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Road infrastructure as a driver of territorial development: a bibliometric review

Infraestructura vial como eje de desarrollo territorial: una revisión bibliométrica

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Abstract

This study analyzed global scientific production on road infrastructure as a driver of territorial development using a quantitative and descriptive bibliometric approach. A total of 458 documents from Scopus were examined using VOSviewer and Bibliometrix, identifying thematic trends, collaboration networks, and publication dynamics. The results reveal a growing interdisciplinary field since 2010, focused on social, environmental, and economic sciences, with key topics such as connectivity, sustainability, and territorial planning. However, technical and economic approaches predominate, relegating spatial justice, socio-environmental conflicts, and local governance. China, the United States, and Spain lead production, while sub-Saharan Africa and Latin America are underrepresented, despite their connectivity and equity challenges. The findings provide an empirical basis for reorienting research and strengthening public policies that integrate connectivity, equity, and environmental conservation from contextualized and critical approaches.

Keywords: road infrastructure, territorial development, sustainability

Resumen

Este estudio analizó la producción científica global sobre infraestructura vial como eje del desarrollo territorial mediante un enfoque bibliométrico cuantitativo y descriptivo. Se examinaron 458 documentos de Scopus con VOSviewer y Bibliometrix, identificando tendencias temáticas, redes de colaboración y dinámicas de publicación. Los resultados revelan un campo interdisciplinario en crecimiento desde 2010, enfocado en ciencias sociales, ambientales y económicas, con temas clave como conectividad, sostenibilidad y planificación territorial. Sin embargo, predominan enfoques técnicos y económicos, relegando justicia espacial, conflictos socioambientales y gobernanza local. China, Estados Unidos y España lideran la producción, mientras África subsahariana y América Latina están subrepresentadas, pese a sus desafíos de conectividad y equidad. Los hallazgos proporcionan una base empírica para reorientar investigaciones y fortalecer políticas públicas que integren conectividad, equidad y conservación ambiental desde enfoques contextualizados y críticos.

Palabras clave: infraestructura vial, desarrollo territorial, sostenibilidad

Introduction

Road infrastructure is a fundamental pillar of territorial development, facilitating economic integration, social accessibility, and spatial cohesion (Brisc & Bodocan, 2025; Martínez & Ruiz, 2025). Its strategic planning not only enhances connectivity between urban and rural regions but also influences land use patterns, demographic dynamics, and decentralization processes (Henríquez et al., 2025; Xu et al., 2024). In this context, road infrastructure transcends its technical function, becoming a tool for territorial governance and spatial equity.

Recent literature has examined this relationship from interdisciplinary perspectives. Studies in urban and regional planning underscore how road networks shape peri-urban growth and generate environmental externalities, such as landscape fragmentation and loss of forest cover (Moschella, 2023; Ortiz-Báez et al., 2023).

Meanwhile, research in sustainable mobility has incorporated tools such as Geographic Information Systems (GIS) and spatial simulation models (e.g., Dyna-CLUE) to assess territorial impacts and optimize routes (Henríquez et al., 2025; Mangiameli et al., 2025). Additionally, a positive correlation has been observed between road endowment and economic performance, measured through indicators such as GDP per capita and accessibility to basic services (Rizzi et al., 2023; Shartova et al., 2023). In developing contexts, road infrastructure is linked to regional integration, sustainable tourism, and territorial resilience (Ballo et al., 2025; Coronado et al., 2025; Mareï & Lombard, 2024).

However, significant gaps remain in global research. First, scientific production is disproportionately concentrated in Asia and Europe, with scant representation from regions such as Sub-Saharan Africa and Latin America, despite facing critical challenges in connectivity and territorial development. Second, while there are sector-specific studies on environmental, economic, or social impacts, a systemic synthesis is lacking that visualizes thematic trends, key actors, and the conceptual evolution of the field on a global scale. This gap hinders academic understanding of the subject and limits policymakers' ability to design integrated strategies that balance growth, equity, and environmental conservation across diverse contexts.

