Railway Sciences

High-speed rail and socioeconomic inequality: a systematic bibliometric analysis of research trends, methodologies and thematic structures

783

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Abstract

Purpose – This paper investigates how high-speed rail (HSR) influences socioeconomic inequality by providing the first systematic bibliometric review of research trends, methodological approaches and thematic structures. It examines whether HSR fosters balanced regional development or reinforces spatial disparities.

Design/methodology/approach – Using the Bibliometrix *R* package, 237 records were retrieved from the Web of Science (1985–2024). Citation indicators, keyword co-occurrence and collaboration networks were combined with natural language processing (NLP) to classify studies by territorial scale, methodology, economic variables and inequality outcomes.

Findings – The paper offers the first structured overview of how the literature conceptualizes the link between HSR and inequality. It highlights persistent gaps – scarcity of city-level analyses, limited socioeconomic indicators and reliance on Chinese case studies – providing a foundation for more comparative and interdisciplinary research.

Originality/value – This paper contributes by offering a structured overview of how the literature has conceptualized and measured the relationship between HSR and inequality. By identifying persistent research gaps – such as the scarcity of city-level analyses, limited use of socioeconomic indicators, and overreliance on Chinese case studies – it provides a foundation for more comparative and interdisciplinary approaches. The study informs policymakers and researchers on how to design future infrastructure projects that balance efficiency with equity.

Keywords High-speed rail, Socioeconomic inequality, Spatial disparity, Regional development, Accessibility, Bibliometric analysis

Paper type Research article

1. Introduction

High-speed rail (HSR) has emerged as a transformative infrastructure since its inception in Japan in 1964 with the Shinkansen, designed to enhance efficiency and stimulate economic growth between major urban centers (Blanquart & Koning, 2017). Since then, governments worldwide have expanded HSR networks, with 59,498 km currently in operation, 19,927 km under construction, and long-term plans projecting more than 129,000 km (UIC, 2023). The Asia-Pacific region leads with over 44,000 km of operational lines, followed by Europe with 12,384 km, while other regions such as North America, the Middle East, Africa, and Latin America are also expanding their networks.

As show in Figure 1, the distribution of these infrastructures varies significantly across regions. The rapid diffusion of HSR has raised critical questions about its socioeconomic

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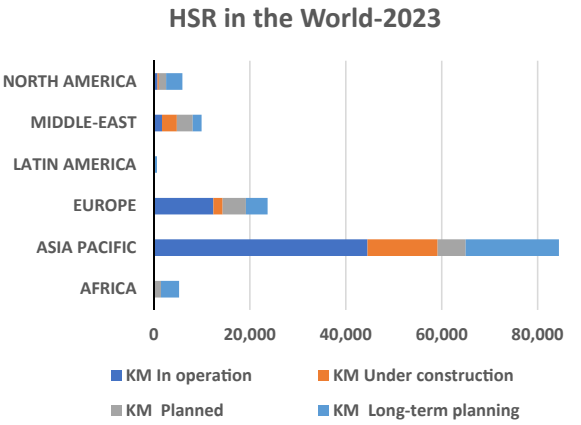

Figure 1. UIC: global hsr network: current and planned expansion. Source: The author on UIC data owns work

consequences, particularly regarding inequality and spatial disparities (Blanquart & Koning, 2017). Evidence shows that while HSR creates jobs and stimulates local economies, its benefits are unevenly distributed. Regions with strong first- and last-mile connectivity experience greater gains, whereas disadvantaged areas may be excluded (Chandra & Mishra, 2024; Ngoc & Nishiuchi, 2022). Urban contexts face additional risks of gentrification and displacement (Venezia, 2023; Wang *et al*., 2024a, b, c, d), while rural areas may lose resources siphoned toward metropolitan cores (Cai, Wu, & Lu, 2022). In this sense, HSR functions not merely as transport innovation but as a complex socio-economic phenomenon that can both mitigate and exacerbate inequality (Ortega, Lopez, & Monzon, 2014; Rungskunroch, Shen, & Kaewunruen, 2022; Di Ruocco & D'Auria, 2024).

Research has identified key *redistribution mechanisms*. The *siphon effect* describes how investment and skilled labor flow from smaller towns to large urban hubs, reinforcing primacy (Zhu *et al*., 2018; Liu, Wan, Ha, Yoshida, & Zhang, 2019; Chen & Haynes, 2015). This aligns with *core–periphery theory* (Krugman, 1991; Krugman & Venables, 1995; Venables, 1996), which stresses the cumulative advantages of agglomeration. However, European evidence suggests that under certain conditions HSR can foster integration by supporting intermediate cities (Cheng, Loo, & Vickerman, 2015; Gutiérrez, 2001). Zhang, Wan, and Yang (2019) provide the most comprehensive framework, identifying contrasting outcomes depending on city size, development stage, and governance context.

Two comparative perspectives dominate: (1) *HSR vs non-HSR cities*, where connected regions often enjoy significant advantages (Gutiérrez, 2001; Li, Huang, Li, & Zhang, 2016; The World Bank, 2014; Ureña, Menerault, & Garmendia, 2009), though inequalities may increase nationally; and (2) *different levels of HSR cities*, where large metropolitan areas capture most benefits, while smaller cities show mixed trajectories (Bonnafous, 1987; Chen & Haynes, 2015; Cheng *et al*., 2015; Qin, 2017; Campante & Yanagizawa-Drott, 2018). These contradictory findings confirm that HSR's distributive effects are highly context dependent.

Given this complexity, there is a need for *systematic and transparent review methods*. The field has expanded significantly only in the last decade, producing diverse and sometimes contradictory evidence. Traditional narrative reviews are no longer sufficient to capture these dynamics. Bibliometric methods (Aria & Cuccurullo, 2017; Aria, Misuraca, & Spano, 2020) enable structured analysis of scientific output, thematic clusters, and emerging gaps, as already applied in fields as diverse as information technology (Yang *et al*., 2019a, b), medicine (de Vasconcelos Silva, Araujo, Spiegel, & da Cunha Reis, 2022), psychology (Weleff *et al*., 2021),

business and finance (Janbaz, Hassan, Floreani, Dreassi, & Jiménez, 2022), political science (Cepiku & Mastrodascio, 2021), and transport safety (Scarano, Aria, Mauriello, Riccardi, Montella, 2023).

Building on this approach, the present study provides a *systematic bibliometric review* of research on HSR and inequality. It aims to:

(1) Map the evolution of the literature, identifying key themes and influential contributions.

(2) Compare regional research patterns, with attention to differences between China, Europe, and other contexts.

(3) Highlight methodological approaches and their implications for interpreting results.

(4) Identify persistent gaps and propose directions for future research.

This structured review offers a foundation for further empirical studies and informs policy debates on ensuring that HSR contributes to *equitable and inclusive regional development*.

2. Data and methodology

The quality of a systematic literature review depends on the quality of the employed data. To ensure reliability, it is essential that the data reflect three core attributes: consistency, authority, and clarity. These attributes enable the creation of meaningful and dependable statistics for analysis. The Web of Science (WoS) Core Collection (available at http://www.webofknowledge.com) was chosen as the primary data source due to its extensive collection of high-impact scientific records covering peer-reviewed journals, conference proceedings, and books. WoS is recognized as one of the oldest and most authoritative citation databases, ensuring that indexed journals meet rigorous quality criteria before being included. The database follows a continuous curation process, removing journals that fail to maintain high academic standards, making it a reliable foundation for bibliometric analysis (Li & Hale, 2016; Yunus *et al.*, 2013).

