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Pumping hash cash, saves on gas, gas, gas

9 July, 2026

Researchers have developed a benchmarking framework to assess whether artificial intelligence (AI) can generate decentralised finance (DeFi) smart contracts that are efficient and cost-effective, lowering computational costs, known jargonistically as "gas". The work might address a key problem seen in blockchain-based financial systems. Decentralised finance (DeFi) is a blockchain-based financial system that provides services such as lending, trading, and asset management without the need for conventional intermediaries such as banks. It uses smart contracts, which are self-executing programs that automatically enforce agreed rules, to allow financial applications to operate on decentralised networks. There is a computational cost associated with transactions, the gas. Reducing gas consumption is the key to lowering costs for users. The study in the *International Journal of Agile Systems and Management* looked at Code Llama and Code Llama–Python. These two large language models (LLMs) can generate computer code across three DeFi applications: digital tokens, tokenised vaults, and flash loans [...]

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334-353	Strategic financing management in high-speed rail project development: a systematic literature review Indra Putra Salim; Manlian Ronald A. Simanjuntak; Oei Fuk Jin DOI: 10.1504/IJASM.2026.154946
354-374	The effect of task, team and technology on performance in agile virtual teams: an empirical study using PLS-SEM Ali El Idrissi; Mohamed Amine Marhraoui; Mohamed Fourka DOI: 10.1504/IJASM.2026.154945
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Strategic financing management in high-speed rail project development: a systematic literature review

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Abstract: This systematic literature review explores the financing management of high-speed train projects with cases related to this topic. It plays an active role in overcoming various challenges in the transportation sector, such as congestion, and supporting increased environmental sustainability and inter-city connectivity. This large-scale project financing process provides complex challenges because it requires significant financial resources with high management risks. Even though the government provides initial funding, public-private cooperation is still needed to implement this project successfully. Financial risks, including considerations related to construction costs and unexpected policy changes affecting project financing, are always a possibility. Therefore, it is essential to know proactive risk mitigation strategies. Through this systematic review of literature, it is hoped that it will provide knowledge regarding funding sources, methods, and other external factors so that it can be used in developing and making future policy decisions regarding high-speed trains.

Keywords: financing management; high-speed train; project development; strategic implications; transportation sector.

Reference to this paper should be made as follows: Salim, I.P., Simanjuntak, M.R.A. and Jin, O.F. (2026) 'Strategic financing management in high-speed rail project development: a systematic literature review', *Int. J. Agile Systems and Management*, Vol. 19, No. 3, pp.334–353.

Biographical notes: Indra Putra Salim is a Project Management enthusiast known for his role in the Jakarta–Bandung High-Speed Railway project. He holds Civil Engineering degrees from Harbin Institute of Technology and Tarumanagara University and is nearing completion of his Doctorate in Construction Management.

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1 Introduction

Infrastructure development such as high-speed trains has become a global ideal and priority to overcome various problems in Indonesia, such as overcoming congestion, reducing environmental carbon emissions, and increasing connectivity between cities in Indonesia (Huihui et al., 2020). The high-speed train project in Indonesia connecting Jakarta with Bandung aims to improve mass transportation performance and support sustainable economic growth in the surrounding area (Tetama et al., 2022). During the administration of President Joko Widodo, the Indonesian government prioritised the construction of high-speed trains to be realised immediately to increase the efficiency of Indonesian transportation (Zakiyya and Purnama, 2022). Apart from the economic and technical benefits obtained, this high-speed train project also has legal and social effects, such as the need for public consultation on land acquisition. Study results show that high-speed trains can positively affect community welfare and economic growth in the surrounding area (Salim et al., 2023). In addition to its economic and technical benefits, the high-speed train project linking Jakarta and Bandung is poised to address critical infrastructure challenges in Indonesia, particularly by alleviating congestion and reducing travel times between major urban centres (Nath and Raganata, 2020). This ambitious initiative underscores Indonesia's commitment to modernising its transportation network to meet the demands of a growing population and economy. Furthermore, the project aims to foster regional integration and boost tourism by improving accessibility and connectivity across Java Island. As a transformative infrastructure endeavour, the high-speed train is expected to stimulate economic activities, create employment opportunities, and enhance overall regional social cohesion.

In addition to its primary objectives, this research delves deeply into risk management strategies to ensure the successful completion of the project. It systematically addresses a range of potential challenges, including securing adequate funding, overcoming

construction obstacles, and mitigating operational risks. By thoroughly analysing these aspects, the research aims to develop comprehensive solutions that will enhance the project's overall resilience and sustainability (Wijaya, 2024).

The challenges that arise in the field of financing high-speed rail infrastructure projects are unavoidable. Things like this cannot be avoided when developing significant long-term projects. This project requires relatively large financial resources for designing, building, and operating a sophisticated and efficient high-speed rail system. Therefore, project financing management is crucial to ensure a high-speed train's smooth implementation and success. This is because high-speed trains are one of the aspirations of the Indonesian nation, considering the significant investment required. Financial risks that arise need to be managed effectively and efficiently. Effective project financing management involves securing initial funding and navigating through potential financial risks and uncertainties that may arise during different project phases (Liao and Katada, 2021). These risks include fluctuations in construction costs, changes in government policies, and volatility in financial markets, all of which can impact the overall budget and timeline of the high-speed rail project. Mitigating these risks requires proactive strategies such as establishing contingency funds, negotiating stable financing agreements with lenders, and maintaining transparent communication with stakeholders. Additionally, leveraging innovative financing mechanisms like public-private partnerships (PPPs) and exploring alternative funding sources can provide greater financial resilience and flexibility to adapt to changing circumstances (Chang et al., 2019; Yuan et al., 2020). By adopting a comprehensive approach to project financing management, Indonesia can enhance its capability to successfully deliver and sustain its high-speed rail aspirations, contributing to long-term economic growth and societal development (Ampratwum et al., 2023).