In light of this landscape, this study poses the following research question: How has global scientific production on road infrastructure as a driver of territorial development evolved, and what trends, actors, and geographical gaps characterize this field? The aim is to analyze this production using a bibliometric approach to identify emerging thematic areas, collaboration networks, and opportunities to strengthen research and public action in underrepresented regions.

This study maps the existing scientific knowledge and provides a solid empirical foundation that benefits public policymakers, territorial planners, researchers, and professionals interested in the relationship between road infrastructure and territorial development. By identifying thematic trends, key actors, and geographical gaps, it offers strategic insights to guide research agendas, investments in sustainable infrastructure, and the design of inclusive policies across various contexts.

Methodology

This study adopts a quantitative and descriptive bibliometric approach to map global scientific production regarding road infrastructure as a driver of territorial development. Bibliometrics allows for analyzing knowledge patterns using statistical techniques applied to large sets of academic literature, facilitating the identification of thematic trends, key actors, and emerging conceptual structures in interdisciplinary fields (Donthu et al., 2021).

The systematic search was conducted in the Scopus database, selected for its multidisciplinary coverage, indexing rigor, and extensive representation of high-impact scientific journals. The following search equation was applied:

> TITLE-ABS-KEY (("Road infrastructure" OR "Road network" OR "Roads and roads" OR "Transportation infrastructure" OR "Road transportation network") AND ("territorial development" OR "Territorial planning" OR "Territorial management" OR "Regional development" OR "Local development" OR "Territorial policy" OR "Territory management"))

No temporal limits were imposed to capture the historical evolution of the field. The inclusion criteria were:

- Documents in any language;
- Document types: articles, reviews, conference proceedings, and book chapters;
- Publications indexed in Scopus with complete metadata (authors, affiliations, keywords, references).

Exclusion criteria included:

- Documents lacking sufficient bibliographic information (e.g., editorials, brief notes without substantive empirical or theoretical content);
- Duplicate or misclassified publications (identified during the cleansing process).

Data extraction was carried out on October 3, 2025, resulting in a corpus of 458 documents. The methodological flow was structured in four sequential stages:

1. Data extraction from Scopus.
2. Cleansing of metadata (removal of duplicates and filtering by thematic relevance).
3. Bibliometric analysis using the Bibliometrix package in R (version 4.5.0).
4. Knowledge network visualization with VOSviewer (version 1.6.20).

The analysis was conducted using two complementary tools:

- Bibliometrix (Aria & Cuccurullo, 2017): This tool enabled characterizing global indicators (annual production, citations, authors, countries, sources, thematic areas) and evaluating the dynamics of the literature through impact and collaboration metrics.

- VOSviewer (Van Eck & Waltman, 2010): It was used to construct network maps based on different types of connections:

a) Co-occurrence of keywords: to identify central themes and conceptual clusters (minimum threshold: 5 occurrences);
b) Co-authorship: to map collaboration networks among authors, institutions, and countries;
c) Co-citation and bibliographic coupling: to explore the intellectual foundation of the field (though not reported in depth in this article, these analyses were conducted as complementary).

T All raw and processed data have been deposited in the open repository Zenodo (DOI: https://zenodo.org/records/17263839), ensuring transparency, reproducibility, and open access.

This methodological approach will provide a comprehensive insight into how scientific literature has addressed the intersection between road infrastructure and territorial development, identifying trends, key authors, leading institutions, and areas of opportunity for future research in this field.

Results and discussion

The analysis identified 458 documents indexed in Scopus from 1966 to 2025, with an average annual growth rate of 7.09%, 14.02 citations per document, and a mean age of 7.51 years (Figure 1). These indicators confirm that research on road infrastructure and territorial development has reached a phase of academic consolidation. The presence of 2,241 authors, 267 editorial sources, and over 3,000 keywords emphasizes the conceptual richness and interdisciplinarity of the field. This dynamism directly responds to the challenges highlighted in the introduction: the need to integrate connectivity, equity, and sustainability within territorial planning (Martínez & Ruiz Pulpón, 2025; Xu et al., 2024). However, the mere existence of an extensive corpus does not guarantee balanced consideration of the social, environmental, and political dimensions of territorial development, a tension explored in the following findings.