2.1 Data collection

The search was conducted on 26 July 2024, covering the period 1985–2024. The initial query returned 9,418 records, which included many irrelevant results due to the acronym "HSR" also referring to medical and biological terms (e.g. Heat Shock Response). To address this, a stepwise filtering approach was applied, as illustrated in Figure 2, was implemented to progressively refine the dataset.

(1) Filtering by topic (income distribution, urban–rural divides, human capital, etc.).

(2) Exclusion of medical and unrelated scientific fields.

(3) Inclusion of relevant WoS categories (transportation, economics, urban planning, geography, environmental studies, regional development, etc.).

This process reduced the dataset to 237 records, ensuring that only studies explicitly related to high-speed rail and socio-economic inequality were retained.

Given the variability in terminology, a broad and inclusive search strategy was employed. Alternative terms were incorporated for both high-speed rail ("High-Speed Rail," "Bullet Train," "HSR") and inequality ("Income Inequality," "Spatial Disparity," "Economic Disparity," "Human Capital," "Skill Distribution"), using Boolean operators. Records were further cleaned by standardizing keywords (e.g. merging singular/plural forms and synonyms such as "Inequalities" → "Inequality"), enabling reliable co-word and thematic analysis.

The final Web of Science query is reported below in Figure 2 for replicability:

Following the data cleaning phase, all records were systematically processed to ensure metadata uniformity. This structured approach ensured a comprehensive and reproducible

```
TS = ("High-Speed Rail" OR "Bullet Train" OR "HSR" OR
"Electric Multiple Unit" OR “EMU”)
AND
TS=("Income Inequality"
OR "Income Distribution"
OR "Economic Disparity"
OR "Urban-Rural Divide"
OR "Spatial Inequality"
OR "Inequality"
OR "Income"
OR "Disparity"
OR "Inequalities"
OR "High-Skill"
OR "High Skill"
OR "Education Inequality"
OR "Educational Attainment"
OR "Skill Distribution"
OR "Highly Skilled Workers"
OR "Human Capital"
OR "Knowledge Workers")

AND WC = ("Transportation"
OR "Economics"
OR "Environmental Studies"
OR "Transportation Science Technology"
OR "Environmental Sciences"
OR "Green Sustainable Science Technology"
OR "Geography"
OR "Management"
OR "Engineering, Civil"
OR "Operations Research & Management Science"
OR "Social Sciences, Interdisciplinary"
OR "Regional & Urban Planning"
OR "Business"
OR "Multidisciplinary Sciences"
OR "Urban Studies"
OR "Development Studies"
OR "Public Administration"
OR "Political Science"
OR "Sociology"
OR "Geography, Economic"
OR "Planning & Development"
OR "Economics, Regional")

AND LA="English"
AND DT=("Article" OR "Review")
AND PY=1985-2024
```

Figure 2. Final web of science query for replicability (1985–2024). Source: Authors’ own work

dataset, providing a robust foundation for bibliometric analysis of HSR’s socioeconomic implications. The workflow summarizing the data collection and refinement process is illustrated in Figure 3.

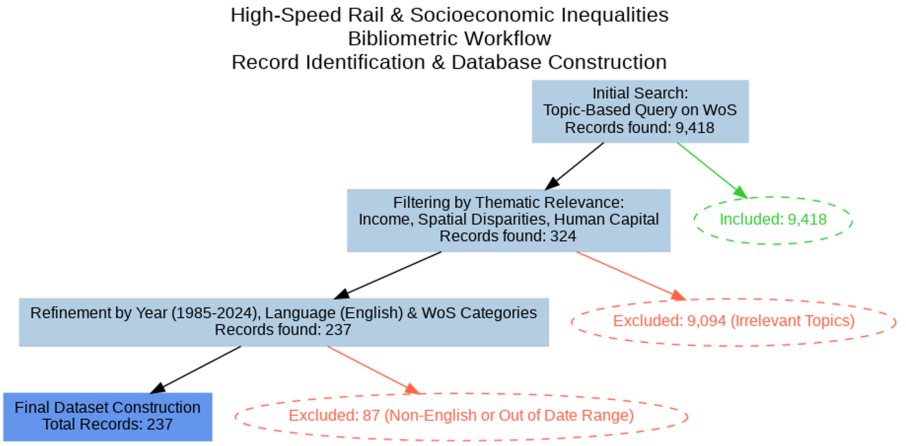

Figure 3. Data selection workflow. Source: Authors' own work

This structured approach ensured a comprehensive and reproducible systematic literature review, enabling a robust bibliometric analysis of high-speed rail's impact on economic inequalities.

This review covers 1985–2024 to ensure replicability over the full modern period of HSR research indexed in Web of Science. Although the time window starts in 1985, our search finds no relevant contributions before 2010, with the first papers appearing in 2011 and a sharp rise only after 2016, as shown in Figure 4. To address terminological variability, we consider alternative labels for high-speed rail, including "Bullet Train" and "Electric Multiple Units (EMU)," while applying semantic screening to exclude non-HSR uses (e.g. EMU not referring to high-speed services). This dual clarification—temporal scope and terminology—improves transparency and replicability of the review.

2.2 Data analysis

Systematic reviews require structured methodologies to map research trends and gaps (Chabowski, Mena, & Gonzalez-Padron, 2011; Glänzel, 2003; Valenzuela-Fernández, Serrano-López, Graña, Bao, & Zhang, 2019). In this study, a bibliometric approach was chosen because the HSR–inequality literature has grown rapidly and is too fragmented for a purely narrative review. Bibliometrics allows for a transparent, replicable, and quantitative synthesis of research output, complementing traditional qualitative assessments.

The analysis was conducted using the Bibliometrix *R* package (Aria & Cuccurullo, 2017), combining three main techniques:

(1) Citation-based metrics (counts, co-citation, bibliographic coupling) to identify intellectual linkages and schools of thought (Small, 1997; Ferreira-Vanegas, Amaral, & Gonzalez, 2022).

(2) Keyword co-occurrence analysis to track thematic evolution and highlight emerging versus mature topics (Aria *et al.*, 2020).

(3) Collaboration networks to map institutional and geographic patterns of research activity.

For co-citation, bibliographic coupling, and keyword co-occurrence networks, edges were weighted using cosine similarity on normalized occurrence and citation vectors. Community detection was performed primarily with the Louvain algorithm, which optimizes modularity to

Completeness of metadata -- **237** docs from **Isi**

Metadata	Description	Missing Counts	Missing %	Status
AB	Abstract	0	0.00	Excellent
C1	Affiliation	0	0.00	Excellent
AU	Author	0	0.00	Excellent
RP	Corresponding Author	0	0.00	Excellent
DT	Document Type	0	0.00	Excellent
SO	Journal	0	0.00	Excellent
LA	Language	0	0.00	Excellent
PY	Publication Year	0	0.00	Excellent
TI	Title	0	0.00	Excellent
TC	Total Citation	0	0.00	Excellent
CR	Cited References	1	0.42	Good
DI	DOI	4	1.69	Good
ID	Keywords Plus	15	6.33	Good
DE	Keywords	20	8.44	Good
WC	Science Categories	237	100.00	Completely missing

Figure 4. Metadata analysis. Source: Authors' own work

identify cohesive thematic clusters. Additional algorithms available in Bibliometrix (such as Walktrap, Infomap, and Fast Greedy) were tested as robustness checks, yielding consistent results. Cluster labels were derived from the most frequent keywords and core references, while cluster characteristics were summarized through measures of centrality (linkage to other themes) and density (internal cohesion).

In addition, metrics such as annual growth rates, compound annual growth rate (CAGR), and author- and institution-level indicators were computed. Highly cited works were also highlighted, as citation frequency is widely considered a proxy for relevance within a field (Garfield, 1979). All these metrics are calculated automatically within Bibliometrix tool, whose algorithms are documented in detail in Aria and Cuccurullo (2017).

