 2023YFF1304700, 2022YFF1301200), International Partnership Program of Chinese Academy of Sciences (grand No. 132c35kysb2020007) and Ningbo Commonweal Science and Technology Planning Project (grand No. 2021S081).

Corresponding author at: Key Lab of Urban Environment and Health, Institute of Urban Environment, Chinese Academy of Sciences, Xiamen 361021, China.

E-mail address: hye@iue.ac.cn

Urban Critical Infrastructure Resilience and the Sustainable Development Goals

Abstract

Urban critical infrastructures (UCIs) such as energy, cyber and transportation are essential to the development of modern cities, not only to support economic activities and daily life, but also to make cities resilient to natural disasters and social challenges. Using data mining and evidence integration methods, we analyze the landscape of research literature on UCIs resilience, including their interconnectivity and their interactions with the Sustainable Development Goals (SDGs). The results of the study found that the energy sector had the most research papers, almost twice as many as any other sector, while we observe an increasing number of interdependencies being explored, particularly in energy, transport and cyber infrastructure. Energy, communications and transport-related services dominate our functional mapping, with almost 80 % more relevant papers than research focusing on essential services such as water and waste management and healthcare. We identify key linkages between the infrastructure sectors explored and 47 targets within the 9 SDGs. The study highlights the importance of interdisciplinary research and multi-sector collaboration, which can help to develop a robust understanding of the complexity and dynamics of urban infrastructure systems and provide a scientific basis for the development of integrated strategies and policies.

1. Introduction

UCIs, such as energy, cyber, transportation, water and healthcare systems, are the foundations of modern urban development, not only supporting the economic activities of cities and the daily lives of residents, but also being essential for cities to address the challenges of social and natural disasters. The resilience of the infrastructure - capacity to withstand the impacts of disasters and to recover quickly and continue to provide services - is particularly important as global climate change, population growth, and resource constraints become more severe (Shakou et al., 2019). However, infrastructures in many cities currently have deficiencies in building resilience, with some older systems not adapting to new challenges and emerging projects failing to adequately consider potential risks (Carter et al., 2015). For example, infrastructure in coastal cities is particularly vulnerable to the threat of sea level rise and extreme weather events (Hallegatte et al., 2013), while fast-growing megacities face traffic congestion, communication failures, and energy shortages (Rahman and Rahman, 2015). These problems not only threaten the sustainable development of cities, but also challenge the quality of life of residents (Adshead et al., 2024). The SDGs provide a global framework designed to promote the harmonization of economic growth, social inclusion, and environmental protection (Griggs et al., 2013). Linking the SDGs to the building of resilience in critical urban infrastructure offers the potential for a more holistic approach to the complex challenges of cities (Fuldauer et al., 2022).

The comprehensive nature of the SDGs, covering economic, social, and environmental aspects, necessitates an integrated approach in infrastructure planning and development. For instance, the implementation of SDG 7 (Clean Energy) and SDG 13 (Climate Action) can facilitate the adoption of environmentally friendly and sustainable energy technologies, leading to reduced Greenhouse Gas (GHG) emissions and improved energy system resilience (Fuso Nerini et al., 2018). SDG 9 (Industry, Innovation, and Infrastructure) promotes the utilization of innovative technologies to enhance infrastructure adaptability and flexibility, thereby increasing resilience to future challenges (Gera et al., 2023). The resilience of UCIs is crucial for achieving the SDGs, particularly in SDG 11 (Sustainable Cities and Communities), which underscores the importance of urban infrastructure in withstanding natural disasters and adapting to environmental changes (Mukherjee et al., 2023). Robust energy systems can advance SDG 7 by ensuring energy supply stability and reliability during extreme weather events (Jayachandran et al., 2022). Similarly, resilient transportation systems can help mitigate GHG emissions, support SDG 13, and contribute to SDG 3 (health and well-being) by providing safe and efficient transportation options (Ipingbemi and Akogun, 2021).

A number of studies have investigated the resilience of UCIs and SDGs, including for single systems or sectors (Perera & Hong, 2023; Mitoulis et al., 2023; Biermann et al., 2022; Vinuesa et al., 2020; Giannetti et al., 2020), thereby lacking a holistic examination that encompasses multiple critical infrastructure sectors and various SDGs. Studies, including by Thacker et al. (2019), Fuldauer et al. (2022), and Fuso Nerini et al. (2018), which have addressed this limitation, examining doing so examining multiple sectors and SDGs, albeit using an expert elicitation methodology. Within this study, we build on this previous research, by looking at multiple sectors, systems and SDGs, whilst also using a novel data mining and evidence integration methodology.

Evidence synthesis methodology serves as a structured approach that allows for the extraction of valuable insights from extensive and diverse datasets, unveiling intricate interrelations among them. As highlighted in recent research, a comprehensive review of evidence has resulted in the creation of a framework for evaluating the potential of ecosystem services in supporting green infrastructure (GI), offering a fresh perspective on the role of urban GI within the food-energy-water-habitat (FEWH) nexus (Ruan et al., 2023). Moreover, scholarly works emphasize the importance of interdisciplinary cooperation in advancing concerted efforts towards addressing climate change and other SDGs (Fuso Nerini et al., 2019). The literature further showcases the effectiveness of evidence synthesis in tackling environmental policy challenges, thereby enhancing the scientific basis and practicality of policy recommendations (Nesshöver et al., 2017). Through an integrative analysis, Huan et al. (2021) evaluated the global progress of various countries and regions in attaining the SDGs, emphasizing the critical necessity for cross-sectoral policy integration.

