SOCIOLOGÍA & TECNOCIENCIA

EDICIONES Universidad de Valladolid

Transferencia de Tecnología e Intercambio de Conocimientos Bajo la Iniciativa del Cinturón y Ruta: el caso del Proyecto del Tren de Alta Velocidad Yakarta-Bandung

Technology Transfer and Knowledge Exchange Under Belt and Road Initiative: the case Jakarta-Bandung High-Speed Rail Project

ARIE KUSUMA PAKSI
Department of International Relations, Universitas Muhammadiyah Yogyakarta,
Jl. Ring Road Selatan, Tamantirto, Kabupaten Bantul, Yogyakarta 55184, Indonesia
ariekusumapaksi@umy.ac.id
https://orcid.org/0000-0001-7738-6851

Recibido/Received: 21-05-2025. Aceptado/Accepted: 16-08-2015.
Cómo citar/How to cite: Kusuma Paski Arie (2026). Technology Transfer and Knowledge Exchange Under Belt and Road Initiative: the case Jakarta-Bandung High-Speed Rail Project. *Sociología y Tecnociencia,* 16 (1), 132-150. DOI: https://doi.org/10.24197/bkg1sd25

Resumen: Este artículo ofrece un análisis exhaustivo de la transferencia de conocimiento y la integración tecnológica facilitada por el proyecto del Tren de Alta Velocidad (HSR) Jakarta-Bandung, una iniciativa clave bajo la Iniciativa de la Franja y la Ruta (BRI) de China. El estudio se centra en los esfuerzos colaborativos entre Indonesia y China en la introducción de tecnologías ferroviarias avanzadas, incluyendo el sistema de comunicación GSM-R, las máquinas tuneladoras (TBM), las Unidades Múltiples Eléctricas (EMU) CR400AF, y los sistemas de vía sin balasto. Estas tecnologías no solo están transformando la infraestructura de transporte de Indonesia, sino que también están fomentando una transferencia de conocimiento significativa, dotando a los ingenieros y profesionales indonesios de habilidades y experiencia esenciales en tecnología de alta velocidad ferroviaria. Los hallazgos subrayan el papel crítico del proyecto en la mejora de las capacidades tecnológicas de Indonesia y en su contribución a los objetivos más amplios de modernización y desarrollo económico del país.
Palabras clave: Indonesia, China, Iniciativa de la Franja y la Ruta (BRI); Transferencia de Tecnología; Tren de Alta Velocidad; Transferencia de Conocimiento

Abstract: This paper provides a comprehensive analysis of the knowledge transfer and technology integration facilitated by the Jakarta-Bandung High-Speed Rail (HSR) project, a key initiative under China's Belt and Road Initiative (BRI). The study focuses on the collaborative efforts between

Indonesia and China in introducing advanced railway technologies, including the GSM-R communication system, Tunnel Boring Machines (TBMs), CR400AF Electric Multiple Units (EMUs), and ballastless track systems. These technologies are not only transforming Indonesia's transportation infrastructure but are also fostering significant knowledge transfer, equipping Indonesian engineers and professionals with essential skills and expertise in high-speed rail technology. The findings underscore the project's critical role in enhancing Indonesia's technological capabilities and contributing to its broader goals of modernization and economic development.

Keywords:
Indonesia, China, Belt and Road Initiative (BRI); Technology Transfer; High-Speed Rail; Knowledge Transfer

1. INTRODUCTION

The Jakarta-Bandung High-Speed Rail (HSR) project is often highlighted as a cornerstone of China's Belt and Road Initiative (BRI) in Indonesia, celebrated for its potential to enhance regional connectivity and foster economic growth. As the first high-speed rail project in Southeast Asia, much of the discourse has centered on its geopolitical and economic implications, particularly its role in strengthening the strategic partnership between China and Indonesia (Lingfei Weng et al., 2021;) However, while these aspects are widely discussed, the critical processes of knowledge transfer and technology exchange—integral to the project's long-term success—remain underexplored.

This research aims to address this gap by focusing on the under-discussed, yet pivotal, aspect of the Jakarta-Bandung HSR project: the transfer of advanced technologies and the associated knowledge exchange. The project introduces cutting-edge technologies, such as the Global System for Mobile Communications-Railway (GSM-R), adherence to International Union of Railways (UIC) standards, and the Whoosh high-speed rail technology, which are expected to significantly elevate Indonesia's transportation infrastructure (Rusdiyanta, Bambang Pujiyono, 2023). Despite the transformative potential of these technologies, the mechanisms by which they are transferred and adapted to the local context, as well as their implications for building local expertise and capacity, are seldom the focus of existing studies.

The limited discussion around these critical elements raises important questions about how effectively such technology transfers are being implemented and sustained within Indonesia. Given the complexities involved—ranging from coordination challenges between Chinese and Indonesian stakeholders to the cultural and institutional barriers that influence the process—the success of this technology transfer is far from guaranteed (Yuniarto, 2021; Thalib, 2016) . This study, therefore, seeks to bring these hidden aspects to the forefront, offering a detailed analysis of the technology and knowledge transfer processes involved in the Jakarta-Bandung HSR project.