2.3 Data visualization

To classify methodological approaches in the dataset, we used a zero-shot NLP procedure based on the Gemini 1.5 Flash API. Abstracts were processed individually, with prompts designed to extract (1) the specific methodology employed and (2) a generalized methodological category (e.g. regression, difference-in-differences (DID), synthetic control method (SCM), spatial analysis, case study, survey, descriptive statistics, network analysis, transportation demand modeling, other/unspecified).

The implementation was carried out in Python. Each abstract was submitted to Gemini with a standardized prompt, and the model returned structured labels. To ensure replicability, outputs were post-processed into two fields: *Methodology* (specific) and *Generalized Method* (category). Requests were sent sequentially with a randomized delay to avoid API rate limits.

To ensure robustness, all abstracts were manually reviewed after the automated classification. The manual coding served both as a verification step and as the final quality

control, guaranteeing full consistency between automated and human labels. In practice, Gemini provided a first-pass classification, which was subsequently checked and, where necessary, corrected by the author. This process ensured 100% concordance between the final dataset and human judgment.

While alternative NLP approaches such as Latent Dirichlet Allocation (LDA) or BERTopic can be used to identify thematic structures, we found that Gemini's structured labels were more directly aligned with the analytical dimensions of this review (territorial scale, methodology, economic variables, and inequality outcomes). Given the manual validation of all entries, the classification can be considered both replicable and reliable.

2.4 Data visualization

To interpret and present findings, *science mapping techniques* were applied (Börner, Chen, & Boyack, 2003; Morris & Van Der Veer Martens, 2008). Specifically:

(1) *Co-citation networks* were used to highlight clusters of foundational studies.

(2) *Keyword co-occurrence maps* revealed dominant and emerging research themes (Callon, Courtial, Turner, & Bauin, 1991; Cobo, López-Herrera, Herrera-Viedma, & Herrera, 2011).

(3) *Collaboration networks* showed co-authorship patterns and cross-country ties, while geospatial maps illustrated the global distribution of contributions (Zou *et al.*, 2020a, b; Sarkar & Maiti, 2020).

(4) *Co-word analysis* was employed to classify themes by centrality and density, distinguishing between well-established topics (e.g. metropolitan economic impacts) and emerging areas (e.g. distributive outcomes such as wages or the Gini index).

By combining these tools, the study provides a *macroscopic overview* of research on HSR and inequality, while ensuring that results are *interpretable, replicable, and linked to broader theoretical and policy debates.*

3. Results

The bibliometric analysis conducted on the Web of Science (WoS) database identified *237 documents* relevant to the relationship between high-speed rail (HSR) and socioeconomic inequalities. The selection process, illustrated in Figure 2, progressively refined an initial set of 9,418 records by excluding studies unrelated to income distribution, spatial disparities, or human capital. This ensured that the final dataset included only research explicitly addressing the socioeconomic implications of HSR infrastructure.

Further details on metadata completeness and bibliometric attributes are reported in Figure 4, generated with Bibliometrix. The analysis confirms the dataset's robustness and suitability for bibliometric research. Most fundamental fields (author names, document type, journal, language, publication year, title, total citations) exhibit full completeness, providing a reliable basis for citation mapping and trend analysis. Minor gaps are present in cited references and DOI fields (<2%). The most notable absence concerns Web of Science *Science Categories* (100% missing), which prevents direct classification by predefined domains. However, this limitation does not hinder thematic clustering and co-word analysis. Overall, the dataset demonstrates high integrity, enabling reliable bibliometric evaluation of HSR's socioeconomic impacts.

3.1 Publication trend

Academic interest in HSR and inequality is relatively recent. Although the search covered 1985–2024, no relevant contributions were found before 2010. The first articles appeared in

2011, but research remained sparse until 2016. From that point, output steadily increased, with a sharp rise after 2020 (see Figure 5). To smooth short-term fluctuations, a two-period moving average was added, which confirms the strong upward trajectory since 2016. The number of publications more than doubled between 2019 and 2022, peaking at *51 articles in 2023* and *49 in 2024*.

This surge reflects growing scholarly attention to the economic and social dimensions of HSR, likely influenced by large-scale infrastructure investments and policy debates on regional development. The calculated annual growth rate of *27.1%* underscores the rapid expansion of the field. While early work focused primarily on aggregate economic benefits, recent studies increasingly address distributional outcomes, such as spatial and social disparities. This trend highlights the importance of systematic reviews that clarify both the positive and unintended redistributive effects of HSR.

3.2 Source

Sources in bibliometric analysis refer to journals, books, or conference proceedings where the selected documents were published. The 237 documents are distributed across multiple outlets, with a concentration in interdisciplinary journals. The *ten most relevant sources*, listed in Table 1, together account for *48% of the dataset*.

The most frequent outlet is *Sustainability* (13% of documents, IF 3.3), reflecting the growing interest in linking HSR research to broader debates on sustainable development. Leading transportation journals (*Transportation Research Part A*, *Transport Policy*, *Journal of Transport Geography*) also feature prominently, underscoring the field's policy orientation. Other contributors include *Land*, *Socio-Economic Planning Sciences*, *Cities*, and *Applied Geography.*

The prominence of generalist journals such as *Sustainability* suggests that the debate is not confined to transport economics but increasingly intersects with issues of *regional development, spatial equity, and governance frameworks*.

3.3 Authors

The *ten most productive authors* in the field are presented in Table 2, ranked by number of documents and total citations (TC). The analysis does not distinguish between lead, corresponding, or co-author roles.

The most prolific researcher is *Jiao Jingjuan* (Beijing Jiaotong University), with six publications and 462 citations, followed by *Lin Shanlang* (Tongji University, 5 publications,

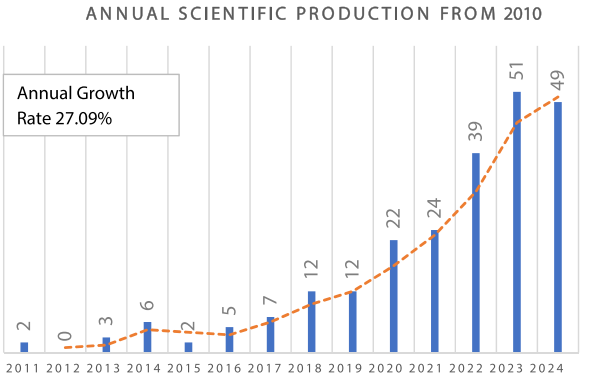

Figure 5. Annual scientific production from 2010. Note: Bars indicate yearly counts; the line shows the two-period moving average. Source: Authors' own work

Table 1. The ten most relevant sources per number of documents

Sources	# of documents	% of documents	2024 IF
Sustainability	30	13	3.3
Transportation Research Part A-Policy and Practice	19	8	6.3
Journal of Transport Geography	15	6	5.7
Transport Policy	14	6	6.3
Land	8	3	3.2
Socio-Economic Planning Sciences	7	3	6.2
Transportation Research Record	7	3	1.6
Cities	5	2	6.0
Plos One	5	2	2.9
Applied Geography	4	2	4.0
Sum of the ten most relevant sources	114	48	–
Total database	237	100	–

Note(s): Abbreviations: IF = Impact Factor

Source(s): Authors' own work

Table 2. The ten most productive authors

Authors	Institution	Country	Documents	TC
Jiao Jingjuan	Beijing Jiaotong University	China	6	462
Lin Shanlang	Tongji University	China	5	256
Liu Yahong	Xuzhou University Of Technology	China	5	24
Tang Daisheng	Beijing Jiaotong University	China	5	24
Kato Hironori	University Of Tokyo	Japan	4	46
Kumagai Junya	Fukuoka University	Japan	4	20
Managi Shunsuke	Kyushu University	Japan	4	20
Wang Lei	University Of Manchester	UK	4	155
Yoo Sunbin	Kyushu University	Japan	4	20
Zhang Anming	University of British Columbia	Canada	4	453

Note(s): Abbreviations: TC = Total Citations that represent the number of times an author is cited in all sampled documents

Source(s): Authors' own work

256 citations). Several other Chinese scholars (Liu Yahong, Tang Daisheng) have contributed multiple studies, though with lower citation impact. Japanese authors such as *Kato Hironori* (University of Tokyo) and *Managi Shunsuke* (Kyushu University) reflect Japan's early engagement with HSR, while *Wang Lei* (University of Manchester) represents a key UK contributor (4 publications, 155 citations).

