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Determining future high speed rail review topics through bibliometric analysis

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Review article

Determining future high speed rail review topics through bibliometric analysis

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ABSTRACT

As High Speed Rail (HSR) has proliferated globally, so has a related research field dedicated to exploring and addressing its unique issues. Yet, studies to understand and classify the HSR research domain are limited. This paper addresses the gap, using bibliometric analysis to identify future research areas and 20 candidate topics for literature review based on keyword analysis through VOSviewer. Article and review papers related to HSR published in the last 20 years (2003–2022) were retrieved from Scopus, and then analyzed to determine the split in knowledge between languages, the collaboration between countries and institutions, highly productive and cited journals, and research topics which have and have not been reviewed. Approximately 30% of the search results were published exclusively in Chinese, highlighting the importance of extending the evaluation to cover both languages. This is a novel aspect of the work, which has enabled the recognition of potential knowledge gaps. It is recommended that future reviews incorporate works in both languages, possibly through international collaboration. Institutions in China and other countries that are strong collaborators have been identified, as well as relevant, highly cited journals.

1. Introduction

High Speed Rail (HSR) has developed as a unique subset of railway transport, with its own characteristics and requirements. Since the first Shinkansen line opened in Japan in 1964, HSR has proliferated globally, with networks in commercial operation in 20 countries and under construction or planned in a further 24 countries [1]. The rapid expansion of HSR in China has placed the country in a leading position globally, accounting for 40000 km of the world's total 59000 km operational network.

It follows that, alongside the growth of HSR networks across the world, researchers have been delving into the topic and the specific characteristics of high-speed railway operations. Despite some regional divergences over the numerical threshold for "high-speed", there is consensus that HSR necessitates specific technical requirements to achieve those speeds safely with respect to rolling stock, track, infrastructure, power, and signaling and control systems [2].

The growing interest in HSR, within and beyond academia, is perhaps a response to growing concerns over transport emissions and the sector's contribution to climate change. Railways generally emit less CO_2 than other transport modes [3] and can compete with e.g., air travel on long-distance routes where they are economically justifiable [4].

To better understand the research landscape, the authors propose bibliometric analysis. This is an approach that enables large volumes of data to be evaluated to present the state of the intellectual structure of a research domain and understand trends such as publication performance and collaboration patterns [5]. Examples of bibliometric analysis of HSR literature are scarce and primarily target specific sub-topics such as socioeconomic impacts [6], use of artificial intelligence [7], and Chinese HSR policy [8]. To the authors' knowledge, it has only been applied to develop a broader understanding of the whole field by Chen and Liu [9]. In this case, the researchers used the Web of Science to retrieve 4127 articles related to high speed rail research and evaluated author, institution and country co-authorship; journal, document and author co-citations; and keywords (to determine research hot topics and frontiers) using CiteSpace. The results included > 99% English language articles ranging from 1900 to 2019. The research presented in this paper builds upon the work conducted in Ref. [9], using Scopus search to retrieve 9769 articles and reviews published in the last 20 years in both English and Chinese. This is a much larger dataset, focussed on more recent research with a reduced bias towards English language publications, and includes reviews. VOSviewer is used rather than CiteSpace to support a clearer visualization of keyword co-occurrence.

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Given the large volume of available literature, there is an opportunity for researchers to contribute to HSR development by consolidating existing knowledge into high-quality, digestible summaries, as well as producing novel research on topics of interest. Whether a gap exists between the topics covered by English and Chinese language publications is not known. As such, this work specifically targets an understanding of the split in knowledge between languages, the collaboration between countries and institutions, and research topics that have and have not been reviewed. This is to support researchers in identifying partners for international collaboration, journals to target for publication and future review topics and research areas. The contributions of this work are:

1) development of a comprehensive dataset of recent HSR research articles and reviews for analysis (Section 2)
2) evaluation of high-speed rail publication languages (Section 3.1)
3) assessment of the extent of international collaboration on HSR research (Section 3.2)
4) indication of international partnerships and highly collaborative institutions (Section 3.2)
5) summary of key journals publishing HSR research, as well as highly cited journals reflecting popular research areas, in both English and Chinese language (Section 3.3)
6) outline of the differences in knowledge availability between English and Chinese language publications (Section 3.4)
7) identification of research topics that should be consolidated through review (Section 3.4)

Section 2 introduces the research methodology and the four research questions which form the basis of the work. Section 3 presents the results and discussion arising from each research question. Section 4 summarises the main findings and recommendations.

2. Methodology

The search for HSR literature was conducted using the Scopus database. Scopus was chosen because it is one of the largest indexing databases of peer-reviewed research, drawing from over 25,000 active journals from over 5000 international publishers [10]. The document search allows bibliographical and citation information to be exported, supporting bibliometric analysis of the resultant datasets. Of particular interest to this study are the publication language, author affiliations and keywords.

Fig. 1 presents an overview of the analysis process, including the screening criteria, how the dataset is split (based on document type and language) and the questions targeted for analysis. It follows a similar approach to identification and screening to that taken by Ciani et al. [11] for their evaluation of human reliability in railway engineering.

An initial search of keywords based on the terms high speed rail, high speed line and high speed train resulted in 18,536 documents published between 1941 and 2023. To evaluate recent trends, the search was limited to the last 20 full years, i.e., excluding results from 2023—as is typical in other reviews [11,12]. To target only peer-reviewed research, the source type was limited to journal, and only "article" and "review" documents with an identifiable author at the final publication stage were selected. The distinction between article and review is important to determine what coverage the reviews have of the available literature and thus identify remaining areas for synthesis.

In contrast to previous works, the publication language has not been restricted to English. A preliminary analysis, detailed in Section 3.1, found that the contemporary publication volumes in the Chinese language are such that they cannot be excluded without losing a third of the dataset. The use of the term Chinese for the language is to reflect that used in Scopus. Therefore, the comparison between English and Chinese publications has been embraced as a key, novel aspect of this study. The final dataset includes 9576 articles and 193 reviews.

The full Scopus query string is given below, where *X* was set to either "ar" for article or "re" for review and *Y* set to either "English" or "Chinese" with all other languages excluded (four searches in total).

KEY ("high speed rail*" OR ("high speed line" AND "rail*") OR ("high speed train" AND "rail*") OR ("HSR" AND "rail*") OR ("HSL" AND "rail*") OR ("HST" AND "rail*") OR "shinkansen") AND PUBYEAR > 2002 AND PUBYEAR < 2023 AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (EXCLUDE (PREFNAMEAUID, "Undefined")) AND (LIMIT-TO (DOCTYPE, **X**)) AND (LIMIT-TO (LANGUAGE, **Y**))

The results of the Scopus queries were exported as CSV files, which were then imported into MATLAB and VOSviewer for analysis and visualization. A series of bespoke MATLAB programs were developed to collate and present information of interest in each analysis. VOSviewer is a software tool for creating, visualising and exploring maps of bibliometric network data [13]. It was used to support the investigation of collaborative relationships between countries and the primary tool for keyword analysis.

3. Results and discussion

3.1. What languages is HSR literature published in?

3.1.1. Prevalent languages

An overview of the publication language of the articles and reviews is given in Figs. 2 and 3, respectively. The bar charts summarise the proportion of literature available in different languages (listed in the legend), and the line graphs show the publication trend since 2003.

English is the most dominant publication language, with Chinese a strong second. Over a third of all articles and 27% of all reviews are published exclusively in Chinese. Publication in other languages is minimal in comparison. The next most dominant language for articles is Korean, accounting for just 0.86%, followed by 0.67% in Japanese and 0.48% in Spanish. It is surprising that Japan, which developed the first high-speed railway in 1964, has such a small proportion of literature available in its native language. Whether this is due to a preference for English language publication by Japanese institutions or because Japanese language sources are not indexed in Scopus is worth investigating. A small number of reviews are available in French, Spanish, Japanese and German.

