Connecting Continents, Reshaping Tomorrow's Transit

— *International Knowledge-Sharing Workshop on Intelligent Transport Systems*

April 2025

CONTENTS

SUMMARY

Following the approval of the concept note for the Integration, Social and Sustainable Development Program of Maceió (the Project), which aims to enhance urban mobility and promote sustainable transport solutions, the New Development Bank (**NDB**) organized a dedicated knowledge-sharing workshop focused on intelligent transport systems (**ITS**). The primary objective of the workshop was to support the design and implementation of the Project's ITS component by drawing on practical experiences, operational insights, and international best practices in the field.

The workshop brought together key stakeholders from the Project design and implementation team in Maceió, Brazil, and facilitated targeted knowledge exchange through case studies of ITS deployment in China[1]. The program featured two principal site visits: the first to Yinchuan, home to the NDB-financed Ningxia Yinchuan Integrated Green Transport Development Project, and the second to Shanghai, a pioneer in innovative public transport systems, notably the flagship Bus Rapid Transit (**BRT**) Line 71 and other market leading ITS solution providers.

In **Yinchuan**, the delegation engaged with representatives from the implementing agency and conducted in-depth field visits to several ITS-related assets. These included the city-wide transport operations coordination center, public mobility platforms, electric bus fleets and depots, charging infrastructure, and an operational BRT corridor. The Yinchuan project has already demonstrated tangible improvements in public transport efficiency, integrated mobility management, and data-driven decision-making. The visit was complemented by a series of thematic seminars covering ITS architecture and operations, applications of AI in smart bus systems, and ITS software and hardware integration.

In **Shanghai**, the delegation experienced the journey of BRT Line 71, observing first-hand its customer-focused design and high-performance features. This was followed by a technical visit to the city's ITS operations center and discussions with leading practitioners involved in BRT planning, ITS system integration, and data platform development. Key topics included the latest scalable and innovative ITS applications such as electronic fare collection systems, real-time surveillance and monitoring tools, contactless smartcard and mobile payment technologies, and the use of big data for system optimization.

The workshop successfully provided a platform for cross-country exchange of knowledge and expertise, contributing directly to the refinement of the ITS component of the Maceió Project. Furthermore, the initiative supports a core objective under NDB's General Strategy 2022–2026, which emphasizes the Bank's role as a catalyst for knowledge sharing and innovation among its member countries.

This report consolidates key lessons, operational insights, and technical considerations emerging from the workshop, with the aim of informing project preparation and strengthening the design of ITS solutions under the proposed Project

[1]Note: Any reference to companies or products during the workshop is utilized solely for the purpose of technical discussion and do not imply any endorsement, recommendation, or preference by the bank.

1. LEVERAGING CHINA'S EXPERIENCE AND NDB'S KNOWLEDGE HUB ROLE FOR MACEIÓ'S SMART BRT:

Key Insights from Maceió, Yinchuan, & Shanghai's Transport Exchange

A Turning Point in Urban Crisis: Maceió's BRT Vision

Maceió, a vibrant coastal city in northeastern Brazil with a population of nearly one million, plays a crucial role in regional development. Despite its significance, the city's per capita GDP is slightly over half the national average, highlighting both its economic potential and the opportunities for growth and modernization. In 2018, it suffered one of Brazil's worst geological disasters—a massive mining collapse that permanently damaged 30% of its land, devastating infrastructure and disrupting the urban transport system.

Faced with the significant challenge of post-disaster reconstruction, Maceió's municipal government is taking a proactive, future-oriented approach by developing a sustainable urban development strategy for the next 10 to 20 years, with a strong emphasis on green mobility. At the heart of this vision is a new BRT corridor, designed to transform the city's transportation system, improve residents' travel experiences, and support urban renewal through a modern, efficient public transport network.

Photo: Exchange on Public Transport and BRT Systems

Profile of Maceió's Bus System

Currently, Maceió's public transport system serves approximately about 123,000 passengers daily, playing a vital role in the city's mobility[2]. The bus network includes 103 routes with 514 buses managed by three companies. Notably, Maceió offers some of the lowest fares among Brazilian state capitals, with a "free transfer within one hour" policy and discount cards for seniors and students.

