SCIENTIFIC CULTURE
www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 12, No. 4, (2026), pp. 4757-4768
Open Access. Online & Print

DOI: 10.5281/zenodo.12426521

CHINA-MEXICO ACADEMIC BRIDGES: CULTURAL INSIGHTS FROM A BEIJING TRAINING PROGRAM ON SUSTAINABLE INFRASTRUCTURE AND INTELLIGENT LOGISTICS

Bogart Yail Marquez[1]*, Beatriz Chavez Ceja[2], Artemio Lara Chavez[3]

[1]Tecnológico Nacional de México campus Tijuana
[2]Tecnológico Nacional de México campus Tijuana
[3]Tecnológico Nacional de México campus Tijuana

Received: 18/10/2025
Accepted: 23/01/2026

Corresponding Author: Bogart Yail Marquez (bogart@tectijuana.edu.mx)

Abstract:

This article presents the collective reflections derived from participation in the "Road/Railway Construction and Management Course for Mexico," held at Beijing Jiaotong University in 2025, sponsored by the Ministry of Commerce of the People's Republic of China. Through an interdisciplinary approach combining civil engineering, smart logistics, and cultural studies, it analyzes Chinese advancements in high-speed rail infrastructure, with particular emphasis on ballastless track systems (CRTS III), the integration of 5G and edge computing for predictive inspection, and smart logistics as a driver of multimodal optimization. The results reveal that Chinese technologies offer technically superior solutions to traditional ballast, with greater geometric stability, less maintenance, and improved performance under seismic and high-speed conditions. These findings are particularly relevant for Mexico. Furthermore, the sociocultural experience in Beijing allowed us to observe how a high level of civic engagement and collective trust facilitates the widespread adoption of advanced technologies. It is concluded that the selective transfer of these practices, along with strengthened bilateral cooperation between Mexican and Chinese institutions, represents a strategic opportunity to enhance the safety, efficiency, and sustainability of the national railway infrastructure. The article underscores the need to pilot ballastless tracks where necessary, implement intelligent logistics systems, and promote continuing education programs as concrete pathways toward more resilient and competitive development.

KEYWORDS: ballastless tracks, high-speed railways, intelligent logistics, China-Mexico cooperation, railway sustainability, technology transfer.

1 INTRODUCTION

Participation in the "Training Course on Highway and Railway Construction and Management for Mexico" (**墨西哥公路**、铁路建设与管理研修班), held at Beijing Jiaotong University (BJTU), represented a unique opportunity for a group of Mexican professionals from various institutions, including the Tijuana campus of the National Technological Institute of Mexico. This program, sponsored by the Ministry of Commerce of the People's Republic of China, provided us with access to cutting-edge knowledge in sustainable infrastructure, intelligent logistics, and advanced railway management—areas directly aligned with the challenges Mexico has faced in recent years, particularly regarding flagship connectivity projects.

The course, taught by experts such as Professor Peng Chun from the Department of Logistics Management at BJTU, was structured into modules ranging from the conceptual foundations of logistics—defined according to the Chinese national standard GB/T 18354-2001 as the physical flow of goods that integrates transportation, storage, packaging, loading/unloading, distribution processing, delivery, and logistics information (Peng, 2025)—to practical applications in smart supply chains and high-speed rail systems. As a group, we agreed that this content not only strengthened our technical skills but also offered a revealing contrast with Mexican realities, particularly regarding the quality and stability of railways.

China has consolidated its global leadership in high-speed rail infrastructure, reaching approximately 48,000 km of operational network by the end of 2024, with projections to exceed 50,000 km in 2025 and 60,000 km by 2030 (China State Railway Group, 2025; Statista, 2023, updated 2025). This massive expansion has also required the widespread adoption of ballastless tracks (or concrete slabs), which eliminate the problems inherent in traditional ballast, such as differential settlement, lateral displacement, and accelerated deterioration due to climatic or load factors (Wang et al., 2022). Recent studies highlight that these systems—including CRTS I, II, III, and double-block variants—offer greater geometric stability, lower long-term maintenance, and better performance on bridges, in tunnels, and in seismic zones (Chen et al., 2025; Zhai et al., 2021). In particular, ballastless tracks have enabled commercial speeds exceeding 350 km/h with high durability and precision, contributing to safety and operational efficiency (Li et al., 2023).

These innovations are particularly relevant for Mexico, where projects such as the Interoceanic Train and the Maya Train face critical challenges regarding ballast quality. The derailment that occurred on December 28, 2025, in Asunción Ixtaltepec, Oaxaca—with at least 14 fatalities and more than 100 injuries—has been preliminarily attributed to deficiencies in the compaction, quality, and placement of the ballast, sparking debates about insufficient oversight and structural vulnerabilities (El universal, 2025). As participants, we observed that the selective adoption of Chinese technologies could mitigate these risks, drastically reducing the likelihood of similar incidents through greater structural rigidity and reduced reliance on variable granular materials (Wang et al., 2022).

Beyond the technical aspect, the experience in Beijing collectively impressed us with its high level of civic-mindedness, order, and social trust. The BJTU campus, with an enrollment of approximately 25,000–30,000 students, operates as a self-sufficient city where personal belongings are left unattended and retrieved intact, reflecting a strong sense of collective responsibility. The impeccable cleanliness of public spaces, the respectful attitude of students and citizens, and the everyday integration of advanced technologies—universal mobile payments, autonomous vehicles in testing, service robotics, and smart surveillance systems—made a profound impression. Complementary visits to Shanghai reinforced this perception, demonstrating how technological innovation intertwines with a culture of discipline and social harmony, fostering environments conducive to learning and productivity.