By focusing on these underexplored dimensions, this research aims to provide a more comprehensive understanding of the project's significance beyond its immediate economic and geopolitical impacts. It will explore how the successful transfer and localization of advanced technologies can contribute to Indonesia's broader goals of technological advancement and economic modernization, thereby filling a critical gap in the existing literature on the BRI.

2. RESEARCH FRAMEWORK

Understanding technology transfer and knowledge exchange within international development projects, such as those propelled by the Belt and Road Initiative (BRI), demands a sophisticated and integrated theoretical approach. This approach should combine traditional models of technology transfer with modern insights from the knowledge-based theory of firms and the concept of absorptive capacity. These components collectively provide a comprehensive framework that encapsulates the complexities of adapting technologies across diverse geopolitical and cultural landscapes.

Traditional models of technology transfer, which primarily consider the process as a linear and transactional transfer of skills and systems from developed to developing regions, form the foundation of this framework. However, these models are often criticized for their limited scope, as they typically overlook the nuanced dynamics of how technologies are subsequently adapted and integrated into the recipient's socio-economic environment. Bozeman (2000) highlights the need for a broader perspective that incorporates policy and institutional factors, which can significantly influence the effectiveness of technology adoption. Additionally, Rosenberg (1994) discusses the importance of the recipient's technological and absorptive capabilities, suggesting that the actual impact of transferred technology is heavily contingent on local conditions.

Expanding upon these traditional models, the knowledge-based theory of firms introduces a more dynamic element to the framework. It suggests that knowledge acts as a strategic asset, essential for the successful transfer and integration of technology. This theory emphasizes that effective technology transfer goes beyond the mere dissemination of explicit knowledge to include the transfer of tacit knowledge, which requires customized learning processes and adaptation by the receiving entities. The sticky nature of tacit knowledge, as described by Szulanski (2016), underscores the challenges inherent in transferring such deeply embedded and context-specific information.

The concept of absorptive capacity, developed by Cohen and Levinthal (1990) , further enriches this framework. It defines absorptive capacity as the ability of organizations to recognize the value of new information, assimilate it, and apply it effectively. This capacity is pivotal in determining how well new technologies are integrated into existing systems and can be enhanced through strategic changes within the organization or nation. The development of absorptive capacity is essential for not only adopting new technologies but also for adapting them to local needs and creating new innovations based on them. Bernard M. Hoekman, Keith E. Maskus, & Kamal Saggi (2004) research on international technology transfer introduces three key criteria for assessing the success of these transfers: the costs of technology transfer, the assimilation of the imported technology, and the contribution of the transfer to the development of indigenous technological capabilities within the technology-importing enterprise and economy. This perspective is crucial as it links the contents of technology transfer to the evolving levels of technological capability, offering a layered understanding of the process.

Similarly, the study by Mohammed Ali Berawi & Perdana Miraj (2023) provides empirical evidence on the distribution of technology capabilities across local institutions in Indonesia, highlighting how developing countries combine various local resources to assimilate complex technological systems. Their work illustrates that as technologies become more complex, developing countries benefit not merely from accumulating capabilities through transfer but also from learning within systemic environments.

Integrating these insights into a cohesive model, the Holistic Technology Absorption and Knowledge Adaptation (HTAKA) framework emerges. This framework does not only consider the physical transfer of technology but also stresses the importance of strategic knowledge management and the development of local capabilities. By recognizing the complexities involved—from initial transfer to full integration, adaptation, and innovation—the HTAKA framework offers a nuanced approach to managing technology transfer in international development projects. It ensures that technology transfer is not merely about relocating technology across borders but about creating lasting impacts through capacity building and systemic innovation.

The application of this framework in BRI projects, for instance, facilitates a deeper analysis of how technologies and methodologies are adapted to local conditions, ensuring not only the transfer but also the sustainability of technological advancements. This holistic approach helps address the socio-economic, cultural, and organizational factors that significantly impact the success of technology transfer initiatives, thereby ensuring they meet the immediate needs and long-term developmental goals of recipient nations.

The integration of traditional and contemporary theories within the HTAKA framework provides a comprehensive tool for understanding and facilitating technology transfer under large-scale initiatives like the BRI. It aids in navigating the complexities of cross-cultural technology transfer, ensuring that the technologies are not only transferred effectively but are also adapted and utilized in a manner that maximizes their benefit and sustainability.

3. RESEARCH METHOD

This study employs a qualitative research methodology, focusing on secondary data analysis to explore the processes and impacts of technology transfer in the Jakarta-Bandung HSR project under the BRI. Qualitative research is particularly suitable for examining complex social phenomena, such as international technology transfer, where understanding the context, relationships, and underlying mechanisms is crucial (Creswell, J. W., & Poth, C. N., 2017).

The primary data sources for this study include academic journal articles, government reports, news articles, and technical documents related to the BRI, the Jakarta-Bandung HSR project, and technology transfer practices. These sources were selected to provide a comprehensive overview of the project's implementation, the technological systems involved, and the challenges faced during the process. The selection of secondary data allows the researcher to gather a broad range of insights from multiple perspectives, which is essential for a thorough analysis of the project's impact on technology transfer in Indonesia (Flick, 2018).

