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Promoting Sustainable Healthcare Transport in Health Education in Sub-Saharan Africa: A Bibliometric Analysis of Research Trends and Gaps

Abstract

Amid growing climate change concerns, healthcare systems are under increasing pressure to adopt sustainability principles, especially in logistics and transportation. However, the extent to which green mobility concepts are integrated into healthcare education remains largely unexplored. This study conducts a bibliometric analysis to map the intellectual landscape at the intersection of sustainable healthcare transport and health education. Drawing from Scopus and Web of Science databases (1970–2025), the analysis utilizes VOSviewer and the Bibliometrix R package to examine co-authorship networks, publication trends, thematic clusters, and keyword co-occurrences. Results indicate growing interest in electric medical vehicles, telemedicine-enabled transport, and low-carbon healthcare logistics. Despite these advancements, sustainability remains marginal in healthcare curricula. This study highlights a significant pedagogical gap and calls for integrating climate-smart transport knowledge into professional training. The findings offer practical insights for educators, curriculum developers, and policymakers aiming to align health education with global sustainability and climate resilience goals. By bridging research silos, this study advances a cross-disciplinary understanding and supports the development of a health workforce prepared for low-carbon, adaptive systems.

Keywords: *Bibliometric analysis, sustainable healthcare transport, healthcare education, green logistics, climate-smart healthcare*

1 Introduction

Climate change has emerged as a defining global challenge with far-reaching implications for human health and the functioning of healthcare systems, manifesting in extreme weather events that damage healthcare infrastructure and disrupt supply chains, thereby complicating the delivery of care (Gkouliaveras et al. 2025). Health institutions are not only on the frontlines of responding to climate-induced health crises but are also contributors to environmental degradation, particularly through energy consumption, waste generation, and transportation-related emissions (Selvakumar et al. 2025; Schwab et al. 2025). Recent estimates suggest that the healthcare sector contributes nearly 4%–5% to global net emissions (Cristiano et al. 2024), with a substantial portion, approximately 60% coming from the procurement and transportation of medical supplies and pharmaceuticals (Austin et al. 2024;

WHO 2021). As global efforts intensify toward achieving the Sustainable Development Goals (SDGs), particularly SDG 3 (Good Health and Well-being) and SDG 13 (Climate Action), there is an increasing demand to embed sustainability principles not only in healthcare delivery systems but also in workforce training and institutional development (United Nations 2023).

Transport plays a critical role in healthcare delivery. Whether through ambulance services, patient transfers, medical supply chains, or outreach services in remote areas, effective mobility systems underpin both quality care and equitable access (Özdoğan & Mulgan 2024). However, traditional healthcare transport practices heavily rely on fossil fuels, contributing to air pollution, carbon emissions, and operational inefficiencies (Suthagar & Mishra 2025). Innovations such as electric ambulances, solar-powered mobile clinics (Sütheö et al. 2025), telemedicine-enabled patient transfers (Varughese et al. 2024), and bicycle-based logistics offer promising low-carbon alternatives (Wolniak & Turoń 2025). These innovations not only reduce emissions but also enhance the resilience and reach of the healthcare system, particularly in underserved areas.

Despite growing evidence of climate change and investment in green mobility solutions, a critical dimension remains underexplored: the integration of sustainability principles in healthcare education and training. Existing curricula in medical and public health education often emphasize clinical competencies, health promotion, and epidemiology, while paying minimal attention to sustainable logistics, transport emissions, or climate-smart healthcare infrastructure (Ghosh et al. 2024; Selvakumar et al. 2025). This gap raises concerns about whether future healthcare professionals are being adequately prepared to navigate and lead in environmentally responsible systems. As sustainability becomes a core principle of 21st-century healthcare delivery, educational institutions worldwide must reimagine training frameworks to include knowledge, attitudes, and skills relevant to climate-smart healthcare (Hamid & Ibrahim 2025).

This concern is especially urgent in Sub-Saharan Africa (SSA), where healthcare systems face a double burden of fragile infrastructure and intensifying climate risks. While SSA countries increasingly engage in sustainability-focused health interventions, the extent to which healthcare education in the region reflects transport-related sustainability remains unclear. The region is also underrepresented in scholarly discourse on curricular innovation in this field, an omission that may hinder the development of localized, low-carbon solutions tailored to SSA contexts.

This study addresses the lack of evidence on how sustainable healthcare transport intersects with health education. It explores this intersection through a comprehensive bibliometric analysis of scholarly literature published between 2000 and 2025. Drawing data from Scopus and Web of Science, the study employs advanced bibliometric tools, including VOSviewer and the Bibliometrix R package, to examine publication trends, co-authorship networks, thematic clusters, and keyword co-occurrence patterns. These techniques are well established

for mapping knowledge domains and identifying gaps in emerging interdisciplinary fields (Alaassar et al. 2025).

The analysis reveals how concepts such as green logistics, low-emission mobility, and telemedicine transport are situated within health education literature. It further uncovers underrepresented themes, particularly the absence of pedagogical frameworks and competency models for integrating transport sustainability into health training programs. These insights are of practical significance to educators, curriculum developers, and health sector policymakers aiming to align professional development with broader climate action and sustainability agendas.