There has been exponential growth in articles, from less than 100 a year in 2007 to 1249 in 2022. HSR reviews are also generally increasing, with a peak of 31 reached in 2021. The growth in Chinese language publications coincides with the opening of China's first high speed line in 2008 [1]; before this point, both articles and reviews in Chinese were scarce. At a peak in 2013, over half of all the HSR articles published that year were exclusively available in Chinese, but this proportion has since dropped.

3.1.2. Publication language conclusions

There is a clear trend that indicates growth in the number of articles and reviews published on HSR topics in both English and Chinese. Not including Chinese language publications in the evaluation of HSR literature would dismiss approximately a third of all work generated in the last 20 years. Given the difference in scale between article and review numbers it is unlikely that the reviews cover the whole of the published material in either language. To ensure knowledge is not inaccessible to HSR researchers, the gap between topics covered by English and Chinese language should be evaluated in future reviews and appropriate measures should be put in place to support knowledge transfer (whether this be the translation of existing literature or research partnerships on specific topics).
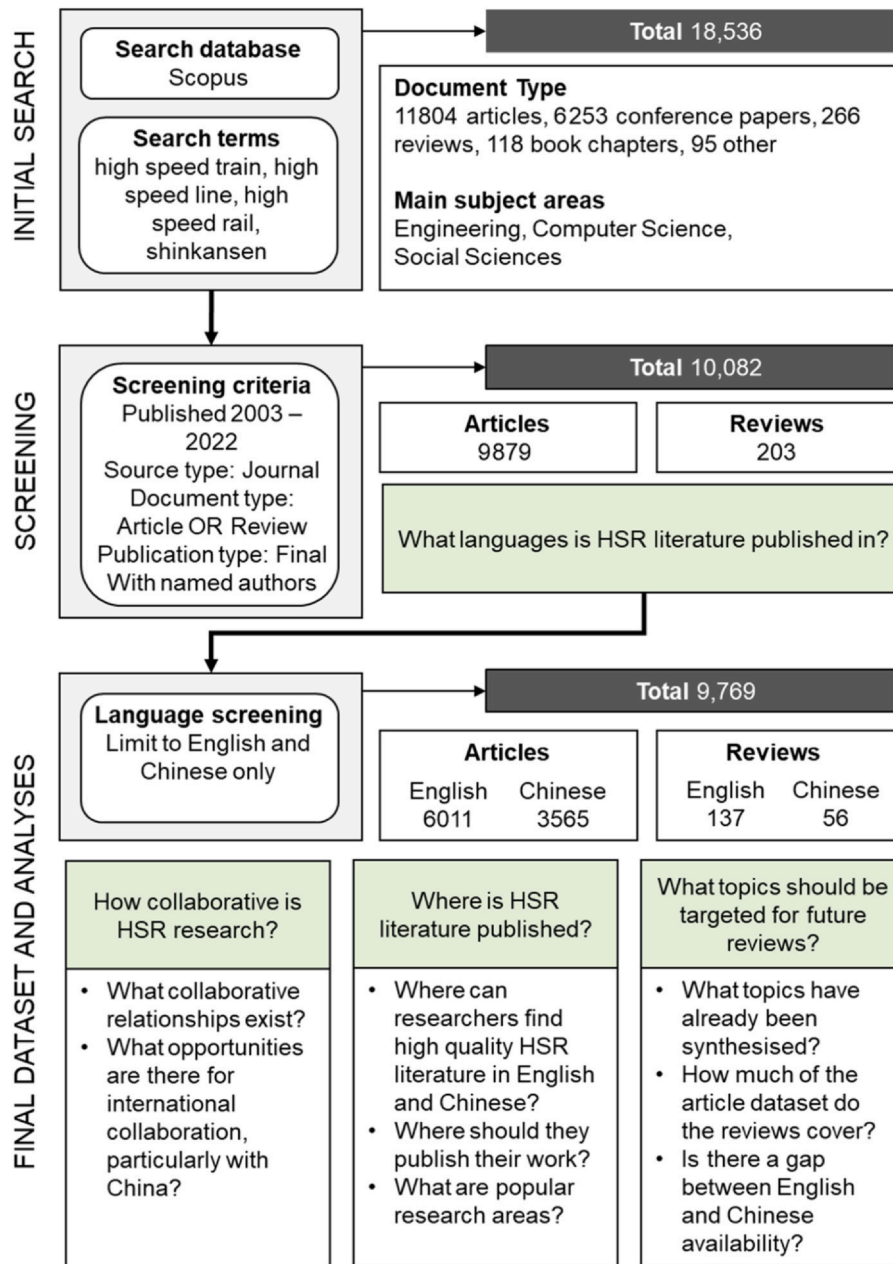
Figure

INITIAL SEARCH		
Search database Scopus		**Total 18,536**
Search terms high speed train, high speed line, high speed rail, shinkansen		**Document Type** 11804 articles, 6253 conference papers, 266 reviews, 118 book chapters, 95 other **Main subject areas** Engineering, Computer Science, Social Sciences

SCREENING		
Screening criteria Published 2003 – 2022 Source type: Journal Document type: Article OR Review Publication type: Final With named authors		**Total 10,082** **Articles** 9879 — **Reviews** 203 What languages is HSR literature published in?

FINAL DATASET AND ANALYSES		
Language screening Limit to English and Chinese only		**Total 9,769** **Articles** English 6011 Chinese 3565 — **Reviews** English 137 Chinese 56

How collaborative is HSR research?
- What collaborative relationships exist?
- What opportunities are there for international collaboration, particularly with China?

Where is HSR literature published?
- Where can researchers find high quality HSR literature in English and Chinese?
- Where should they publish their work?
- What are popular research areas?

What topics should be targeted for future reviews?
- What topics have already been synthesised?
- How much of the article dataset do the reviews cover?
- Is there a gap between English and Chinese availability?

Fig. 1. Literature review process including questions targeted by the analyses.

3.2. How collaborative is HSR research?

3.2.1. National and international collaboration

By analysing the affiliations of authors, it is possible to gauge how collaborative HSR research is. Publications have been grouped as follows:

1) None-collaborative: produced by a single institution
2) Nationally collaborative: produced by multiple institutions within a single country
3) Internationally collaborative: produced by one or more institutions in two or more countries

Figs. 4 and 5 present an overview of how collaborative the articles and reviews in English and Chinese are. The bar charts summarise the proportion of the literature that has been produced exclusively by China (inclusive of Taiwan province, Hong Kong Special Administrative Region (SAR) and Macao SAR), based on the listed author affiliations.

Approximately 15% of the articles and reviews have been produced through international collaboration, with 75% of these featuring China as one of the collaborating countries.

As expected, the majority of the Chinese language articles and reviews are produced exclusively by institutions in China. Seventy-one articles were collaborations between at least one Chinese institution and institutions in other countries. The biggest collaborators are the US (25 papers), followed by the UK (7), France (6) and Japan (6). Three articles were produced in Chinese language by institutions in South Korea and Japan. Reviews are produced exclusively by Chinese institutions, except for 3 papers developed by Chinese and UK institutions.