Figure 1

General indicators of the Bibliometric corpus

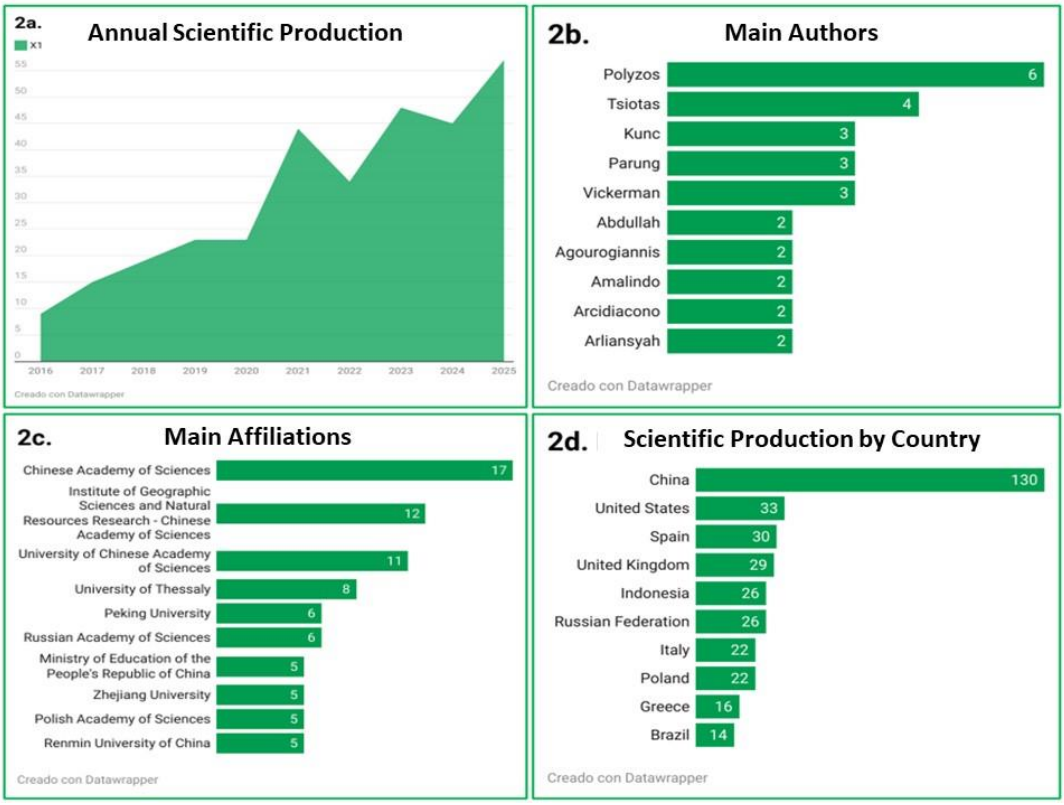


Note. Summary extracted from Bibliometrix, based on metadata regarding the scientific approach to road infrastructure as a driver of territorial development, sourced from Scopus.

The production experienced a marked acceleration beginning in 2010, rising from 13 documents that year to 57 by 2025 (Figure 2a). The most prolific author is Polyzos, with six publications, followed by Tsiotas with four (Figure 2b). Leading institutions are dominated by Chinese centers: the Chinese Academy of Sciences (17 documents), the Institute of Geographic Sciences and Natural Resources Research (12), and the University of Chinese Academy of Sciences (11) (Figure 2c). Geographically, China accounts for 28% of the production (130 documents), followed by the United States (33), Spain (30), and the United Kingdom (29) (Figure 2d). This pattern reflects a strong alignment with national agendas for regional development, as seen in studies on megaprojects in Asia (Chen et al., 2023; Mao & Chen, 2023). However, it contrasts sharply with the critical underrepresentation of Sub-Saharan Africa and Latin America—regions where, according to Ballo et al. (2025) and Mareï & Lombard (2024), road infrastructure is crucial for regional integration, sustainable tourism, and territorial resilience. This geographical gap limits the global applicability of the findings and reinforces the initial warning about the lack of contextually grounded synthesis in the Global South.