BRT as the Strategic Engine for Maceió's Green Transformation

The planned BRT system in Maceió will stretch approximately 14 kilometers, featuring 23 stations and serving around 640,000 residents along its route. The city government aims to make this project a model of technological innovation and social inclusion, steering it toward a green, smart, and high-efficiency urban mobility.

Insights from Yinchuan: Sustainable Operations from Financial Support to Business Expansion

The implementing agency of the NDB-financed Ningxia Yinchuan Integrated Green Transport Development Project—Yinchuan Bus—shared insights into its urban transport system. The Yinchuan Project received funding of up to USD 300 million from the NDB, making it the largest development bank-backed project in the history of Ningxia. The Yinchuan Project has a bus fleet of over 2,000 vehicles, with daily ridership of 420,000. Like the Maceió Project, the Yinchuan Project also offers discount cards and a one-hour free transfer. Additionally, Yinchuan continues to implement measures, such as electric bicycles, aimed at improving public transportation. The electric bicycles operation consists of 16,200 vehicles, generating revenue nearly equal to its core bus operations.

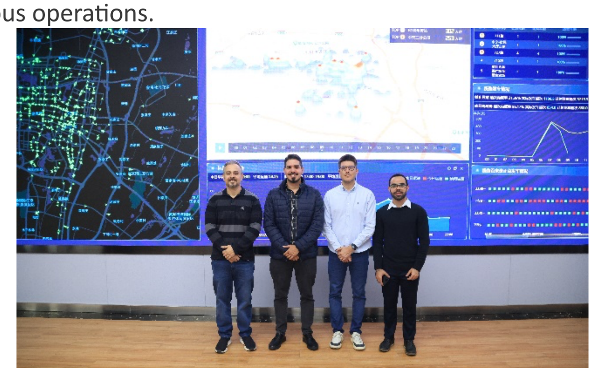


Photo: Delegation's visit to Yinchuan's ITS Center

[2] Alagoas Gazette, January 2024.

2. INTELLIGENT TRANSIT SYSTEMS, PLATFORM INTEGRATION, AND DATA-DRIVEN APPROACHES:

Technical Dialogue on Future BRT Systems Between Maceió, Yinchuan, and Shanghai

2.1 ITS Platforms: Architecture, Data, and Real-World Effectiveness

Yinchuan's Intelligent Dispatch Center: Practice and Challenges

All buses are fitted with passenger-counting sensors and utilize a "tap-on, no-tap-off" fare system, which records boarding data without capturing personal data. This setup provides important insights into route usage and passenger demand. For instance], the system recorded an annual average of 0.764 boardings per vehicle-kilometer, meaning here are approximately 0.764 passengers boarding each bus for every kilometer the bus travels. This provides valuable information about route density and identifying high-traffic routes. However, real-time data contained some anomalies, such as unrealistically high speeds during the day and unusually low speeds at night highlighting challenges in data quality and reliability. These observations underscore the importance of accurate data collection and processing. When designing future ITS systems, ensuring data accuracy is essential for supporting effective, evidence-based decision-making and optimizing transit operations.

The "Yinchuan Zhixing" app, which currently has 30,000 active users, plays a crucial role in promoting smart mobility by offering real-time bus tracking, route information, and personalized service options, thereby improving the overall passenger experience and operational efficiency.

Five-Layer ITS Architecture in Yinchuan

Presented by Beijing Urban Construction Design & Development Group, Yinchuan's ITS platform consists of:

- **Perception Layer:** Data collection from vehicles, stations, depots, and passengers, including pilot use of driver health bracelets for fatigue and distraction detection (still in early refinement).
- **Basic Support Layer:** Servers, computing, and network infrastructure.
- **Data Support Layer:** Centralized data platform and resource library.
- **Business Application Layer:** Service modules for scheduling, energy management, and customized bus services.
- **Presentation Layer:** Real-time visualization for operators and public information.