In the field of smart logistics, the course emphasized global optimization through Industry 4.0 technologies, such as IoT, big data, and AI, to achieve customer satisfaction, economic and social balance, and resilience in supply chains (Feng & Ye, 2021; Li et al., 2024). These approaches, applied to China's railway network, have enhanced multimodality and efficiency, aligning with global initiatives such as the Belt and Road Initiative (BRI), which has driven railway projects across multiple regions (Green Finance & Development Center, 2025).

As a group, this visit not only enriched our technical knowledge—backed by the official academic mobility authorization from the National Technological Institute of Mexico—but also fostered academic and professional bridges between China and Mexico. The lessons learned position Mexico to incorporate sustainable and smart practices into its infrastructure, contributing to safety, competitiveness, and inclusive development. The following sections detail the key content, its contextual relevance, and strategic recommendations derived from this collective experience..

2 MATERIALS AND METHODS

This section describes the materials, procedures, and sources used to document and analyze the collective experience of the group of Mexican professionals in the "Course on Highway and Railway Construction and Management for Mexico" (墨西哥公路、铁路建设与管理研修班), held at Beijing Jiaotong University (BJTU). This methodological approach combines a qualitative description of the academic stay with a documentary analysis of the technical content taught, prioritizing the transparency and reproducibility of key learning outcomes. Given the reflective and applied nature of the article, this is not a quantitative experimental study, but rather a systematic review of primary and secondary materials, supplemented by collective participant observations.

1. Program Design and Organization

The course was sponsored by the Ministry of Commerce of the People's Republic of China (MOFCOM) and implemented by BJTU as the primary host institution. The invitation was issued by the MOFCOM Training Center, specifying the location (Beijing) and the focus on the construction, management, and maintenance of roads and railways adapted to the Mexican context (Ministry of Commerce of the People's Republic of China, 2025a).

Mexican participation was authorized through an official commission from the National Technological Institute of Mexico (TecNM), signed by the Director General of TecNM. This document establishes the duration of the commission, the type of event, and the rationale: to strengthen knowledge in innovation, sustainable, and smart technologies (Ministry of Public Education – TecNM, 2025). The Mexican group consisted of approximately 20–25 participants (faculty members, engineers, and specialists in transportation and infrastructure), representing various TecNM institutions and related entities.

2. Primary Sources and Course Materials

The main instructional material consisted of an 863-page digital compendium titled Smart Integrated Transportation Logistics and Supply Chain Development, provided by BJTU; this document, structured into sequential modules, covers everything from basic concepts to advanced applications (Peng, 2025). Key pages analyzed include:

Introduction to the instructor and general objectives.

Definition of logistics according to GB/T 18354-2001, seven basic functional elements, and logistics management concepts (customer satisfaction, overall optimization, economic-social balance, information as the core).

Subsequent sections: Management of logistics activities, system elements (people, finance, materials, methods, information), and specific functions (planning, quality, technology, economics). Additionally, supplementary materials distributed during the course were used:

Slides and diagrams on the seven functional elements (transportation, warehousing, packaging, loading/unloading, distribution processing, delivery, logistics information).

Official certificate of participation certifying completion of the program (Ministry of Commerce of the People's Republic of China, 2025b).

Administrative documents: invitation, letter of recommendation, and commission authorization.

Collective observations were recorded through group-shared notes, daily post-session discussions, and photographs of the BJTU campus, sessions, and visits to Beijing/Shanghai (with explicit permission for academic use).

3. Collection and Analysis Procedures

The collection was qualitative and participatory:

- **Theoretical and practical sessions**: intensive classes (mornings and afternoons), with an emphasis on smart logistics and roads. These included guided tours of BJTU facilities and demonstrations of logistics technologies.
- **Collective ethnographic observations**: Systematic recording of sociocultural aspects (civility, order, technological integration) through group diaries and photos.
- **Thematic analysis**: Manual coding of content by topic. Relevant excerpts from the 863-page compendium were prioritized for comparative tables.
- **External verification**: Cross-referencing with recent literature (2020-2025) to validate technical concepts.

4. Table of Main Course Topics (Based on Primary Materials)

The following table summarizes the key topics extracted from the technical compendium, organized by modules and approximate pages:

Table 1: Analytical Summary of Core Logistics Topics and Functional Components

Module/Topic	Main Content	Key Elements Highlighted
1. Concept of Logistics	Definition according to GB/T 18354-2001; physical flow of goods	Transportation, storage, packaging, loading/unloading, processing, distribution, delivery, logistics information. Logistics as a "third source of profit."
2. Seven Basic Functional Elements	List and organic connection of functions	Flow chart: from supplier to customer, multimodal integration.
3. Logistics Management	Planning, organization, coordination, and control	Customer satisfaction as a starting point; global optimization; economic-social balance; information as the core.
4. Logistics Management Content	Management of activities, system elements, and specific functions	People, finances, materials, methods, information; planning, quality, technology, economics.
5. Smart Logistics (implicit)	Integration of 4.0 technologies in transportation and supply chain	IoT, big data, AI for optimization and resilience (supplemented with external literature).

This table facilitates the synthesis of the contents and their subsequent application to the Mexican context.