We develop a foundational framework to establish an evidence synthesis pathway aimed at investigating the connections between UCI resilience and the SDGs. The study poses several key questions to guide this exploration: (1) What are the primary sectors encompassed by UCIs resilience, and what is the current status of research in these specific areas? (2) What are the key services and functions offered by various types of critical infrastructure to urban areas and their residents, and what is the distribution of research in this field? (3) Is it possible to quantify the correlation between urban infrastructure resilience and the SDGs? Through an analysis and synthesis of existing literature, this study delves into the principal sectors of UCIs resilience research and the services and functions associated with each sector in the context of urban and human development. Additionally, it seeks to measure the interaction between UCIs resilience and the SDGs by focusing on the primary sectors and the services and functions they deliver. In doing so, we aim to provide a scientific foundation for urban planners and policymakers to enhance their comprehension and management of the intricate nature of urban infrastructure. This comprehensive approach amalgamates existing knowledge to facilitate a deeper understanding of the synergies and challenges inherent in the intersection of urban resilience and sustainable development.

2. Data and methodology

2.1. Data collection and pre-processing

The study utilized the Web of Science (WoS) database from Clarivate Analytics as the primary data source for investigating the resilience of UCIs. WoS, a globally recognized multidisciplinary academic literature search database, was chosen for its high-quality content (Li et al., 2018). While other databases, notably Scopus, also offer extensive and authoritative literature coverage, WoS was deemed sufficient for supporting the study's analysis (Pranckutė, 2021). Furthermore, the Science Citation Index Expanded (SCIE) was utilized for additional screening to ensure the international applicability and comparability of the study findings. On 20th May 2024, a search was conducted for peer-reviewed journal articles published before this date using specific keywords related to “Urban”, “Critical Infrastructures”, and “Resilience”, resulting in 1686 records comprising Articles, Proceeding Papers, Review Articles, and Editorial

Materials.

The advanced search capabilities of the WoS database were employed to identify literature closely aligned with the study's focus. During the data extraction phase, emphasis was placed on extracting essential information such as titles, authors, abstracts, and keywords, which served as a foundation for evaluating the academic significance and influence of the literature (Paul and Criado, 2020). For this study, we include article and review articles only. Data cleaning procedures involved eliminating duplicate entries and incomplete records to ensure data integrity and consistency. The data was then further refined to include records where the main text and keywords were in machine readable formats – enabling further processing and analyses.

2.2. Methodology

2.2.1. Domain network

The first step of the methodology is to derive a domain network through analysis of the scientific literature to enhance our understanding of the UCI sectors and the connections among them (Fig.1a). Using the bibliometrix package, keyword extraction was conducted on UCIs-related literature to identify the top 100 frequently used author keywords, which were then refined for synonyms and morphological variations (Derviş, 2019). Through frequency analysis, it was determined that energy, cyber, transportation, healthcare, and water were the five key infrastructure systems under study (see Text S1 in Supplementary Materials) and were used to classify the literature. Subsequent analysis involved examining the screened literature in depth, including the identification of instances where multiple infrastructure systems co-occurred, thereby unveiling patterns in interdisciplinary research. The extracted literature, along with annual average citation data (more details see Table S2 in Supplementary Materials), was visualized using Gephi software to create a domain network illustrating the distribution of research domains and the interrelationships between them (Bastian et al., 2009). This visualization offered a comprehensive overview of the research landscape in the field of urban infrastructure.

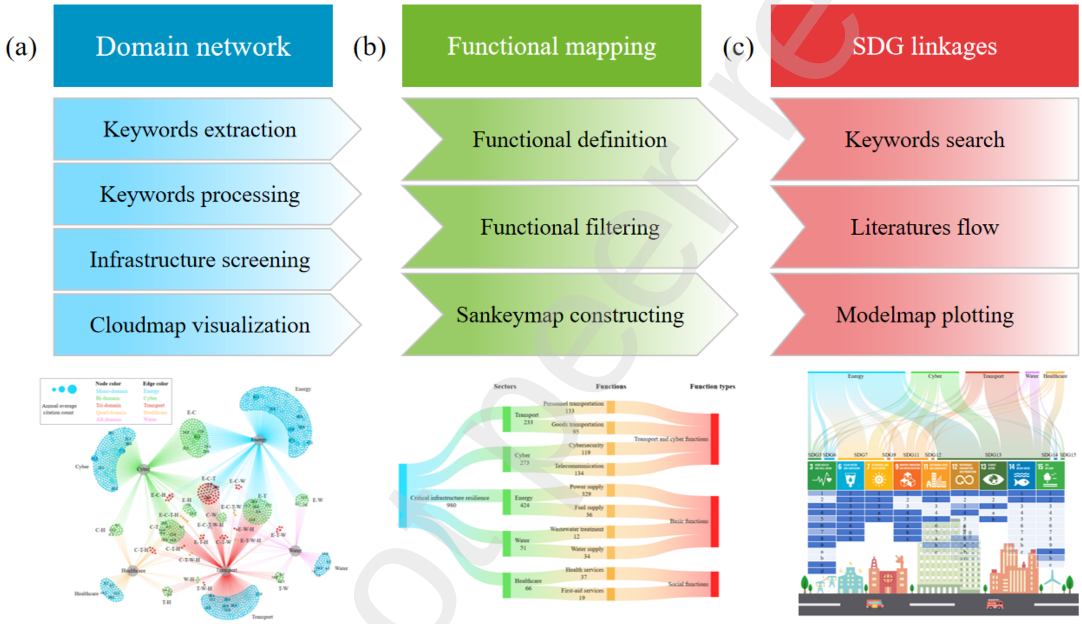

Fig. 1 Methodological framework for urban critical infrastructure resilience and the SDGs.

2.2.2. Functional mapping

The second step of the methodology is to develop a functional mapping for different UCI sub-sectors (Fig.1b). By conducting a thorough examination of literature abstracts pertaining to five key infrastructure types derived from domain network analysis, we were able to ascertain the urban system functions associated with each infrastructure (see Table S3 in Supplementary Materials). The construction of the functional mapping involved the independent identification of each infrastructure type and its corresponding services to form a layered structure. Throughout this process, we accounted for duplicate instances in the literature to acknowledge the interdisciplinary nature of urban infrastructure research, where a single study may contribute to various facets of urban services. For specific critical infrastructure types, we opted to focus on the top two urban system services linked to each type for further investigation. This method not only streamlines the process of identifying connections between infrastructure and services but also enriches the depth of analysis, enabling a more comprehensive understanding of the intricate dynamics within urban critical infrastructure systems.