The study employs thematic analysis to identify and analyze patterns within the collected data. Thematic analysis is a flexible method that allows for the identification of recurring themes and insights across qualitative data, making it particularly useful for understanding the complexities of technology transfer and international collaboration (Braun, 2006). The data were systematically reviewed and coded, with themes such as "technology adoption," "knowledge transfer," and "challenges in implementation" emerging as central to the analysis. This approach enables the researcher to draw connections between the different data sources and to construct a coherent narrative around the key issues addressed in the study.

To ensure the validity and reliability of the findings, the study triangulates data from multiple sources. Triangulation involves cross-verifying information from different types of sources to confirm the consistency and credibility of the findings (Denzin, N. K., 2017). Additionally, the research adheres to ethical standards in data analysis, ensuring that all sources are properly cited and that the interpretations of the data are grounded in the original context.

One limitation of this study is the reliance on secondary data, which may not capture all the nuances of the on-ground realities of the Jakarta-Bandung HSR project. While secondary data analysis provides valuable insights, it is dependent on the availability and quality of existing information. Future research could benefit from incorporating primary data, such as interviews with key stakeholders involved in the project, to gain deeper insights into the challenges and successes of technology transfer in this context.

This methodological approach allows for a comprehensive examination of the Jakarta-Bandung HSR project, providing a detailed understanding of the processes and outcomes of technology transfer within the framework of the BRI. The findings from this study contribute to the broader discourse on international technology transfer and the role of large-scale infrastructure projects in facilitating technological and economic development in emerging economies.

4. FINDINGS AND ANALYSIS

This section provides a detailed examination of the knowledge transfer and technological innovations embedded within the Jakarta-Bandung HSR project, a flagship endeavor under China's BRI. The project stands as a testament to the strategic collaboration between China and Indonesia, aimed at enhancing Indonesia's infrastructure through the integration of cutting-edge technologies and best practices. First, it will discuss the knowledge transfer facilitated by this project, which extends beyond the mere physical deployment of advanced systems to include building local capacity, improving technical skills, and fostering innovation in Indonesia's industrial sector. The section will then explore the significant technological innovations introduced in the Jakarta-Bandung HSR project, focusing on four key areas: the integration of advanced communication systems with GSM-R technology, the implementation of innovative tunneling techniques to overcome complex geological challenges, the deployment of the CR400AF Electric Multiple Units (EMUs) that blend cultural significance with technological sophistication, and the adoption of a state-of-the-art ballastless track system. Each of these technologies plays a pivotal role in ensuring the operational efficiency, safety, and long-term sustainability of the HSR system, while also contributing to the broader goal of modernizing Indonesia's infrastructure and enhancing its connectivity on a global scale.

4.1. BRI, Jakarta-Bandung speed train and knowledge transfer

The BRI is positioned as a transformative framework aimed at enhancing global connectivity through strategic investments in infrastructure, trade, and technological collaboration. Central to the BRI's mission is the transfer of advanced technologies from China to participating countries, with the goal of fostering development and modernizing local industries (Xinhua Headlines: Indonesia's first high-speed railway comes into service, heralding new era, 2023). In Indonesia, the BRI has been particularly impactful in the domain of high-speed rail, with the Jakarta-Bandung HSR project serving as a flagship example of this collaboration. The project is not only a major infrastructure endeavor but also a significant vehicle for technology transfer, promising to introduce cutting-edge railway technologies that could elevate Indonesia's transportation infrastructure to global standards (Berger, 2023; Paksi, 2023).

One of the core promises of the BRI in Indonesia is the facilitation of knowledge transfer, which extends beyond the mere physical deployment of high-tech systems. The Jakarta-Bandung HSR project exemplifies this through the systematic transfer of technological know-how from Chinese experts to Indonesian engineers and technicians. This process is crucial for building local capacity, improving technical skills, and fostering innovation within Indonesia's burgeoning industrial sector. The knowledge transfer encompasses a wide range of activities, including the operation and maintenance of sophisticated systems like the GSM-R, the adoption of ballastless track technology, and the use of Tunnel Boring Machines (TBMs) equipped with real-time monitoring systems (Kartiko Putranto; Don Stewart; Graham Moore, 2001).

A significant aspect of the knowledge transfer in the Jakarta-Bandung HSR project is the comprehensive training programs and workshops conducted by Chinese experts. These programs are designed to equip Indonesian professionals with the necessary skills to manage and maintain the advanced technologies introduced by the project. The training covers various facets, from the technical aspects of high-speed rail operations to safety protocols and project management techniques. This holistic approach ensures that Indonesian engineers and technicians are not only familiar with the new technologies but are also capable of innovating and adapting them to suit local conditions (Klabisch, 2023).

Furthermore, the knowledge transfer extends to the broader aspects of project execution and management. The Jakarta-Bandung HSR project has introduced Indonesian professionals to new construction methodologies and project management frameworks that are critical for the successful implementation of large-scale infrastructure projects. For instance, the use of advanced grouting techniques in tunnel construction and the deployment of the Girder Launcher for efficient bridge construction are techniques that were previously unfamiliar in Indonesia but have now been successfully integrated into local practices. This exposure to new technologies and methodologies is instrumental in enhancing Indonesia's overall infrastructure capabilities and sets a precedent for future projects within the country.