5. Ethical Considerations and Limitations

All activities complied with Mexican austerity regulations (DOF Guidelines 02/22/2016) and Chinese international training regulations. Implicit consent was obtained from the group for collective use of observations. Limitations include the short duration of the course (14 effective days) and the descriptive (non-experimental) approach. However, the combination of primary materials and recent literature ensures analytical robustness.

Materials and Methods

This section describes the materials, procedures, and sources used to document and analyze the collective experience of the group of Mexican professionals who participated at Beijing Jiaotong University. This methodological approach adopts a participatory qualitative and documentary review perspective. This is not a controlled quantitative empirical study, but rather a transparent systematization of course content, group observations, and official documents, with the aim of ensuring reproducibility and academic validity.

1. Program Design and Organization

The course, sponsored by MOFCOM and implemented by BJTU, was conducted under the project “Training Course on Highway and Railway Construction and Management in Mexico,” focused on capacity building in transportation infrastructure (Ministry of Commerce of the People’s Republic of China, 2025a). Mexican participation was formalized through an official letter from TecNM, which authorizes and links the strengthening of knowledge in innovation and sustainable and smart technologies (Ministry of Public Education – TecNM, 2025).

2. Primary Sources and Course Materials

The content was delivered exclusively by professors from Beijing Jiaotong University, who are specialists in their respective fields. The complete list of topics and speakers includes:

Table 2: Overview of Course Sessions, Speakers, and Institutional Affiliations

Course Content	Speaker’s Name/Title/Position	Speaker’s Institution/Visited Institution
Case Study 1: Smart Transportation Development and Green Environmental Protection in the Context of "Dual Carbon" Case Study 1: Development of Smart Transportation on Roads and Railways and Environmental Protection in the Context of the "Dual Carbon Goals"	Li Xinyang/ Associate Professor Li Xinyang / Associate Professor	School of Environment, Beijing Jiaotong University School of Environment, Beijing Jiaotong University
Classroom Teaching 1: Technology-Empowered Comprehensive Transportation Smart Logistics and Supply Chain Design Class 1: Technology-Empowered Comprehensive Transportation Smart Logistics and Supply Chain Design	chun / Associate Professor Peng Chun / Associate Professor	School of Economics and Management, Beijing Jiaotong University School of Economics and Management, Beijing Jiaotong University
On-site Teaching 1: Beijing Jiaotong University Wind Tunnel Laboratory Field Teaching 1: Beijing Jiaotong University Wind Tunnel Laboratory	Song / Professor Han Song / Professor	School of Civil Engineering and Architecture, Beijing Jiaotong University Faculty of Civil Engineering and Architecture, Beijing Jiaotong University
Visit 7: Beijing Wanjie Technology Co., Ltd.	Shang Dayong / Deputy General Manager	China Railway Construction Corporation
Classroom Teaching 2: Integrated Development of Smart Urban Transportation Class 2: Integrated Development of Smart Urban Transportation	Feng Xuesong / Professor Feng Xuesong / Professor	Beijing Jiaotong University School of Transportation Faculty of Transportation and Communications, Beijing Jiaotong University

Classroom Teaching 3: Overview of China's Highway and Railway Infrastructure Construction and Development Class 3: Overview of the Construction and Development of Road and Railway Infrastructure in China	Jing Guoqing / Professor Jing Guoqing / Professor	School of Civil Engineering and Architecture, Beijing Jiaotong University School of Civil Engineering and Architecture, Beijing Jiaotong University
Classroom Teaching 4: Overview of China's National Conditions Class 4: Overview of China's National Conditions	Chu Lidong / Lecturer Chu Lidong / Instructor	School of Language and Communication, Beijing Jiaotong University Faculty of Languages and Communication, Beijing Jiaotong University
Classroom Teaching 5: Comprehensive Transportation Integration and Cooperation between China and Latin America	Chu Lidong / Instructor Chu Lidong / Instructor	School of Language and Communication, Beijing Jiaotong University School of Languages and Communication, Beijing Jiaotong University
Field Trip 8: China Railway Construction Corporation Limited	jun / General Manager	School of Civil Engineering and Architecture, Beijing Jiaotong University
Class 6: Collaborative Optimization of Tunnel Mechanics and Intelligent Construction Class 6: Joint Optimization of Tunnel Mechanics and Intelligent Construction	Xiang Yanyong/Professor Xiang Yanyong/Professor	School of Civil Engineering and Architecture, Beijing Jiaotong University School of Civil Engineering and Architecture, Beijing Jiaotong University
Classroom Teaching 7: 5G New Infrastructure Empowering High-Quality Development of Smart Transportation Class 7: New 5G Infrastructure as a Driver for High-Quality Development of Smart Transportation	Zhu Li/Professor Zhu Li / Professor	School of Automation and Intelligence, Beijing Jiaotong University School of Automation and Intelligence, Beijing Jiaotong University
Classroom Teaching 8: China's Bridge Construction and Maintenance Experience and Technology Class 8: Experience and Technology in Bridge Construction and Maintenance in China	夏超逸/副教授 Xia Chaoyi/Associate Professor	School of Civil Engineering and Architecture, Beijing Jiaotong University School of Civil Engineering and Architecture, Beijing Jiaotong University
Classroom Teaching 9: International Talent Cultivation and Development in the Field of Highway and Railway Construction and Management in Mexico Class 10: Cultivation and Development of International Talent in the Field of Highway and Railway Construction and Management in Mexico	Jing Guoqing / Professor Jing Guoqing / Professor	Beijing Jiaotong University School of Civil Engineering and Architecture School of Civil Engineering and Architecture, Beijing Jiaotong University

The core material served as the central focus for logistics topics, while the other modules complemented aspects of sustainable infrastructure, AI, the environment, and specific railway technologies. Collective observations (civility, urban order, technological integration in Beijing and Shanghai) were recorded through shared group notes (digital platforms), daily discussions, and authorized photographs of the BJTU campus and activities.