Over half of the English language articles are produced exclusively by institutions in China, with a further 17.4% produced in collaboration with at least one institution in China. Of the English language reviews, over a third are also produced exclusively by Chinese institutions, with 21 produced in collaboration with at least one institution in China. This means that China is the biggest contributor to HSR literature regardless of document type and publication language by a significant margin—it
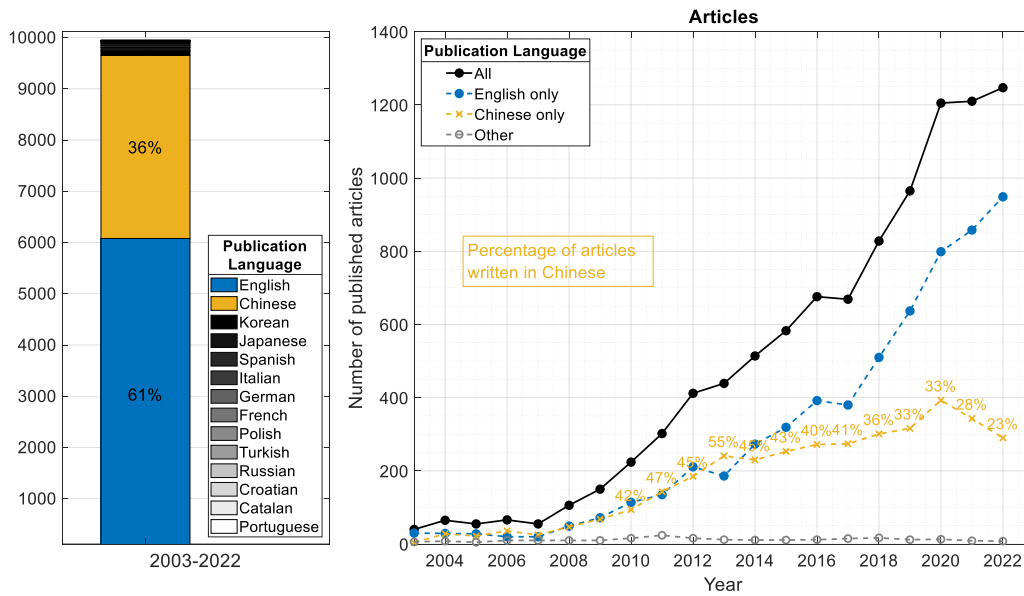
Fig. 2. Publication language of HSR articles.

accounts for 83% of all search results. The next most dominant countries for English language article publication are Japan, Spain, the UK, the USA, Italy, and South Korea. In terms of reviews, Japan, the UK, the USA and Spain also contribute most to English language publications, alongside India.

In recent years, there has been a marked increase in English articles from national and international collaborations in China, and a slow but sustained growth in national and international collaboration in other countries until 2020 (Fig. 6). The most significant growth in English language publications in the last 5 years has been in articles developed through national collaboration in China. It appears Chinese institutions are starting to shift away from publication exclusively in Chinese towards publication in English, a trend that may become clearer over time.

Table 1 lists the top 10 institutions contributing to the English language articles produced through international collaboration—these institutions may be particularly well-placed to develop further collaborations. The top three institutions produce the greatest volume of publications, regardless of whether the data is split by publication

language or type of collaboration, by a considerable amount.

3.2.2. Collaborating countries

As of 2022, 44 countries have HSR lines that are either in operation, under construction, or planned [1]. However, papers in the HSR dataset have been produced by 50 countries independently (by single or multiple institutions within the country), and through international collaboration with a further 21 countries. HSR research is therefore clearly of interest not only to the countries that operate it, but also globally.

The dataset contains articles produced both independently (noneor nationally collaborative) and through international collaboration by 37 of the 44 countries [1] (see Appendix A). The 7 remaining countries all have lines planned but none in operation, which may explain why work is yet unpublished. No articles are affiliated with Bahrain, Hungary or Lithuania. Only internationally collaborative articles feature Chile, Estonia and South Africa, whereas Latvia contributes independent but not collaborative articles. As Rail Baltica develops, further research and collaboration by Latvia, Lithuania and Estonia might
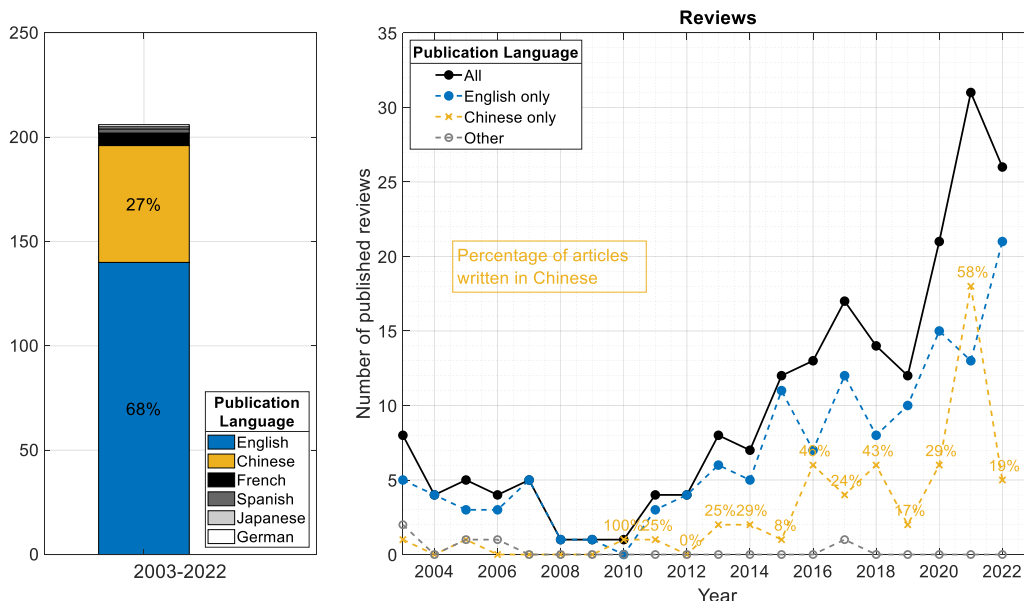

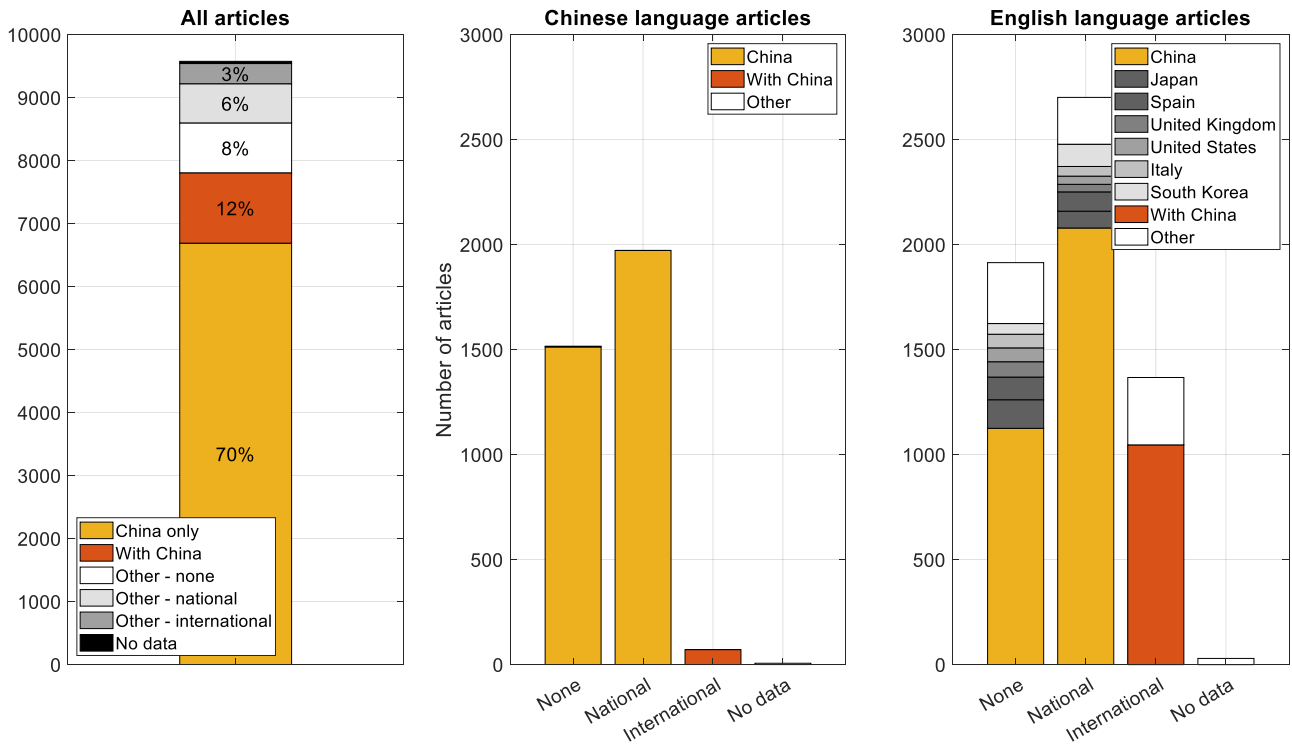**Fig. 3.** Publication language of HSR reviews.