2.2 Shanghai's Pioneering ITS Solutions

Shanghai's "Suishenxing" or Mobility as a Service (MaaS)

Shanghai's MaaS platform exemplifies a large-scale, integrated ITS. The core function of this system lies in serving as an authoritative, centralized, and real-time data hub for the entire Shanghai transportation network, providing a foundation for government decision-making and system-wide traffic management; however, it is not directly used for public bus operations. This platform breaks down modal silos, creating a coordinated urban mobility system and offering a replicable digital infrastructure model for global megacities. It consolidates information, payments, and operations across:

- 1,500 bus routes (18,000 buses)
- 900 km of metro lines
- 50,000 taxis, 200,000 ride-hailing vehicles, and over 20 million bicycles

Photo: Delegation's visit to MaaS in Shanghai

Data Middle Platform: Shanghai Aoma Information System

Aoma Information Technology, serving major operators like Jiushi Bus, provides a data middle platform covering 8,000 buses and over 500 routes. This database is specifically designed for the real-time monitoring and management of Shanghai's public bus system, leveraging big data and AI to enable efficient urban transit operations, with part of its data sourced from the MaaS platform mentioned above. Its core functions include:

- **Cost Reduction & Efficiency:** Optimized scheduling, maintenance, and human resources.
- **Safety Operations:** Machine vision for real-time video surveillance and hazard detection.
- **AI Integration:** Since 2024, "digital dispatchers" powered by AI and large language models enable human-machine collaboration in bus scheduling.
- **Public-Private Data Governance:** Open data sharing with transport authorities, flexible business models, and a competitive market approach.

2.3 New Technologies and Solutions: Safety, Electrification, and Passenger Experience

Passenger Safety through Smart Bus Stops and Security Depots

Smart electronic bus stop signage, widely used in China, improves passenger safety and is built to withstand vandalism and environmental challenges—an important factor for Maceió. Additionally, Yinchuan's depots are equipped with intelligent security systems, including thermal monitoring to detect hazards like smoking or fires in real-time, ensuring safe parking and charging for electric buses.

Energy Management and Customized Services

Yinchuan's ITS enhances the operation of new energy buses by providing comprehensive tools for efficient charging management, depot heat mapping to monitor thermal conditions, and real-time energy scheduling to optimize power usage.

2.4 Data-Driven Decision-Making and Lessons Learned

Performance Metrics and Service Optimization

NDB consultants highlighted three key service indicators:

- Operating speed
- On-time performance
- Station accessibility
  Detailed methodologies for measuring passenger volumes, peak hour flows, and route turnover enable targeted operational improvements.

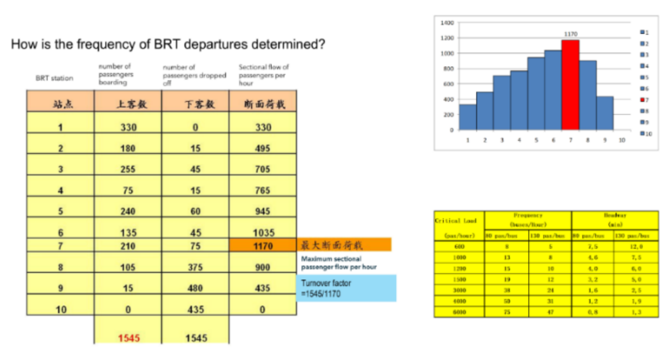
Global Best Practices: Reward-Penalty Mechanisms

- **Singapore:** Ties operator incentives and penalties to performance metrics, driving service quality.
- **World Bank Tianjin Project:** Data-driven investments in non-motorized connections around metro stations, recognized with the 2024 Global Sustainable Transport Award.

Key Lessons from Yinchuan

- Holistic ITS integration and data-driven management are foundational for modern transit.
- Open data standards and modular system design ensure scalability and adaptability.
- Ongoing refinement and localization of new technologies, such as driver health monitoring, are essential.
- Collaboration between public and private sectors, with transparent data governance, underpins sustainable innovation.