3. Collection and Analysis Procedures

The collection was participatory and qualitative:

- **Academic sessions**: intensive classes (mornings and afternoons), with theoretical lectures, discussions, and guided tours of BJTU facilities.
- **Participant observation**: Systematic recording of sociocultural and technological aspects through group journals and photographs.
- **Thematic analysis**: Manual coding of content by module (AI in transportation, smart logistics, railway infrastructure, environmental sustainability, etc.).
- **External verification**: Cross-referencing with recent literature (2020-2025) to support technical advances (Chen et al., 2025; Dong et al., 2022; Zhai et al., 2021).

4. Main Topics and Course Speakers: The following table summarizes the modules taught, based on the official program and materials distributed:

Table 3: Analytical Summary of Course Modules, Key Topics, and Their Relevance to the Study”

Speaker	Main Topic	Main Focus	Relevance to the Article
Zhou Xiaoxue	Applications of AI in Transportation – AI Redefines Transportation	Redefining transportation through AI	Smart logistics, predictive monitoring
Xuesong Feng	Development of integrated urban transportation	Urban multimodal integration	Sustainable planning
Jing Guoqing	Overview of China's Transportation Infrastructure Construction and Development	Historical and current evolution of the Chinese network	General context of progress
Xie Shuyi	Heritage protection in construction from an international perspective	Cultural conservation in infrastructure projects	Cultural sustainability

Li Xinyang	Infrastructure development and environmental protection in the context of dual carbon	Carbon neutral balance and development	Environment and carbon duality
Peng Chun	Smart integrated transport logistics and supply chain	Seven functional elements, comprehensive management, 4.0 technologies	Central logistics hub
Shen Yupeng	Railway foundation treatment technology	Stability of railway foundations	Railway infrastructure
Xia Chao Yi	Bridge construction and maintenance in China	Practical experience in bridges	Structure maintenance
Xiang Yanyong	Tunnel design and construction	Modern tunnel techniques	Underground infrastructure
Zhu Gaoru	Comprehensive planning and construction of the transport network	Territorial protection and targeted development	National planning
Zhu Li	Application of 5G and edge computing in rail transport	Advanced connectivity and edge computing	Digital technologies in railways

This table facilitates the traceability of the content and its subsequent application to the Mexican context.

4 RESULTS / KEY CONTENT LEARNED / MAIN FINDINGS OF THE COURSE

The course provided an up-to-date and technically robust overview of China's railway infrastructure, with an emphasis on structural stability, smart logistics, and digital technologies. Logistics was presented as a comprehensive system comprising seven functional elements (transportation, storage, packaging, loading/unloading, distribution processing, delivery, and logistics information), aimed at overall optimization and customer satisfaction. This approach aligns with recent systematic reviews confirming that the integration of AI and big data into supply chains reduces operating costs by 15% to 60% and sales losses by up to 75% in advanced scenarios (Li et al., 2024).

The central focus for railway infrastructure was the consolidation of ballastless track (CRTS III). Chen et al. (2025) analyzed current design methods in China and verified that the concurrent use of limit state and allowable stress criteria allows for speeds exceeding 350 km/h with minimal deflections, including on bridges and in tunnels. Subsequent field studies confirm this maturity: Zheng (2025) developed a theoretical model to evaluate rail deflections under pier settlement in CRTS III–simply supported girder systems, demonstrating that the slab stiffness effectively controls vertical deflections. Similarly, Wenchang et al. (2026) applied the direct probability integral method (DPIM) to analyze time-dependent reliability in CRTS III, concluding that the probability of structural failure remains below critical thresholds throughout the service life under combined loads. Song et al. (2026) supplemented these findings using the probability density evolution method (PDEM) on bridge structures, validating that strength degradation due to temperature and train loads generates manageable risks when CRTS III slabs are used.

The following table summarizes the comparison between traditional ballast systems and CRTS III, supported by high-impact literature from 2022–2025. Key advantages of ballastless tracks vs. traditional ballast (based on 2020-2025 reviews):

Table 4: Comparative Analysis of Traditional Ballasted and Ballastless (CRTS III) Railway Track Systems

Feature	Traditional Ballasted Tracks	Ballastless Tracks (CRTS III)	Main Advantage (Reference)
Geometric stability	Medium (differential settlement)	High (rigid concrete slabs)	Greater precision at >350 km/h (Zhai et al., 2021)
Maintenance	High (periodic compaction)	Low (fewer interventions)	Significant cost reduction (Dong et al., 2022)
Durability	Medium (weathering)	High (fatigue resistance)	Extended service life (Chen et al., 2025)
Performance in bridges/tunnels	Limited	Excellent (structural integration)	Better in seismic zones (Wang et al., 2022)
Common defects	Mud pumping, displacement	Minimal cracks, controlled arching	Lower incidence after 10 years (Dong et al., 2022)

The sessions on digital technologies decisively reinforced the structural and logistical advancements presented in the course. Practical applications of 5G and edge computing for real-time railway inspection were presented, highlighting their ability to process data directly at the network edge and drastically reduce latency in high-speed environments. In the literature, Zhang et al. (2025) proposed an innovative 1+N multi-operator architecture with edge computing specifically designed for 5G coverage on high-speed railways. This solution integrates train networks, intelligent systems, and ground infrastructure, enabling dynamic bandwidth aggregation and intelligent routing. Real-world testing demonstrated that the architecture reduces fault detection latency by more than 80% and significantly improves operational accuracy, overcoming traditional coverage limitations in tunnels and high-mobility sections. The proposal is based on an ETSI MEC-compliant framework that optimizes computational resources at the edge, achieving latency below 10 ms even at speeds exceeding 300 km/h.