Fig. 4. Collaboration in HSR articles.

be expected. A Scopus search of Rail Baltica yields 59 results from the three countries, but they do not include any keywords to associate them with HSR, so they were not found in the dataset search. It is possible that other relevant HSR projects have not been included because of the keyword selection of the authors.

3.2.3. Collaboration conclusions

The analysis of affiliations indicates that most HSR research is produced by a single institution or through collaborations within country borders, predominantly in China. There appears to be a trend towards English language publication – in particular, Chinese researchers collaborating abroad almost exclusively publish their work in
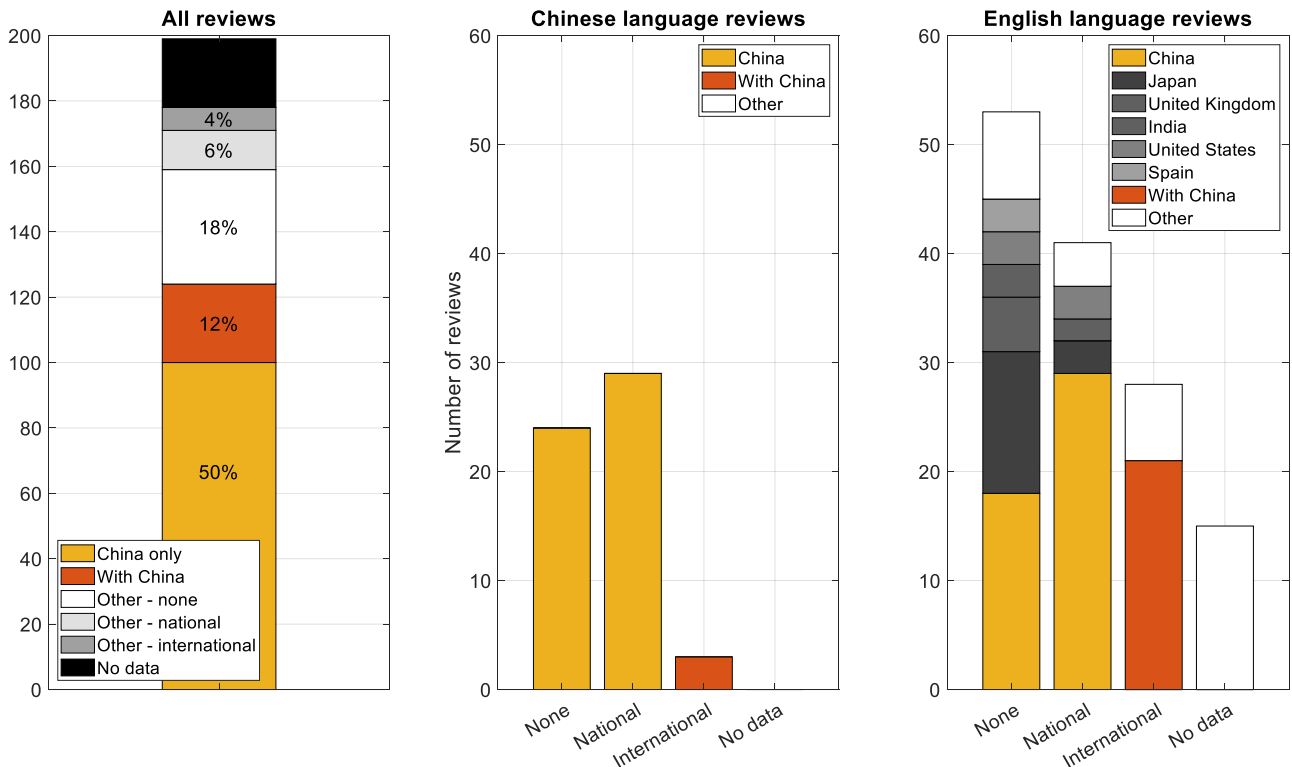

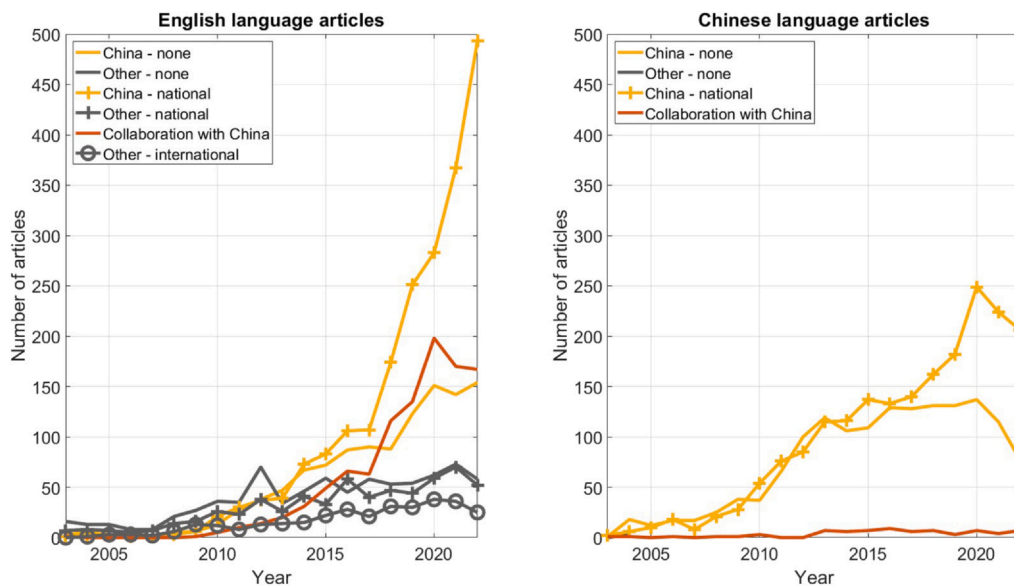**Fig. 5.** Collaboration in HSR reviews.

Fig. 6. Collaboration trend in HSR articles and reviews.

Table 1
Top institutions contributing to internationally collaborative English language articles in the HSR dataset.

	Institution	Country	Occurrences
1	Southwest Jiaotong University	China	311
2	Beijing Jiaotong University	China	272
3	Central South University	China	208
4	Hong Kong Polytechnic University	China	71
5	Southeast University	China	58
6	Tongji University	China	55
7	University of British Colombia	Canada	42
8	Chinese Academy of Sciences	China	40
9	University of Birmingham	UK	37
10	Chalmers University of Technology	Sweden	36

English, which is of benefit to the wider HSR community. More countries that are currently operating or planning HSR contribute to the field, with strong internationally collaborative institutions in China, the UK, Canada and Sweden (see Table 1). Researchers looking to develop international HSR research collaborations may benefit from targeting countries with strongly established links that are actively pursuing HSR research, as indicated by Fig. 6.

3.3. Where is HSR literature published?

3.3.1. Most prolific journals

Table 2 summarises the Number of Documents (TD) and Number of Unique Journal Publications (TJ) for each group in the dataset, with further information provided on the top 5 most prolific journals, in terms of their citations, H-index and CiteScore. This approach is similar to the journal analysis presented in Ref. [9]. TD/TJ indicates that reviews are distributed across fewer journals than articles and that Chinese language documents are concentrated in fewer sources than English language documents. This is confirmed by comparing the Percentage of the Group Covered (PC) and the Cumulative Percentage of the Group Covered (PCC) by the most prolific sources.

English language articles are spread across 1162 disparate sources. Of the most prolific sources, only the first is railway specific, one is a multidisciplinary open access journal, and the others indicate topics of interest in the HSR domain: sustainability, aerodynamics and vehicular technology, specifically communications, transportation control systems and vehicular electronics. IEEE Access and Sustainability Switzerland have been established in the last 10 years

indicating a recent trend towards open access publication and sustainability-focused research. All the journals have a respectable H-index and CiteScore, implying they are well recognized in the HSR domain.