Theoretically, this paper contributes to the literature by mapping an underexplored intersection between sustainable healthcare transport and health education, revealing the fragmented nature of scholarly engagement across these domains. It offers new insights into the thematic composition of this interdisciplinary field by surfacing how concepts such as low-emission logistics, digital transport innovations, and environmental sustainability are addressed within academic discourse on healthcare training. Practically, the study aims to provide evidence-based guidance for educators, curriculum developers, and policymakers seeking to align healthcare training programs with broader climate action goals. It acknowledges that limited integration observed in the literature may reflect both a research gap and a need for direct curricular analysis, especially in underrepresented regions such as SSA. In doing so, the study supports the transition toward a healthcare workforce equipped to lead in low-carbon, climate-resilient systems.

1.1 Sub-Saharan Africa

Sub-Saharan Africa (SSA) faces a unique set of challenges and opportunities at the intersection of healthcare delivery, transport logistics, and sustainability. The region's healthcare systems are often characterized by underdeveloped infrastructure (Anand et al. 2024), fragmented supply chains (Marais et al. 2020), and limited mobility options, particularly in rural and peri-urban areas (Eisner et al. 2024). These conditions are further strained by the intensifying effects of climate change, which disrupt service delivery and compound existing inequalities in healthcare access (Osho & Sareen 2024). According to the World Health Organization (2021), countries in SSA bear a disproportionate burden of climate-sensitive health risks, ranging from vector-borne diseases to extreme weather-related health emergencies.

Transport logistics in SSA are critical to healthcare functionality but are frequently hindered by poor road networks, unreliable fuel supplies, and limited investment in low-carbon technologies (Züfle & Wunu 2025). These structural challenges underscore the importance of sustainable transport innovations, such as solar-powered mobile clinics, bicycle ambulances, and telemedicine-linked outreach, which lower carbon emissions (Madan 2025). However, the integration of these innovations into formal healthcare education and professional training remains limited (Sanchez & Khreis 2020). There is a need for new educational frameworks

that can accommodate the complexities of sustainable transport interventions and promote interdisciplinary collaboration (Winters et al. 2024).

Educational systems in SSA are at a pivotal juncture. Institutions like Kenya Medical Training College, Makerere University School of Public Health, and Ethiopia's College of Health Sciences have initiated reforms to incorporate sustainability topics as part of a broader trend to integrate planetary health and environmental sustainability into health professions education across Africa (Irlam et al. 2023). Yet, a region-wide framework for embedding climate-smart healthcare transport into curricula is still lacking (Zolo et al. 2024). By contextualizing the bibliometric findings within SSA, this study contributes to addressing the documentation and curriculum integration gaps and offers insights that are geographically and institutionally relevant to health systems in the region.

2 Methodology

2.1 Research Design

This study adopted a quantitative bibliometric research design to explore the intellectual landscape, publication trends, and thematic developments at the intersection of sustainable healthcare transport and health education. Bibliometric analysis provides a systematic approach to mapping large volumes of scholarly work by uncovering co-authorship patterns, thematic structures, and research gaps (Marvi & Foroudi 2023). This method is particularly well-suited for interdisciplinary fields, such as these that span health systems, sustainability, and education. The study aims to provide a comprehensive overview of scholarly engagement in the field while identifying emerging directions and underexplored areas.

2.2 Data Sources and Search Strategy

The bibliographic data were retrieved from two major academic databases: Scopus and Web of Science (WoS), chosen for their wide coverage of peer-reviewed literature across health sciences, environmental studies, and education (Caputo & Kargina 2022; Cebrián et al. 2025). The search was conducted in May 2025 and covered the period from 1970 to 2025. The 1970–2025 timeframe was selected to capture the growth and evolution of sustainability-related research in healthcare transport and education, particularly following the launch of global frameworks such as the Millennium Development Goals and the Sustainable Development Goals. This period marks an increase in scholarly attention to environmental health, digital innovation, and curricular integration within health systems. Only English-language journal articles, conference papers, and book chapters were considered.

To ensure relevant retrieval, a Boolean search strategy was developed to target three intersecting themes: sustainable transport, health education, and environmental sustainability. The following search string was applied in both databases:

("sustainable transport" OR "green mobility" OR "low-carbon mobility" OR "healthcare transport*" OR "medical transport*" OR "patient transport*" OR "medical logistics" OR "emergency medical service*" OR "non-motorized transport" OR "ambulatory services") AND ("health education*" OR "health promotion*" OR "public health" OR "health training" OR "healthcare education" OR "community health education" OR "health literacy") AND ("sustainab*" OR "environmental health" OR "climate change" OR "resilient health systems" OR "sustainable development goal*" OR "low-carbon development")*

The Boolean operators "AND" and "OR" allowed for thematic intersection and inclusion of synonymous concepts. Keywords were selected to reflect the study's conceptual scope, ensuring coverage of research relevant to sustainable transport, educational integration, and environmental health.

2.3 Inclusion Criteria and Data Screening

Studies were included if they addressed sustainable healthcare transport systems and connected these to health education, training, or curriculum development. Publications focusing solely on clinical care, general public health promotion, or unrelated transport technologies were excluded. Retrieved records from both databases were merged, and duplicates were removed using the deduplication tool within the Bibliometrix R package, resulting in a clean dataset for analysis.