The effectiveness of these knowledge transfer efforts is particularly evident in the progressive shift towards greater local involvement in the operation and maintenance phases of the project. Initially, much of the technical expertise was provided by Chinese professionals, but over time, Indonesian engineers and technicians have increasingly taken on these roles, reflecting the success of the training and capacity-building initiatives. This transition is crucial for the long-term sustainability of the project, as it ensures that the Jakarta-Bandung HSR can be operated and maintained independently by local professionals, thereby reducing dependency on foreign expertise (Wijaya, 2024).

In addition to the technical knowledge transfer, the BRI framework also promotes the exchange of managerial and operational best practices. The Jakarta-Bandung HSR project has exposed Indonesian stakeholders to the rigorous project management practices employed by Chinese companies, including advanced planning, risk management, and quality control processes (Wijaya, 2024). These practices are essential for the successful execution of large-scale infrastructure projects and have been adapted to fit the specific context of Indonesia, thereby enhancing the overall efficiency and effectiveness of the project.

Overall, the Jakarta-Bandung HSR project under the BRI framework represents a significant leap forward in Indonesia's infrastructure development. The project's emphasis on knowledge transfer and capacity building is not only transforming the country's transportation sector but also contributing to the broader goal of technological modernization. By equipping local professionals with the skills and expertise needed to operate and maintain advanced rail systems, the BRI is helping Indonesia to bridge the technological gap with more developed nations and to achieve its developmental goals more rapidly (Zheng, 2023).

As the project progresses, it is not only reshaping the nation's transportation infrastructure but also serving as a conduit for the transfer of cutting-edge technologies from China to Indonesia. The following sections delve into four of the most notable high technologies that have been integrated into this ambitious project: advanced communication systems, innovative tunneling techniques, state-of-the-art train models, and the implementation of a ballastless track system. Each of these technologies plays a crucial role in ensuring the operational efficiency, safety, and long-term sustainability of the Jakarta-Bandung HSR, while also contributing to the broader goal of modernizing Indonesia’s infrastructure and enhancing its global connectivity.

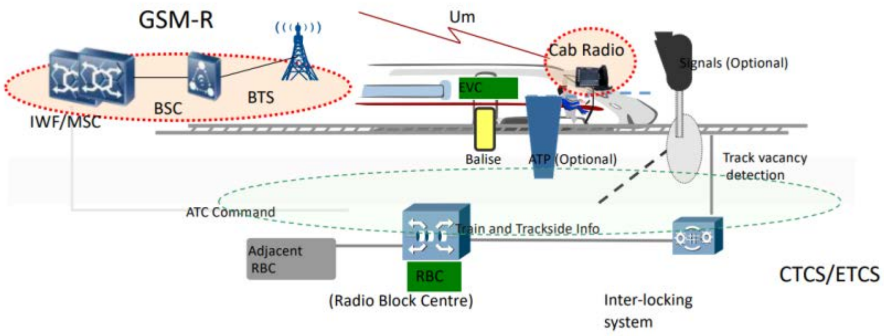
4.2. Technological innovation in the Jakarta-Bandung high speech rail project

This section delves into the key technological components that have been integrated into the project, each playing a crucial role in ensuring the efficiency, safety, and sustainability of the HSR system. The discussion will explore four major areas of innovation: the advanced communication systems with the integration of GSM-R technology, the cutting-edge tunneling techniques employed to overcome complex geological challenges, the culturally significant yet technologically sophisticated CR400AF EMUs, and the implementation of a state-of-the-art ballastless track system (Railway Technology, 2022). Together, these innovations not only elevate the operational standards of the Jakarta-Bandung HSR but also position Indonesia as a leader in modern rail transport within the region.

a. Communication Technology

The Jakarta-Bandung HSR project represents a milestone in Indonesia's transportation infrastructure, particularly through the integration of the GSM-R technology (see Picture 1). GSM-R is a specialized communication platform designed to meet the rigorous demands of high-speed railway operations. As of recent advancements, GSM-R has evolved to support not only voice and data communications but also enhanced features like Emergency Call (EIRENE) standards and Location Dependent Addressing (LDA), which are critical for the safe and efficient operation of high-speed trains (UIC, 2022). The adoption of GSM-R within the Jakarta-Bandung HSR project aligns Indonesia's railway infrastructure with these cutting-edge global standards, ensuring that the country’s systems are in sync with international benchmarks as established by the UIC (KCIC, 2021).

Picture 1: GSM-R Communication System



Source: (Regina Riyantika & Dadang Gunawan, 2023)

The GSM-R system is indispensable for the operation of high-speed trains, providing a robust communication link between trains and control centers. Recent studies highlight the system's ability to support critical functions such as real-time data transmission, seamless voice communication, and the relay of safety-critical signals, all of which are essential for maintaining operational safety and efficiency at high speeds. The implementation of GSM-R in the Jakarta-Bandung HSR project not only introduces advanced communication technology to Indonesia's railway network but also facilitates substantial knowledge transfer. Recent collaborative training programs have been instrumental in equipping Indonesian engineers with the necessary expertise to independently manage and sustain the GSM-R system, thereby fostering long-term operational sustainability (KCIC, 2021).