Figure 2

Annual scientific production, authors, institutions, and countries

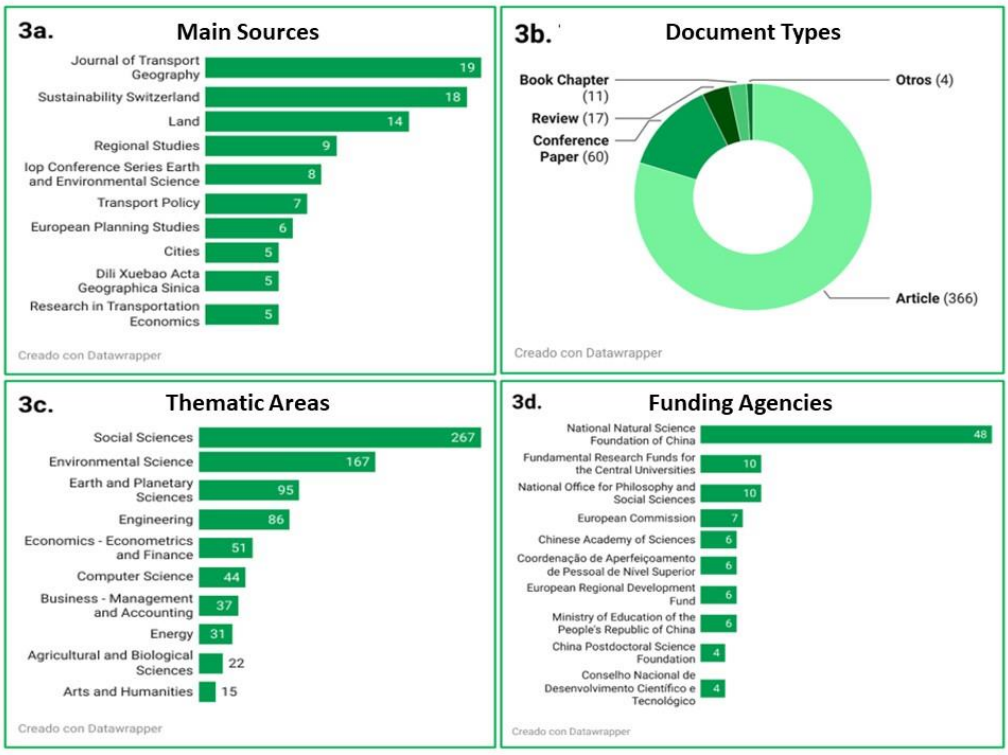


Note. Elaborated based on metadata obtained from Scopus and processed in Datawrapper.

The most active journals include the Journal of Transport Geography (19 documents), Sustainability (18), and Land (14) (Figure 3a). Original articles dominate (366; 80% of the total), indicating a focus on empirical research (Figure 3b). The main thematic areas are Social Sciences (267), Environmental Sciences (167), and Earth Sciences (95) (Figure 3c), confirming the anticipated interdisciplinarity. Nonetheless, while externalities such as landscape fragmentation are mentioned (Ortiz-Báez et al., 2023; Moschella, 2023), these appear as secondary topics rather than central axes of analysis. Funding is led by the National Natural Science Foundation of China (48 projects), followed by European sources (Figure 3d). This suggests that research is more responsive to public policy priorities in advanced economies than to challenges of rural connectivity or territorial equity in peripheral contexts, as highlighted in the introduction.