Figure: Estimate BRT Service Frequency Based on Passenger Demand



BRT station 站点	number of passengers boarding 上客数	number of passengers dropped off 下客数	Sectional flow of passengers per hour 断面荷载
1	330	0	330
2	180	15	495
3	255	45	705
4	75	15	765
5	240	60	945
6	135	45	1035
7	210	75	1170
8	105	375	900
9	15	480	435
10	0	435	0
	1545	1545	

Critical Load (pas/hour)	Frequency (buses/hour)		Headway (min)	
	80 pas/bus	130 pas/bus	80 pas/bus	130 pas/bus
600	8	5	7,5	12,0
1000	13	8	4,6	7,5
1200	15	10	4,0	6,0
1500	19	12	3,2	5,0
3000	38	24	1,6	2,5
4000	50	31	1,2	1,9
6000	75	47	0,8	1,3

This example shows how to calculate a BRT line's recommended frequency using peak-hour boarding and alighting data. By analyzing the passenger load between each pair of consecutive stations, we identify the maximum load segment, divide it by a BRT vehicle's capacity to get the required buses per hour, and then calculate the optimal headway by dividing 60 by that number.

3. PLANNING, DESIGN TO OPERATION OF BRT:

A Case Study in Shanghai

Field Visit and Operational Overview: Shanghai BRT Line 71

The workshop featured an on-site visit to Shanghai's BRT Line 71, providing practical insights into the planning, design, and operation of a high-capacity urban bus rapid transit corridor.

- **System Description:**
  The Shanghai BRT Line 71 operates a dual-source trolleybus fleet of 70 vehicles (40 articulated 18-meter and 28 standard 12-meter buses, plus 2 spares). It connects major urban destinations including Huashan Hospital, Shanghai Theatre Academy, schools, and the Bund, one of Shanghai's busiest corridors.

- **Ridership and Capacity:**
  By 2025, peak daily ridership is expected to reach approximately 36,000. Currently, during the morning peak, up to 3,000 passengers travel in a single direction per hour. This high capacity is supported by bus headways of just 2 minutes.

- **Fare Collection and Infrastructure:**
  Fares are collected on board without station gates, facilitating quick boarding. The open exclusive-lane design enables rapid clearance of disabled, enhancing emergency response and operational reliability.

Intelligent Scheduling and Signal Priority

- **Signal Priority System:**
  Buses use inductive loops to trigger green lights selectively at intersections, reducing delays and improving schedule adherence—a feature noted by the Brazilian delegation for further study.

- **Lane Design Advantages:**
  The center-running, open exclusive lanes improve bus speed and reliability while allowing emergency vehicles to access the corridor quickly.

Photo: Delegation's visit to Line 71 in Shanghai

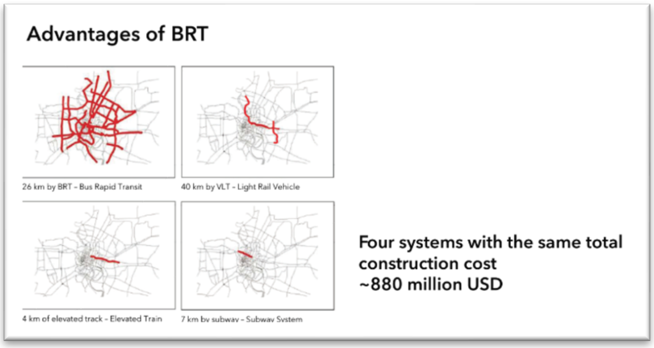
Global BRT

1) Core Logic and Global Experience

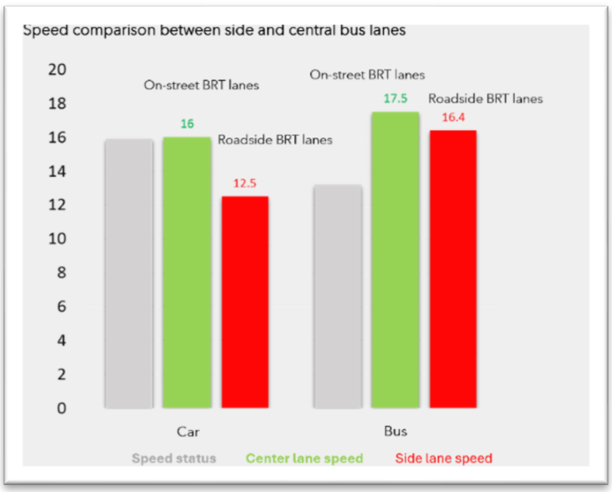
"Move people, not vehicles." A single efficient BRT lane can match the capacity of 22 mixed-traffic lanes. Curitiba and Bogotá established the global BRT benchmark of "bus-first, efficiency-first."