Moreover, the adoption of UIC standards in the Jakarta-Bandung HSR project further emphasizes the project's commitment to global best practices. UIC standards, which have been updated to incorporate the latest in railway safety and interoperability, ensure that the Jakarta-Bandung HSR's technology and operations are compatible with international rail systems, thereby potentially facilitating future cross-border rail connectivity. Adhering to these standards simplifies maintenance and operational processes, reduces the likelihood of technical failures, and enhances overall system reliability. Recent studies underscore the importance of such standardization, particularly in large-scale infrastructure projects where consistency and interoperability are critical to long-term success.

In addition to the GSM-R communication system, the Jakarta-Bandung HSR project has integrated the latest Whoosh high-speed rail technology. This technology, designed to drastically reduce travel times between Jakarta and Bandung, incorporates advanced propulsion and braking systems, ensuring not only faster but also safer and more energy-efficient travel. The integration of Whoosh technology, coupled with GSM-R and UIC standards, represents a comprehensive modernization of Indonesia's railway infrastructure (KCIC, 2021). This modernization is holistic, extending beyond physical construction to encompass the transfer of critical knowledge and skills to the local workforce. Recent reports emphasize that such knowledge transfer is crucial for Indonesia’s ability to maintain and upgrade its railway systems independently, ensuring long-term sustainability and self-reliance.

b. Tunnel Construction

The construction of tunnels within the Jakarta-Bandung HSR project represents a critical aspect of this ambitious infrastructure undertaking, involving the introduction of advanced technologies to tackle the complex geological challenges. The project includes the construction of 14 tunnels, among which Tunnel 2 has garnered significant attention due to the particularly difficult geological conditions. However, the overall tunnel construction process has incorporated a range of cutting-edge technologies to ensure safety, efficiency, and structural integrity across all tunnel segments (China Report ASEAN, 2023).

One of the most significant challenges encountered during the construction was the presence of clay shale, a highly unstable and water-sensitive soil type. Clay shale's tendency to swell upon exposure to moisture posed a serious risk of ground deformation and tunnel collapse. To address these challenges, the project employed advanced grouting techniques. Grouting, which involves injecting a cementitious mixture into the ground, was further enhanced with the use of nano-modified grouts that provide superior penetration and bonding strength, effectively stabilizing the soil and reinforcing the tunnel structure (China Report ASEAN, 2023). This technique was crucial in Tunnel 2 but was also applied in other sections where similar geological risks were identified, showcasing the project's proactive approach to mitigating potential hazards.

Beyond grouting, the Jakarta-Bandung HSR project introduced several other high-tech solutions to overcome the geological complexities and ensure efficient construction. One such innovation is the use of TBMs equipped with advanced monitoring systems. These TBMs, designed to operate in challenging ground conditions, are fitted with sensors that provide real-time data on soil pressure, moisture content, and tunnel alignment. This data is crucial for making immediate adjustments during the boring process, thereby reducing the risk of tunnel deformation and ensuring that the tunnel remains within the designed specifications. Additionally, the TBMs used in this project are capable of automatic segmental lining installation, which significantly accelerates the construction process while maintaining high safety standards.

The project also utilized the New Austrian Tunneling Method (NATM) in certain segments, which is particularly effective in unstable geological formations like those found in parts of the Jakarta-Bandung HSR route. NATM involves careful monitoring of the rock behavior and adjusting the support structures in real-time during excavation. This method enhances the flexibility and safety of the tunneling process, making it well-suited for the variable conditions encountered along the HSR route.

Picture 2: Girder Launcher in Jakarta-Bandung Speed Train Project
Source


:

Xinhua 2022

A key element in the construction of the Jakarta-Bandung HSR tunnels was the use of the Girder Launcher (see Picture 2), particularly in areas where the tunnels transitioned into elevated sections. The Girder Launcher is an advanced piece of equipment designed to place large girders without disrupting ongoing traffic or daily activities in the surrounding areas. This technology was essential in maintaining the project schedule, as it allowed for the rapid and precise placement of girders, which are crucial for supporting the elevated tracks that connect various tunnel sections (Xinhua, 2022). The efficiency and precision offered by the Girder Launcher minimized the potential disruptions that could have been caused by more traditional construction methods, ensuring that the project proceeded without significant delays.

The incorporation of these high-tech methods and tools highlights the Jakarta-Bandung HSR project's commitment to innovation and safety in construction. By leveraging advanced technologies like nano-grouting, TBMs with real-time monitoring, and the NATM approach, the project has successfully navigated the complex geological challenges of tunnel construction. This integration of cutting-edge engineering solutions, combined with the expertise of both local and international specialists, has been pivotal in advancing the construction of the tunnels, ensuring that the Jakarta-Bandung HSR meets its structural and operational goals.

c. Train Model

The Jakarta-Bandung HSR project features the deployment of CR400AF-type EMUs, developed by CRRC Qingdao Sifang, a leading Chinese manufacturer of rolling stock. The selection of these EMUs marks a significant technological milestone for Indonesia, as they integrate state-of-the-art high-speed rail technology into the country's transportation infrastructure (Railway Technology, 2022). The CR400AF (see Picture 3), part of China's prestigious "Fuxing" series, is designed to operate at speeds of up to 350 km/h, making it one of the fastest trains globally. This model is not only a testament to China's advancements in high-speed rail but also a strategic component of China's rail export strategy under the BRI (CGTN, 2022). Its deployment in Indonesia underscores the deepening collaboration between the two nations in infrastructure development.