2.4 Data Analysis Tools and Procedures

The screened records were exported in CSV and BibTeX formats for analysis (Albarrati et al. 2025) using two bibliometric tools: VOSviewer and Biblioshiny (Thomas et al. 2023), the web-based interface for the Bibliometrix R package. VOSviewer was used to visualize co-authorship patterns, keyword co-occurrence networks, and citation relationships. Biblioshiny was employed to assess annual publication trends, author and journal impact, thematic clusters, and geographical distribution of scientific output. This analytical approach enabled both structural and thematic mapping of the literature.

2.5 Ethical Considerations

The study relied exclusively on secondary data from publicly available databases. As it involved no human participants or sensitive data, ethical clearance was not required (Ackland & Vivanco 2024). Nonetheless, academic integrity was upheld by properly citing all sources included in the analysis.

2.6 Limitations of the Method

While bibliometric analysis provides valuable insights, it has inherent limitations. The method depends on the accuracy and completeness of metadata in Scopus and WoS, which may exclude grey literature or region-specific studies not indexed in these databases.

Restricting the search to English-language publications may also introduce language bias. Moreover, keyword-based retrieval can omit relevant studies where key themes are present but not explicitly mentioned in searchable fields, leading to biased inferences (Khan et al. 2024).

3 Results

3.1 Publication Output Trends

The volume of publications addressing sustainable healthcare transport in health education has grown significantly over the last two decades, as indicated in Figure 1. While early literature prior to 2000 was sporadic and limited in scope, a steady increase began after 2005. Notably, research output accelerated between 2017 and 2023, peaking in 2022 with over 30 publications. This surge aligns with the growing global focus on sustainability in healthcare systems, the influence of the Sustainable Development Goals (particularly SDG 3 and SDG 13), and post-pandemic policy shifts emphasizing green infrastructure and climate-resilient health services. The consistent output in 2024 and 2025 reflects the field's sustained relevance and signals growing interdisciplinary interest across public health, transport logistics, and education.

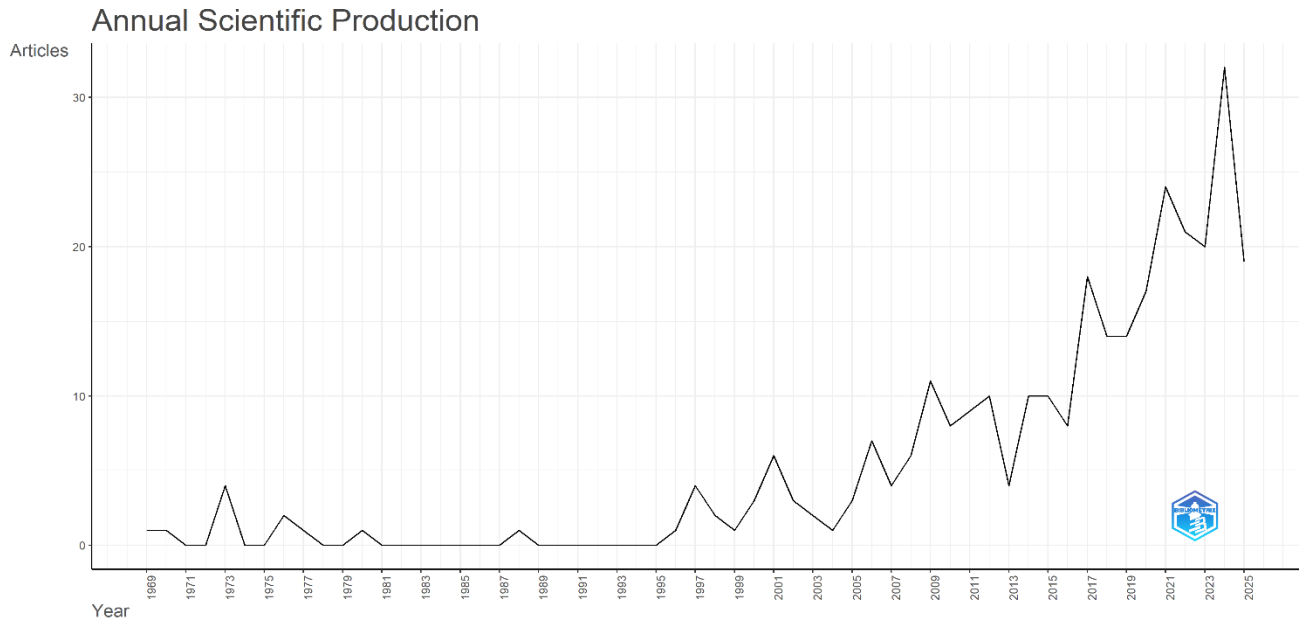

Figure 1: Annual scientific production from 1970 to 2025 on sustainable healthcare transport in health education (Source: Scopus and Web of Science; visualized using Biblioshiny).

3.2 Most relevant Sources

The analysis of source productivity presented in Table 1 revealed that Sustainability (Switzerland) was the most active journal in publishing research on sustainable healthcare

transport in health education, contributing 11 articles. This was followed by the International Journal of Environmental Research and Public Health, which accounted for eight publications. Other key journals included PLOS ONE, Prehospital and Disaster Medicine, and Transportation Research Record, each contributing five documents. Journals such as Public Health, Health Promotion International, and the Journal of Environmental Health also featured prominently, demonstrating the topic's cross-disciplinary appeal across public health, transport studies, and environmental science. The presence of both generalist journals and specialized outlets reflects a growing academic convergence on integrating sustainability into health systems and educational curricula.