2) Advantages of BRT over Rail Systems

- **Cost and Speed:**
  BRT systems require significantly less capital investment and shorter construction times compared to metro or light rail. For example, a US $880 million investment in BRT can cover over 20 times more urban area than the same amount invested in rail infrastructure.



- **Operational Efficiency:**
  As was demonstrated by the cities of Curitiba and Bogotá, a transportation approach that puts buses at the forefront often leads to efficient passenger transportation. A single efficient BRT lane can match the capacity of 22 mixed-traffic lanes since BRT embodies the principle of "Move people, not vehicles." In Guangzhou, the open-operated BRT transformed congested mixed-traffic corridors into segregated lanes. This swift resulted in improved travel for both buses and private vehicles.



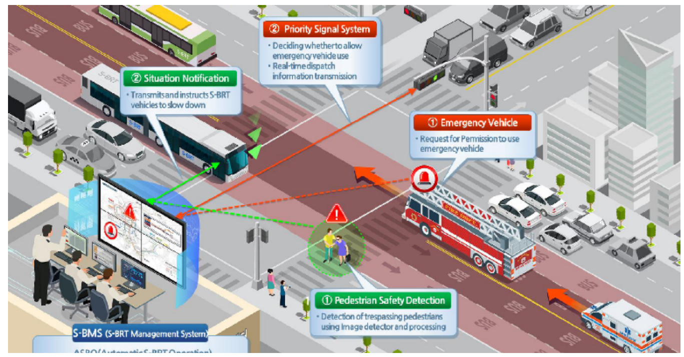
3) Key Technical Elements of BRT

- **Dedicated Lane Design:**
  Center-running lanes are preferred over curbside lanes as they avoid conflicts with street-hailing and intersections, improving speed and reliability.

- **Station Design:**
  Various station configurations exist—curbside, center-island, offset-center, and staggered-offset platforms. The recommended design is the staggered center-side platform, which balances operational efficiency with open traffic flow, successfully implemented in Yinchuan, Guangzhou, and Yichang.

- **Vehicle Selection:**
  Electric buses are preferred, with emphasis on maximizing vehicle length and door count to reduce dwell times and increase throughput.

- **Intelligent Transport Systems (ITS):**
  ITS is essential for optimizing scheduling, real-time operations, and passenger information.