2.2.3. SDG linkages

The third and final step of the methodology concerns identifying linkages between UCIs and the SDGs (Fig.1c). 980 documents were reassessed using keywords from each target and compared to the method of classifying SDGs in Web of Science to determine the number of documents associated with each SDG. Documents corresponding to each sector were searched to match interlinked documents. Subsequently, we search the literature obtained above for each SDG based on the keywords corresponding to each sector to obtain the number of documents interlinking UCIs resilience with SDGs, thus creating a linkage known as a 'literature flow' (see Table S4 in Supplementary Materials). Using Origin 2021 software, we visually represented the literature flows through Sankey diagrams, creating a visual representation that illustrates the interconnectedness.

Following the literature linkage between UCIs resilience and SDGs established based on the literature flow described above, we achieve the quantification of the relationship between UCIs resilience and SDGs through keyword searches and review of literature abstracts. To do this, the corresponding SDGs literature was searched based on the keywords for each sector to determine if a link exists. Finally, abstracts of literature where a link between the two exists are reviewed to determine the strength and direction of the link that exists within them. To enhance the clarity of the relationships between urban critical infrastructure resilience and the SDGs, we classified these relationships into three levels: 0 indicating no association, 1 representing a unidirectional relationship, and 2 denoting a bi-directional relationship (see Table S5 in Supplementary Materials). Subsequently, we visualized the connection between urban critical infrastructure resilience and the SDGs, offering a comprehensive overview of their intricate interactions.

3. Results

3.1. UCI resilience research areas

Since 2004, the field of UCIs resilience has seen significant advancements in research, particularly focusing on energy, cyber, transportation, healthcare, and water sectors (Fig. 2). Individual sectors such as energy, cyber, and transportation have been extensively studied, with a notable number of publications in Mono-domain, reaching 424, 273, and 233, respectively. The healthcare and water sectors have also garnered attention, with over 50 articles published in each. Connection studies have shown that energy, cyber, and transportation sectors are frequently studied together, with a substantial number of articles focusing on their interactions. The number of articles in the Bi-domain Energy and Cyber, Energy and Transportation, and Cyber and Transportation reached 138, 95, and 73, respectively. Energy, cyber, and transportation reached 51 articles in the Tri-domain. While healthcare and water sectors have received less attention, they have still been analyzed alongside other sectors. Notably, energy, cyber, and transportation industries have been the most common subjects of connection studies across the three infrastructures. However, there are only a limited number of studies involving four or five sectors (11 and 2 studies, respectively).

In terms of article attention, the energy, cyber, and transport sectors have been heavily cited in the literature, with significantly higher average annual citations compared to other sectors, averaging 19.0, 14.0, and 9.9, respectively. One highly cited article focusing on energy and cyber infrastructures had an average annual citation of 84.1. In the healthcare and water sector, research attention is more attenuated compared to the energy and networking sectors, with average annual citations of 3.9 and 2.9 respectively. Studies examining the intersection of bi-domains, such as energy and cyber, energy and transportation, cyber and transportation, have also attracted interest, with average annual citations ranging from 3.7 to 9.0. Analyzing the attention garnered by articles in the literature provides valuable insights for understanding the services and functions within each industry type and for exploring the interplay between different sectors.

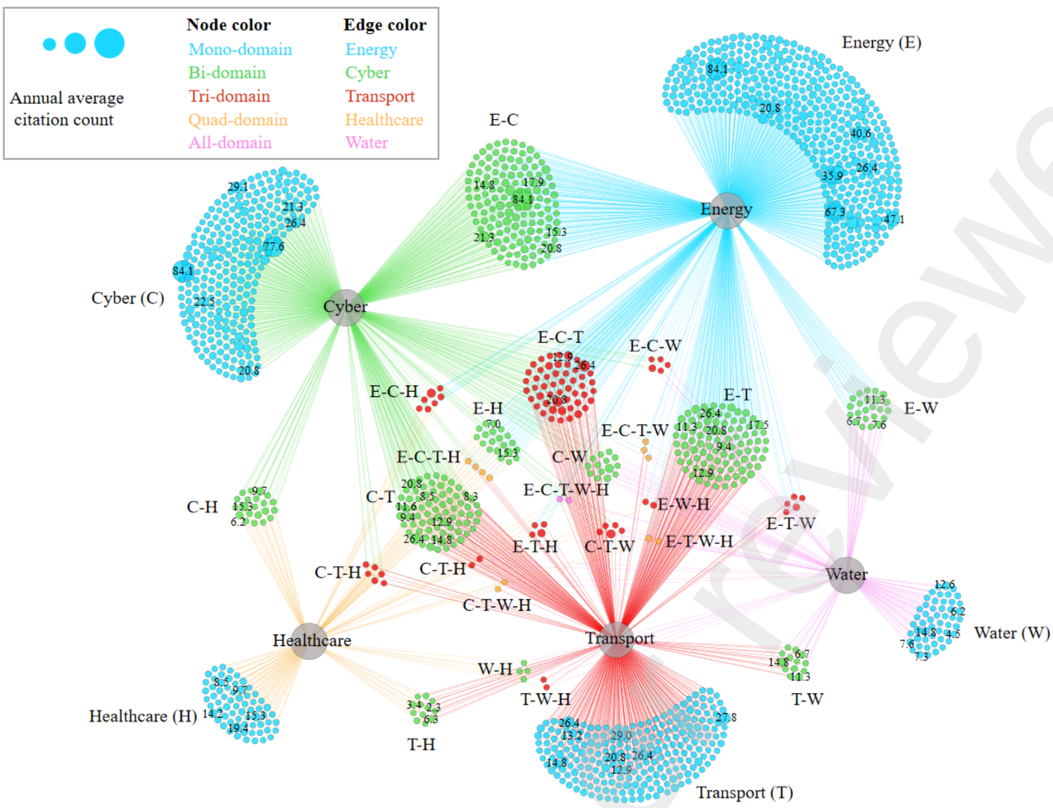

Fig. 2 Domain network for urban critical infrastructure resilience research.