Previous research states that financing for high-speed rail projects is guaranteed from a combination of public and private investment (Elisabeth, 2021). Although the government usually initiates initial funding for large-scale infrastructure projects such as the Jakarta-Bandung high-speed train, there is still a need for involvement from other parties from the private sector with PPPs. Coordination and collaboration from several parties are very effective and necessary to overcome the complex financial challenges that arise and can support the success of related projects (Dzakky, 2021). PPPs offer a robust framework for sharing risks and leveraging private sector efficiencies in financing high-speed rail projects. These partnerships diversify funding sources and bring expertise in project management and operational efficiency, enhancing the overall project quality and sustainability. Moreover, international financial institutions play a crucial role by providing additional funding and technical expertise, bolstering high-speed rail initiative's financial viability and credibility. By fostering collaboration among governments, private investors, and international organisations, Indonesia can navigate the complexities of financing and ensure the successful implementation of its high-speed train projects, contributing to the country's infrastructure development goals and economic prosperity.

The contribution of this paper is to provide valuable insights into the management of financing for high-speed rail projects in Indonesia, shaping robust policies and strategies for the development of sustainable and efficient high-speed rail systems. The findings aim to foster long-term economic growth and societal benefits. Suppose this high-speed train project is associated with financial risks. In that case, it will have various impacts, such as reflection on construction costs, changes in government policy, and the

emergence of financial market volatility (Abdullah, 2020). This impact will have a felt effect on overall project financing. Therefore, identifying, releasing, and mitigating financial risks can be integral to high-speed rail project financing management. Various steps need to be taken to manage this financial risk effectively and efficiently for the success of the large Jakarta-Bandung high-speed train project (Kumar, 2019). Moreover, establishing a comprehensive risk management framework is essential for anticipating and mitigating potential financial risks associated with the high-speed train project. This involves conducting thorough risk assessments at different stages of the project lifecycle, from planning and design to construction and operation. Implementing contingency plans and risk mitigation strategies tailored to specific challenges, such as regulatory changes or economic downturns, can help safeguard project financing and ensure resilience against unforeseen circumstances. Additionally, maintaining open communication channels among stakeholders and regularly monitoring key performance indicators can facilitate the early detection of emerging risks and enable prompt corrective actions. By proactively managing financial risks, Indonesia can enhance investor confidence, maintain project momentum, and ultimately successfully deliver its high-speed rail infrastructure goals.

The rest of the paper is structured as follows, the literature review discusses the management of high-speed train project financing. This can be used to gain a good understanding of the various sources of income and the best strategies for managing the financial aspects of large-scale projects. By using a system literature review, it is hoped that we can gain valuable insight into how to overcome project financing challenges in order to achieve long-term financial desires. This review will focus on identifying potential risks and guide the decision-making process in managing costs. The author hopes that this information can provide knowledge about policies and the best ways to develop high-speed train projects in the future. Furthermore, synthesising insights from this literature review can inform policymakers and project managers on adopting adaptive financial strategies that enhance the resilience of high-speed rail projects. Understanding the diverse sources of funding, ranging from public investment to innovative financing mechanisms like green bonds, enables stakeholders to diversify financial resources and mitigate dependency risks. Stakeholders can navigate uncertainties effectively by emphasising proactive risk management and cost-effective measures, such as leveraging digital technologies for project monitoring and optimisation. Ultimately, this knowledge contributes to shaping robust policies and strategies for developing sustainable and efficient high-speed train projects, fostering economic growth and societal benefits in the long term.

2 Methods

The author adheres to systematic observation guidelines using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method to obtain more thorough and transparent results (Page et al., 2021). In using PRISMA, we carry out several stages, namely keyword development (Section 2.2), database search (Section 2.3), and data cleaning and sorting (Section 2.4).

2.1 *Research questions*

PRISMA method will be continued by answering the questions that have been created previously, namely as follows:

- 1 How are high-speed rail project financing sources developed and implemented in various global contexts?
- 2 What are the strategic financing management to financing high-speed rail projects?
- 3 What external factors exist in managing high-speed train project financing?
- 4 What strategies are implemented to mitigate the negative impacts that arise and can increase the financial viability of projects that reach their peak?

2.2 *Keyword development*

The paper search process was adjusted based on research topics focused on project financing management on high-speed trains. In systematic literature observation, the first thing to do is to determine categories or string coding. This stage was carried out to find papers relevant to the research. The author uses several keywords such as “project financing management AND high-speed rail strategies in project financing management AND approaches in project financing management AND achievements in project financing management AND methods in project financing management for high-speed railway projects” and “project financing management AND OR high-speed train strategy in project financing management AND OR approach in project financing management AND OR achievements in project financing management AND OR methods in project financing management for high-speed train projects” to ensure that comprehensive coverage results are obtained in the stages this search. Papers were obtained using the Publish or Perish (PoP) version 8 application using the search string, and then the data reduction and extraction process continued.

Following the initial search using PoP version 8, the following steps involved data reduction and extraction, focusing on refining the relevance and reliability of selected papers. This systematic approach ensures a comprehensive coverage of current literature on project financing management for high-speed train projects. The review aims to provide nuanced insights into practical strategies, approaches, achievements, and methods in project financing management by synthesising findings across various research methodologies. The rigorous categorisation and analysis of retrieved papers contribute to a robust understanding of best practices and potential challenges in financing high-speed rail infrastructure, guiding future research and practical applications.

2.3 *Database search*

This systematic literature review utilises several accessible journal search portals, such as Google Scholar, Scopus, and CrossRef. This search process uses a publication time filter from 2018 to 2024. First, 2606 papers were obtained in various languages, such as Indonesian and English. The next stage is to reduce and extract data by eliminating duplicate papers and identifying the topic's relevance based on the title, abstract, and completeness of inclusion and exclusion.