Table 1: **Relevant sources of documents. Most relevant journals publishing on sustainable healthcare transport in health education (Source: Biblioshiny, Scopus and Web of Science data).**

Sources	Articles
SUSTAINABILITY (SWITZERLAND)	11
INTERNATIONAL JOURNAL OF ENVIRONMENTAL RESEARCH AND PUBLIC HEALTH	8
PLOS ONE	5
PREHOSPITAL AND DISASTER MEDICINE	5
TRANSPORTATION RESEARCH RECORD	5
INTERNATIONAL JOURNAL OF GYNECOLOGY AND OBSTETRICS	4
JOURNAL OF ENVIRONMENTAL HEALTH	4
PUBLIC HEALTH	4
HEALTH PROMOTION INTERNATIONAL	3
INTERNATIONAL ENCYCLOPEDIA OF TRANSPORTATION: VOLUME 1-7	3

3.3 Country Collaboration Networks

The co-authorship network in Figure 2 visualizes collaborative relationships between countries publishing on sustainable healthcare transport in health education. The United States stands out as the most influential and highly connected country, forming strong partnerships with the United Kingdom, Germany, Canada, and Australia. The United Kingdom also emerges as a central node, linking various regional clusters and playing a key role in transnational knowledge exchange.

The network reveals regional collaboration patterns, including a dense European cluster (Germany, Switzerland, Spain, the Netherlands, and Italy), a growing Asia-Pacific axis (India, China, Australia, and New Zealand), and an emerging African network involving South Africa, Ethiopia, and Rwanda. These patterns underscore the interdisciplinary and global relevance of sustainability in healthcare systems, particularly in the wake of climate change and the need for resilient health logistics and education models.

The interconnectedness of both high- and middle-income countries reflects an increasing commitment to addressing shared challenges through international research collaboration.

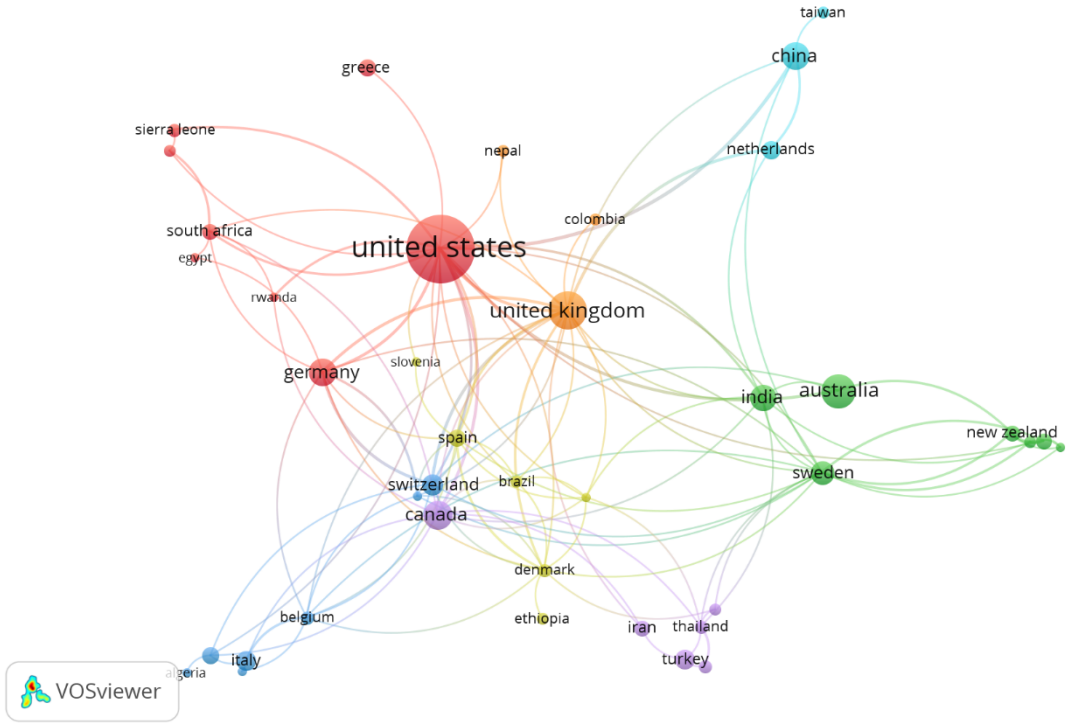

Figure 2: International co-authorship network in sustainable healthcare transport and health education (Source: VOSviewer, based on Scopus/Web of Science data).

3.4 Keyword Co-occurrence and Thematic Clusters

The keyword co-occurrence map displayed in Figure 3 reveals a well-structured research landscape with several distinct yet interconnected thematic clusters. The red cluster, located on the right, emphasizes core topics related to **sustainable transportation, urban mobility, air pollution, transportation policy**, and **climate change.** These terms highlight a growing body of work focusing on low-carbon and environmentally sustainable healthcare logistics in urban contexts.

The green and yellow clusters are centered around **healthcare delivery, emergency medicine, patient transport,** and **healthcare quality,** reflecting literature concerned with operational aspects of health systems and emergency logistics.

On the left of the map, the blue and purple clusters are dominated by terms such as **disaster, public health service, health facilities,** and **environmental health,** which align with emergency response, disaster preparedness, and resilience themes within healthcare systems.

At the center of the map, bridging keywords such as **public health, humans**, and **climate change** highlight their pivotal role in connecting sustainability, transport, and health education discourse. The proximity of **epidemiology, health literacy,** and **environmental sustainability** suggests emerging interdisciplinary intersections.