3.2. Critical infrastructure functions

UCIs are essential components of city operations, serving various functions crucial for the safety, development, and effective functioning of urban areas (Figure 3). Through a comprehensive examination of scholarly literature, we identified the top two ranking infrastructure functions within each sector. It was observed that within the energy sector, over 70% of studies concentrated on electricity supply, with approximately 10% focusing on hydrocarbon fuel supply such as oil and natural gas. In the realm of transportation, around 60% of published articles emphasized passenger transportation modes like rail and urban mass transit, while 41% of research articles delved into freight transportation methods such as ferries and airlines.

Regarding the cyber sector, more than 90% of research efforts were directed towards communication and cybersecurity services. In the water infrastructure sector, the primary focus was on water supply and wastewater treatment, particularly emphasizing water supply, which constituted 67% of research papers in this domain. In the healthcare sector, 67% of research was centered on healthcare services, while emergency services accounted for 16% of the research output. These infrastructural elements not only cater to the daily requirements of urban inhabitants but also play a pivotal role in advancing the SDGs, underscoring the indispensable contribution of infrastructure in fostering societal progress and environmental sustainability.

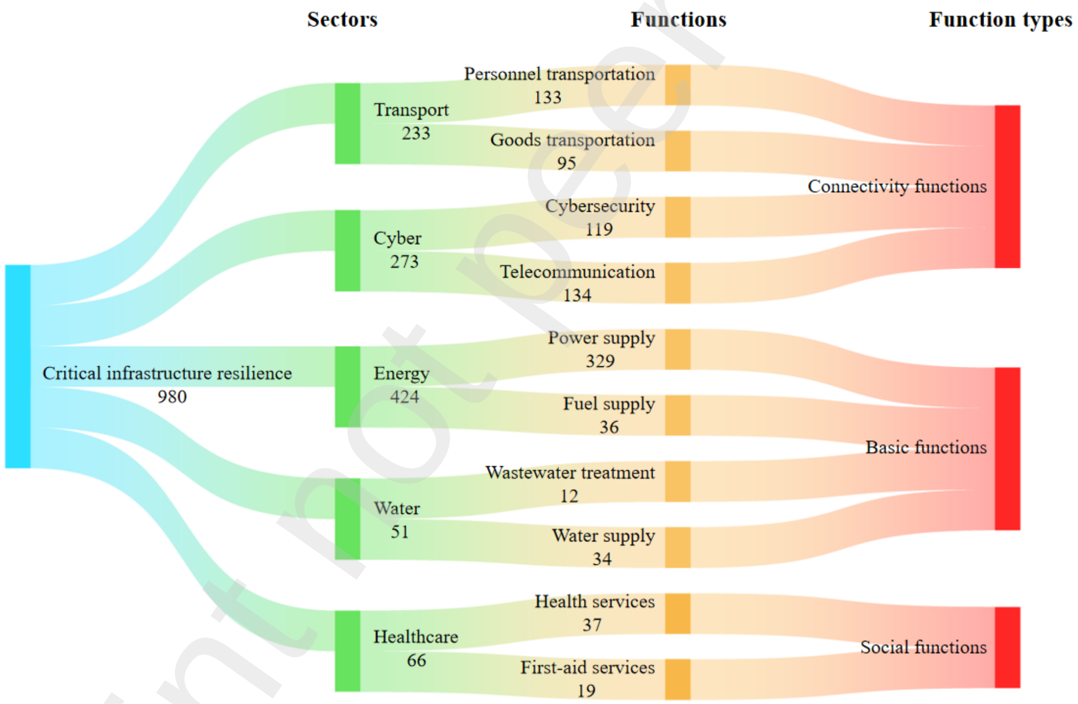

Fig. 3 Functional mapping of urban critical infrastructures research, including the number of articles in each area.

3.3. UCIs resilience and the SDGs

Based on the analysis of research articles, a network comprising five sectors - energy, cyber, transportation, water, and healthcare - was established, illustrating their interconnections with the targets of the SDGs (Figure 4a). The analysis revealed that the energy sector had documented linkages with SDG3, SDG6, SDG7, SDG9, SDG11, SDG12, SDG13, SDG14, and SDG15 in a total of 424 articles, with the most robust connections observed with SDG7, SDG11, and SDG13, represented by 85, 34, and 126 articles respectively. Similarly, the cyber sector exhibited stronger associations with SDG7 and SDG13, each supported by over 30 articles. In the transportation sector, the connections with SDG11 and SDG13 were more pronounced, with 33 and 94 connections identified for each, respectively. Within the water and healthcare sectors, SDG13 emerged as the most closely linked target, with 24 related connections for each sector.

A significant correlation was identified between UCIs resilience and the targets of the SDGs, as illustrated in Figure 4b. Specifically, in terms of human health and well-being, bolstering UCIs resilience supports the achievement of targets within SDG3 (target3.1, target3.3, target3.4, target3.6, target3.8, target3.9, target3.c, and target3.d). Furthermore, strengthening UCIs resilience in addressing basic needs aligns with the targets of SDG6, SDG7, SDG14 (target14.1 and target14.2), and SDG15 (target15.1, target 15.2, and target 15.a). Additionally, in the realm of sustainable policies, enhancing UCIs resilience aids in achieving over 50% of the targets within SDG9 and SDG13, along with a few targets in SDG11 and SDG12.

Moreover, the attainment of the SDGs plays a pivotal role in fortifying UCIs resilience. Evidence suggests that the accomplishment of SDG3, SDG6, SDG7, SDG9, SDG11, SDG12, SDG13, SDG14, and SDG15 contributes to the enhancement of UCIs resilience. Notably, more than half of the targets within SDG3, SDG6, SDG7, SDG9, and SDG13 support the reinforcement of UCIs resilience. Furthermore, specific aspects of SDG11 (target1, target2, and target5), SDG12 (target1 and target4), SDG14 (target1 and target2), and SDG15 (target1, target2, and target a) also play a role in bolstering UCIs resilience from distinct perspectives. In essence, there exist synergies between UCIs resilience and the SDGs, collectively contributing to sustainable urban development.