The vast array of literature covered by the Google Scholar generation offers the chance to access more diverse, pertinent, and closely linked sources to the subject of study. Scopus is a comprehensive coaxial journal database with rigorous journal selection, the calibre of the literature retrieved is guaranteed. Selecting Scopus as one of the sources will add more reputable and trustworthy references to the review result. CrossRef is a popular DOI registration service that provides very accurate electronic document identification. This source guarantees that easily searchable, well-documented literature is available for replication or validation. Its coverage is restricted to particular periodicals and frequently leaves out smaller publishers or particular geographical areas, with a significant bias towards literature from major publishers. Furthermore, due to WoS's strict selection criteria, some of the most significant and pertinent research in particular fields may be overlooked. Google Scholar, Scopus, and CrossRef can be accessed for free (Google Scholar) or more conveniently through subscriptions (Scopus and CrossRef). Compared to WoS, this makes it simpler and faster for scholars to look for literature. The PRISMA phases of identification, screening, eligibility, and inclusion of literature were all met by the chosen sources. This procedure would provide better procedure would provide better.

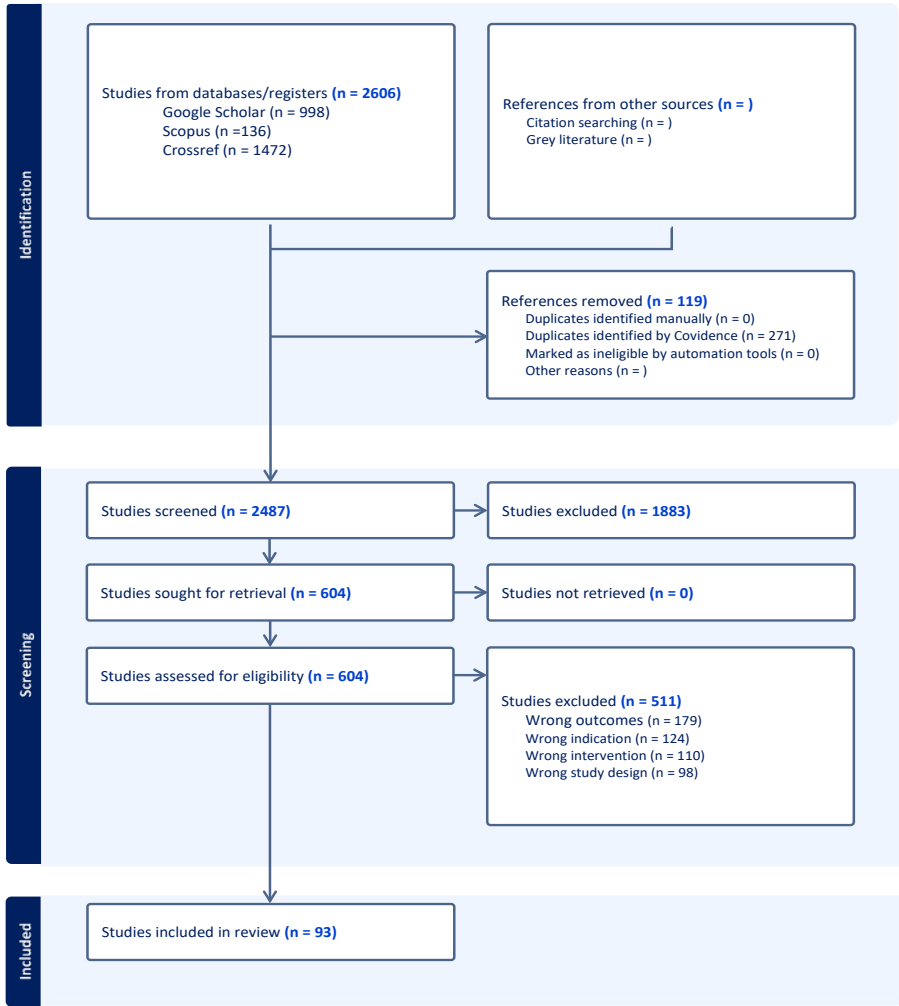
After obtaining 2606 papers from Google Scholar, Scopus, and CrossRef within the publication time frame of 2018–2024, the systematic literature review progresses to the crucial data reduction and extraction stage. This involves employing rigorous methods to eliminate duplicate entries and assess the relevance of each paper based on criteria such as alignment with the research topic, completeness of information, and adherence to inclusion and exclusion criteria. By meticulously filtering the retrieved papers, the review aims to ensure a focused and comprehensive analysis of project financing management strategies and practices related to high-speed train projects. This methodological approach enhances the reliability and validity of findings, providing valuable insights for policymakers, researchers, and practitioners involved in infrastructure development and financing.

2.4 Data cleaning and sorting

This study uses the PRISMA guidelines in the literature selection process. This is done to ensure transparency and accuracy when compiling a systematic review. This study established criteria and exclusions to limit the scope of paper identification so that researchers can map relevant factors in mapping results with the research topic. A total of 2606 papers were identified from three primary databases, namely Google Scholar (998 papers), Scopus (136 papers), and Crossref (1472 papers). After combining the search results, 119 papers were removed due to duplication. Automation tools were used to remove duplication (Covidence found 271 duplications). Citation data from 2606 papers, downloaded in RIS format, were initially screened to remove duplicates, resulting in 2487 papers. After that, initial screening was conducted. 2487 papers were selected based on the title and abstract, and 1883 papers were excluded because they did not meet the study inclusion criteria. If the findings of the research paper have been identified, they can then be assessed and interpreted using a system literature review (Tupan and Rosiyan, 2022). Papers with irrelevant titles, abstracts, and keywords will then be reduced. Likewise, papers with unclear methodology, inappropriate theories, and not meeting other criteria must be reduced from the selection process. After that, the search and eligibility assessment were conducted. A total of 604 papers are in the process of

full-text review. No papers were ineligible for the analysis process. Of the 604 papers tested, 511 were excluded because they did not meet the inclusion criteria due to irrelevant results ($n = 179$), wrong indications ($n = 124$), inappropriate interventions ($n = 110$), and inappropriate study designs ($n = 98$). This stage caused 511 to be eliminated and reduced to 93. As many as 93 of this paper can then be explained further. Figure 1 shows the paper screening process using PRISMA.