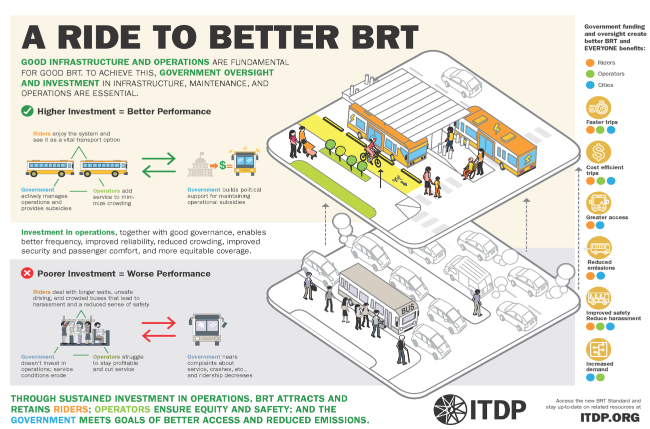


4) Adaptability to Different Corridors

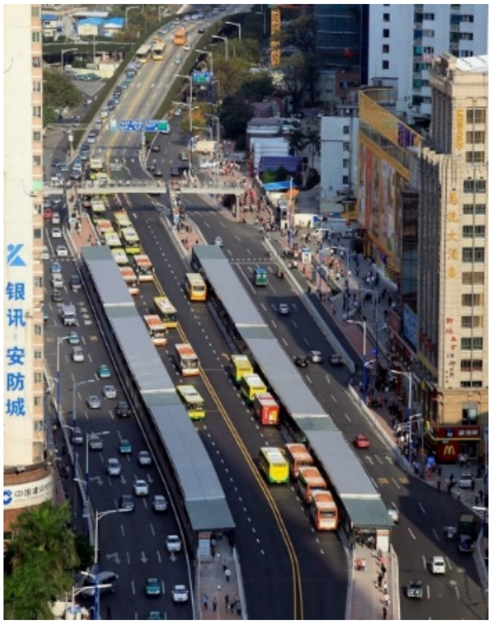
BRT can flexibly serve 2,000–4,000 passengers per hour (pph) corridors (e.g., Shanghai 71) up to 45,000 pph (e.g., Bogotá's TransMilenio or Guangzhou BRT).

		BRT System		
	Belt Exclusive towards Bus	Low Ability Transportation	Average Ability Transportation	Discharge Ability Transportation
Ability from Passengers	2000-4000 People by hour	3000-8000 People by hour	6000-10000 People by hour	8000-45000 People by hour
Cost from Implantation	300-800 10 thousand people/km	1000-3000 10 thousand people/km	3000-4000 10 thousand people/km	4000-6000 10 thousand people/km
Speed Average	12-17km/h	17-19km/h	18-21km/h	21-27km/h
Cases of Cities	São Paulo, Brazil Lima, Peru Taipei, China Kunming, China	Jakarta, Indonesia León, Mexico Quito Ecuador Brisbane Australia Rennes, France Changzhou, China	Curitiba Brazil Jinan, China Zhengzhou, China	Bogota, Colombia Guangzhou, China

5) Standards & Case Studies



- Follow ITDP's 2024 BRT Standard: prioritize speed, cost-benefit, accessibility, low emissions, safety, and growing ridership.
- Other cities that have followed the ITDP standard in their BRT systems and achieved good results are Guangzhou and Yichang. In Guangzhou, the center-side platforms with multiple sub-stations and passing lanes services a peak single-direction ridership of 28,000 pph, using 350 buses/hour (one every 10 seconds).



- **Guangzhou BRT:** Opened in 2010, this high-capacity system carries over 850,000 passengers daily, with peak single-direction ridership reaching 28,000 passengers per hour and 350 buses per hour—one every 10 seconds. This 22.5 km corridor features center-side platforms, multiple sub-stations, and dedicated passing lanes, enabling smooth high-frequency operations.

Pioneering a direct-service model with no terminals or transfers, the system uses mostly standard 12-meter buses operated by both public and private companies—improving efficiency and reducing complexity for riders.

Fully integrated with metro lines, bike lanes, and a co-developed bike-sharing network, the system has cut bus travel times by 30%, reduced wait times by 15%, and significantly improved service quality.

Guangzhou BRT proves that bus systems can deliver metro-level speed, capacity, and convenience, offering a powerful, cost-effective model for rapidly growing cities worldwide.

- **Yichang BRT:** the BRT was custom designed for the terrain and uses all double-door vehicles, open operation.

Yichang, a city of over 4 million and home to the iconic Three Gorges Dam, is redefining sustainable transport with its high-performing BRT system. Adapted to complex terrain with diverse platforms and a modern fleet of double-door buses, the open BRT system delivers impressive capacity—peaking at 5,400 passengers per hour with 94 buses/hour—making it the most efficient among cities of its size.

The 23-kilometer corridor runs through the city center with 37 stations and is expected to cut cross-city travel times by one-third. Since its 2015 launch, the system has rapidly expanded, with full Phase 1 completion in early 2016. Integrated with improvements for pedestrians and cyclists, upgraded public spaces, and a planned bike-sharing network, the BRT anchors transit-oriented development and offers a compelling model for small and mid-sized cities across the region.