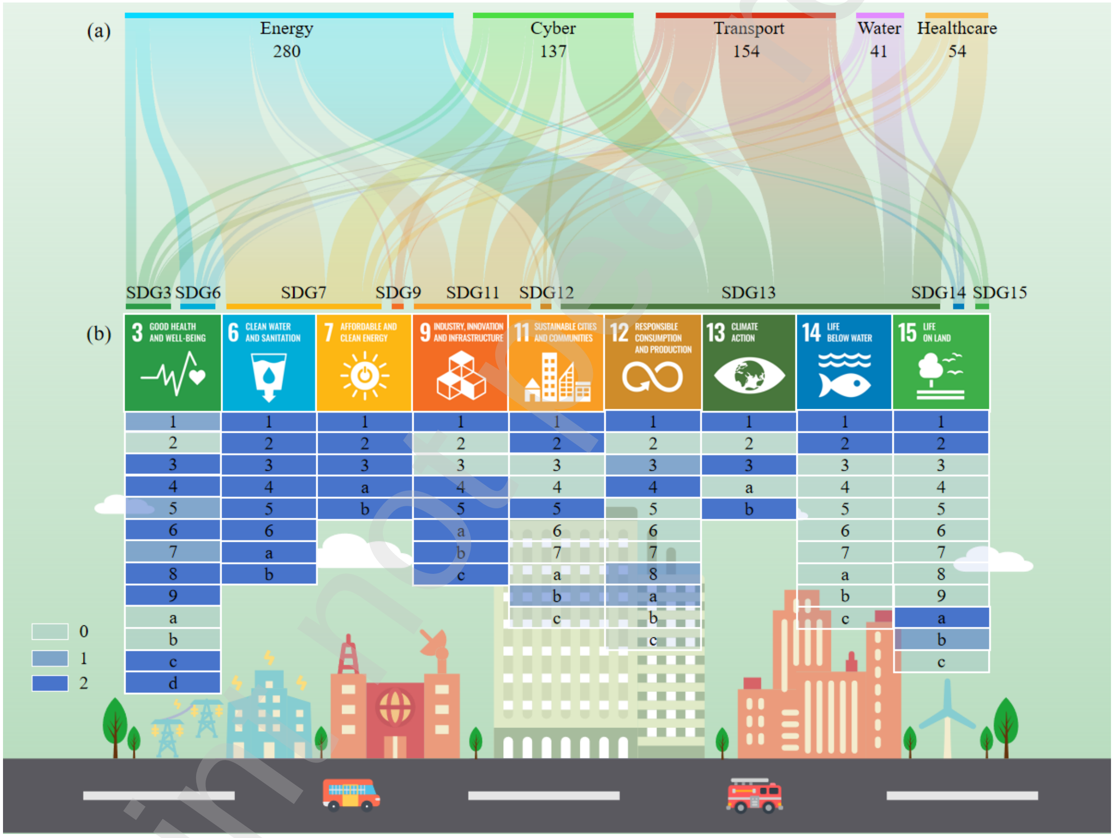

Fig.4 Linkage identification for UCIs resilience and SDG research. (a) The flow of literature linking UCIs sectors to the SDGs, the numbers in the figure represent the amount of literature linking the SDGs to each sector. (b) Interconnections between UCIs resilience and each of the targets under the SDGs. 0 indicating no association, 1 representing a unidirectional relationship, and 2 denoting a bi-directional relationship.

4. Discussion

4.1. Cross-sectoral interdependencies

UCIs are systems that are known to have a number of cross-sectoral connections or interdependencies (Hall et al., 2016). Through an analysis of the co-occurrence and interconnection of keywords within the academic literature, we discern a pattern: the energy, cyber, and transport sectors are frequently examined in conjunction. Notably, the interdependency effects between energy and cyber, energy and transportation, and cyber and transportation have garnered significant scholarly interest (Rajkumar et al., 2023; Wu et al., 2022; Mohebbi et al., 2020). The recurrent pairing of energy and transport sectors in research underscores their pivotal role in combating climate change, a theme that resonates throughout the literature (Shakya and Shrestha, 2011; Creutzig et al., 2015). Such research has focused not only on the individual mitigation strategies of each sector but also on the synergistic interactions between them. Particularly, the role of stable network operations in fostering harmony between the transport and energy sectors is highlighted for its positive impact on climate change mitigation strategies (Bel and Joseph, 2018). This coordination is instrumental in crafting a more cohesive and potent approach to addressing climate change, while also shedding light on the untapped potential for cross-sectoral collaboration that may have been previously neglected in the existing body of work.

Moreover, the burgeoning field of the Energy Internet, a notable area of research where energy and cyber sectors frequently intersect, exemplifies the robust nexus between energy transformation and the enhancement of systemic resilience. By amalgamating diverse energy forms such as thermal, refrigeration, and gas energies, and leveraging Internet technologies, the Energy Internet promises to augment the efficacy and reliability of energy systems (Wu et al., 2021). Furthermore, it can bolster urban resilience against the vagaries of climate change and other hazards (Agboola and Tunay, 2023). The symbiotic relationship between the cyber and transport sectors, characterized by the optimization of transportation networks and the fortification of energy supply stability, is shown to markedly enhance urban resilience to both natural hazards and human-induced incidents (Serdar et al., 2022). This, in turn, ensures the uninterrupted delivery of essential services and bolsters the city's capacity for swift response and recovery from unexpected events (Zhu et al., 2020). Collectively, these studies underscore the imperative for urban areas to cultivate cross-sectoral collaboration and integration strategies aimed at bolstering overall resilience, with an emphasis on sustaining operational continuity and swift recovery in the aftermath of shocks.