Figure 1 PRISMA flow diagram (see online version for colours)



Following the initial screening process using PRISMA methodology, which reduced the initial 2606 papers to 2487 after eliminating duplicates, the study conducted a rigorous assessment of relevance and quality. Papers were scrutinised based on predefined criteria to ensure alignment with the research topic and methodological soundness. This systematic approach facilitated the exclusion of 511 papers with irrelevant titles, abstracts, or methodologies that did not meet the study's criteria, resulting in a refined selection of 93 papers for further detailed analysis. The next phase involves synthesising

and interpreting the findings from these selected papers to derive meaningful insights into project financing management for high-speed train projects, as Tupan and Rosiyan (2022) outlined in their systematic literature review methodology.

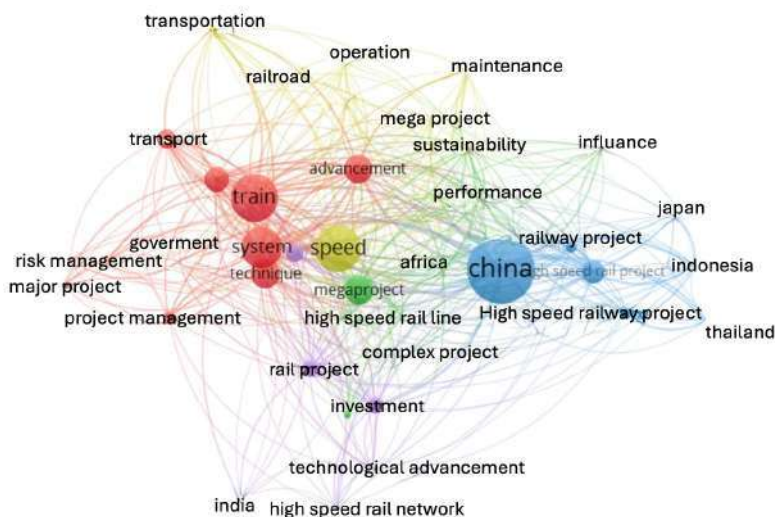
3 Results

3.1 Results

This section presents the results of the data analysis, organised into five subsections: classification by publication year (Section 4.1.1), project management (Section 4.1.2), investment and infrastructure development (Section 4.1.3). A sample of journals was collected using the PoP application, then analysed and processed with VOSviewer to identify patterns and trends in the related literature (Yu et al., 2020).

Figure 2 shows that the papers obtained mainly discuss ‘China’, ‘train’, ‘speed’, ‘system’, ‘advancement’, ‘mega project’, ‘technique’, ‘transport’, ‘investment’, ‘rail project’, ‘high-speed railway project’, ‘public private partnership’, ‘technological advancement’, ‘project management’, ‘major project’, ‘risk management government’, ‘railroad’, ‘operation’, ‘funding’, ‘sustainability’, ‘performance’, ‘influence’, ‘maintenance’, ‘Japan’, ‘Indonesia’, ‘Thailand’, ‘Africa’, ‘complex project’, ‘India’, as indicated by the increasing size of the circles. The connections between these substantial areas signify that this subfield is most frequently linked to other subfields, including ‘project management’, which is also connected by these five subfields.

Figure 2 Research topic distribution (see online version for colours)

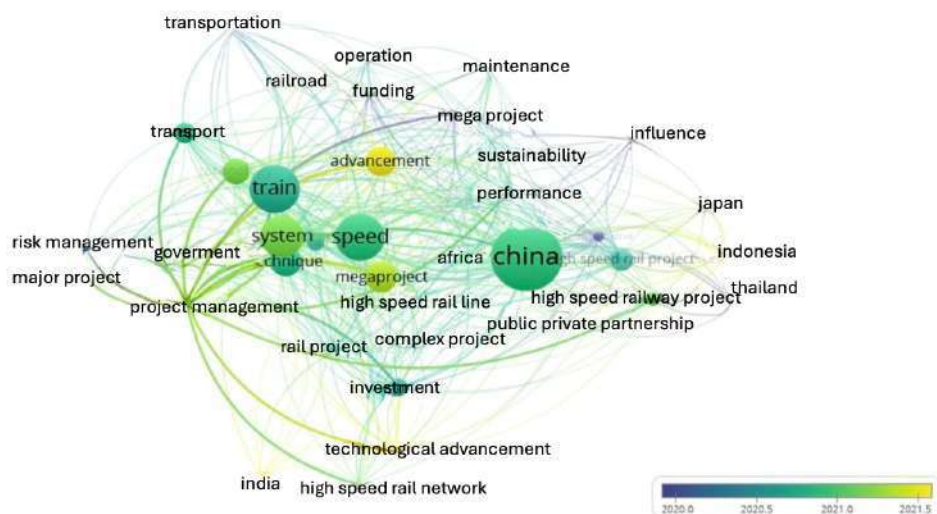


3.2 Classification based on the publication year

Bibliometric analysis using VOSviewer helps provide a comprehensive visualisation of research trends from 2018 to 2024, as shown in Figure 3. In this figure, each year cluster is represented by a different colour. Clusters coloured yellow indicate that the research was carried out in the most recent year. If you look at the scale, most research on this

topic was carried out in 2021–2022. Dark blue and green clusters indicate research conducted in the previous year. Dark blue clusters show that the papers obtained mainly discuss ‘funding’, ‘megaproject’, ‘influence’, and ‘risk management government’, and ‘road initiative’. Green clusters show that the papers obtained mainly discuss ‘china’, ‘train’, ‘speed’, ‘system’, ‘technique’, ‘megaproject’, ‘investment’, ‘rail project’, ‘high speed railway project’, ‘public private partnership’, ‘project management’, ‘major project’, ‘technological advancement’, ‘project management’, ‘major project’, ‘risk management government’, ‘railroad’, ‘operation’, ‘sustainability’, ‘performance’, ‘maintenance’, and ‘transportation’. Clusters related to each other through the same theme can show the latest trends and topics that are stable or frequently discussed. In 2022, it can be seen that several keywords, ‘Indonesia’, ‘technological progress’, ‘megaprojects’, ‘technological advancement’, and ‘project management’, form a bright yellow group and begin to experience publication volume.