Picture 3: Uni Model of Jakarta-Bandung Speed Train

Source: (CNBCIndonesia, 2019)

The CR400AF EMUs are specifically tailored to reflect Indonesian cultural heritage, an approach that highlights the project's sensitivity to local identity while showcasing international engineering excellence. The exterior of the train is inspired by the Komodo dragon, an iconic species native to Indonesia, symbolizing strength and resilience. This design choice resonates with Indonesia's national pride and cultural symbolism. Inside, the trains feature traditional Indonesian Megamendung batik motifs, which are known for their cloud-like patterns symbolizing tranquility and hope. This fusion of cultural elements with cutting-edge technology demonstrates an effort to create a high-tech product that is also culturally resonant, making the CR400AF not just a mode of transport but a cultural ambassador on rails (CGTN, 2022).

The CR400AF EMUs are equipped with advanced features designed to enhance passenger comfort and convenience. These trains offer multiple classes, including VIP, first, and second class, catering to a wide range of passenger preferences and needs. The inclusion of modern amenities such as dining car facilities allows passengers to enjoy meals during their journey, while the availability of charging ports and dedicated facilities for disabled passengers reflects a strong commitment to accessibility and inclusivity in modern rail travel. Additionally, the trains are designed with ample luggage storage space to accommodate the varying needs of travelers, further enhancing the overall travel experience (CGTN, 2022).

By April 2022, all 11 EMUs designated for the Jakarta-Bandung HSR project had been completed. The unveiling of the first of these high-speed EMUs in August 2022 marked a significant milestone in the project's development. Alongside the EMUs, Indonesia also received a Comprehensive Inspection Train (CIT), a critical asset for ensuring the ongoing safety and reliability of the rail network. The CIT is equipped with cutting-edge diagnostic tools capable of detecting track conditions, measuring overhead electrical systems, inspecting communication and signaling equipment, and analyzing wheel-rail dynamics (CGTN, 2022). This train plays a crucial role in maintaining the high operational standards required for a high-speed rail network, as it collects, processes, and analyzes data in real time, providing vital insights that ensure smooth and safe operations.

The deployment of the CR400AF EMUs and the CIT in Indonesia represents a significant leap forward in the country's rail transport capabilities. The integration of these advanced trains into Indonesia's rail network is expected to drastically reduce travel times between Jakarta and Bandung, transforming the daily commute between these two major cities (VOI, 2022). Furthermore, the CR400AF EMUs are part of a broader initiative to modernize Indonesia's transportation infrastructure, aligning it with international standards and enhancing the country's connectivity on a global scale. This modernization effort not only improves domestic travel efficiency but also positions Indonesia as a key player in the regional high-speed rail network, potentially opening up new economic opportunities through improved logistics and mobility.

d. Ballastless Track System

The Jakarta-Bandung HSR project integrates a state-of-the-art ballastless track system across 85.3 kilometers of its 142.3-kilometer mainline, covering approximately 60% of the entire route. This advanced track system was selected for its superior stability, durability, and efficiency, which are essential for supporting high-speed rail operations where trains travel at speeds of up to 350 km/h. The scale of the project is underscored by the requirement for 30,177 ballastless track slabs, reflecting the complexity and precision involved in its construction (Xinhua, Construction of ballastless track slabs completed for Indonesia's Jakarta-Bandung High-Speed Railway, 2023).

Unlike traditional ballasted tracks, which utilize crushed stone to stabilize the track bed, ballastless tracks employ concrete or asphalt slabs. These materials provide enhanced rigidity, a critical factor in withstanding the dynamic loads imposed by high-speed trains. The choice of ballastless track offers several significant advantages, including reduced maintenance costs, improved track stability, and a longer operational lifespan. These benefits are crucial for ensuring the reliable and efficient operation of the high-speed rail system, making ballastless tracks a preferred choice for modern high-speed rail projects globally (Wang et al., 2023).

The installation of the ballastless track system in the Jakarta-Bandung HSR project involves the use of specialized heavy machinery (see Picture 4), each designed to perform specific tasks in the construction process. One of the key pieces of equipment is the CPG500 Ballast Track Laying Machine, which is responsible for laying the track panels, including rails and sleepers. This machine operates with high precision, ensuring that the track is laid accurately, thereby providing a stable and reliable foundation for the high-speed trains.

Picture 4: Instalation of Ballastless Track

Source: (Xinhua, Construction of ballastless track slabs completed for Indonesia's Jakarta-Bandung High-Speed Railway, 2023)

Another crucial machine in this process is the WZ 500-ty Ballastless Track Laying Hauling Vehicle, which transports and positions the heavy track panels. Its capacity to handle the substantial weight and dimensions of the track components is vital for maintaining construction efficiency, particularly given the scale of the

Project. The SPZ-100 Ballast Deformating Vehicle plays a pivotal role in adjusting and deforming the ballastless track slabs to achieve perfect alignment and stability before the final installation. This alignment process is essential to ensure that the track can endure the high dynamic loads from the trains, preventing issues such as track misalignment or deformation, which could jeopardize the safety and performance of the rail line.

To ensure that the track slabs are securely fixed in place, the DC-32K Tamping Vehicle is used to compact and stabilize the track bed. Proper tamping is crucial as it prevents any movement of the track slabs, which could lead to operational issues such as misalignment or track deformation over time. The importance of this process cannot be overstated, as even minor shifts in the track alignment could lead to significant disruptions in high-speed rail operations.