4.2. Planning and management

The planning and management of UCIs serve as a pivotal driver in the transition of cities towards enhanced resilience and sustainable development. Effective planning methodologies and management protocols not only bolster the resilience of UCIs, ensuring their durability against various shocks and stresses, but also contribute to the advancement of the SDGs. By bringing together interdisciplinary expertise and technological advancements, urban planners and administrators have enhanced the resilience of UCIs such as energy, transportation, and cyber systems. For instance, by augmenting the diversity and efficiency of the energy grid, it not only ensures the stability of electricity provision but also promotes the wider adoption of clean energy sources, aligning closely with the objectives of SDG7 (Affordable and Clean Energy) and SDG13 (Climate Action) (Swain and Karimu, 2020; Chirambo, 2018). Concurrently, the planning and management of urban infrastructures drive progress towards the SDGs by optimizing resource allocation, enhancing service efficiency, and fostering the utilization of eco-friendly technologies (Adshead et al., 2019; Thacker et al., 2019). In the realm of transportation, the establishment of a proficient public transit network not only alleviates urban congestion but also diminishes greenhouse gas emissions, thereby synergizing with SDG11 (Sustainable Cities and Communities) and SDG13 (Shehata et al., 2022; Avotra and Nawaz, 2023).

The planning and management of UCIs assume a pivotal role in advancing the realization of the SDGs. By harmonizing with the aims and benchmarks of the SDGs, urban planning initiatives consider not only the immediate infrastructure requirements but also the enduring environmental and societal repercussions. For instance, by constructing resilient water systems, it secures a reliable water supply (SDG6: Clean Water and Sanitation) while fostering ecological equilibrium by mitigating flood risks (SDG13) and safeguarding aquatic ecosystems (SDG14: Life Below Water and SDG15: Life on Land) (Tortajada, 2020; Di-Vaio et al., 2021; Garcia et al., 2023). A symbiotic relationship exists between the planning and management of UCIs and the achievement of the SDGs. This synergy not only expedites the fortification of urban resilience but also bolsters the comprehensive realization of the SDGs. Through this reciprocal facilitative association, cities are better equipped to address global challenges like climate change, resource scarcity, and population growth, while concurrently cultivating healthier, more equitable, and prosperous living environments for their residents (Flörke et al., 2018; He et al., 2021). Consequently, forthcoming urban planning and management endeavors can exploit this synergy to accelerate the transition towards more sustainable and resilient urban development.

5. Conclusion

The resilience of UCIs plays a vital role in mitigating the impacts of natural and social hazards on urban environments, thereby sustaining the connection between urban critical infrastructure and the SDGs. The body of research in this domain has expanded significantly as the understanding of the roles of UCIs and the connections among various sectors has deepened. Nonetheless, there remains a notable gap in the literature regarding quantitative analyses of the contributions of SDGs from the perspectives of systemic interdependencies. To enhance the capacity of UCIs to support sustainable urban development, it is imperative that future management and planning efforts adopt a resilience-oriented approach that integrates advances from network science and deep learning, to exploit existing knowledge and opportunities to address global challenges. The innovation of this study is primarily demonstrated through a comprehensive analysis of the existing literature on UCI resilience and the SDGs, that covers multiple sectors and dimensions of sustainable development. This synthesis organizes the literature pertaining to multi-sectoral interdependencies and the functions of UCIs, providing new insights to support the decision making on UCIs and the SDGs. It also highlights where further research can be developed that addresses the evolving nature of both infrastructure systems and the global development goals. Future work could address limitation within this study, including the expanding the literature pool, expansion of keyword searches and critical infrastructure functions. In addition, it could explore the connections between UCIs and other global agendas, such as the New Urban Agenda, Sendai Framework for Disaster Risk Reduction, Paris Agreement on Climate Change, or the Universal Declaration on Human Rights. Such research will bet an important tool for decision makers to help transition our infrastructure systems, and the societies that they support, towards a more sustainable and resilient future for all.

Acknowledgments

The authors wish to give their sincere gratitude to the Institute of Urban Environment, Chinese Academy of Sciences 'Select the best candidates to undertake key research projects' (grand No. IUE-JBGS-202215), National Natural Science Foundation of China (grand No. 42271299), Ministry of Science and Technology of China (MSTC) with National Key Research and Development Programs (grand No. 2023YFF1304700, 2022YFF1301200), International Partnership Program of Chinese Academy of Sciences (grand No. 132c35kysb2020007) and Ningbo Commonweal Science and Technology Planning Project (grand No. 2021S081).

Adshead, D., Paszkowski, A., Gall, S. S., Peard, A. M., Adnan, M. S. G., Verschuur, J., & Hall, J. W. (2024). Climate threats to coastal infrastructure and sustainable development outcomes. Nature Climate Change, 14(4), 344-352. https://doi.org/10.1038/s41558-024-01974-8

Adshead, D., Thacker, S., Fuldauer, L. I., & Hall, J. W. (2019). Delivering on the Sustainable Development Goals through long-term infrastructure planning. Global Environmental Change, 59, 101975. https://doi.org/10.1016/j.gloenvcha.2019.101975

Agboola, O. P., & Tunay, M. (2023). Urban resilience in the digital age: The influence of Information-Communication Technology for sustainability. Journal of Cleaner Production, 428, 139304. https://doi.org/10.1016/j.jclepro.2023.139304

Avotra, A. A. R. N., & Nawaz, A. (2023). Asymmetric impact of transportation on carbon emissions influencing SDGs of climate change. Chemosphere, 324, 138301. https://doi.org/10.1016/j.chemosphere.2023.138301

Bastian, M., Heymann, S., & Jacomy, M. (2009). Gephi: an open source software for exploring and manipulating networks. In Proceedings of the international AAAI conference on web and social media, 3(1), 361-362. https://doi.org/10.1609/icwsm.v3i1.13937

Bel, G., & Joseph, S. (2018). Climate change mitigation and the role of technological change: Impact on selected headline targets of Europe's 2020 climate and energy package. Renewable and Sustainable Energy Reviews, 82, 3798-3807. https://doi.org/10.1016/j.rser.2017.10.090

Biermann, F., Hickmann, T., Sénit, C. A., Beisheim, M., Bernstein, S., Chasek, P., ... & Wicke, B. (2022). Scientific evidence on the political impact of the Sustainable Development Goals. Nature Sustainability, 5(9), 795-800. https://doi.org/10.1038/s41893-022-00938-0