Chinese language articles are published in a much smaller number of journals, only 189, with almost half available in just five sources. Three of the most prolific sources are railway specific, whilst the others focus on mechanical engineering and transportation, respectively. From this it is difficult to elucidate specific topics of interest. The H-indexes and CiteScores are much lower than those of the English language articles. This may be because the pool of researchers citing the literature is smaller (Chinese speakers only).

English language reviews are again spread across a range of sources, with few concentrated in any single journal. The articles in *Transportation Safety and Environment* and *Proceedings of the IMechE, Part F: Journal of Rail and Rapid Transit* are relatively well cited compared with the other sources.

Chinese language reviews are published in a smaller number of journals, with over half available in just five sources, three of which are also the most prolific sources of Chinese language articles. The top two are transport specific, with the subsequent two railway specific; *Acta Automatica Sinica* was discontinued in 2017.

3.3.2. Highly cited journals

The H-index and CiteScore results in Table 2 imply that the most prolific journals are not necessarily the most cited, particularly for reviews. Table 3 summarises higher H-index journals on specific topics for each group to determine popular research areas in HSR. It appears that there is interest in studies related to structures, construction, materials and geotechnics, published in both English and Chinese, which have likely been synthesized to some extent through English reviews. Articles related to transportation policy, dynamics, control systems and wear may be more readily available in English than in Chinese. These results help support the keyword analysis in Section 3.4.

3.3.3. Publishing journals conclusions

Research on HSR, particularly in the English language, is spread across a significant number of journals. Many of the most prolific sources are generic railway, transportation or engineering sources, making it difficult to determine popular topics from journal information alone. Chinese language literature is more concentrated in fewer journals, and researchers could be confident of finding a high coverage of HSR literature through the sources mentioned.

Table 2
Evaluation of most prolific journals publishing HSR literature.

Group	TD, TJ, TD/TJ	Most prolific journals	D	PC	PCC	TC	TC/D	H-index	First article	Last article	CiteScore 2022
English Articles	6011, 1162, 5.2	Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit	175	2.9	2.9	2523	14.4	27	2003	2022	4.5
		Journal of Wind Engineering and Industrial Aerodynamics	151	2.5	5.4	4716	31.2	39	2004	2022	8.1
		Sustainability Switzerland	113	1.9	7.3	876	7.8	16	2015	2022	5.8
		IEEE Access	106	1.8	9.1	1390	13.1	18	2016	2022	9.0
		IEEE Transactions on Vehicular Technology	101	1.7	10.7	2266	22.4	27	2004	2022	13.6
Chinese Articles	3565, 189, 18.8	Tiedao Xuebao/Journal of the China Railway Society	638	17.9	17.9	4175	6.5	26	2004	2022	1.6
		Journal of Railway Engineering Society	421	11.8	29.7	843	2.0	9	2013	2022	0.8
		Zhongguo Tiedao Kexue/China Railway Science	388	10.9	40.6	2513	6.5	21	2004	2022	1.6
		Jixie Gongcheng Xuebao/Journal of Mechanical Engineering	147	4.1	44.7	1219	8.3	19	2010	2022	2.2
		Xinan Jiantong Daxue Xuebao/Journal of Southwest Jiaotong University	145	4.1	48.7	898	6.2	15	2005	2022	1.3
English Reviews	137, 86, 1.6	Japanese Railway Engineering	11	8.0	8.0	6	0.5	1	2006	2016	0.1
		Transportation Safety and Environment	6	4.4	12.4	220	36.7	5	2019	2021	4.5
		Railway Gazette International	6	4.4	16.8	3	0.5	1	2003	2004	-
		Taiwan Review	5	3.6	20.4	0	0	0	2004	2007	-
		Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit	4	2.9	23.4	45	11.3	3	2016	2022	See above
Chinese Reviews	56, 25, 2.2	Jiaotong Yunshu Gongcheng Xuebao/Journal of Traffic and Transportation Engineering	16	28.6	28.6	146	9.1	7	2014	2022	2.3
		Xinan Jiaotong Daxue Xuebao/Journal of Southwest Jiaotong University	5	8.9	37.5	137	27.4	5	2016	2018	See above
		Tiedao Xuebao/Journal of the China Railway Society	4	7.1	44.6	19	4.8	3	2013	2021	See above
		Journal of Railway Engineering Society	3	5.4	50.0	16	5.3	3	2016	2018	See above
		Acta Automatica Sinica	3	5.4	55.4	58	19.3	3	2018	2019	4.1

[For each group] TD: Number of documents; TJ: Number of unique journals.
[For each specified journal] D: Number of documents; PC: Percentage of group covered; PCC: PC cumulative; TC: total citations; H-index: Number of documents (h) in D that has been cited at least h times; CiteScore 2022: from Scopus, calculated 5 May 2022.

Table 3
Highly-cited journals and potential topics of interest to the HSR research community.

Group	Most prolific lowest H-index, L	Number of additional journals with H-index ≥ L	Specific journals (H-index)	Potentially popular topics
English Articles	16	20	Wear (28), Engineering Failure Analysis (20), Tunnelling and Underground Space Technology (21), Engineering Structures (32), Construction and Building Materials (28), Soil Dynamics and Earthquake Engineering (28)	condition monitoring, maintenance; track design, structures, tunnels, embankments, bridges, construction, materials, earthquake proofing
			IEEE Transactions on Instrumentation and Measurement (19), Mechanical Systems and Signal Processing (19), IEEE Transactions on Intelligent Transportation Systems (30), Transportation Research Part C: Emerging Technologies (21)	control systems, signaling, data processing, big data, machine learning, artificial intelligence
			Journal of Sound and Vibration (34), Vehicle System Dynamics (27), Transportation Research Part A: Policy and Practice (38), Transport Policy (29), Journal of Transport Geography (40), Transportation Research Part D: Transport and Environment (24)	dynamics, aerodynamics, noise; policy, modal shift, modal interaction, economics, environmental impacts
Chinese Articles	9	11	Yantu Lixue/Rock and Soil Mechanics (15), Yanshilixue Yu Gongcheng Xuebao/Chinese Journal of Rock Mechanics and Engineering (12), Yantu Gongcheng Xuebao/Chinese Journal of Geotechnical Engineering (12), Zhendong Yu Chongji/Journal of Vibration and Shock (13)	track design, structures, embankments, bridges, earthquake proofing
			Gaodianya Jishu/High Voltage Engineering (10), Diangong Jishu Xuebao/Transactions of China Electrotechnical Society (9)	traction systems, catenary
English Reviews	0	12 (L set to 2)	Transportation Safety and Environment (5), Journal of Vibration and Control (2), Engineering Structures (3), Construction and Building Materials (4), Transportation Geotechnics (2)	dynamics, accidents, noise, control systems; track design, structures, tunnels, embankments, bridges, construction, materials, earthquake proofing
Chinese Reviews	3	0	N/A	

This review considers articles published before 2023. It is worth noting that in 2023, Beijing Jiaotong University began publishing a journal dedicated to HSR. High-speed Railway is an international, interdisciplinary, peer-reviewed, open-access journal published in English that aims to provide a platform for those working in the HSR realm to publish novel and original findings [14]. As such, it addresses some of the issues identified in this review: first, by reducing the number of disparate sources for HSR research and second, by providing an English language platform to "enhance the influence of China's high speed railway industry and the development of relevant technologies globally" [14].

3.4. What topics should be targeted for future work?

3.4.1. Dataset review coverage and topics

Despite the large number of publications, only a small percentage of the literature is referenced in reviews. Fig. 7 summarises how many English and Chinese language articles from the HSR database are referenced by the reviews: 12% of the English articles and 6% of the Chinese articles. The bar chart provides a further breakdown of how many articles are referenced by English reviews, Chinese reviews or reviews in both languages. For example, 63 English language articles are cited by one or more reviews in both languages, an additional 525 by reviews written in English and a further 128 by reviews written in Chinese.

The fact that reviews in English are referencing Chinese articles and Chinese reviews are referencing English articles indicates that there is bilingualism in authorship teams. Whether this relates to specific individuals or a collaboration of authors of different nationalities, the result is that some knowledge is being passed over language barriers. However, most articles in both languages have not yet been synthesized into review papers. There is an opportunity, therefore, to categorize the remaining literature into topics that can form the basis of future reviews, with the intention of furthering understanding of existing gaps and thereby directing future research.