This map affirms the cross-cutting nature of sustainable healthcare transport, situated between public health imperatives, environmental sustainability goals, and the operational logistics of health service delivery.

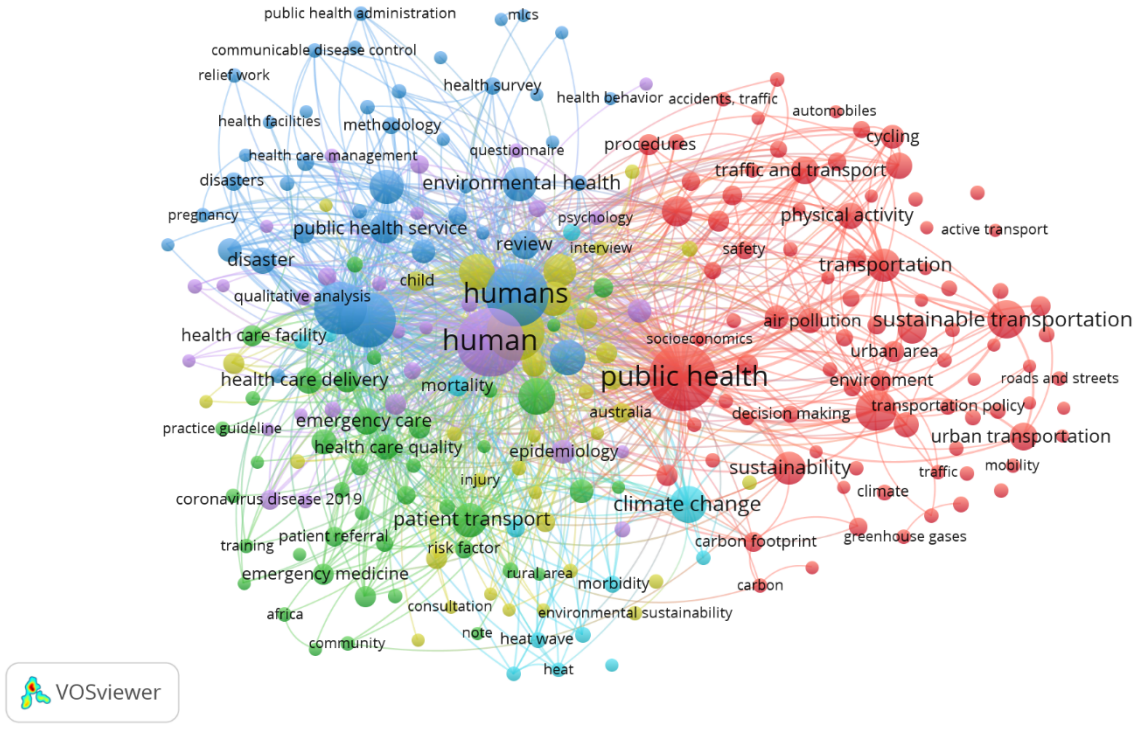

Figure 3: Keyword co-occurrence network showing thematic clusters in sustainable healthcare transport and health education research (Source: VOSviewer).

3.5 Thematic Evolution

The thematic evolution map in Figure 4 reveals a dynamic shift in research priorities in the field of sustainable healthcare transport and health education over time. In the earlier period (left side, red cluster), dominant themes include sustainable development, transportation, air pollution, climate change, and public health. These topics indicate early scholarly interest in environmental sustainability and transport emissions within broader public health discussions.

In contrast, the more recent period (right side, blue cluster) exhibits a transition toward themes emphasizing healthcare delivery, emergency health services, patient transport, epidemiology, and health system organization. This evolution reflects an increasing focus on

operational aspects of health logistics, quality of care, and the role of emergency systems in climate-resilient healthcare.

The continuity of bridging terms, such as public health, humans, and environmental health, across both clusters underscores their foundational role in sustaining scholarly dialogue. Meanwhile, the emergence of newer themes, such as healthcare personnel, COVID-19, and emergency care costs, suggests that real-world events and system shocks (e.g., pandemics) have expanded the research agenda to address resource efficiency and service accessibility.

Overall, the thematic transition illustrates how early environmental concerns have matured into applied inquiries about sustainable and equitable healthcare logistics, aligning with global calls for climate-adapted and education-informed health systems.