Figure 3 Distribution of the subject based on publication by years (see online version for colours)



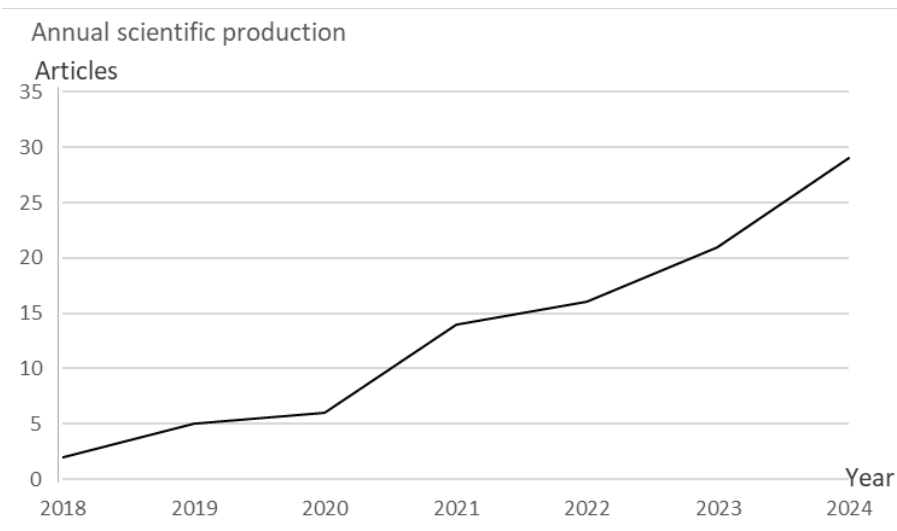
This increase in the number of publications can be attributed to the completion of the high-speed train project program in Indonesia, which has been stalled and is ready to be used for the Jakarta-Bandung route. This train has now been inaugurated in 2023 and is named ‘Whoosh’. The results of observations using VOSviewer can be used to see research gaps and research that can potentially develop. These areas that have not been widely explored can provide an overview of promising prospects for progress in this field.

The bibliometric analysis using VOSviewer also highlights emerging areas that require further exploration, thereby guiding future research endeavours. For instance, while the clusters indicate significant research on ‘technological progress’ and ‘project management’, there is a noticeable gap in studies focusing on the socio-economic impacts of high-speed rail projects in developing countries, particularly in Southeast Asia. Additionally, there is potential for more in-depth research on the environmental sustainability of high-speed rail systems, especially concerning their long-term ecological impacts and the integration of renewable energy sources. Researchers can contribute to a

more holistic understanding of high-speed rail development by identifying these underexplored areas. Furthermore, the analysis reveals the importance of interdisciplinary approaches, combining insights from engineering, environmental science, economics, and urban planning to address complex challenges associated with large infrastructure projects. This comprehensive perspective can lead to more innovative solutions and enhance the overall effectiveness and sustainability of high-speed rail projects globally.

Based on the total publication trend seen in Figure 4, the management of high-speed train project financing from 2018 to 2024 shows a significant increase. It can be seen that the peak of research publications related to this topic will occur in 2024. The volume of these publications has continued to increase every year since 2018 because Indonesia has a construction process for a mega high-speed train project on the Jakarta-Bandung route. This is further supported by the fact that in 2023 the Jakarta-Bandung high-speed train will officially operate. Financing management for this high-speed train project is vital in large-scale infrastructure development because it prevents errors. Thus, this topic has been proven to be an increasing trend and is suitable for further exploration.

Figure 4 Total publications from 2018 to 2024

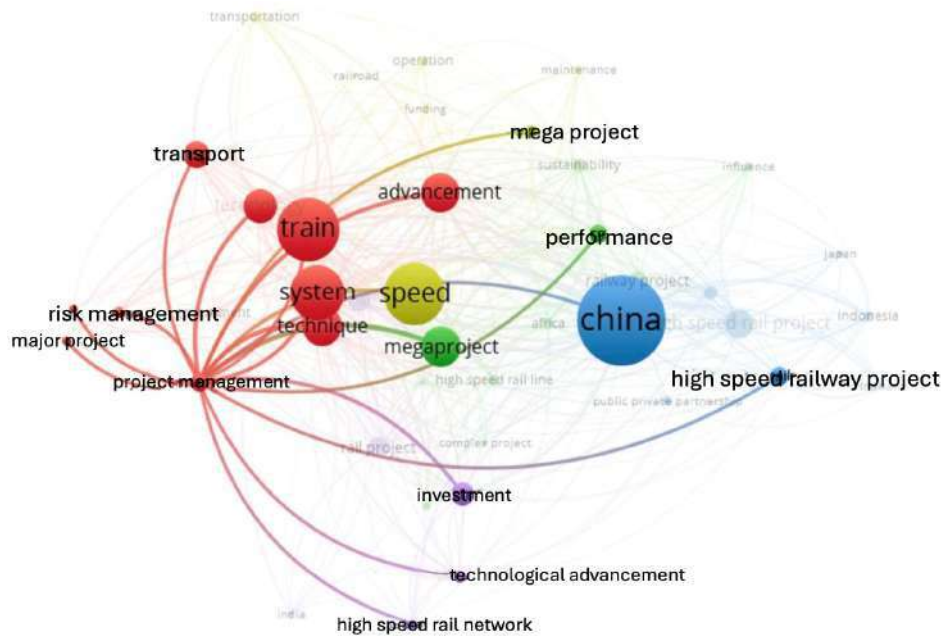


3.3 Classification based on the project management

The project management stage is critical in monitoring high-speed train project's planning, implementation, and completion, especially in countries with significantly advanced transportation infrastructure. The rapid development of railway networks in other countries shows the country's lack of commitment to technological progress and innovation in the transportation sector. This high-speed train construction project is significant because of its complexity and requires a considerable investment. Therefore, it is essential to use effective project management to ensure the successful implementation of this significant project. Based on the correlation between research subjects and high-speed rail project financing management shown in Figure 5, it explains that there is a relationship between project management and high-speed rail, China, progress, transportation, mega projects, investment, and technological progress, which is marked

by the appearance of lines that connects several of these topics. These subjects are vital in project financing management practices, encouraging progress and innovation in the transportation sector.