To determine which topics are covered by the reviews, network visualizations based on the co-occurrence of keywords (author and index keywords) were created using VOSviewer. The maps were created using bibliographic data from the Scopus search for Chinese language reviews (Fig. 8) and English language reviews (Fig. 9) using the full counting method and default analysis parameters. A thesaurus was written and used to omit keywords directly related to the search terms (such as high speed, railway, track) and consolidate multiple versions of the same keyword (e.g., Finite Element Method (FEM)). By limiting to keywords that occur at least twice, visualizations were reduced to 93 and 151 keywords, respectively, making themes easier to identify. The circle and label size of each keyword is determined by the number of documents in which it appears, the lines represent co-occurrences of keywords, and the distance between two keywords approximately indicates their relatedness. Keywords are colored based on their assigned cluster, which is determined by the Variational Object-Oriented Simulation (VOS) clustering technique (for further detail, see Ref. [13]).

Reviews in the Chinese language tend to focus on technical topics related to vehicles, infrastructure and their dynamic interactions. This includes aerodynamics and noise (bottom right); wheel-rail adhesion, brakes and fault detection (top right); vehicle performance, dynamics and vibrations (top left); bridge and seismic design (bottom left); damage detection, crashworthiness and safety (bottom left) and power systems (bottom middle), as shown in Fig. 8. Reviews in the English language cover some of these technical topics, including aerodynamics and tunnels, bridge design and power systems, but several additional topics are also evident. These include a cluster focused on materials inclusive of alloys, corrosion and tensile strength (right), a cluster on wireless communication systems (top right), a cluster on economic and environmental impacts (bottom left), and a cluster on wider transportation modes (middle left), as shown in Fig. 9.
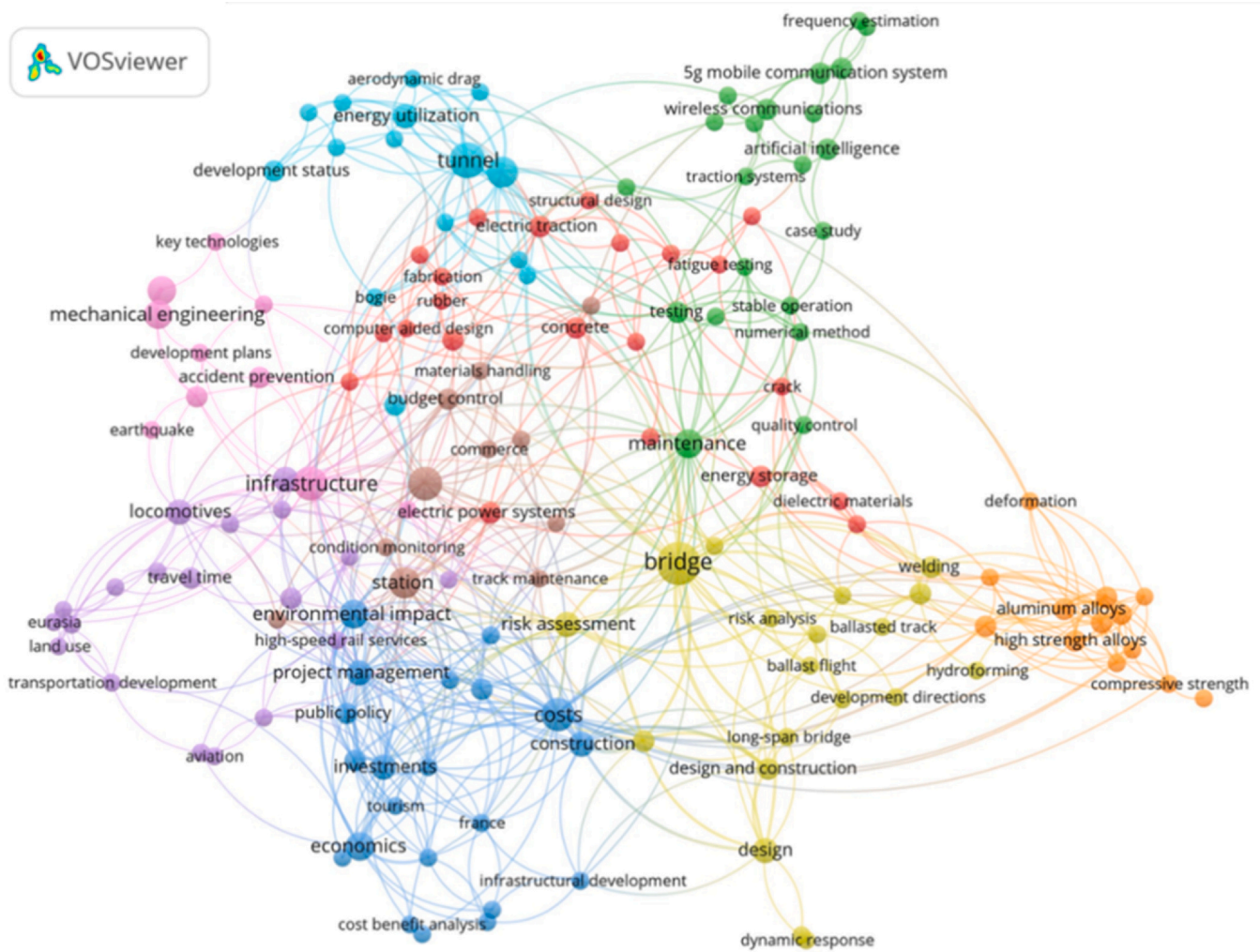
Fig. 7. Coverage of the articles by the reviews within the HSR dataset.

Fig. 8. Chinese language review keyword co-occurrence (93 keywords).

Fig. 9. English language review keyword co-occurrence (151 keywords).

Table 4

Cluster keywords and review topics, based on keyword co-occurrence analysis of English language articles not included in the dataset reviews.

Cluster	Cluster keywords	Potential review topics
1	Accessibility, aviation, Beijing, China, Shanghai, Spain, costs, economic and social effects, economics, environmental impact, infrastructure, public transport, sustainable development, decision making, regression analysis, transport policy, transportation development, transportation planning, travel time, urban transport	Focus on HSR in China: • Economic and environmental impact • Transport policy, planning and development
2	Construction, design, dynamic analysis, dynamic loads, embankment, experimental study, finite element method, foundation, loading, numerical model, pile, soil-structure interaction, soils, structural design, subgrade	• HSR track-bed structural design and dynamic response
3	5 G mobile communications, communications, wireless telecommunications, millimeter waves, efficiency, energy efficiency, energy utilization, genetic algorithm, integer programming, integer methods, optimization, scheduling, station, stochastic systems	• Communications for HSR • HSR energy efficiency • HSR optimization approaches
4	Automobile bodies, damping, dynamic response, dynamics, frequency domain analysis, geometry, locomotives, resonance, stiffness, suspension, time domain analysis, track irregularity, vibration, vibration analysis	• Vehicle dynamic response • Impact of vibrations
5	Acoustic noise, aerodynamic drag, aerodynamic performance, aerodynamics, computational fluid dynamics, crosswind, numerical method, numerical models, numerical simulation, simulation, tunnel, vehicle performance, wind tunnel	• Aerodynamic and vehicle performance • Aerodynamic simulation methods
6	Axles, brakes, cracks, fatigue of materials, friction, microstructure, temperature, wear of materials, wheels	• Wear of wheels, brakes, axles and/or materials
7	Electric current collection, electric power systems, electric traction, maintenance, overhead lines, pantograph, quality control, sensitivity analysis	• Electric power system design and maintenance
8	Algorithm, bogie, deep learning, failure analysis, fault detection, forecasting, human	• Condition monitoring, fault detection and prediction
9	Ballasted track, ballastless track, concrete, deformation, monitoring	• HSR track choice
10	Bridge, earthquake, uncertainty analysis	• Seismic design for HSR track and/or bridges

Table 5

Cluster keywords and review topics, based on keyword co-occurrence analysis of Chinese language articles not included in the dataset reviews.