Carter, J. G., Cavan, G., Connelly, A., Guy, S., Handley, J., & Kazmierczak, A. (2015). Climate change and the city: Building capacity for urban adaptation. Progress in planning, 95, 1-66. https://doi.org/10.1016/j.progress.2013.08.001

Chirambo, D. (2018). Towards the achievement of SDG 7 in sub-Saharan Africa: Creating synergies between Power Africa, Sustainable Energy for All and climate finance in-order to achieve universal energy access before 2030. Renewable and Sustainable Energy Reviews, 94, 600-608. https://doi.org/10.1016/j.rser.2018.06.025

Collier, M. J., Nedović-Budić, Z., Aerts, J., Connop, S., Foley, D., Foley, K., ... & Verburg, P. (2013). Transitioning to resilience and sustainability in urban communities. Cities, 32, S21-S28. https://doi.org/10.1016/j.cities.2013.03.010

Creutzig, F., Jochem, P., Edelenbosch, O. Y., Mattauch, L., Vuuren, D. P. V., McCollum, D., & Minx, J. (2015). Transport: A roadblock to climate change mitigation?. Science, 350(6263), 911-912. DOI: 10.1126/science.aac8033

Derviş, H. (2019). Bibliometric analysis using bibliometrix an R package. Journal of scientometric research, 8(3), 156-160. doi: 10.5530/jscires.8.3.32

Di Vaio, A., Trujillo, L., D'Amore, G., & Palladino, R. (2021). Water governance models for meeting sustainable development Goals: A structured literature review. Utilities Policy, 72, 101255. https://doi.org/10.1016/j.jup.2021.101255

Flörke, M., Schneider, C., & McDonald, R. I. (2018). Water competition between cities and agriculture driven by climate change and urban growth. Nature Sustainability, 1(1), 51-58. https://doi.org/10.1038/s41893-017-0006-8

Fuldauer, L. I., Thacker, S., Haggis, R. A., Fuso-Nerini, F., Nicholls, R. J., & Hall, J. W. (2022). Targeting climate adaptation to safeguard and advance the Sustainable Development Goals. Nature communications, 13(1), 3579. https://doi.org/10.1038/s41467-022-33518-z

Fuso Nerini, F., Sovacool, B., Hughes, N., Cozzi, L., Cosgrave, E., Howells, M., ... & Milligan, B. (2019). Connecting climate action with other Sustainable Development Goals. Nature Sustainability, 2(8), 674-680. https://doi.org/10.1038/s41893-019-0334-y

Fuso Nerini, F., Tomei, J., To, L. S., Bisaga, I., Parikh, P., Black, M., ... & Mulugetta, Y. (2018). Mapping synergies and trade-offs between energy and the Sustainable Development Goals. Nature Energy, 3(1), 10-15. https://doi.org/10.1038/s41560-017-0036-5

Garcia, C., López-Jiménez, P. A., Sánchez-Romero, F. J., & Pérez-Sánchez, M. (2023). Assessing water urban systems to the compliance of SDGs through sustainability indicators. Implementation in the valencian community. Sustainable Cities and Society, 96, 104704. https://doi.org/10.1016/j.scs.2023.104704

Gera, R., Chadha, P., Banerjee, S. P., Sharma, M., Pandey, A. K., Kampani, S., ... & Gatea, M. A. (2023). A narrative review on use of biomaterials in achieving SDG 9: Build resilient infrastructure, promote sustainable industrialization and foster innovation. In E3S Web of Conferences (Vol. 391, p. 01180). EDP Sciences. https://doi.org/10.1051/e3sconf/202339101180

Giannetti, B. F., Agostinho, F., Eras, J. C., Yang, Z., & Almeida, C. M. V. B. (2020). Cleaner production for achieving the sustainable development goals. Journal of Cleaner Production, 271, 122127. https://doi.org/10.1016/j.jclepro.2020.122127

Griggs, D., Stafford-Smith, M., Gaffney, O., Rockström, J., Öhman, M. C., Shyamsundar, P., ... & Noble, I. (2013). Sustainable development goals for people and planet. Nature, 495(7441), 305-307. https://doi.org/10.1038/495305a

Hall, J. W., Tran, M., Hickford, A. J., & Nicholls, R. J. (Eds.). (2016). The future of national infrastructure: A system-of-systems approach. Cambridge University Press. doi:10.1017/CBO9781107588745

Hallegatte, S., Green, C., Nicholls, R. J., & Corfee-Morlot, J. (2013). Future flood losses in major coastal cities. Nature climate change, 3(9), 802-806. https://doi.org/10.1038/nclimate1979

He, C., Liu, Z., Wu, J., Pan, X., Fang, Z., Li, J., & Bryan, B. A. (2021). Future global urban water scarcity and potential solutions. Nature Communications, 12(1), 4667. https://doi.org/10.1038/s41467-021-25026-3

Huan, Y., Liang, T., Li, H., & Zhang, C. (2021). A systematic method for assessing progress of achieving sustainable development goals: A case study of 15 countries. Science of the Total Environment, 752, 141875. https://doi.org/10.1016/j.scitotenv.2020.141875

Ipingbemi, O., & Akogun, O. (2021). Transportation: The Missing Link in the Achievement of SDGs. In Industry, Innovation and Infrastructure (pp. 1229-1236). Cham: Springer International Publishing. doi:10.1007/978-3-319-95873-6_105

Jayachandran, M., Gatla, R. K., Rao, K. P., Rao, G. S., Mohammed, S., Milyani, A. H., ... & Geetha, S. (2022). Challenges in achieving sustainable development goal 7: Affordable and clean energy in light of nascent technologies. Sustainable Energy Technologies and Assessments, 53, 102692. https://doi.org/10.1016/j.seta.2022.102692

Li, K., Rollins, J., & Yan, E. (2018). Web of Science use in published research and review papers 1997–2017: A selective, dynamic, cross-domain, content-based analysis. Scientometrics, 115(1), 1-20. doi: 10.1007/s11192-017-2622-5