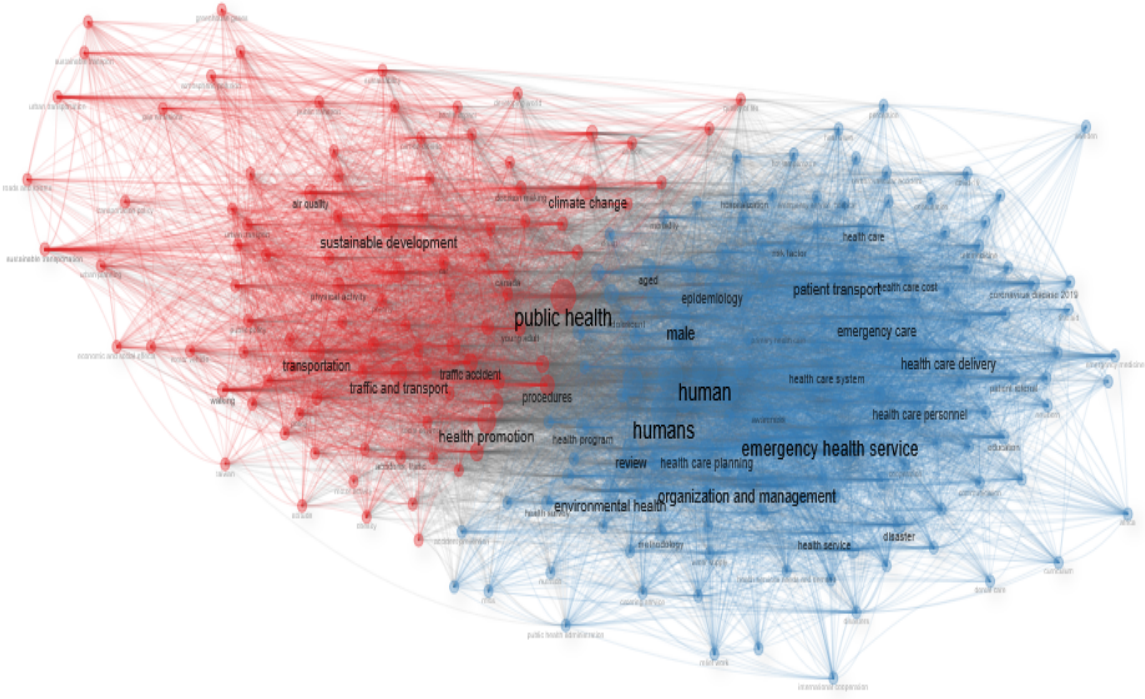

Figure 4: Thematic evolution of research on sustainable healthcare transport and health education (Source: Biblioshiny, based on Scopus/Web of Science data).

4 Discussion

4.1 Theoretical Implications

This study addresses the research question concerning the extent to which scholarly work has integrated sustainable healthcare transport with health education, while identifying thematic gaps and emerging trends within this interdisciplinary field. The results demonstrated a

progressively expanding but disjointed body of literature that links climate-smart mobility and public health systems, yet exhibits limited engagement with educational frameworks.

As depicted in Figure 3, the keyword co-occurrence analysis revealed that scholarly attention has been concentrated around themes such as electric vehicles, telemedicine, and healthcare logistics. However, educational constructs such as health training and curriculum development remain marginal. Notably absent were pedagogical keywords such as "instructional design," "learning outcomes," "competency-based education," or "health curriculum frameworks," which are essential markers of education-focused inquiry. This finding supports the observation by Uddin (2022) and Redding et al. (2019), who noted the persistent absence of pedagogical considerations in environmental health and transport-related research.

The evidence contributes to theoretical advancement by exposing the lack of a unified conceptual model that integrates climate-resilient transport solutions with competency-based healthcare training. There is a compelling need for a comprehensive environmental literacy framework to be embedded within health curricula. Such a framework would bridge disciplinary divides across public health, mobility systems, and sustainability sciences. Its development would also benefit from drawing on curriculum theories from the field of health education, yet these are largely missing from the sources analyzed. This integrative perspective aligns with the argument advanced by Kahlmeier et al. (2023), who emphasized the need to prepare health systems through educational readiness for active and sustainable transport solutions.

The thematic evolution visualization in Figure 4 illustrates a shift in academic discourse from broad environmental health concerns to more specialized subtopics such as low-emission ambulatory services, digital transport innovations, and non-motorized mobility. Despite this thematic diversification, the absence of citations from mainstream health education journals or curriculum development literature suggests a siloed knowledge base. This gap highlights a missed opportunity for theoretical synthesis between transport sustainability and pedagogy. The lack of integrative theoretical linkages continues to present an opportunity to formulate cohesive models that reflect the realities of both mobility and healthcare education.

To address this, curriculum integration frameworks such as Taba's Model of Curriculum Development, which emphasizes grassroots, teacher-led approach to instructional design, or the Spiral Curriculum developed by Jerome Bruner, which supports the progressive reinforcement of concepts over time, can be adapted to embed sustainability competencies into healthcare education. The Integrated Curriculum Model (ICM), commonly used in gifted education, also offers a basis for aligning health logistics content with real-world challenges by blending interdisciplinary knowledge with core academic outcomes. These models provide conceptual pathways for integrating green transport principles into both pre-service and in-service training programs.

Furthermore, a Competency-Based Education (CBE) framework tailored for sustainable healthcare logistics in SSA is warranted. This CBE model would emphasize demonstrable capabilities in areas such as low-emission medical transport planning, eco-friendly procurement, and climate risk mitigation. Its development could draw from existing WHO and UNEP frameworks on sustainable health systems while being refined through localized case-based learning, especially in climate-vulnerable settings such as rural Kenya, Ethiopia, and Uganda. By proposing and adapting these educational theories, the paper contributes a foundational theoretical entry point for future curricular reform. It underscores the need for interdisciplinary alignment between logistics, environmental health, and medical pedagogy.

4.2 Policy Relevance Focusing on the SSA

In Sub-Saharan Africa (SSA), the intersection of limited transport infrastructure and heightened climate vulnerability amplifies the urgency of embedding sustainability-related content into healthcare education. The predominance of scholarly outputs from European and North American institutions, as shown in Table 1, underscores the need for SSA countries to tailor their policy responses in ways that are locally relevant and contextually appropriate.