A notable figure is *Zhang Anming* (University of British Columbia), with four papers and 453 citations, demonstrating high scholarly influence despite a smaller output compared to Chinese authors. Overall, the distribution shows a concentration of productivity in *China and Japan*, with strong contributions also from the UK and Canada.

This pattern mirrors the geography of HSR development itself: China dominates both in infrastructure expansion and in research output, while Japan, Europe, and North America contribute more selectively.

3.4 Most productive institutions

Table 3 presents the ten most productive affiliations contributing to research on HSR and socioeconomic inequalities. All top institutions are based in *China*, underscoring the country's dominance in both infrastructure development and academic research.

Table 3. The ten most productive affiliations

Affiliation	Documents	Country	QS rank 2025
BEIJING JIAOTONG UNIV	51	China	901–950
TONGJI UNIV	24	China	192
CHINESE ACADEMY OF SCIENCES	21	China	*
ZHEJIANG UNIV	21	China	47
WUHAN UNIV	17	China	194
EAST CHINA NORMAL UNIV	16	China	501
PEKING UNIV	16	China	14
CHONGQING UNIV	13	China	489
SOUTHEAST UNIV	12	Bangladesh	428
JINAN UNIV	11	China	580

Note(s): * = Non included in QS Rankings
Source(s): Authors' own work

Beijing Jiaotong University leads with 51 publications, followed by *Tongji University* (24) and the *Chinese Academy of Sciences* (21). Among the top-ranked universities, *Zhejiang University* (21 documents, QS rank 47) and *Peking University* (16 documents, QS rank 14) demonstrate that research on HSR is not limited to technical universities but also engages China's most prestigious institutions. Other contributors include Wuhan University (17), East China Normal University (16), and Nanjing University (11).

This distribution highlights two complementary dynamics:

(1) *Specialized institutions* such as Beijing Jiaotong play a leading role in applied, transport-oriented research.

(2) *Comprehensive universities* like Peking and Zhejiang provide broader analytical contributions, connecting HSR to urban planning, economics, and social sciences.

Overall, the concentration of output within Chinese universities confirms China's central role in shaping global debates on the socioeconomic implications of HSR.

3.5 Most productive countries

Table 4 reports the country-level distribution of publications. *China dominates the field with 154 documents (65%)*, far surpassing the USA (8.4%), Japan (6.3%), and European contributors such as Italy and the UK (both 3%). Smaller but significant contributions come from Korea, Thailand, Germany, Spain, and Singapore.

International collaboration patterns reveal important differences. China's multiple-country publication rate (MCP = 20.1%) is lower than that of the USA (50%), UK (57.1%), and Singapore (66.7%). This indicates that while China leads in volume, its research is more domestically oriented. In contrast, Western countries and Singapore exhibit stronger integration into global research networks.

3.6 Most cited documents

The most cited papers (Table 5) have been central in shaping academic debates on HSR's socioeconomic implications. Here a resume of the most significative.

(1) Qin (2017): Using a *difference-in-differences* design, shows that HSR upgrades in China increased GDP (gross domestic product) in connected counties but harmed bypassed ones, highlighting *distributional asymmetries.*

Table 4. Country production, collaborations, and citations

Country	Articles	Articles %	SCP	MCP	MCP %	TC
CHINA	154	65.0	123	31	20.1	2,722
USA	20	8.4	10	10	50.0	849
JAPAN	15	6.3	12	3	20.0	132
ITALY	7	3.0	5	2	28.6	233
UK	7	3.0	3	4	57.1	166
KOREA	5	2.1	5	0	0.0	53
THAILAND	5	2.1	4	1	20.0	19
GERMANY	4	1.7	3	1	25.0	15
SPAIN	4	1.7	3	1	25.0	100
SINGAPORE	3	1.3	1	2	66.7	333

Note(s): Abbreviations: SCP = Single Country Publication, MCP = Multiple Countries Publication that indicates, for each country, the number of documents in which there is at least one co-author from a different country, hence measures the international collaboration intensity of a country

Source(s): Authors' own work

(2) Chen and Haynes (2017): Employing *panel regressions*, find that HSR fosters *regional convergence*, especially in less developed areas, stressing the role of accessibility.

(3) Dong, Zheng, and Kahn (2020): Demonstrate that HSR enhances *knowledge diffusion* and academic productivity, reinforcing the importance of connectivity for innovation economies.

(4) Zhang, Wan, and Yang (2019): Provide a seminal review identifying the *siphon effect* and core-periphery dynamics, stressing that HSR often benefits large metropolitan hubs disproportionately.

(5) Cascetta, Cartenì, Henke, and Pagliara (2020): An ex-post evaluation of Italy's HSR shows GDP growth and accessibility gains but warns that benefits remain unevenly distributed across regions.

(6) Kim and Sultana (2015) and Liu and Zhang (2018): Both highlight accessibility improvements in Korea and China yet also confirm that spatial disparities persist.

(7) Yang *et al.* (2019a, b, 2021): Introduce environmental and innovation perspectives, showing that HSR reduces emissions and fosters technological growth, but in ways contingent on city size and governance.

Other influential works (e.g. Jiao, Wang, Jin, & Dunford, 2014; Wang & Duan, 2018; Zhou & Zhang, 2021; Pan, Shroff, & Zhang, 2023) extend the debate to urban restructuring, industrial effects, and unintended market consequences.

Collectively, these studies reveal a *dual narrative*:

(1) HSR is a driver of *growth, accessibility, and innovation.*

(2) But it also acts as a *polarizing force*, intensifying inequalities between connected and peripheral regions.

This body of highly cited literature forms the foundation for interpreting the mixed evidence reported in Tables 6–9.