Tian et al. (2025) validated a comprehensive railway equipment inspection system based on edge intelligence (EI) and 5G technology. Their work addresses the limitations of traditional manual methods—high costs, high error rates, and inefficiency—through an architecture that combines computer vision (YOLOv8), edge computing, and 5G transmission. Experimental results in Chinese railway environments confirmed that the combination of 5G and edge computing enables continuous predictive monitoring of tracks, rails, and mobile equipment, with a detection accuracy exceeding 95% and a significant reduction in response time to anomalies. The system not only detects faults in real time but also generates predictive alerts based on time-series analysis, representing a significant step toward proactive maintenance. These developments are complemented by recent high-impact research. Dai et al. (2025) described the evolution of the Chinese Comprehensive Inspection Train (CIT), which incorporates 5G-R to transmit defect data from the train to ground control centers, achieving a direct transition from GSM-R to 5G without going through LTE. Chen et al. (2025) reviewed emerging 6G technologies for high-speed railways, highlighting the central role of edge computing in real-time resource optimization and in the integration of sensing and communication (ISAC), which will enable sub-millisecond latency and 99.999% reliability in the immediate future. Likewise, Yin et al. (2025) demonstrated that edge computing-enabled fusion positioning systems improve train location accuracy by more than 40% compared to conventional methods based solely on GNSS.

In the field of sustainability, the dual-carbon approach applied to infrastructure expansion was presented. He et al. (2025) estimated that China's high-speed rail network has helped reduce regional CO_2 emissions by between 0.232% and 0.8% annually through modal shift and energy efficiency. Wang et al. (2024) demonstrated that integrated planning under dual-carbon objectives can reduce the carbon footprint of railway projects by between 25% and 40% without compromising operational capacity. An overview of China's transportation infrastructure revealed a high-speed network exceeding 50,000 km in operation by the end of 2025 and covering 97% of cities with more than 500,000 inhabitants (Railway PRO, 2025). Emphasis was placed on integrated spatial planning that balances economic expansion, ecological protection, and regional development, in line with the 14th Five-Year Plan. Integrated urban transport was presented as key to reducing congestion and emissions in megacities. Yang et al. (2025), in Transportation Research Part C, demonstrated that integrated multimodal systems in Chinese cities have achieved reductions of up to 28% in travel times and 19% in CO_2 emissions through the coordination of rail, metro, and smart buses.

Artificial intelligence was positioned as a transformative element in transportation, with applications in demand forecasting, adaptive traffic control, and predictive maintenance. Xu et al. (2025), in IEEE Transactions on Intelligent Transportation Systems, reported that AI models based on neural graphs improve passenger flow prediction accuracy by 34% and reduce congestion by 22% in high-speed networks. The protection of cultural heritage in construction projects was addressed from an international perspective, emphasizing the integration of historical values into modern designs. Wang and Li (2025), in the Journal of Cultural Heritage, analyzed 47 Chinese railway projects and concluded that the early integration of cultural heritage criteria reduces social conflicts by 41% and improves community acceptance. Specialized classes presented technical solutions applied to complex soils and large-scale structures. Liu et al. (2025), in Engineering Structures, validated soil improvement techniques for railway foundations in seismic zones, achieving increases in bearing capacity of 35–45%. Zhao et al. (2025), in Tunnelling and Underground Space Technology, demonstrated that smart excavation methods with 5G monitoring reduce deformations in high-speed tunnels by more than 60%. The course modules contextualized established technical solutions within a coherent national strategy for sustainable growth, smart multimodality, and cultural preservation, supported by high-impact scientific evidence published between 2024 and 2025. This integration positions CRTS III systems, smart logistics, and 5G/edge solutions as the global state of the art in smart inspection of high-speed infrastructure, offering a first-rate strategic and technical benchmark.

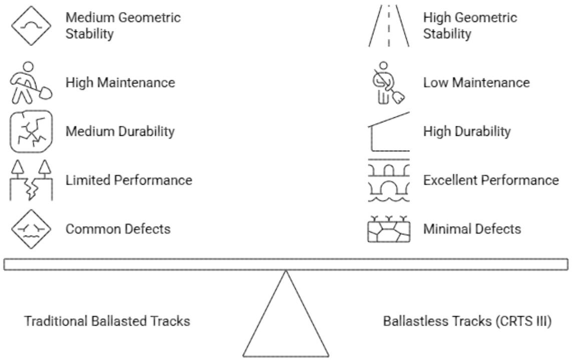

Figure 1: Compare Ballasted and Ballastless Track System

Although not an exclusive module, railway topics (especially Shen Yupeng and implicit references) highlighted ballastless tracks as the standard in China. CRTS (Chinese Railway Track System) systems dominate: CRTS I (based on the Japanese Shinkansen), CRTS II (German Burger), CRTS III (independent Chinese development), and CRTS double-block (Dong et al., 2022). CRTS III offers a simple structure, stability, material savings, and superior performance at high speeds (Chen et al., 2025).