For the continuity and integrity of the rail line, the K922 Movable Flash Welder is employed to weld the rail joints, creating seamless connections between the rail sections. This welding process is critical for reducing the risk of rail fractures or failures that could disrupt operations. Additionally, the GMC 48JS Rail Grinding Car is utilized to smooth out any irregularities on the rail surface, which helps reduce friction and wear on the train wheels. Regular rail grinding is an essential maintenance process that also helps to prevent track-related issues like corrugation, which can negatively affect ride quality and increase maintenance costs.

Finally, the GC-220 Rail Car is used for transporting various track components to the installation site, facilitating the efficient assembly of the track system. This vehicle plays a crucial role in ensuring that all necessary components are available on-site, allowing the construction process to proceed smoothly and without delays. The combination of these specialized machines ensures that the ballastless track system is installed with the precision and durability required for the high-speed rail operations of the Jakarta-Bandung HSR Project.

In short, the Jakarta-Bandung High-Speed Rail project exemplifies the integration of advanced technologies to create a modern, efficient, and sustainable transportation system in Indonesia. Through the deployment of GSM-R communication systems, cutting-edge tunneling techniques, the CR400AF Electric Multiple Units, and a state-of-the-art ballastless track system, the project sets new standards for railway infrastructure in the region (Railway Technology, 2022). These innovations not only enhance the operational efficiency and safety of the HSR system but also position Indonesia as a leader in modern rail transport. As the project continues to progress, it will serve as a model for future infrastructure developments, demonstrating the transformative potential of strategic technological collaboration and innovation in fostering national growth and regional connectivity.

5. Conclusion

The Jakarta-Bandung HSR project, under the Belt and Road Initiative (BRI), exemplifies the successful transfer of advanced technologies and knowledge from China to Indonesia. Through the integration of cutting-edge technologies such as the GSM-R communication system, TBMs, CR400AF EMUs, and a state-of-the-art ballastless track system, the project significantly enhances Indonesia's transportation infrastructure. These technological advancements are not only pivotal in modernizing the country's rail system but also play a crucial role in fostering local capacity building.

The systematic knowledge transfer facilitated by the project has equipped Indonesian engineers and technicians with essential skills in high-speed rail technology. This includes comprehensive training programs and on-the-job learning opportunities, which have been integral to ensuring that these technologies are effectively adapted and sustained within the local context. The collaboration between Chinese and Indonesian stakeholders has set a new benchmark for international infrastructure projects, highlighting the importance of knowledge exchange in achieving long-term developmental goals.

To ensure the continued success of technology transfer in BRI projects, several policy measures should be considered. First, a bilateral technology transfer task force can be established to institutionalize coordination between stakeholders and identify gaps in absorptive capacity. Second, integrating high-speed rail education into Indonesian university and vocational curricula would help sustain technical expertise and foster innovation. Third, fiscal incentives such as tax breaks or research and development grants could motivate local firms to adapt and further develop imported technologies. Fourth, a robust monitoring and evaluation framework should be implemented to periodically assess the effectiveness of technology transfer, including metrics on skill acquisition and local innovation. Finally, strengthening intellectual property rights protections and clarifying co-ownership regulations can build trust in collaborative innovation and ensure equitable benefits between partners.

Overall, the Jakarta-Bandung HSR project stands as a landmark in Indonesia's journey towards technological modernization. It not only bridges the technological gap between Indonesia and more developed nations but also enhances the country's position within the global infrastructure landscape. With the integration of these policy recommendations, future BRI projects can evolve beyond infrastructure development to become platforms for technological empowerment and inclusive, sustainable development. As a model for future BRI projects, the success of this initiative underscores the transformative potential of strategic international collaborations in fostering sustainable development.

REFERENCES

Berger, B. H. (2023, 11 11). *The Jakarta-Bandung High-Speed Railway: Indonesia's Lessons Learned*. Retrieved from The Diplomat: https://thediplomat.com/2023/11/the-jakarta-bandung-high-speed-railway-indonesias-lessons-learned/

Bernard M. Hoekman, Keith E. Maskus, & Kamal Saggi. (2004). *Transfer Of Technology To Developing Countries: Unilateral and Multilateral Policy Options.* World Bank Policy Research Working Paper 3332, 2004 .

Bozeman, B. (2000). Technology transfer and public policy: a review of research and theory. *Research Policy, 29(4-5),* 627-655.

Braun, V. &. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3(2),,* 77-101.

CGTN. (2022, 08 07). *12 China-made high-speed trains for Indonesia roll off production line*. Retrieved from CGTN: https://news.cgtn.com/news/2022-08-06/12-China-made-high-speed-trains-for-Indonesia-roll-off-production-line-1chAcBnOzxS/index.html

China Report ASEAN. (2023, 11 10). *Construction of the Jakarta-Bandung High-Speed Railway required overcoming world-level challenges with myriad technological breakthroughs*. Retrieved from PR Newswire: https://en.prnasia.com/releases/apac/construction-of-the-jakarta-bandung-high-speed-railway-required-overcoming-world-level-challenges-with-myriad-technological-breakthroughs-426512.shtml

CNBCIndonesia. (2019, 07 30). *Keren, Mewahnya Kereta Cepat China Rute Jakarta-Bandung*. Retrieved from KCIC: https://kcic.co.id/keren-mewahnya-kereta-cepat-china-rute-jakarta-bandung/

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. **Administrative Science Quarterly, 35*(1),* , 128-152.