Table 5. The twenty most global cited documents

Title	Authors	Year	Source	TC	TC/Y
"No County Left Behind?" The Distributional Impact Of High-Speed Rail Upgrades In China	Qin Y	2017	Journal Of Economic Geography	310	38.8
Impact Of High-Speed Rail On Regional Economic Disparity In China	Chen Z; Haynes Ke	2017	Journal Of Transport Geography	275	34.4
The Role Of Transportation Speed In Facilitating High Skilled Teamwork Across Cities	Dong X; Zheng S; Kahn Me	2020	Journal Of Urban Economics	209	41.8
Impacts Of High-Speed Rail On Airlines, Airports And Regional Economies: A Survey Of Recent Research	Zhang A; Wan Y; Yang H	2019	Transport Policy	195	32.5
Impacts Of High-Speed Rail Lines On The City Network In China	Jiao J; Wang J; Jin F	2017	Journal Of Transport Geography	169	21.1
Can High-Speed Rail Reduce Environmental Pollution? Evidence From China	Yang X; Lin S; Li Y; He M	2019	Journal Of Cleaner Production	160	26.7
Impacts On Accessibility Of China'S Present And Future Hsr Network	Jiao J; Wang J; Jin F; Dunford M	2014	Journal Of Transport Geography	157	14.3
Economic Growth, Transport Accessibility And Regional Equity Impacts Of High-Speed Railways In Italy: Ten Years Ex Post Evaluation And Future Perspectives	Cascetta E; Carteni A; Henke I; Pagliara; Francesca F	2020	Transportation Research Part A-Policy and Practice	138	27.6
The Impacts Of High-Speed Rail Extensions On Accessibility And Spatial Equity Changes In South Korea From 2004–2018	Kim H; Sultana S	2015	Journal Of Transport Geography	127	12.7
High-Speed Rail Impacts On Travel Times, Accessibility, And Economic Productivity: A Benchmarking Analysis In City-Cluster Regions Of China	Liu L; Zhang M	2018	Journal Of Transport Geography	102	14.6
Does China'S High-Speed Rail Development Lead To Regional Disparities? A Network Perspective	Liu S; Wan Y; Zhang A	2020	Transportation Research Part A-Policy and Practice	97	19.4
Air Transport And Economic Growth: A Review Of The Impact Mechanism And Causal Relationships	Zhang F; Graham Dj	2020	Transport Reviews	93	18.6
Market Power And Its Determinants In The Chinese Airline Industry	Zhang Q; Yang H; Wang Q; Zhang A	2014	Transportation Research Part A-Policy and Practice	92	8.4
Accessibility Impact Of The Present And Future High-Speed Rail Network: A Case Study Of Jiangsu Province, China	Wang L; Liu Y; Sun C; Liu Y	2016	Journal Of Transport Geography	86	9.6
Does High-Speed Railway Promote Regional Innovation Growth Or Innovation Convergence?	Yang X; Zhang H; Lin S; Zhang J; Zeng J	2021	Technology In Society	75	18.8

(*continued*)

Table 5. Continued

Title	Authors	Year	Source	TC	TC/Y
High-Speed Rail Network Development And Winner And Loser Cities In Megaregions: The Case Study Of Yangtze River Delta, China	Wang L; Duan X	2018	Cities	75	10.7
High-Speed Rail And Industrial Developments: Evidence From House Prices And City-Level Gdp In China	Zhou Z; Zhang A	2021	Transportation Research Part A-Policy and Practice	69	17.3
The Dark Side Of Audit Market Competition	Pan Y; Shroff N; Zhang P	2023	Journal Of Accounting \& Economics	64	32.0
Impacts Of High-Speed Railways On Economic Growth And Disparity In China	Jin M; Lin Kc; Shi W; Lee Ptw; Li Kx	2020	Transportation Research Part A-Policy and Practice	58	11.6
Regional Economic Growth And The Role Of High-Speed Rail In China	Yao S; Zhang F; Wang F; Ou J	2019	Applied Economics	57	9.5

Note(s): Abbreviations: TC = Total Citations that measures the number of citations a document has received from the other records contained in the entire database
TC/Y = Total Citation per Year

Source(s): Authors' own work

Table 6. Distribution of level of analysis in HSR studies

Level of analysis	Frequency	Percentage (%)
National/Interregional	127	53.6
Provincial	37	15.6
City	37	15.6
Regional	28	11.8
Not Addressed	8	3.4
Total	237	100.0

Source(s): Authors' own work

4. Keywords analysis

The keyword analysis was conducted to identify the most frequently occurring terms in the literature on high-speed rail (HSR) and its socioeconomic impacts. As shown in the word cloud in Figure 6, the most prominent terms include impact (66), accessibility (58), and high-speed rail (57), indicating a strong research focus on the consequences of HSR expansion. The presence of growth (36), disparity (31), and agglomeration (27) highlights the ongoing debate on whether HSR contributes to regional economic convergence or exacerbates inequalities. Several key themes emerge from the keyword frequency distribution. Integration (32), network (31), and infrastructure (21) reflect discussions on how HSR is incorporated into broader transportation and urban systems, while economic-growth (25) and investment (14) underscore the role of HSR in fostering development. Additionally, mobility (13), transportation (17), and transport (18) confirm that accessibility improvements remain a central concern in HSR research. The analysis also reveals a strong emphasis on equity (14), inequality (16), and regional equity (9), suggesting an increasing interest in the redistributive effects of HSR and the disparities it may generate between connected and non-connected

Table 7. Most used methodological approach or technique

Approach or technique	Occurrences	References
Difference-in-differences	53	An, Wei, Yuan, and Chen (2022), Cao (2024), Chang and Zheng (2022), Chen and Chen (2024), Dong *et al.* (2020), Gao, Song, and Zou (2025), He, Chen, and Feng (2023), Hu, Liu, and Yang (2024), Hu, Ma, Shen, and Zhou (2022), Hu and Xu (2022), Huang, Zhu, and Su (2024, p. 202), Jin, Shi, Liu, Xu, and Li (2022), Li *et al.* (2022a, b, p. 202), Gao *et al.* (2025), Li and Zhang (2024), Zhou *et al.* (2024a, b), Li *et al.* (2022a, b), Lin, Dhakal, and Wu (2021, Yang *et al.* (2023), Liu, Tang, Bu, and Wang (2022), Liu *et al.* (2024a, b, p. 2), (Ma, Tan, and He (2023), Meng, Ding, and Wang (2023), Meng, Lin, and Ren (2022), Miwa, Bhatt, and Kato (2022), Miwa *et al.* (2022), Pan, Gao *et al.* (2023), Qin, Yang, Zhang, and Zhu (2023), Qin (2017), Sun, Zhao, Zhang, and Chen (2023), Sun and Mansury (2016), Tan and Pan (2024), Tang, Zhang, Fan, and Wang (2024), Wang *et al.* (2024a, c), Wang, Miwa, Jiang, and Morikawa (2021), Wang *et al.* (2024a, b, c, d), Wang and Lu (2022), Wang, Zhou, and Hua (2020) , Wang, Tang, Liu, and Bu (2023), Wang, Liang, Kong, and Wang (2019), Wang *et al.* (2022a, b), Xiong, Cang, and Yang (2023), Gao *et al.* (2025, p. 202), Gao *et al.* (2025), Xu and Zheng (2023), Xu and Ou (2022), Xu and Zhu (2024), Yang *et al.* (2019a, b), Yang *et al.* (2021), Yang *et al.* (2020), Yao *et al.* (2019, p. 202), Yoshino and Abidhadjaev (2017), Yuan *et al.* (2024), Yuan and Fan (2023, p. 202), Zhang *et al.* (2022a, b), Zhang and Xu (2023)
Panel data regression	28	Bashir, Ain, Tariq, and Iqbal (2022), Bu, Tang, Tang, and Liu (2022), Chen *et al.* (2021a, b), Chen and Guo (2023), Chen and Haynes (2017), Chen, Li, and Wang (2020), p. 2020), Fan, Kato, Yang, and Li (2022), Gao, Song, and Sun (2024), Guo, Lai, Lu, and Cao (2022), Jia, Wang, Li, and Gao (2024, p. 2024), Lang, Zhang, Wu, and Chen (2025), Li, Yang, Qian, and Xu (2024), Liang and Zong (2024, p. 202), Liu *et al.* (2022a, b), Liu, Tang, Wang, and Bano (2023), Ma and Gao (2024), Qi *et al.* (2024), Rehman, Islam, Miao, and Metwally (2023), Sheng and Montgomery (2024), Tang, Bi, Sun, Xu, and Wang (2023), Wang *et al.* (2024a), Wang, Liu, and Wang (2018), Xu and Ou (2024), Yan and Park (2023), Yang *et al.* (2023), Zhang and Qi (2021), Zhang *et al.* (2023a, b, p. 202), Zou *et al.* (2021)
Spatial analysis and econometrics	20	Fan *et al.* (2022), He, Mei, and Wang (2021), Huang and Xu (2021), Jain and Jehling (2020, Jiao *et al.* (2014, Jiao, Wang, and Jin (2017), Jin, Lin, Shi, Lee, and Li (2020), (2024), Li *et al.* (2024), Liu *et al.* (2024a, b), Lu and Li (2024), Luo, Zhao, Cui, Zhong, and Ma (2023), Ouyang, Zhao, and Gong (2024), Wang (2018), Wang *et al.* (2020), Zeng *et al.* (2018), Yang *et al.* (2020), Zhang *et al.* (2020), Zhang *et al.* (2023a, b), Zhou *et al.* (2024a, b), Zhu *et al.* (2016)
Regression analysis	9	Chen, Hao, and Chen (2021), Fageda and Flores-Fillol (2024), Ge, Zhu, Zhang, and Kong (2023), Liu and Zhang (2018), Petricek, Komarek, Marada, and Randak (2022), Wang, Zhang, and Wang (2024b, p. 202), Xia *et al.* (2024), Yang and Lin (2024), Zhou and Zhang (2021)