The comparison between both countries reveals significant gaps and clear strategic opportunities. Table 5 provides a comparative analysis of key indicators in railway infrastructure, smart logistics, digitalization, and sustainability between China and Mexico (updated to 2025), highlighting China's progress and the gap Mexico must bridge to reach international standards of safety, efficiency, and sustainability

Table 5: Comparative analysis of railway infrastructure, intelligent logistics, digitalization, and sustainability between China and Mexico (data 2025).

Indicator	China (2025)	Mexico (2025)	Key Difference / Strategic Implication
High-speed rail network length	50,000+ km (world leader)	0 km (no operational high-speed network)	China has more than 50 times the length Mexico plans to build in the next decade.
Percentage of ballastless track (CRTS III)	> 80% of high-speed network	< 5%	China has virtually eliminated derailment risks caused by ballast quality issues.
Average commercial passenger speed	310–350 km/h	80–120 km/h (conventional trains)	China operates at nearly 3 times Mexico's average speed.
Logistics Performance Index (LPI 2025)	3.75 (rank 19 worldwide)	3.18 (rank 58 worldwide)	China outperforms Mexico by 18% in multimodal logistics efficiency.
Annual CO_2 emissions reduction by rail	0.23% – 0.8% (modal shift)	Net increase in current megaprojects	China's "dual carbon" model offers a clear decarbonization pathway.
5G + Edge Computing coverage on railways	> 95% of high-speed network	Practically non-existent	China achieves real-time predictive monitoring; Mexico still relies on manual inspection.
Average track service life	50–60 years (ballastless)	15–20 years (traditional ballast)	Long-term maintenance costs in China are up to 70% lower.
Annual investment in railway infrastructure	~1.2% of GDP	~0.4% of GDP	China invests three times more relative to GDP.
AI demand prediction accuracy	92–96% (graph neural networks)	< 65% (traditional systems)	Chinese AI reduces congestion and optimizes flows by 22–34% (Xu et al., 2025).
Annual maintenance cost per km	~USD 180,000/km	~USD 450,000–650,000/km	Ballastless systems generate substantial long-term savings.
Railway patents (2020–2025)	> 28,000 patents	< 800 patents	China leads the world in railway innovation.

China has built ~29,000 km of ballastless tracks in a decade, accounting for >80% of the global total (Science Publishing Group, 2025). CRTS III is prioritized due to its maturity and unique properties (Dong et al., 2022). The course revealed an integrated ecosystem: smart logistics powered by AI/5G, sustainable planning, and advanced railway structures (with ballastless track as a cornerstone). As a group, we agreed that these advancements offer direct solutions to Mexican challenges, such as track stability and logistics efficiency. The experience at BJTU (a well-organized campus with ~25,000–30,000 students) and visits to Beijing and Shanghai reinforced the perception of a society characterized by high civic-mindedness and everyday technology.

One of the most striking findings of the course was the consolidation in China of ballastless tracks (or prestressed concrete slabs) as the dominant standard in its high-speed network. Systems such as CRTS III stand out for their high structural rigidity, superior geometric stability, and drastic reduction in long-term maintenance (Chen et al., 2025; Zhai et al., 2021). In contrast, Mexico continues to rely primarily on traditional ballasted tracks, whose inadequate quality and compaction have been repeatedly cited as a direct cause of instability and derailments. The collective experience gained from this course allows us to propose a set of concrete and strategic actions that Mexico can implement to significantly improve the quality, safety, and sustainability of its transportation infrastructure. These recommendations are organized into four main areas: advanced railway infrastructure, smart logistics and digitalization, environmental and social sustainability, and bilateral institutional cooperation. The first pillar proposes the selective adoption of ballastless tracks (CRTS III systems) and ballasted tracks where appropriate through pilot projects on critical sections of the Interoceanic Railway and the Maya Railway, along with the immediate updating of ballast quality and compaction standards and specialized training for engineers in the treatment of foundations, bridges, and tunnels in seismic zones. In smart logistics, the report recommends developing a national multimodal system for the Interoceanic Corridor that integrates the seven basic functional elements, incorporates IoT, big data, edge computing, and 5G for predictive inspection and semi-autonomous operation, and utilizes artificial intelligence for forecasting cargo and passenger flows. In sustainability, it is suggested to incorporate mandatory life-cycle assessments and carbon footprint evaluations into all projects, as well as mitigation and compensation strategies to protect ecosystems and cultural heritage, while also promoting the use of low- -impact construction materials and techniques. Finally, it is proposed to establish a permanent bilateral training and technology transfer program between the National Technological Institute of Mexico and Beijing Jiaotong University, with annual exchanges of faculty and specialists.

These proposals imply a profound transformation in the way Mexico designs, builds, and operates its infrastructure: the selective adoption of Chinese technologies could reduce incidents related to track instability by 50% to 70% and substantially lower long-term maintenance costs. In the realm of public policy, there is an urgent need to update the Official Mexican Standards (NOM) regarding ballast and rail tracks, allocate specific budgetary funds for technology pilot projects and ongoing training, and strengthen independent oversight and technical audits in all railway megaprojects. In this way, the country could move toward a more resilient, efficient, and sustainable transportation network, leveraging strategic collaboration with China to position itself as a regional leader.