Mitoulis, S. A., Argyroudis, S., Panteli, M., Fuggini, C., Valkaniotis, S., Hynes, W., & Linkov, I. (2023). Conflict-resilience framework for critical infrastructure peacebuilding. Sustainable Cities and Society, 91, 104405. https://doi.org/10.1016/j.scs.2023.104405

Mohebbi, S., Zhang, Q., Wells, E. C., Zhao, T., Nguyen, H., Li, M., ... & Ou, X. (2020). Cyber-physical-social interdependencies and organizational resilience: A review of water, transportation, and cyber infrastructure systems and processes. Sustainable Cities and Society, 62, 102327. https://doi.org/10.1016/j.scs.2020.102327

Mukherjee, M., Abhinay, K., Rahman, M. M., Yangdhen, S., Sen, S., Adhikari, B. R., ... & Shaw, R. (2023). Extent and evaluation of critical infrastructure, the status of resilience and its future dimensions in South Asia. Progress in Disaster Science, 17, 100275. https://doi.org/10.1016/j.pdisas.2023.100275

Nesshöver, C., Assmuth, T., Irvine, K. N., Rusch, G. M., Waylen, K. A., Delbaere, B., ... & Wittmer, H. (2017). The science, policy and practice of nature-based solutions: An interdisciplinary perspective. Science of the total environment, 579, 1215-1227. https://doi.org/10.1016/j.scitotenv.2016.11.106

Paul, J., & Criado, A. R. (2020). The art of writing literature review: What do we know and what do we need to know?. International business review, 29(4), 101717. https://doi.org/10.1016/j.ibusrev.2020.101717

Perera, A. T. D., & Hong, T. (2023). Vulnerability and resilience of urban energy ecosystems to extreme climate events: A systematic review and perspectives. Renewable and Sustainable Energy Reviews, 173, 113038. https://doi.org/10.1016/j.rser.2022.113038

Pranckutė, R. (2021). Web of Science (WoS) and Scopus: The titans of bibliographic information in today's academic world. Publications, 9(1), 12. doi:10.3390/publications9010012

Rahman, S., & Rahman, M. A. (2015). Climate extremes and challenges to infrastructure development in coastal cities in Bangladesh. Weather and Climate Extremes, 7, 96-108. https://doi.org/10.1016/j.wace.2014.07.004

Rajkumar, V. S., Ştefanov, A., Presekal, A., Palensky, P., & Torres, J. L. R. (2023). Cyber attacks on power grids: Causes and propagation of cascading failures. IEEE Access. doi: 10.1109/ACCESS.2023.3317695

Ruan, T., Xu, Y., Jones, L., Boeing, W. J., & Calfapietra, C. (2023). Green infrastructure sustains the food-energy-water-habitat nexus. Sustainable Cities and Society, 98, 104845. https://doi.org/10.1016/j.scs.2023.104845

Serdar, M. Z., Koç, M., & Al-Ghamdi, S. G. (2022). Urban transportation networks resilience: indicators, disturbances, and assessment methods. Sustainable Cities and Society, 76, 103452. https://doi.org/10.1016/j.scs.2021.103452

Shakou, L. M., Wybo, J. L., Reniers, G., & Boustras, G. (2019). Developing an innovative framework for enhancing the resilience of critical infrastructure to climate change. Safety science, 118, 364-378. https://doi.org/10.1016/j.ssci.2019.05.019

Shakya, S. R., & Shrestha, R. M. (2011). Transport sector electrification in a hydropower resource rich developing country: Energy security, environmental and climate change co-benefits. Energy for Sustainable Development, 15(2), 147-159. https://doi.org/10.1016/j.esd.2011.04.003

Shehata, N., Obaideen, K., Sayed, E. T., Abdelkareem, M. A., Mahmoud, M. S., El-Salamony, A. H. R., ... & Olabi, A. G. (2022). Role of refuse-derived fuel in circular economy and sustainable development goals. Process Safety and Environmental Protection, 163, 558-573. https://doi.org/10.1016/j.psep.2022.05.052

Swain, R. B., & Karimu, A. (2020). Renewable electricity and sustainable development goals in the

EU. World Development, 125, 104693. https://doi.org/10.1016/j.worlddev.2019.104693

Thacker, S., Adshead, D., Fay, M., Hallegatte, S., Harvey, M., Meller, H., ... & Hall, J. W. (2019). Infrastructure for sustainable development. Nature Sustainability, 2(4), 324-331. https://doi.org/10.1038/s41893-019-0256-8

Tortajada, C. (2020). Contributions of recycled wastewater to clean water and sanitation Sustainable Development Goals. NPJ Clean Water, 3(1), 22. https://doi.org/10.1038/s41545-020-0069-3

Vinuesa, R., Azizpour, H., Leite, I., Balaam, M., Dignum, V., Domisch, S., ... & Fuso Nerini, F. (2020). The role of artificial intelligence in achieving the Sustainable Development Goals. Nature communications, 11(1), 1-10. https://doi.org/10.1038/s41467-019-14108-y

Wu, F., Yang, J., Jiang, H., Zhan, X., Liao, S., Xu, J., ... & Liang, J. (2022). Cascading failure in coupled networks of transportation and power grid. International Journal of Electrical Power & Energy Systems, 140, 108058. https://doi.org/10.1016/j.ijepes.2022.108058

Wu, Y., Wu, Y., Guerrero, J. M., & Vasquez, J. C. (2021). A comprehensive overview of framework for developing sustainable energy internet: From things-based energy network to services-based management system. Renewable and Sustainable Energy Reviews, 150, 111409. https://doi.org/10.1016/j.rser.2021.111409

Zhu, C., Wu, J., Liu, M., Luan, J., Li, T., & Hu, K. (2020). Cyber-physical resilience modelling and assessment of urban roadway system interrupted by rainfall. Reliability Engineering & System Safety, 204, 107095. https://doi.org/10.1016/j.ress.2020.107095