(*continued*)

Table 7. Continued

Approach or technique	Occurrences	References
GIS-based accessibility analysis	8	Gong *et al.* (2023), Kim and Sultana (2015), Miao, Dai, and Song (2023), Ortega *et al.* (2014), Qian *et al.* (2023), Theerathitichaipa *et al.* (2024), Wang, Liu, Sun, and Liu (2016), Yu and Fan (2018)
Instrumental variable regression	7	Chen and Chen (2023), Wang *et al.* (2022a, b), Wong, Zhao, and Lee (2022), Yoo *et al.* (2023), Yoo *et al.* (2024), Zhou (2023)
Mixed logit modeling	5	Lin, Susilo, Shao, and Liu (2018), Mahardika, Irawan, and Bastarianto (2022), Pan *et al.* (2023), Yang and Chang (2011), Zhao *et al.* (2023, p. 202)
Stated preference modeling	5	Abouelela, Al Haddad, Islam, and Antoniou (2022), Chen, Yao, Yang, Pan, and Liu (2024), Jou, Chien, and Wu (2013), Karmarkar, Jana, and Velaga (2023), Ngoc and Nishiuchi (2022)
Comparative analysis	4	Kim and Kim (2020), Liu and Zhang (2021), Yoo *et al.* (2024, p. 20220), Zhong *et al.* (2014)
Computable general equilibrium (CGE) modeling	4	Hiramatsu (2018a, 2018b), Kim and Yi (2019), Yang *et al.* (2023)
Sum	143	
Share over total	60.3%	

Source(s): Authors' own work

Table 8. The most used economic variables

Variable	Frequency	Percentage (%)
Accessibility	181	76.4
Wage	65	27.4
Income	39	16.5
GDP	37	15.6
Innovation	24	10.1
Environmental Impact	23	9.7
Investments	18	7.6
Consumption	14	5.9
Not Addressed	3	1.3
At least one Economic Variable*	129	54.4

Note(s): *Economic Variables include Wage, Income, GDP, Consumption, and Investments

Source(s): Authors' own work

Table 9. Effects of HSR on inequality

Inequality outcome	Frequency	Percentage
Economic Inequality Increases	70	29.5
Mixed Economic Impact on Inequality	57	24.1
Economic Inequality Decreases	39	16.5
Other Effects (Not Inequality-Specific)	71	30.0
Total	237	100.0

Source(s): Authors' own work

Figure 6. Cloud of keyword generated by Bibliometrix. Source: Authors' own work

areas. The presence of urbanization (10), specialization (9), and public transport (8) suggests that researchers are exploring how HSR influences urban-rural dynamics and economic specialization. Furthermore, competition (10) and efficiency (19) indicate a focus on the interactions between HSR and other transport modes, particularly in relation to air and conventional rail networks. Overall, this keyword analysis provides a clear indication of the dominant themes in HSR research, emphasizing its impact on economic development, spatial disparities, transport efficiency, and regional connectivity. These insights help delineate the scope of existing studies while guiding future research on the broader implications of high-speed rail expansion.

The network visualization of high-speed rail (HSR) research themes in Figure 7 highlights the structural organization of the field, revealing key clusters and their interconnections. This

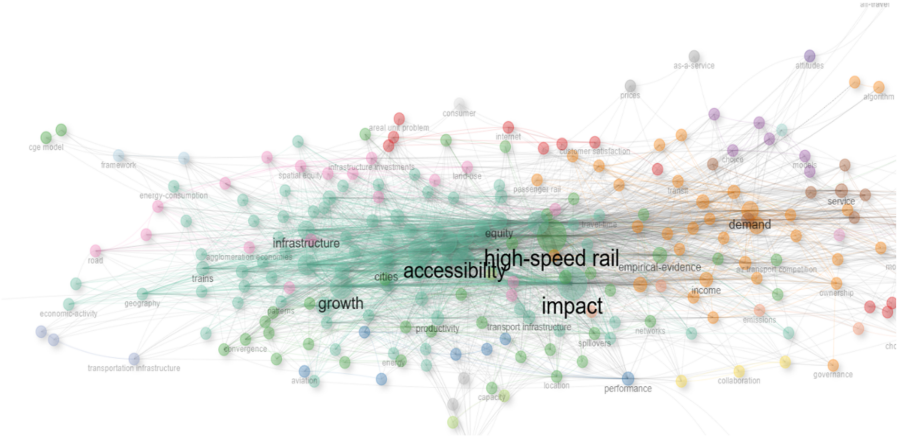

Figure 7. Network topic analysis generated by Bibliometrix. Source: Authors' own work

approach emphasizes the relational nature of research topics, allowing us to examine how different themes interact and evolve within the academic discourse. At the core of the network, themes related to "impact," "accessibility," and "high-speed rail" dominate both in centrality and density. Their prominence suggests that these concepts are fundamental to the field, structuring debates around economic and spatial transformations induced by HSR development. "Impact" serves as a bridge between multiple research strands, linking infrastructural expansion to socioeconomic effects, while "accessibility" captures the broader implications of HSR in terms of spatial equity and regional development.

One of the most striking findings is the centrality of inequality-related themes, particularly "disparity," "equity," and "regional equity." These themes form a dense sub-network, indicating that disparities in economic growth and accessibility are not peripheral concerns but rather core issues in HSR research. This cluster is deeply interconnected with topics such as "urbanization," "economic growth," and "infrastructure investments," reinforcing the idea that the expansion of HSR networks has uneven regional consequences. The close association between "agglomeration" and "inequality" further suggests that while HSR enhances connectivity, it often reinforces existing economic hierarchies, disproportionately benefiting larger metropolitan areas at the expense of peripheral regions. The demand and efficiency cluster forms another key sub-network, linking "demand," "service," and "transport infrastructure." These themes highlight the functional aspects of HSR, focusing on operational performance, passenger behavior, and market responsiveness. "Choice" also emerges in this area, suggesting an ongoing discussion on modal competition, particularly between rail and air transport, and the role of pricing and service quality in shaping traveler preferences. A distinct policy and governance cluster emerges around themes like "reform," "framework," and "allocation." These keywords indicate an active research area concerned with regulatory strategies, investment decisions, and the broader governance of HSR systems. The presence of "state" within this cluster suggests that national policies play a crucial role in shaping HSR expansion, particularly in terms of funding mechanisms and regional development strategies. Finally, a peripheral yet interconnected cluster relates to "emissions" and "environmental impact," reflecting growing concerns about the sustainability of HSR networks. While this theme does not appear as central as economic or accessibility-related topics, its presence signals an emerging debate on HSR's role in carbon reduction and climate change mitigation. The network structure suggests that inequality is structurally embedded in HSR research, with disparities in economic and spatial development emerging as a dominant theme. These concerns are closely linked to discussions on urbanization, growth, and infrastructure investment. Demand and operational efficiency represent a major research focus, emphasizing the need for performance evaluation, passenger behavior analysis, and service optimization. Policy and governance debates are gaining traction, particularly in relation to funding strategies, regional planning, and regulatory frameworks. Environmental concerns remain an emerging but growing area, signaling a potential shift in research priorities toward sustainability. The thematic connections identified suggest that future research should further explore the long-term socioeconomic effects of HSR while integrating sustainability considerations into discussions of accessibility and regional equity. Understanding these interconnections will be critical in shaping balanced and inclusive transportation policies.