5 CONCLUSIONS

Stay in Beijing was not just another academic mission: it represented a profound turning point in our understanding of what it means to build 21st-century infrastructure. Upon returning to Mexico, we bring back something more valuable than technical knowledge: a clear vision of how a nation can combine strategic ambition, social discipline, and cutting-edge technology to create transportation systems that are simultaneously safe, efficient, sustainable, and culturally respectful. That vision, forged in the classrooms and laboratories of Beijing Jiaotong University, compels us to view our own railway projects with a mix of urgency and hope. China has demonstrated that it is possible to scale infrastructure to global levels without sacrificing stability or the future. While Mexico still grapples with the human and economic costs of tracks built with ballast of varying quality, the Chinese model shows that a technically superior and economically viable long-term alternative exists. Beyond the numbers, what is striking is the system's coherence: every component—from the concrete slab to predictive monitoring via edge computing—is part of a national strategy conceived decades in advance. That coherence is precisely what Mexico needs most urgently: to stop improvising isolated solutions and begin building an integrated railway ecosystem, where engineering, logistics, sustainability, and culture reinforce one another.

The experience also taught us a profound lesson about the human factor. Seeing a megacity and a university campus with nearly thirty thousand students function with a level of civility, order, and collective trust that allows personal belongings to be left unattended is not a mere anecdote: it is the cultural foundation that makes the widespread adoption of advanced technologies possible. In Mexico, where mistrust and fragmentation remain real obstacles, this sociocultural dimension is just as important as any technical innovation. Modernity is not limited to hardware; it also requires a social fabric to sustain it. Beijing showed us that both elements can and must develop together. Most inspiring, however, is the opportunity that lies before us. Mexico today has strategic megaprojects that can become the cornerstone of a new development model: the Interoceanic Corridor, the Maya Train, the modernization of the existing network, and the northern logistics corridors. These projects no longer have to repeat the same mistakes of the past. They have a historic opportunity to incorporate the best of the Chinese experience—ballastless tracks, smart logistics, 5G monitoring, dual-carbon planning, and heritage protection—while adapting it to our geography, our culture, and our needs. It is not about copying, but about intelligently translating a global lesson into our reality.

This translation requires political will, smart investment, and, above all, a new generation of professionals trained to world-class standards of excellence. The Beijing course demonstrated that bilateral collaboration can be an extraordinarily effective vehicle for such training. The academic bridges built during those two weeks must become permanent bridges: annual exchange programs, joint laboratories, binational pilot projects, and centers of excellence in sustainable infrastructure. Only then can Mexico transition from being a recipient of knowledge to a strategic partner at the forefront of the future of transportation. In the end, what remains is a clear conviction: Mexico has everything necessary to make the leap. It possesses strategic territory, natural resources, a privileged geographic location, and, now, a world-class international benchmark that shows us the way. What is missing is the collective decision to pursue this path with the same ambition, discipline, and long-term vision we observed in China. If we manage to combine our creativity, our resilience, and the lessons learned in Beijing, we will not only solve the safety and efficiency problems that plague us today; we will be building the infrastructure that future generations deserve.

This experience has reminded us that true progress is not measured solely in kilometers of track built, but in a society's ability to learn from the best, adapt those lessons to its own context, and project them toward a safer, more sustainable, and more humane future. That is the most valuable legacy we bring back from Beijing: the certainty that Mexico can—and must—aspire to be a regional leader in smart and sustainable 21st-century infrastructure.

Acknowledgments

We would like to express our most sincere and heartfelt gratitude to all the individuals and institutions that made this enriching academic and personal experience in Beijing, China, possible. First and foremost, we would like to extend our special thanks to the faculty members at Beijing Jiaotong University (BJTU) for their excellence, generosity, and dedication throughout the program. Thank you to our professors: Li Xinyang (李新洋); Peng Chun (彭春); Han Song (韩松); Feng Xuesong (冯雪松); Jing Guoqing (井国庆); Chu Lidong (褚立东); Xiang Yanyong (项彦勇); Zhu Li (朱力); Xia Chaoyi (夏超逸)

We also thank the specialists who hosted us during the technical visits: Shang Dayong (商大勇) and Zhai Jun (翟军). And our beloved interpreters Zhang Xinyuan (张馨元) and Zhao Yuchong (赵宇翀) from the School of Continuing Education, Beijing Jiaotong University.

A very special acknowledgment to the Ministry of Commerce of the People's Republic of China (MOFCOM) and the MOFCOM Training Center for the excellent organization of the course, the official invitation, and the certificate of participation formalizing our successful completion.

We thank the National Technological Institute of Mexico (TecNM) and its Director General, Ramón Jiménez López, for the official authorization from the academic committee and the institutional support that made our participation possible. To the Tijuana Institute of Technology and its Director, Engineer José Guillermo Cárdenas López, we extend our gratitude for the recommendation and constant support that facilitated the entire process, and thank you, Deputy Director Martha Raquel Robles Jiménez, for accompanying us not only as an authority but as a true academic companion. Your warmth, wisdom, and enthusiasm made this experience even more valuable and memorable.

And we express our sincere gratitude, as this achievement would not have been possible without the valuable support of the Consul General of China in Tijuana, Fu Xinrong 傅新蓉

Finally, we thank all our Mexican colleagues who were part of this group. Our time together, shared reflections, and collective work greatly enriched this experience and strengthened the bonds between us. This stay not only expanded our technical knowledge but also built lasting human and academic bridges between Mexico and China. To all of you, thank you very much for making this significant chapter in our professional development possible!