Figure 5 Correlation subject by project management based on high-speed rail approach (see online version for colours)



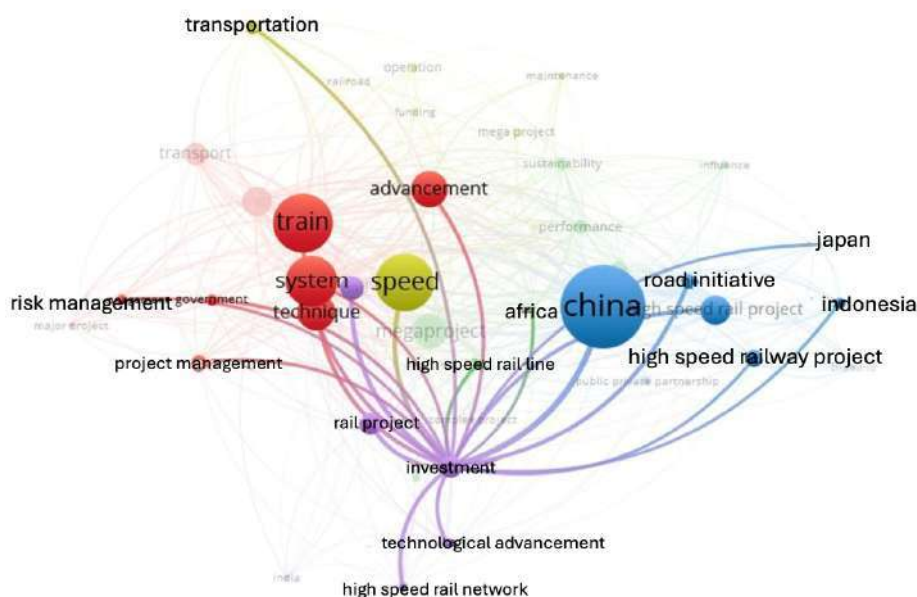
Effective project management is pivotal in navigating the complexities associated with high-speed rail projects, especially given their scale and the substantial investments involved. Essential project management practices include meticulous planning, continuous monitoring, risk assessment, and stakeholder engagement, all of which contribute to mitigating potential issues and ensuring the project adheres to its timeline and budget.

The correlation between project management and high-speed rail development, as highlighted in Figure 5, underscores the interconnectedness of various factors such as technological advancements, investment strategies, and infrastructure development. Figure 5 shows that the papers obtained mainly discuss ‘china’, ‘train’, ‘system’, ‘speed’, ‘megaproject’, ‘technique’, ‘advancement’, ‘transport’, ‘investment’, ‘risk management’, ‘major project’, ‘project management’, ‘technological advancement’, ‘performance’, and ‘high speed rail network’. These connections suggest that successful project management not only enhances the execution of high-speed rail projects but also fosters broader economic and technological progress. By leveraging best practices in project management, countries can overcome funding, regulatory compliance, and technological integration challenges, ultimately leading to the efficient delivery of high-speed rail systems. This, in turn, can stimulate economic growth, enhance connectivity, and promote sustainable transportation solutions.

3.4 Classification based on the investment and infrastructure development

Investment in project financing management practices plays a vital role. Figure 6 shows that the papers obtained mainly discuss 'china', 'speed', 'train', 'system', 'technique', 'advancement', 'project management', 'investment', 'rail project', 'technological advancement', 'high speed rail network', 'risk management', 'government', 'high speed rail line', 'road initiative', 'high speed rail project', 'high speed railway project', 'indonesia', and 'japan'. As evidenced by Figure 6, which shows a correlation between investment as a source of funds and development infrastructure. This is because investment can be utilised optimally for the planning and implementation. An effective risk management strategy can reduce areas and keep the project on track. Apart from that, government policies also greatly influence the investment decisions of China and Japan. The significant investment in the high-speed rail network reflects the country's commitment to technological progress in the transportation sector. Funding mechanisms include partnerships between the government and the private sector and an important international role in supporting investment in transportation infrastructure. Therefore, there is a need for good collaboration between the government, private investors, and international organisations to obtain funding sources and ensure the successful implementation of large projects.

Figure 6 Correlation subject by interconnected dynamics based on high-speed rail approach (see online version for colours)



Furthermore, fostering a collaborative environment between these stakeholders is essential for overcoming financial and operational hurdles. Public-private partnerships (PPPs) offer a robust framework for leveraging the strengths of both sectors, combining public oversight with private sector efficiency and innovation. International organisations, such as the Asian Infrastructure Investment Bank (AIIB) and the World

Bank, can provide financial support, technical expertise, and governance standards that enhance project credibility and attract further investment. Additionally, clear and supportive government policies, including tax incentives, subsidies, and regulatory frameworks, can create a more favourable investment climate, reducing uncertainty and encouraging long-term commitments from private investors. High-speed rail projects can benefit from a more coordinated and strategic approach to funding and implementation by aligning the interests of all parties involved and ensuring transparent and effective communication. This integrated strategy is crucial for meeting deadlines, managing costs, and ultimately delivering a high-speed rail network that meets the needs of modern transportation infrastructure.

4 Discussion

This section is structured into four subsections for discussion: financing sources for high-speed rail projects, strategic implications for project finance management, external factors that affect the management of high-speed rail project finance, and strategies for enhancing the project's financial sustainability.

4.1 *Financing sources for high-speed rail projects have been developed and applied in various global contexts*

Funding sources for the construction of high-speed trains have been widely developed and applied in a global context using various mechanisms. The Indonesian government has played an essential role by providing direct investment, subsidies, and high guarantees. China has built a high-speed train network financed by government funds and private investment (Bharule, 2019; Yurianto and Kadri, 2020). Private investment in Japan, namely public-private partnerships (PPPs), has supported the development and operating of railway lines like the Shinkansen (Majid, 2019). The European Union's Trans-European Transport Network (TEN-T) has also extensively supported PPP performance. By carrying out international cooperation and funding, such as the Asian Development Bank's for the Jakarta-Bandung high-speed train project (Lawrence et al., 2019). Financing in the form of bonds is another essential method; for example, China has issued bonds to cover transportation projects to attract international investors. State-owned enterprises (BUMN) such as China Railway Corporation also play an essential role. Fiscal and monetary policies, starting from subsidies and grants from the European Union, have been proven to support infrastructure development. The European Investment Bank (EIB) and the Asian Infrastructure Investment Bank (AIIB) have provided significant funds. Other bonds, such as green bonds, also contain environmentally friendly projects (Putri and Ma'arif, 2019).