To gain deeper insights into the research landscape of high-speed rail (HSR), we employed a natural language processing (NLP) approach that combines automated text analysis with manual validation. This methodology allowed us to systematically extract and classify relevant information from a large corpus of academic papers, leading to the creation of four tables summarizing key aspects of HSR research. We utilized Gemini 1.5 Pro, a state-of-the-art multimodal model developed by Google's Gemini Team, capable of processing extensive contextual information, handling up to 10 million tokens in a single input. This model was applied to analyze the abstracts of research papers, systematically extracting structured insights across four dimensions:

(1) Level of analysis (e.g. national, regional, urban) to understand the geographical focus of studies in Table 6

(2) Methodological approaches, identifying the most frequently used techniques in HSR research in Table 7

(3) Economic variables (e.g. gross domestic product, wage inequality, accessibility) to identify key socio-economic indicators examined in HSR literature in Table 8.

(4) Effects of HSR on inequalities, summarizing whether research finds HSR to be an equalizing or polarizing force in Table 9.

The adoption of Gemini 1.5 Pro ensured a high level of accuracy in text classification tasks, with retrieval precision rates exceeding 99.7% in large-context information extraction. Recent studies have demonstrated the effectiveness of NLP-based text mining techniques in analyzing transportation research, helping identify trends and research gaps (Das, Sun, & Dutta, 2016). The four tables presented below provide a structured overview of emerging trends in HSR research, highlighting both well-explored and understudied areas, such as economic inequality analysis and the predominant focus on interregional rather than local impacts.

Table 6 provides an overview of the territorial level of analysis adopted in high-speed rail (HSR) research. The findings reveal a strong concentration of studies at the interregional or national level (53.6%), indicating that most research focuses on the broader economic and connectivity impacts of HSR networks rather than localized effects. Regional studies (11.8%) account for research that examines the impact of HSR within a single administrative region, but even these remain less prevalent compared to multi-regional or national analyses.

A critical gap emerges when considering the relatively low number of studies at the provincial (15.6%) and city levels (15.6%). While interregional and national studies are essential for understanding large-scale economic and transport dynamics, they often obscure the granular, place-specific consequences of HSR investments. Provincial and city-level analyses are particularly needed to assess localized effects such as real estate dynamics, employment shifts, socio-economic inequalities, and urban restructuring. The scarcity of localized studies suggests that many key aspects of HSR's impact—such as gentrification, urban agglomeration, and social stratification—may be underexplored. Research at the city level could provide critical insights into how HSR stations drive real estate speculation, increase housing prices, and contribute to displacement and gentrification, particularly in high-demand metropolitan areas. Additionally, it could shed light on how agglomeration economies emerge around HSR nodes, favoring high-skilled industries and business hubs while potentially marginalizing lower-income residents due to affordability constraints. At the provincial level, further research is needed to understand how HSR affects intermediate cities and suburban areas, particularly in terms of labor market integration, firm relocation, and regional commuting patterns. Some studies suggest that smaller urban centers connected to HSR networks may experience either economic revitalization or resource siphoning by larger metropolitan hubs, depending on policy and infrastructure planning. Expanding research at this scale would help clarify whether HSR reinforces regional disparities or fosters balanced economic development. Encouraging more city- and province-level research would allow for a more comprehensive evaluation of HSR's local economic benefits, risks, and policy implications, particularly in the context of urbanization, housing policies, and inclusive transport planning.

The construction of Table 7 revealed that the ten most common methodological approaches together account for 60.3% of all studies, highlighting a strong emphasis on ex-post causal inference, econometric modeling, and spatial analysis. The predominance of Difference-in-Differences (DiD) models, which appeared in 53 studies, reflects the widespread reliance on quasi-experimental frameworks for policy evaluation, particularly in assessing HSR's economic and regional impacts. The extensive use of panel data regressions (28 occurrences)

underscores the preference for longitudinal approaches that track changes over time, while spatial econometric models (20 occurrences) illustrate the focus on territorial dynamics and accessibility improvements resulting from HSR investment.

This methodological classification provides valuable insights into the evolving research trends in HSR studies, demonstrating the field's strong orientation toward data-driven policy evaluation, economic impact assessments, and network analysis. The methodological approaches employed in high-speed rail research highlight a strong emphasis on causal inference, spatial dynamics, and behavioral analysis, with the ten most commonly used techniques collectively accounting for 60.3% of all studies. This concentration underscores the dominant role of econometric and spatial modeling techniques in assessing HSR's multifaceted impacts. Among these, Difference-in-Differences (DiD) emerges as the most frequently utilized approach, appearing in 53 studies. The widespread use of DiD reflects the prevalence of ex-post impact assessments, where researchers leverage quasi-experimental designs to evaluate the effects of HSR implementation by comparing treated and control regions over time. This approach is particularly effective in isolating HSR's contributions to regional economic growth, land use transformation, and accessibility improvements, mitigating confounding influences from broader economic trends.

Panel data regression (28 occurrences) complements these causal studies by offering a robust econometric framework that captures both temporal and cross-sectional variations. The recurrence of this method signals the importance of longitudinal assessments in HSR research, allowing scholars to track shifts in economic indicators, population mobility, and transport infrastructure performance over extended periods. Similarly, spatial analysis and econometric models (20 occurrences) emphasize the territorial dimension of HSR's influence, incorporating GIS-based techniques, spatial lag models, and network analyses to evaluate changes in urban connectivity, accessibility, and regional economic integration. The preference for retrospective methodologies is further evident in regression analysis (9 occurrences), where statistical modeling is used to examine the relationship between HSR expansion and various socioeconomic variables. In parallel, GIS-based accessibility analysis (8 occurrences) highlights the increasing reliance on geospatial techniques to quantify accessibility gains, intermodal competition, and urban restructuring driven by HSR investments. Beyond these econometric approaches, instrumental variable regression (7 occurrences) addresses potential endogeneity issues in causal analyses, ensuring more robust estimations of HSR's impact on economic and transportation systems. Mixed logit modelling and stated preference modeling, each appearing in 5 studies, provide insights into traveler behavior and mode choice, supporting policy decisions on pricing, service optimization, and demand forecasting. These models often incorporate survey data and revealed preferences to understand how passengers select HSR over competing transport alternatives. The comparative analysis method (4 occurrences) extends HSR research beyond single-case studies, offering cross-national and interregional comparisons that help identify best practices and divergent policy outcomes. Similarly, computable general equilibrium (CGE) modeling (4 occurrences) enables macroeconomic simulations, assessing HSR's broader economic ramifications, including labor market effects, productivity shifts, and sectoral adjustments. The dominance of econometric and spatial methodologies in HSR research reflects an overarching focus on ex-post evaluations and quantitative assessments of infrastructure investments. These approaches provide policymakers with evidence-based insights into the benefits and trade-offs of HSR expansion, supporting informed decision-making on future transport infrastructure projects.