Cluster	Cluster keywords	Potential review topics
1	Axles, bogie, crack, fatigue of materials, forecasting, friction, stability, temperature, wear of materials, wheels	See English language articles Cluster 6
2	Deformation, dynamic loads, embankment, field test, foundation, pile, reinforcement, soils, subgrade, testing	See English language articles Cluster 2
3	Beams and girders, box girder bridges, bridge, cable-stayed bridges, cables, earthquake, piers	• Considerations for HSR girder/cable bridges
4	Aerodynamics, computational fluid dynamics, numerical method, numerical models, numerical simulation, simulation, tunnel	See English language articles Cluster 5
5	Acoustic noise, electric current collection, electric power systems, frequency domain analysis, overhead lines, pantograph, quality control	See English language articles Cluster 7
6	Arch bridges, arches, ballastless track, concrete, research purpose, research results, structural design	• Considerations for HSR arch bridges
7	Damping, dynamic characteristics, dynamic response, dynamics, stiffness, vibration, vibration analysis	See English language articles Cluster 4
8	Design, locomotives, mathematical models, operations, optimization, station	• HSR optimization approaches
9	Finite element method	• Applications of FEM in the HSR research domain

3.4.2. Topics for synthesis – keyword analysis

To determine further potential topics for synthesis, additional network visualizations of keyword co-occurrence were created using only the HSR dataset literature,that is not covered by existing reviews (i.e., the 5295 English language articles and 3342 Chinese language articles indicated in Fig. 8). The same thesaurus was applied. Visualizations were limited to keywords that occurred at least 55 times to make sure there was sufficient literature for review and to make the analysis manageable. Applying clustering with a resolution of 1.5 generated 10 clusters from the English language articles and 9 clusters from the Chinese language articles. Tables 4 and 5 list the keywords within each cluster alongside potential review topics – it should be noted that keywords within clusters connect to keywords in other clusters, and for understanding the relationships Figs. 10 and 11 are helpful.

3.4.2.1. English language articles. From the 10 clusters, 15 potential review topics have been identified. Some clusters contain visually separate groups of keywords (distance corresponds to relatedness),
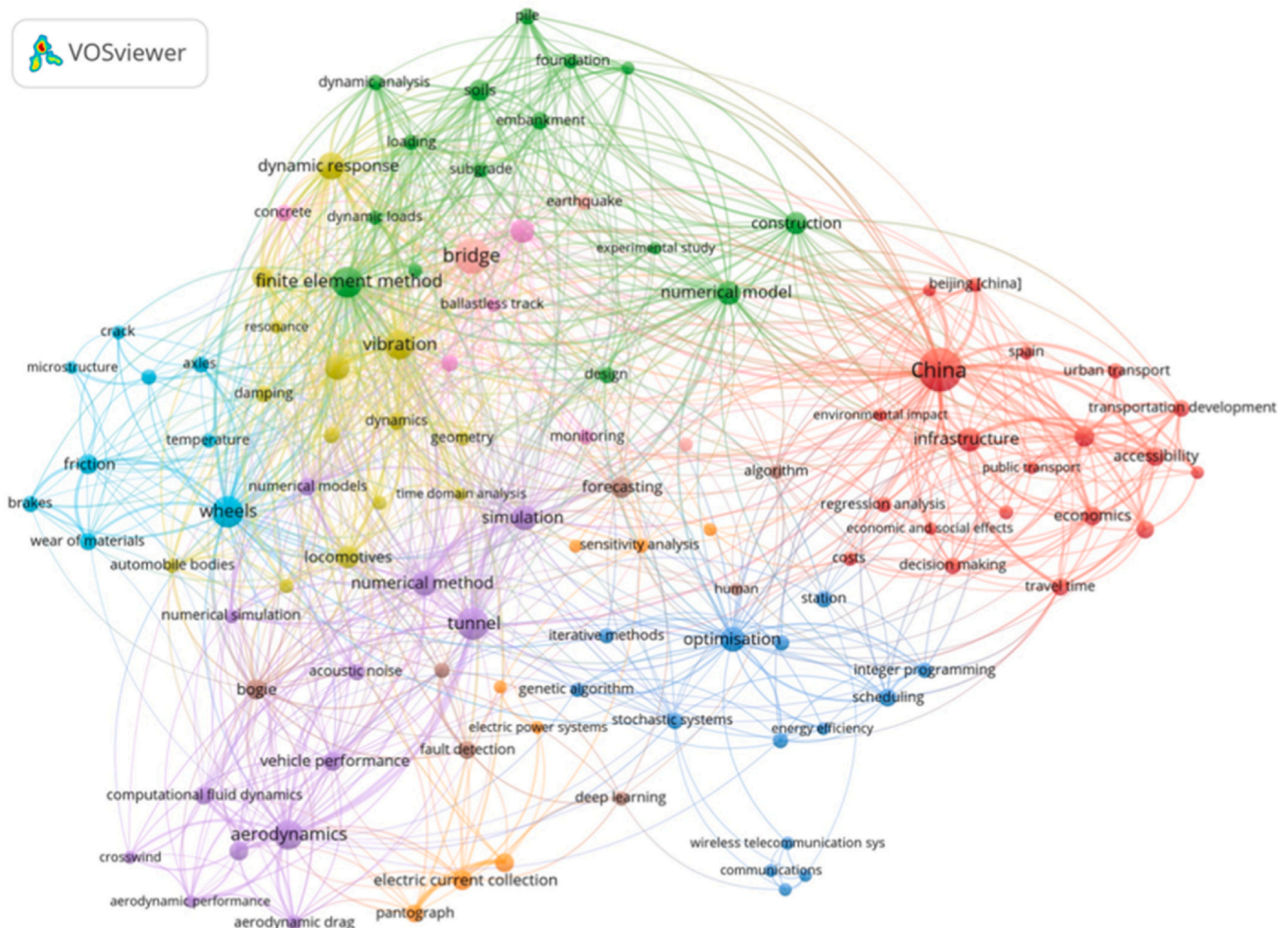