National health training institutions, such as Kenya Medical Training College (KMTC), the Rwanda College of Medicine and Health Sciences, and Ethiopia's College of Health Sciences, are well-positioned to initiate curriculum reforms that include modules on climate-smart logistics, low-carbon mobility, and resilient healthcare transport systems. Professional regulatory agencies like the Nursing Council of Kenya and the Health Professions Council of South Africa can enhance policy alignment by mandating Continuing Professional Development (CPD) credits focused on sustainability and logistics for healthcare practitioners seeking license renewal.

Collaborative engagements between training institutions and private-sector innovators such as electric ambulance startups or solar-powered bike logistics enterprises can facilitate integration of experiential learning into formal education. These partnerships, especially when supported by development actors such as WHO-AFRO and GIZ, could foster resource sharing for transport simulation labs and green mobility pilots within educational programs.

Rather than transplanting strategies from high-income nations, SSA policymakers should prioritize localized solutions that address structural barriers such as inadequate road networks, erratic fuel supply, and the realities of informal settlements. Education and policy must converge to equip health professionals with the practical competencies needed to navigate and lead within climate-adaptive systems.

4.3 Practical and Logistical Challenges

Translating sustainability principles into healthcare education in SSA presents several implementation challenges. Health curricula are already densely packed with clinical competencies, making it difficult to accommodate new content without a significant redesign.

Mundorf et al. (2018) highlighted the shortage of faculty staff trained in sustainability and transport disciplines, a challenge that limits both content delivery and curriculum innovation.

As illustrated in Figure 2, international collaboration networks reveal sparse representation from SSA-based institutions, suggesting a geographic asymmetry in research contributions. The reliance on insights and frameworks from predominantly Global North contexts risks reinforcing approaches that are less applicable to African realities. Enhancing the institutional capacity of SSA-based universities and colleges is therefore critical to ensure that teaching materials, case studies, and skills development strategies are both relevant and scalable.

4.4 Limitations

The study's scope is limited by its exclusive reliance on the Scopus and Web of Science databases, which may omit regionally significant research not indexed in these repositories. The restriction to English-language publications introduces a potential bias that likely underrepresents studies from Francophone and Lusophone Africa. Additionally, the bibliometric methodology, while robust in mapping structural and thematic patterns, does not capture the experiential or qualitative dimensions of health education content, such as pedagogical effectiveness or learner engagement. Importantly, the study did not involve direct curriculum audits, syllabi reviews, or educational policy analysis. Therefore, conclusions about the lack of integration of sustainability topics in healthcare education should be interpreted with caution, as relevant content may exist in formal curricula but remain undocumented in bibliometric literature. Further research involving curriculum audits, stakeholder interviews, and comparative policy analysis would enrich the understanding of how sustainable transport themes are or are not internalized in health education systems.

5 Conclusion and Implications

This bibliometric study examined the integration of sustainable healthcare transport into health education by analyzing research trends, thematic evolution, and institutional contributions across 356 publications spanning 2000 to 2025. The results reveal a maturing body of work on green logistics and climate-smart mobility in healthcare systems. However, while the reviewed literature suggests that educational integration is limited both conceptually and institutionally, this finding should be interpreted in light of the study’s methodological scope, which excluded the direct analysis of curricular documents and formal training content. As such, the absence of sustainability topics in the literature does not conclusively demonstrate their absence in health education practice.

Key findings indicate that although sustainable transport solutions, such as electric ambulances, telemedicine-assisted mobility, and non-motorized logistics, have gained scholarly traction, their pedagogical relevance is seldom articulated. Health education, as it appears in the current literature, is treated more as a context than as a core mechanism for system transformation. This bibliometric gap, while notable, underscores the need for

complementary empirical research that examines whether, if at all, these innovations are reflected in actual curricula and instructional frameworks.

The main scholarly contribution of this study lies in mapping this underexplored intersection and identifying thematic silos that inhibit curricular cohesion. By surfacing the disconnect between transport and education discourse, the paper provides a starting point for new theoretical and applied work that bridges sustainability science with health training. Rather than asserting a definitive lack of integration, the study highlights a documentation gap and the need for triangulation with curricular data. It fills a significant knowledge gap by charting the structural patterns of scholarly engagement and offering evidence for why curriculum reform should be positioned as central, rather than peripheral, to sustainable healthcare transitions.

Practically, the study highlights urgent actions for health training institutions, particularly in climate-vulnerable regions such as Sub-Saharan Africa. The data suggests that curricular models remain largely unresponsive to environmental challenges, and existing professional development pathways rarely include sustainability components. These omissions are consequential. Without health workers trained in logistics resilience, resource efficiency, and low-carbon mobility, system-level adaptation will falter.

The study also highlights missed opportunities in cross-sector partnerships. Institutions publishing actively in this space are predominantly based in the Global North, with limited representation from African universities or health training bodies. Closing this gap will require policy mechanisms that support intersectoral research, incentivize the development of green education content, and finance context-specific innovation. Regional accreditation agencies and health ministries have a strategic role to play in embedding these competencies into licensure, evaluation, and funding frameworks.

In broader terms, this research supports the call to climate-proof health systems not only through infrastructure, but also through people. Preparing a new generation of healthcare professionals to navigate transport disruptions, energy scarcity, and mobility innovations is a climate adaptation strategy in itself. A resilient system is one in which knowledge and practice evolve together, and that evolution must begin with how we train those at the frontline.