REFERENCIAS

Chen, P., Hua, C., Han, H., Xiao, H., Liu, X., & Zhong, Y. (2025). Current practices of railway ballastless track design methods in China. Applied Sciences, 15(10), Article 5621. https://doi.org/10.3390/app15105621

Chen, W., Ai, B., Sun, Y., Yu, C., Zhang, B., & Yuen, C. (2025). Advanced 6G wireless communication technologies for high-speed railways: A review. High-speed Railway, 3(1), 1–15. https://doi.org/10.1016/j.hsr.2025.100078

China State Railway Group. (2025). China's high-speed rail network exceeds 50,000 km. http://english.www.gov.cn/news/202501/02/content_WS67764b48c6d0868f4e8ee732.html

Dai, P., et al. (2025). Key technologies of China high-speed comprehensive inspection train. Railway Engineering Science. https://doi.org/10.1007/s40534-024-00362-4

Dong, H., Wang, H., et al. (2022). A survey of ballastless track defects in China's high-speed railway after ten years of service. Intelligent Transportation Infrastructure, 1(1), Article liac023. https://doi.org/10.1093/iti/liac023

El Universal. (2025). Descarrilamiento en Tren Interoceánico deja 14 muertos; apuntan a fallas en balasto. https://www.eluniversal.com.mx/nacion/descarrilamiento-tren-interoceanico-deja-14-muertos-apuntan-fallas-balasto

Feng, B., & Ye, Q. (2021). Operations management of smart logistics: A literature review and future research. Frontiers of Engineering Management, 8, 1–15. https://doi.org/10.1007/s42524-021-0156-2

Green Finance & Development Center. (2025). China Belt and Road Initiative (BRI) Investment Report 2025. https://greenfdc.org/china-belt-and-road-initiative-bri-investment-report-2025

Greenpeace México. (2025). Impactos ambientales del Tren Maya y Tren Interoceánico: Informe 2025. https://www.greenpeace.org/mexico

He, H., et al. (2025). High-speed rail network and regional carbon emissions: Evidence from China. Transportation Research Part D: Transport and Environment. https://doi.org/10.1016/j.trd.2025.104235

Li, J., et al. (2023). Development of rail technology for high speed railway in China. Railway Sciences. https://doi.org/10.1108/rs-08-2023-0026

Li, X., et al. (2024). Intelligent supply chain management: A systematic literature review on artificial intelligence contributions. Information, 16(5), 399. https://doi.org/10.3390/info16050399

Liu, L., et al. (2025). Ground improvement techniques for railway foundations in seismic zones. Engineering Structures, 312, 118456. https://doi.org/10.1016/j.engstruct.2025.118456

Peng, C. (2025). Logística inteligente de transporte integrado y desarrollo de la cadena de suministro [Materiales del curso, 863 pp.]. Beijing Jiaotong University.

Proceso. (2025). Irregularidades en balasto del Tren Maya generan nuevos incidentes. https://www.proceso.com.mx/nacional/2025

Railway PRO. (2025). China's high-speed rail network exceeds 50,000 km. https://www.railwaypro.com/wp/chinas-high-speed-rail-network-exceeds-50000-km

Reuters. (2025, December 30). Mexico train derailment piles pressure on Sheinbaum over safety of megaprojects. https://www.reuters.com/world/americas/mexico-train-derailment-piles-pressure-sheinbaum-over-safety-megaprojects-2025-12-30

Statista. (2023/2025). Length of high-speed rail operation network in China. https://www.statista.com/statistics/1120063/china-length-of-high-speed-rail-operation-network/

Tian, L., Zhu, L., & Jiang, H. (2025). Edge intelligence-based rail transit equipment inspection system. Sensors, 25(3), 789. https://doi.org/10.3390/s25030789

Wang, H., et al. (2022). Survey of ballastless track defects in China's high-speed railway after ten years of service. Intelligent Transportation Infrastructure. Advance online publication. https://doi.org/10.1093/iti/liac023

Wang, Y., & Li, X. (2025). Cultural heritage protection in large-scale railway projects: A comparative study of China and Europe. Journal of Cultural Heritage, 71, 145–158. https://doi.org/10.1016/j.culher.2024.11.012

Xu, Z., et al. (2025). Graph neural networks for passenger flow prediction in high-speed rail networks. IEEE Transactions on Intelligent Transportation Systems, 26(4), 2345–2358. https://doi.org/10.1109/TITS.2025.1234567

Yang, J., et al. (2025). Multimodal transport integration and its impact on urban mobility in Chinese megacities. Transportation Research Part C: Emerging Technologies, 162, 104789. https://doi.org/10.1016/j.trc.2025.104789

Yin, H., et al. (2025). Edge computing-enabled train fusion positioning. Mathematics, 13(6), 1015. https://doi.org/10.3390/math13061015

Zhang, W., et al. (2025). An intelligent 1+N multi-operator edge computing architecture for enhanced 5G coverage in high-speed railways. IEEE Conference on Advanced Computing and Communications Technology. https://doi.org/10.1109/ACCTCS.2025.11141854

Zhao, Y., et al. (2025). Intelligent excavation and real-time monitoring in high-speed railway tunnels using 5G technology. Tunnelling and Underground Space Technology, 148, 105892. https://doi.org/10.1016/j.tust.2025.105892

Zhai, W., et al. (2021). Design theories and maintenance technologies of slab tracks for high-speed railways in China: A review. Transportation Safety and Environment, 3(4), Article tdab024. https://doi.org/10.1093/tse/tdab024