Fig. 10. English language articles not included in dataset reviews, keyword co-occurrence (108 keywords).
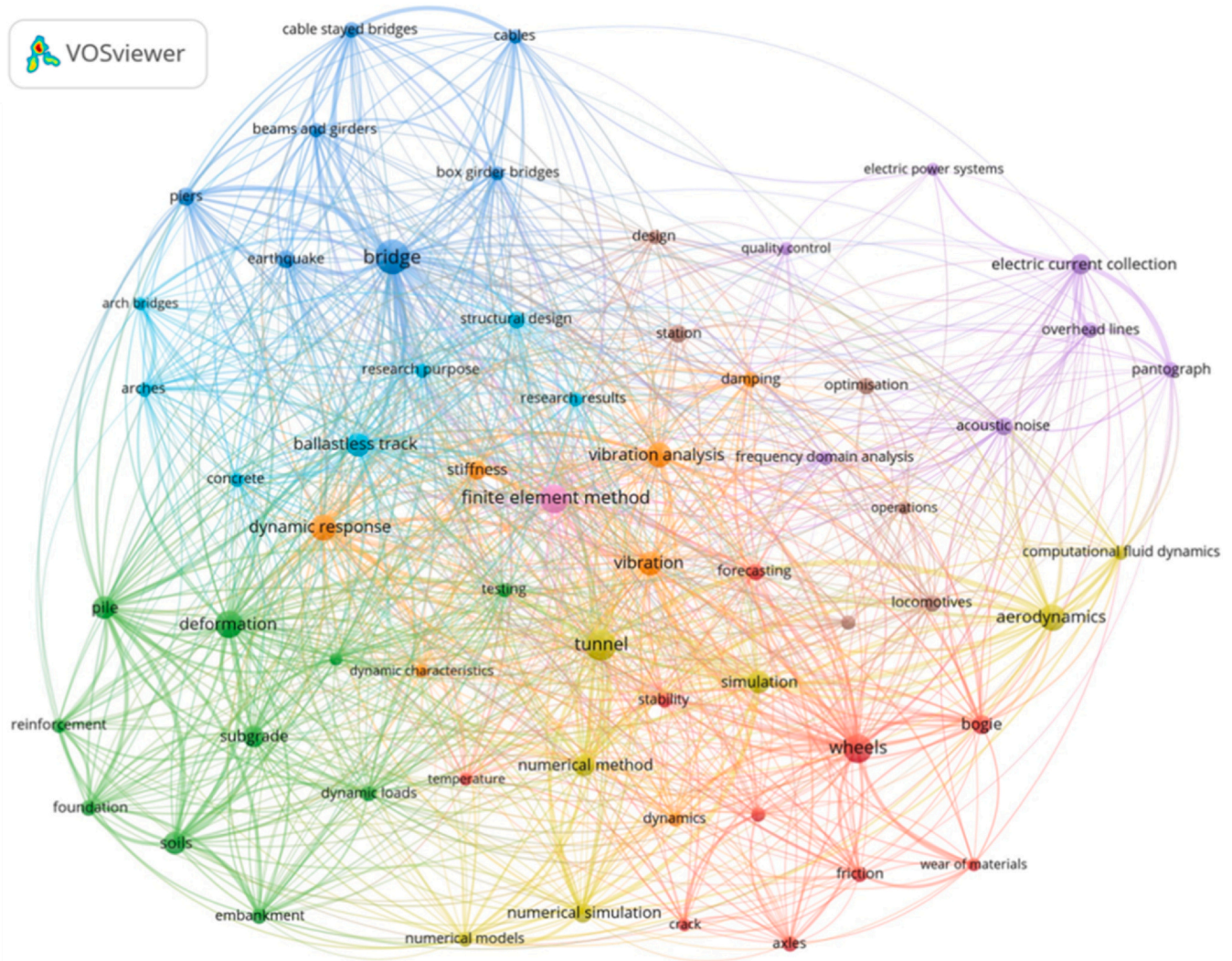
Fig. 11. Chinese language articles not included in dataset reviews, keyword co-occurrence (62 keywords).

indicating multiple topics. For example, within Cluster 3 (lower right of Fig. 11), communications are distinct from optimization. Although some topics align with existing reviews, e.g., aerodynamics, bridges, electric power systems, and economic and environmental impacts, there is evidently a wealth of unreviewed content suggesting nuanced aspects that are yet to be explored or recent advances that have not been incorporated. For example, a specific focus on transportation planning in key Chinese regions might be of interest, or the application of numerical methods for aerodynamics simulation. The potential review topics align with the popular topics indicated by the highly-cited journals in Table 3, suggesting that they would be well received by these journals and the wider research community. One topic that does not overtly stand out in the keyword analysis but may be of interest is artificial intelligence and machine learning in the HSR domain. This is implicitly grouped into cluster 8, which includes "deep learning" and focuses on condition monitoring. An initial review of artificial intelligence applications was conducted in 2020 [7]; an update capturing recent advances could be beneficial.

3.4.2.2. Chinese language articles. For Chinese language articles, there are fewer keywords that meet the 55 occurrences criteria, resulting in fewer keywords per cluster than for the English language analysis. However, many of the resultant clusters relate very closely to those identified in the previous section, meaning that the same potential review topics apply. Novel topics predominantly relate to specific bridge types: girder, cable

and arch bridges. Optimization is recognized within its own cluster, rather than linked with communications. The final cluster contains only "finite element analysis" but inspection of the visualization shows that this links to every other cluster, suggesting that the application of FEM in the HSR domain could be explored. As found in the analysis of Chinese language reviews and highly-cited journals (Table 3), the literature seems to focus on specific technical topics rather than more subjective ones, e.g., social science disciplines.

3.4.3. Future topics conclusions

There are a number of similar topics that could be and synthesized from the English and Chinese language articles. Specifically, these are related to wear of components, HSR track-bed structural design and dynamic response, aerodynamics performance and aerodynamic simulation methods, electric power system design and maintenance, vehicle dynamic response, the impact of vibrations and HSR optimization approaches. Additional topics that appear to be more widely established in the English literature are condition monitoring, economic and environmental impact, energy efficiency, transport policy and communications.

4. Conclusions

This paper evaluated articles and reviews related to high-speed rail between 2003 and 2022 to further understand the research landscape

and ultimately identify research areas for synthesis. Four main questions were considered. The key findings associated with each question are presented below, incorporating higher level conclusions from the whole work.

1) **What languages is HSR literature published in?**

Approximately a third of the HSR literature encountered was published exclusively in Chinese. Incorporating this research into the review is a significant novel contribution, which enabled the authors to compare topics available in English and Chinese to identify gaps. A greater volume of work is available in English, covering more diverse topics. Generally, similar broad technical topics are covered in both languages, though it is expected that there is some nuance that could be elucidated in future targeted reviews. Some specific technical topics, e.g., related to bridges, may be limited to the Chinese language only. It is recommended that future reviews (such as on the suggested topics) do not exclude Chinese language publications, but work to incorporate them or, if this is not possible, to at least evaluate the abstracts to gauge what may be missing by their exclusion. The reasons why minimal literature is available in other languages, e.g., Japanese, should be evaluated in further research.

2) **How collaborative is HSR research?**

Most HSR research is produced by a single institution or through collaborations within a country, predominantly in China. International collaborations tend to be published in English. Researchers affiliated with over 70 countries contributed to the HSR dataset, indicating global interest in the topic beyond those countries operating or planning HSR operations. Strong internally collaborative institutions are detailed in Table 1, with many based in China, notably Beijing Jiaotong University, Southwest Jiaotong University and Central South University. Researchers who want to develop international collaborations may benefit from targeting these institutions or others in countries with strongly established research links actively pursuing HSR research. The affiliation analysis suggests China, Canada, the UK, the USA, Sweden and Australia fall into this category, with Japan, South Korea and Spain also well represented.

3) **Where is HSR literature published?**

English language articles on HSR are published in disparate journals, though there are a number of highly-cited journals targeting specific topics, as outlined in Table 2. Chinese language articles are more concentrated, with almost half contained in just five sources. A new open-access journal dedicated to HSR was established by Beijing Jiaotong University in 2023. The popular topics inferred from highly cited journals align with the potential review topics determined from keyword analysis. See the discussion below. Researchers may wish to target these journals for publication if appropriate to their research area.

4) **What topics should be targeted for future work?**

Approximately 90% of the HSR dataset found through the Scopus search has not been synthesized into one of the HSR reviews, meaning there is a wealth of knowledge yet to be categorized. Although some topics align with existing reviews, e.g., aerodynamics, bridges, electric power systems, and economic and environmental impacts, there are likely nuanced aspects or recent advances to be captured. Similar topics to be synthesized from the English and Chinese language articles relate to wear of components, HSR track-bed structural design and dynamic response, aerodynamics performance and aerodynamic simulation methods,

electric power system design and maintenance, vehicle dynamic response, the impact of vibrations and HSR optimization approaches. Additional topics in the English literature are condition monitoring, economic and environmental impact, energy efficiency, transport policy and communications. These topics should be targeted for future reviews, using the identified keywords as initial search terms and drawing on the expertise of researchers in these specific areas.

The authors anticipate that these findings and recommendations will contribute to a better understanding of academic production in the HSR research community and support the consolidation of the existing research base into new reviews.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

This Appendix lists the countries which currently operate or are planning HSR networks, based on UIC's HSR Atlas 2022 [1]:

Australia, Austria, Bahrain, Belgium, Brazil, Canada, Chile, China, Czech Republic, Denmark, Egypt, Estonia, Finland, France, Germany, Hungary, India, Indonesia, Iran, Israel, Italy, Japan, Latvia, Lithuania, Mexico, Morocco, Norway, Poland, Portugal, Qatar, Russia, Saudi Arabia, Serbia, South Africa, South Korea, Spain, Sweden, Switzerland, Thailand, The Netherlands, Turkey, The UK, The USA, Vietnam.

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