Between Taipei, China, in the north, and Kaohsiung, in the south, the Taiwan High-Speed Rail Corporation (THSRC), also known as the High-Speed Rail (HSR) Corporation, runs 345 km of HSR. One of the biggest privately funded railway construction projects in the world, the project was valued at \$13 billion when it was put into action. Although the company's operations are privately run, the Government of Taipei, China, is a significant stakeholder in the THSRC (Watson et al., 2021). In Europe, nearly all lines in the European Union (EU) are run by private operators, who are supported by EU funds. The interoperability of high-speed trains was the specific goal of

the EU Council Directive of 1996. In 1981, France became the first European nation to offer HSR services. The 2-h Train à Grande Vitesse (TGV) service travels 450 km between Paris and Lyon. In terms of social returns, the observed regional development in recent years exceeded expectations. The government has been encouraged to pay to the building costs and to further expand the network as a result of this initiative (Bharule et al., 2019). Spain created Europe's biggest HSR network in 2010. In 2012, the Spanish railway network was linked to the French railway network as part of an EU Commission project to create an expanded Trans-European Network (TEN) (De Francesco and Castro, 2018). Japan and India signed a 'Memorandum of Cooperation on High-Speed Railways' in 2015. The agreement calls for the Mumbai Ahmedabad High-Speed Rail to use Shinkansen technology from Japan. The Japan International Cooperation Agency's Official Development Aid (ODA) is expected to pay \$16 billion for the project (Yoshimatsu, 2020). In late 2010, the Thailand government authorised five HSR routes. Bangkok, Thailand's capital, is where the entire 1500 km network comes together, despite the fact that each line's condition varies. The estimated cost of the entire network, including airport connections, is \$30 billion. Japan and the PRC each received two lines of the Thai HSR network, which is being developed as an ODA project. The fifth line is still in the proposal stage. As part of the Thai Eastern Economic route (EEC) Project, a 220 km airport link HSR route is being developed in addition to the network. Three international airports are to be connected between Bangkok and Pattaya via the proposed airport link under the EEC project. The project, which was created by a Sino-Thai PPP group, is scheduled to open in 2024 (Bharule et al., 2019). In the USA, the HSR is necessary to link economically underdeveloped areas like California. The American Recovery and Reinvestment Act of 2009 (ARRA), the Transportation, Housing, and Urban Development grant from 2010, and the Cap-and-Trade Program are the sources of funding for HSR projects (Chandra et al., 2021).

Given these global examples, Indonesia can further enhance its high-speed train project financing by exploring additional innovative funding mechanisms. Blended finance, which combines public, private, and philanthropic capital, can effectively de-risk investments and attract a broader range of investors. Establishing infrastructure funds by pooling resources from various stakeholders, including international donors and development banks, can provide more stable and long-term financing. Furthermore, leveraging land value capture mechanisms, where increases in land values due to infrastructure development are used to fund the projects, can provide a sustainable funding source. Emphasising green financing, such as issuing green bonds for environmentally friendly high-speed rail projects, can appeal to environmentally conscious investors and contribute to Indonesia's sustainability goals. Developing a robust regulatory framework that ensures transparency, accountability, and investor protection can boost investor confidence and attract more substantial investment flows. By integrating these diverse funding strategies, Indonesia can create a resilient and comprehensive financial model to support the successful development of its high-speed rail network.

4.2 Strategic implications for project finance management

The application of strategy to the high-speed rail project financing management process has many other essential aspects to ensure the success and desirability of this project. Practical risk allocation and management can help mitigate construction, operational,

financial, and political risks and minimise freezing and swelling of operational costs (Hermelin and Gustafsson, 2022). By utilising PPP, support from the government can be combined with capital efficiency from the private sector.

By utilising PPP, the synergistic combination of government support and the capital efficiency of the private sector can be effectively leveraged. This collaboration not only maximises the utilisation of available resources but also enhances project efficiency and effectiveness, leading to more sustainable and impactful outcomes. The integration of public funding with private sector expertise and efficiency can drive innovation, improve service delivery, and accelerate project timelines. This strategy can also increase the feasibility of large projects. Therefore, diversification of funding sources is also essential, namely from government funds, private investment, international loans, and other innovative mechanisms (Liao et al., 2022). This project will be better with support from the government through favourable policies and incentives and alignment of fiscal and monetary policies. Combining technological advances with sustainable practices will result in a more efficient and effective system. International collaboration and the transfer of insights from developed countries such as Japan and China will provide invaluable knowledge (Wong et al., 2022). Considering the broad economic and social impacts, this project will be able to stimulate growth, increase connectivity, and actively contribute to sustainable development. It can also increase public support and gain relationships in large-scale investments (Thi Hang et al., 2023).

In addition to these strategies, fostering transparency and accountability throughout the project lifecycle is crucial to building stakeholder trust and attracting further investment. Implementing a robust governance framework that includes regular audits, performance reviews, and transparent reporting mechanisms can ensure that the project adheres to its goals and timelines. Engaging in continuous dialogue with local communities and other stakeholders can also help address concerns and foster a sense of ownership and support for the project. Moreover, leveraging cutting-edge technology such as AI and big data analytics can enhance project planning, monitoring, and decision-making processes, ensuring that potential issues are identified and addressed promptly. By emphasising social responsibility and environmental stewardship, the project can align with global sustainability goals, further enhancing its appeal to investors and the public. Overall, a comprehensive approach that integrates financial innovation, technological advancement, stakeholder engagement, and sustainable practices will ensure the high-speed rail project's long-term success and desirability.