Creswell, J. W., & Poth, C. N. (2017). *Qualitative inquiry and research design: Choosing among five approaches (4th ed.).* SAGE Publications.

Denzin, N. K. (2017). *The Research Act: A theoretical introduction to sociological methods.* Routledge.

Flick, U. (2018). *An introduction to qualitative research (6th ed.).* SAGE Publications.

Kartiko Putranto; Don Stewart; Graham Moore. (2001). International technology transfer and distribution of technology capabilities: the case of railway development in Indonesia. *Technology in Society, Volume 25, Issue 1*.

KCIC. (2021, 09 22). *Kereta Api Cepat Jakarta-Bandung Gunakan Teknologi GSM-R Standar UIC*. Retrieved from KCIC: https://kcic.co.id/kcic-siaran-pers/kereta-api-cepat-jakarta-bandunggunakan-teknologi-gsm-r-standar-uic/

Klabisch, J. (2023, 10 11). *A Belt and Road prestige project: A story of the Jakarta-Bandung high-speed railway*. Retrieved from Business & Human Rights Resource Centre: https://www.business-humanrights.org/en/blog/a-belt-and-road-prestige-project-a-story-of-the-jakarta-bandung-high-speed-railway/

Lingfei Weng; Lan Xue; Jeffrey Sayer; Rebecca Anne Riggs; James Douglas Langston; Agni Klintuni Boedhihartono . (2021). Challenges faced by Chinese firms implementing the 'Belt and Road Initiative': Evidence from three railway projects. *Research in Globalization Volume 3*.

Mohammed Ali Berawi & Perdana Miraj. (2023). Rail liberalization for Indonesian railways: Learn from the experience of Germany and France. *Transportation Research Interdisciplinary Perspectives, Vol 22*.

Paksi, A. (2023). *Kerja Sama Indonesia dan Cina dalam Program Belt and Road Initiative*. Komojoyo Press

Railway Technology. (2022, 9 2). *Jakarta-Bandung High-Speed Railway, Indonesia*. Retrieved from Railway Technology: https://www.railway-technology.com/projects/jakarta-to-bandung-high-speed-rail/?cf-view

Regina Riyantika & Dadang Gunawan. (2023). Feasibility Analysis Of Gsm-R System For Railways In Indonesia: Case Study Of Jakarta Bandung High Speed Train. *Journal Research of Social Science, Economics, and Management, Vol. 3 No. 5* .

Rosenberg, N. (1994). *Exploring the black box: Technology, economics, and history.* Cambridge University Press.

Rusdiyanta, Bambang Pujiyono. (2023). Evaluation of the Jakarta-Bandung Fast Train Policy using GSM-R Technology in the Era of the Industrial Revolution (2021–2023). *International Journal of Innovative Research in Engineering & Multidisciplinary Physical Sciences*.

Szulanski, G., Ringov, D., & Jensen, R. J. (2016). Overcoming stickiness: How the timing of knowledge transfer methods affects transfer difficulty. *Organization Science, 27 (2),* , 304-322.

Thalib, A. (2016). Technology Transfer In Indonesia And China: A Comparative Study. *Jurnal Hukum IUS QUIA IUSTUM*.

UIC. (2022, 05 18). *Global System for Mobile communications - Railways*. Retrieved from uic.org: https://uic.org/rail-system/telecoms-signalling/article/gsm-r

VOI. (2022, 10 20). *Specifications For The Jakarta-Bandung High-speed Train That Will Soon Be Enjoyed*. Retrieved from voi.id: https://voi.id/en/news/220131/

Wijaya, T. (2024). "Risk is not Measured, but Contested and Compromised": A Case Study of Jakarta–Bandung High-Speed Railway. *Journal of Contemporary Asia*, 1-25.

Xinhua. (2022, 05 26). *Box girders erected on sections of Indonesia's Jakarta-Bandung high-speed rail*. Retrieved from english.news.cn: https://english.news.cn/20220526/ca21e12467cc4dce92b1afed2d483d1d/c.html

Xinhua. (2023, 02 16). *Construction of ballastless track slabs completed for Indonesia's Jakarta-Bandung High-Speed Railway*. Retrieved from english.news.cn: https://english.news.cn/20230216/47905586a0ac4d4691637b69020f7ba0/c.html

Xinhua Headlines: Indonesia's first high-speed railway comes into service, heralding new era. (2023, 10 03). Retrieved from Xinhua: https://english.news.cn/20231003/2e390731aee349c7aae98d8a7c5b3faf/c.html

Yuniarto, R. (2021). Opportunities and Challenges of Socio-Cultural Cooperation in China's Belt and Road Initiative in Indonesia. *Jurnal Hubungan Internasional, Vol 9, No 2*, 98-111.

Zheng, N. (2023, 10 25). *China Helps Indonesia Hit The Fast Track*. Retrieved from ChinaDaily.co.cn: https://www.chinadaily.com.cn/a/202310/25/WS6538815aa31090682a5ea9b9.html