By drawing attention to an overlooked but urgent research-policy interface, this study lays the groundwork for sustained scholarly inquiry and curriculum transformation. It calls on educators, policymakers, and researchers to co-create a health education paradigm that aligns with environmental realities and positions healthcare workers as active agents of sustainability.

6 Recommendations for Future Research

Building on the bibliometric trends and gaps identified in this study, several targeted research opportunities emerge. One underexplored area is the integration of informal and low-tech transport solutions such as bicycle ambulances, community-operated motorcycle services, and hand-pulled carts into rural healthcare logistics. These modes play a critical role in remote areas but remain largely absent from health education and policy frameworks. A relevant research question is: How can informal transport systems be formally recognized and embedded into health professional training in rural and underserved settings?

Another promising avenue is the regional rebalancing of scholarship. The dominance of publications from Europe and North America limits the contextual relevance in regions such as Sub-Saharan Africa and Southeast Asia, where infrastructure constraints and climate vulnerabilities differ markedly. Future research should employ decolonial and participatory methodologies, such as co-designing curriculum interventions with local institutions, to produce culturally and contextually grounded educational models. A guiding question might be: What context-specific sustainability competencies are most relevant for healthcare workers in climate-vulnerable regions, and how can these be co-developed and tested with local stakeholders?

Lastly, the convergence of smart mobility, eHealth, and carbon accounting presents an emerging intersection worth exploring through systems thinking. This raises questions such as: To what extent are digital health platforms and smart transport systems reducing the carbon footprint of patient mobility, and how can this knowledge be translated into competency-based curricula? Moreover, future research should examine the integration of sustainability topics in accredited health education programs by reviewing mainstream medical and public health curricula, textbooks, and syllabi. A systematic review of education-focused journals such as Medical Education, Teaching and Learning in Medicine, and Health Professions Education could provide a more accurate picture of whether sustainability content is already embedded but underreported in interdisciplinary databases.

Methodological innovations, such as curriculum mapping, instructional audits, and simulation-based learning assessments, should also be employed to evaluate how pedagogical practices support or hinder the integration of transport sustainability in healthcare education. These methods, combined with bibliometric approaches, could yield a more comprehensive understanding of how to integrate sustainability into training for future healthcare professionals.

Additionally, future research should explore the design and piloting of curriculum integration frameworks that embed green transport logistics into healthcare training programs. Comparative studies could test the applicability of classical models like Taba's linear development model, Bruner's Spiral Curriculum, or even interdisciplinary Integrated Curriculum Models within African health education systems. This would provide empirical

insight into how effectively these models accommodate climate-smart logistics content in both theory and practice.

Another promising avenue is the co-development of a Competency-Based Education (CBE) model explicitly focused on sustainability in health logistics. Such a model should articulate core competencies, including carbon budgeting in healthcare transportation, renewable energy logistics planning, and disaster-resilient mobility strategies. It should also explore delivery modes that balance didactic instruction with hands-on simulation and service-learning in low-resource contexts.

The figure below outlines three strategic areas for future research in sustainable healthcare transport and health education. Each research theme includes a core question and matched methodologies, informed by scholarly contributions from Uddin (2022), Redding et al. (2019), and Kahlmeier et al. (2023), ensuring alignment with global and regional sustainability discourse.

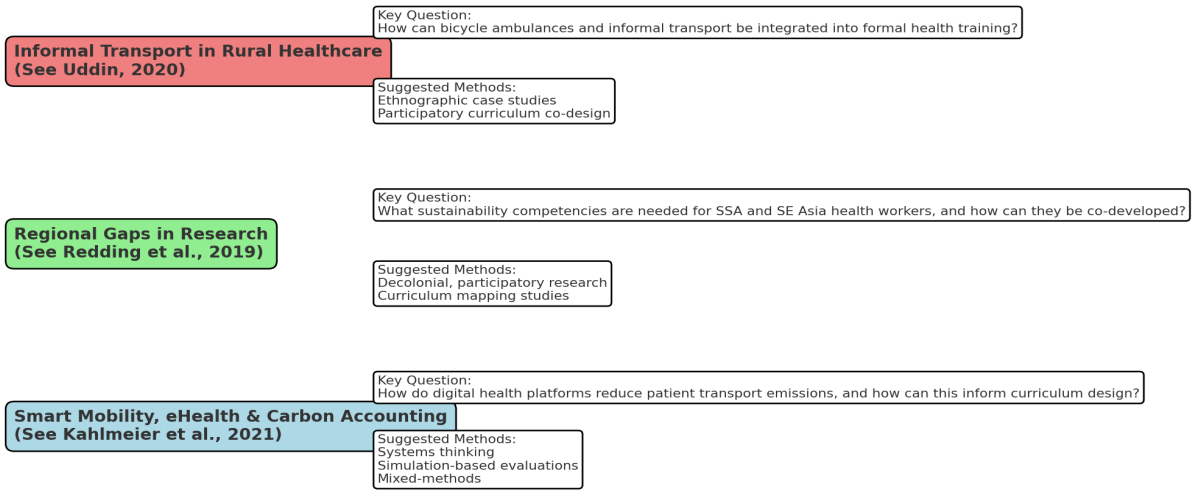

Figure 5: Research agenda highlighting key underexplored areas in sustainable healthcare transport and health education, with corresponding research questions and suggested methods. Color-coded areas indicate thematic priorities aligned with recent bibliometric findings.

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