4.3 External factors affect the management of high-speed rail project finance

External factors can significantly influence the high-speed rail project financing management process. Government policy is critical in providing subsidies, tax incentives, and support by creating laws that can reduce financial risks and increase funding opportunities. Supportive policies must be created so private investors are increasingly interested in joining and facilitating cooperation between the government and the private sector (Zhang et al., 2018). In addition, changes in financial markets, such as changes in interest rates and investor sentiment, can directly impact the financing process and capital availability. This will impact project budgets and financial stability (Liu and Li, 2020). Market volatility also causes a decrease in investment, so a flexible and good financial strategy is needed. Another external factor is the environment. The sudden occurrence of drought or other conditions can cause additional costs and the need to delay the project.

Therefore, proactive project financing management must anticipate these challenges to meet conditions and minimise additional financial disruption (Deng et al., 2020). Thus, it is essential to strictly monitor the financing of high-speed train projects to respond quickly to external factors and minimise the risks involved.

To effectively address these external factors, it is crucial to implement comprehensive risk assessment frameworks that can predict and mitigate potential disruptions. By integrating advanced financial modelling and forecasting tools, project managers can simulate various scenarios and develop contingency plans to maintain financial stability despite market fluctuations and environmental uncertainties. Moreover, establishing strong partnerships with financial institutions can provide additional liquidity and credit support during periods of instability. Regularly updating risk management strategies and maintaining an adaptive approach to project financing will ensure that the high-speed rail project remains resilient and can continue progressing despite external challenges. Active engagement with stakeholders, including local communities and environmental groups, will further enhance the project's adaptability by fostering a collaborative environment where potential issues can be addressed proactively. By leveraging these strategies, high-speed rail projects can better withstand external pressures and achieve long-term success.

4.4 Strategies enhance the project's financial sustainability

The finance of a High-Speed Rail (HSR) project encompasses elements of planning, financing, risk management, and economic sustainability. The world's first HSR projects, such as the Tōkaidō Shinkansen in Japan, began with a rigorous feasibility study. The potential for high traffic between Tokyo and Osaka determined its success. On the other hand, the French Train à Grande Vitesse (TGV) project was successful in Europe because it required shorter travel times between major economic centres such as Paris and Lyon. HSR projects can be funded from various sources, such as government investment, loans from international financial institutions such as the World Bank, and PPPs. For example, the French TGV is primarily funded by government investment because it is considered a strategic infrastructure project. The Taiwanese project (THSRC) uses a PPP model, which divides risks and rewards between the public and private sectors – federal grants support projects such as the California HSR. Measuring a project's economic and social benefits against its costs is at the heart of cost-benefit analysis. Time savings, reduced carbon emissions, and regional economic growth are benefits. A high-speed rail project has shown that faster travel between major cities can boost economic activity. HSR must generate enough revenue to cover operating and maintenance costs and maintain financial sustainability. Passenger fares and government subsidies are the primary sources of this revenue. Risk management means identifying and addressing risks. These include financial (excessive costs), technical (system failures), and demand (passengers not reaching targets) (Praticò and Fedele, 2022).

Efforts to mitigate the negative impact of previous external factors to increase the desirability of the high-speed train project financing process can be made in several ways (Coronado et al., 2019; Ribalaygua and Perez-Del-Caño, 2019). First, it is necessary to develop strong and sturdy government partners and to obtain policy support so that they can provide good stability and reduce the emergence of regulatory risks. An example of this effort is that the government can offer subsidies, tax incentives, and guarantees to attract private investment and reduce the government's financial burden (Öberg et al.,

2018). Second, another essential effort is diversifying funding sources by combining public funds, private investment, and international loans. Apart from that, innovative financing methods such as environmentally friendly bonds and bank infrastructure can have an impact on the field of financial resilience. By implementing robust risk management practices, it is also essential to identify, assess, and mitigate financial, operational, and environmental risks (Chu and Fang, 2019). Utilising PPPs can effectively share the risks and costs that arise between government and private institutions. In addition, taking advantage of technological advances and implementing good sustainable practices can increase project efficiency and compliance with applicable environmental regulations (Zhao et al., 2018). Continuous market analysis and flexible financial planning can help adapt to changes in financial markets to maintain the sustainability of development projects (Ji and Yang, 2020). Finally, by fostering cooperation between the government and international parties, countries can learn from other country's successful projects to provide valuable insights and best practices in improving project management and financial poverty for other large projects.

In addition to these efforts, fostering a transparent and inclusive stakeholder engagement process can significantly enhance the project's attractiveness and viability. Engaging with local communities, businesses, and environmental groups ensures that their concerns and suggestions are considered, thereby reducing opposition and gaining public support. Regular communication and consultations can build trust and provide a platform for addressing potential issues before they escalate. Moreover, adopting best practices in project governance, such as establishing clear accountability, performance metrics, and regular auditing, can improve project oversight and effectiveness. By prioritising sustainability and social responsibility, the project can align with broader societal goals, further enhancing its appeal to investors and stakeholders committed to sustainable development. Ultimately, a multifaceted approach that combines financial innovation, risk management, stakeholder engagement, and sustainable practices will create a more resilient and attractive high-speed train project financing process.

5 Conclusion

Based on the results of a literature review that has been carried out previously, the management of high-speed train financing projects involves several funding sources. It involves good strategies to overcome various complex financial challenges. External factors in the form of government policies, changes in financial markets, and other environmental conditions greatly influence the financing of these large projects. In addition, private investment and PPPs also play an essential role in sharing risks and costs. This has a very significant impact on the success of the construction of this large project. Efforts made to mitigate negative impacts and improve the financial well-being of railway projects are reaching their peak, so strategies such as diversification of funding sources, robust risk management, application of advanced technology, and sustainable practices are needed. The government plays a vital role through direct investment, providing subsidies and guarantees. It is hoped that by implementing this holistic and adaptive approach, high-speed rail projects can continue to be managed effectively so that they can achieve economic and environmental goals in the long term.

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Author contributions

The idea and design of the study were contributed to by all authors. IPS conducted the data analysis and literature search. IPS wrote the original draft of the manuscript, MRS and OFJ provided feedback on earlier drafts. The final manuscript was read and approved by all writers.

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