Figure 3

Sources, document types, thematic areas, and funding

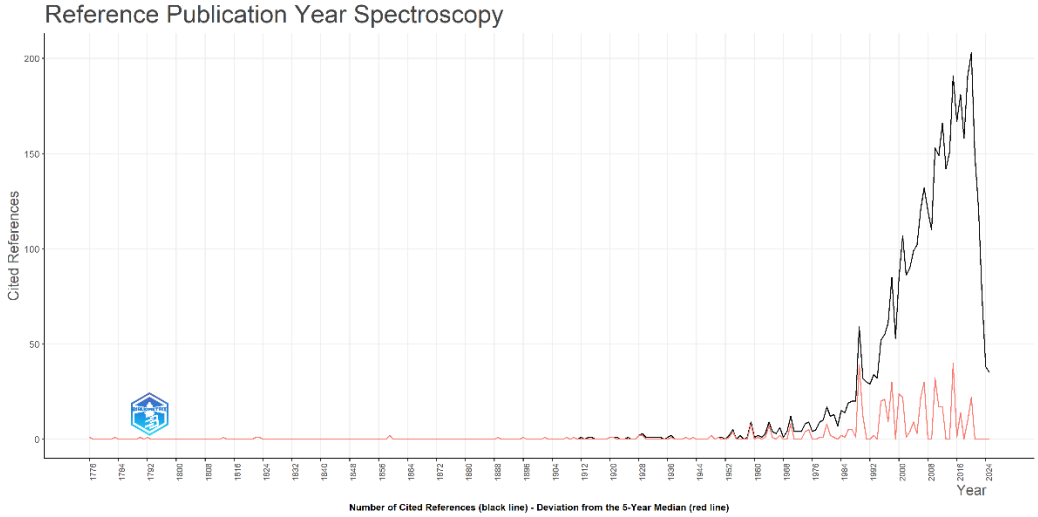


Note. Developed based on metadata obtained from Scopus and processed in Datawrapper.

The reference spectroscopy indicates a rising trend in scientific production regarding road infrastructure and territorial development, reinforcing the notion that road infrastructure is now studied not merely as a technical good, but as a tool for territorial governance, as posited by Henríquez et al. (2025) and Xu et al. (2024). However, the analysis also reveals that this "governance" is predominantly exercised from knowledge centers in the Global North, with limited involvement from local actors in regions where infrastructure generates socio-environmental conflicts or displacement, as noted by Ruwanpura et al. (2020) and Lesutis (2021) (Figure 4).

Figure 4

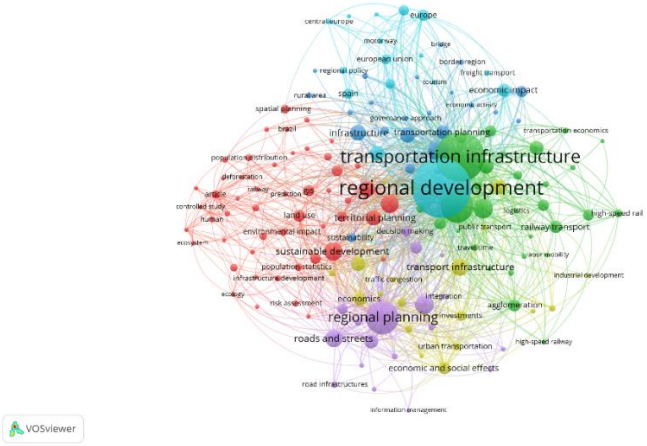
Reference Spectroscopy



Note. Elaborated based on metadata sourced from Scopus and processed in Bibliometrix.

The semantic map exhibits a central cluster around “regional development” (164 occurrences) and “transportation infrastructure” (143), followed by “economic development,” “accessibility,” and “China” (78) (Figure 5). These terms reflect a predominant focus on the economic and spatial impacts of road infrastructure, aligning with findings by Rizzi et al. (2023) and Shartova et al. (2023) regarding the correlation between road endowment and economic performance. However, concepts such as “spatial justice,” “participatory governance,” and “territorial rights”—central to contemporary critiques of megaprojects (Lesutis, 2021; Ruwanpura et al., 2020)—are absent or marginalized. This suggests that, despite theoretical acknowledgment of infrastructure as a tool for equity (Martínez & Ruiz, 2025), empirical study continues to prioritize technical and economic metrics over political and ethical dimensions.