Table 8 summarizes the most frequently analyzed economic variables in high-speed rail (HSR) research. The overwhelming dominance of accessibility (76.4%) suggests that most studies focus on how HSR reshapes spatial integration and transport connectivity, often treating economic impacts as secondary considerations. Even though the selection of papers was based on their relevance to inequality and socio-economic disparities, economic variables such as wage (27.4%), income (16.5%), and GDP (15.6%) appear less frequently than

expected. This highlights a literature gap in directly linking HSR to economic redistribution, wage structures, and broader development outcomes.

One key finding is that only 54.4% of studies explicitly include at least one economic variable (wage, income, GDP, consumption, or investments). This means that even within research addressing inequality, many studies primarily focus on accessibility-related disparities rather than explicitly quantifying economic transformations. This suggests that while HSR research increasingly acknowledges regional and social inequalities, there remains room for stronger empirical assessments of how HSR influences income distribution, labor markets, and investment patterns.

Another notable aspect is the presence of environmental impact analysis in 9.7% of studies, even though the dataset was not selected based on environmental concerns. This suggests that sustainability considerations are increasingly integrated into discussions of economic and social inequality. While most studies in this category likely investigate HSR's role in emissions reduction, pollution displacement, and sustainable mobility, there is potential for further research connecting environmental justice, land use changes, and socio-economic disparities driven by HSR expansion. Similarly, innovation (10.1%) remains an underexplored topic despite its potential relevance to regional competitiveness, firm productivity, and knowledge spillovers. Expanding research in this direction could provide valuable insights into whether HSR primarily benefits already well-developed, innovation-intensive regions or facilitates technological diffusion to peripheral areas. It is important to note that in Table 8, we have not listed specific references for each category because the number of papers covering each topic is simply too extensive. Including all citations would require listing nearly the entire dataset. Instead, this table provides an aggregate summary, allowing for a broader understanding of research trends and gaps in HSR literature. Overall, the data suggest that while accessibility remains the dominant focus in HSR research, there is still a need for a more systematic incorporation of economic indicators to assess how HSR investments shape long-term economic resilience and inequality dynamics.

Table 9 summarizes the effects of high-speed rail (HSR) on inequality as reported in the selected studies. Given that all papers in the dataset were chosen based on their relevance to inequality, this table represents a simplification aimed at capturing broad trends rather than the full complexity of each study's findings. The results indicate that HSR is more frequently associated with increasing inequality (29.5%) rather than reducing it (16.5%), while 24.1% of studies report mixed effects.

The predominance of studies finding that HSR increases inequality aligns with the siphon effect, where economic activity becomes increasingly concentrated in large, well-connected urban centers at the expense of smaller cities and peripheral regions. Many studies report that HSR enhances accessibility for already competitive metropolitan areas, attracting skilled labor, businesses, and investment, while smaller or rural regions—especially those with weaker local economies—struggle to integrate into the new economic landscape. These findings support concerns that HSR can reinforce existing economic hierarchies, leading to greater disparities in income, employment opportunities, and local economic growth.

At the same time, a considerable proportion of studies (24.1%) report mixed effects, indicating that HSR does not have a uniform impact on inequality but depends on regional economic structures, policy frameworks, and sectoral dynamics. This aligns with the core-periphery theory, which suggests that while large urban centers tend to consolidate economic power, some secondary cities along HSR corridors may experience spillover effects, benefiting from increased market access, tourism, and business expansion. In these cases, HSR fosters regional integration, but the benefits remain unevenly distributed, favoring specific industries or locations rather than entire regions.

A smaller proportion of studies (16.5%) find that HSR reduces inequality, typically where investment strategies, regional policies, and complementary transport networks facilitate economic convergence. These studies often highlight the spillover effect, where improved connectivity stimulates economic activity in smaller cities, reduces spatial mismatches in

employment, and enhances access to opportunities for less-developed regions. In these cases, HSR acts as a tool for regional equalization, if policies actively support the integration of lagging areas into the broader economic system.

Finally, a significant share of studies (30.0%) focus on broader economic and spatial transformations without explicitly addressing inequality, highlighting accessibility improvements, environmental factors, or general economic growth rather than distributional consequences. The presence of this category suggests that while HSR research increasingly considers inequality, many studies still lack a structured approach to assessing its redistributive effects.

It is important to note that in Table 9, we have not listed specific references for each category because the number of studies addressing these effects is too large to cite individually. Instead, this table provides a broad summary that helps to identify dominant trends in the literature. The findings suggest that while HSR is often associated with increased inequality, its effects are highly dependent on local economic conditions, governance frameworks, and complementary investments, reinforcing the need for further research on the mechanisms that drive regional disparities or convergence.

5. Discussion and conclusion

This systematic review has mapped the evolution of research on high-speed rail (HSR) and inequality, highlighting thematic clusters, methodological preferences, and persistent gaps. The bibliometric evidence reveals three core findings.

First, the literature is strongly biased toward *macro-level and accessibility-oriented analyses*. Over half of the studies examine HSR at the interregional or national scale, while only 15.6% focus on cities and provinces (Table 6). Similarly, 76.4% of papers assess accessibility, whereas key economic indicators such as wages (27.4%), income (16.5%), and GDP (15.6%) remain underexplored (Table 8). As a result, microeconomic effects on labor markets, housing, and local redistribution are frequently overlooked.

Second, the field lacks consensus on HSR's distributional effects. Nearly one-third of studies report *increasing inequality*, one-sixth identify *equalizing effects*, and about one-quarter highlight *mixed outcomes* (Table 9). This heterogeneity reflects the interplay of three competing mechanisms:

(1) *The siphon effect*, whereby HSR reinforces core urban hubs at the expense of peripheries.

(2) *Spillover effects*, where secondary cities benefit from increased market access and investment.

(3) *Core-periphery dynamics*, where pre-existing hierarchies are consolidated over time.

What remains missing is a clear theoretical and empirical framework for predicting under which conditions these mechanisms dominate.

Third, the literature exhibits a strong *territorial concentration*. Nearly two-thirds of publications are based on China (Table 4), reflecting its unparalleled HSR expansion but limiting generalizability to other governance and institutional contexts. Comparative evidence from Europe, Japan, and North America is thinner, yet crucial for understanding how different policy frameworks and planning traditions mediate the socioeconomic effects of HSR.

Taken together, these findings expose several *research gaps*.

(1) *Spatial scale*: more studies are needed at the city and provincial levels to capture place-specific consequences such as gentrification, employment restructuring, and housing affordability.

(2) *Indicators*: systematic integration of economic variables—income distribution, wages, investment, consumption—is essential to move beyond accessibility.

(3) *Temporal scope*: most analyses are short-term; long-term, longitudinal assessments are required to determine whether disparities persist or diminish over time.

(4) *Governance and comparison*: the dominance of Chinese cases obscures how HSR operates under different institutional frameworks. Comparative, cross-country research would allow stronger generalization.

(5) *Interdisciplinarity*: bridging transport economics with labor studies, urban planning, and economic geography could offer a more holistic view of HSR's redistributive effects.

Policy implications are clear. Infrastructure alone does not guarantee equitable development. Without complementary measures—regional planning, multimodal integration, targeted support for peripheral areas—HSR risks exacerbating polarization. Conversely, with adequate governance frameworks, it can promote convergence and balanced growth.

In conclusion, the debate on HSR and inequality remains unresolved. The evidence suggests that HSR simultaneously generates economic growth and redistributive challenges. Its long-term impact depends less on the technology itself than on the *policies and institutions* that shape how benefits are shared. Future research must therefore adopt an interdisciplinary, multi-scalar, and comparative perspective to provide policymakers with actionable insights on how to ensure that high-speed rail serves both *efficiency and equity* in regional development.

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