Figure 5
Semantic map of keyword co-occurrence

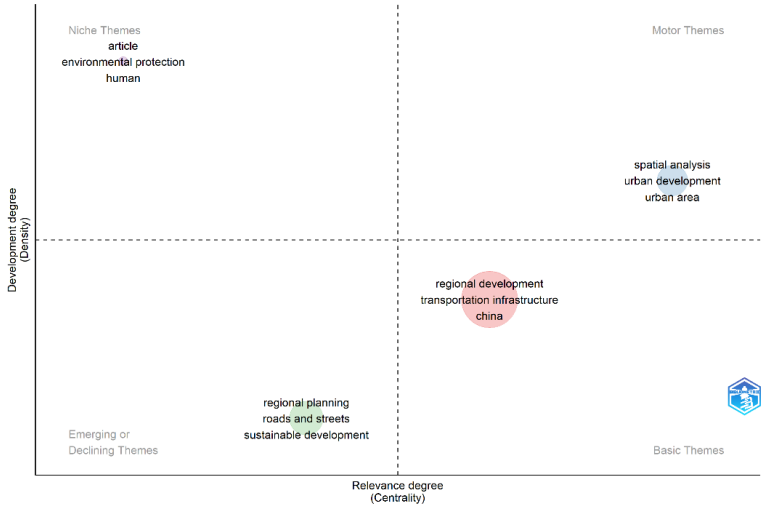


Note. Developed based on metadata obtained from Scopus and processed in VOSviewer.

The network analysis positions "regional development" as the node with the highest PageRank (0.049), confirming its role as a conceptual core (Figure 6). "Infrastructural development" and "China" stand out for their centrality in mediation (betweenness: 1008.21 and 692.20, respectively), acting as bridges between thematic clusters. However, the low closeness centrality in several nodes indicates conceptual fragmentation: technical approaches (engineering, planning) and critical perspectives (political geography, postcolonial studies) coexist but rarely engage in dialogue. This disconnection hinders the comprehensive addressing of the challenges raised in the introduction: balancing growth, equity, and environmental conservation across diverse contexts. Road infrastructure, as currently studied, continues to serve as an instrument of territorial development, but not necessarily as a means of achieving just development.

Figure 6

Thematic map with network metrics



Note. Elaborated based on metadata obtained from Scopus and processed in Bibliometrix.

Conclusions

This study confirms that road infrastructure has become a central axis of territorial development in the global scientific literature, characterized by its interdisciplinary nature, dynamism, and responsiveness to contemporary challenges such as sustainability, accessibility, and regional planning. However, a significant geographical asymmetry persists in knowledge production, with an overwhelming concentration in Asia and Europe and a critical underrepresentation of regions like Sub-Saharan Africa and Latin America, where the challenges of connectivity and territorial equity are more urgent. This inequality limits epistemic diversity and reduces the relevance of public policies in peripheral contexts.

Predominant approaches remain focused on technical and economic dimensions, sidelining essential issues such as spatial justice, socio-environmental conflicts, and local governance. Although road infrastructure is recognized as a tool for territorial cohesion, its empirical analysis does not yet fully reflect its political and social dimensions.

The findings of this work provide an empirical foundation for reorienting research and public action agendas. It is essential to strengthen research capacities in marginalized regions, integrate critical approaches that question the assumed technical neutrality of infrastructure, and promote analytical frameworks that link connectivity, equity, and sustainability.

Ultimately, policymakers must leverage this knowledge to design inclusive territorial strategies that respond to the real needs of communities, particularly in rural, peri-urban, and ecologically vulnerable areas.

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