- More examples at the ITDP library: https://itdp.org/library/standards-and-guides/the-bus-rapid-transit-standard/

2024	Brazil	Niteroi	TransOceânica	**9.0**	2024	55	36	BRT certified
2014	Brazil	Belo Horizonte	MOVE - MOVE - Antônio Carlos	**16.0**	2015	91	79	Silver
2014	Brazil	Belo Horizonte	MOVE - MOVE - Cristiano Machado	**7.1**	2014	89	86	Gold
2014	Brazil	Brasília	Expresso DF - Expresso DF Sul	**36.2**	2015	71	59	Bronze
2013	Brazil	Curitiba	Rede Integrada de Transporte (RIT) - Linha Verde	**7.0**	2013	92	92	Gold
2013	Brazil	Curitiba	Rede Integrada de Transporte (RIT) - Leste	**12.4**	2013	82	82	Silver
2013	Brazil	Curitiba	Rede Integrada de Transporte (RIT) - Oeste	**10.4**	2013	82	82	Silver
2013	Brazil	Curitiba	Rede Integrada de Transporte (RIT) - Norte	**8.9**	2013	82	82	Silver
2013	Brazil	Curitiba	Rede Integrada de Transporte (RIT) - Sul	**10.6**	2013	82	82	Silver
2013	Brazil	Curitiba	Rede Integrada de Transporte (RIT) - Boqueirão	**10.3**	2013	82	82	Silver
2013	Brazil	Curitiba	Rede Integrada de Transporte (RIT) - Circular Sul	**14.5**	2013	82	82	Silver
2014	Brazil	Goiânia	(no BRT system name) - Eixo Anhanguera	**13.5**	2015	68	56	Bronze
2016	Brazil	Recife	Via Livre - Via Livre Leste/Oeste	**8.2**	2017	68	52	BRT certified
2016	Brazil	Recife	Via Livre - Via Livre Norte/Sul	**22.8**	2017	76	64	Bronze
2014	Brazil	Rio de Janeiro	BRT Rio - TransOeste	**52.0**	2014	89	77	Silver
2014	Brazil	Rio de Janeiro	BRT Rio - TransCarioca	**39.0**	2014	89	86	Gold
2013	Brazil	Rio de Janeiro	BRT Rio - TransOeste	**52.0**	2013	90	88	Gold
2016	Brazil	Rio de Janeiro	BRT Rio - TransOlimpica	**23.0**	2017	88	75	Silver
2013	Brazil	São Paulo	(no BRT system Name) - Expresso Tiradentes (Eixo Sudeste)	**12.0**	2013	80	80	Silver
2013	Brazil	São Paulo	Corredor Metropolitano ABD - ABD Diadema	**33.0**	2013	60	60	Bronze
2014	Brazil	São Paulo	Corredor Metropolitano ABD - ABD Extensão Morumbi	**10.8**	2015	52	47	BRT certified
2016	Brazil	Uberaba	VETOR - VETOR Leste-Oeste	**5.1**	2016	82	72	Silver
2014	Brazil	Uberlândia	(no BRT system name) - Corredor Estrutural Sudeste (Av. João Naves de Ávila)	**7.5**	2015	70	70	Silver

2013	China	Beijing	Beijing BRT - Entire Network	**59.0**	2013	57	57	Bronze
2014	China	Changde	Changde BRT - Changde Dadao	**18.9**	2014	58	53	BRT certified
2014	China	Chengdu	Chengdu BRT - Erhuan Lu	**28.8**	2014	72	72	Silver
2013	China	Changzhou	Changzhou BRT - Entire Network	**51.9**	2013	68	68	Bronze
2014	China	Dalian	Dalian BRT - Zhangqian Lu - Songjiang Lu - Huabei Lu - Xi'an Lu	**9.0**	2014	51	51	BRT certified
2013	China	Guangzhou	Guangzhou BRT - Zhongshan Avenue	**22.5**	2013	91	91	Gold
2014	China	Hefei	Hefei BRT - Hefei Line 1 (Changjiang)	**7.2**	2014	57	52	BRT certified
2014	China	Jinan	Jinan BRT - B7 corridor Xierhuan	**7.1**	2014	65	60	Bronze
2013	China	Jinan	Jinan BRT - Beiyuan dajie	**15.0**	2013	67	67	Bronze
2013	China	Jinan	Jinan BRT - Lishan Lu	**4.8**	2013	67	67	Bronze
2013	China	Jinan	Jinan BRT - Erhuandonglu	**8.0**	2013	67	67	Bronze
2013	China	Jinan	Jinan BRT - Gongyebeilu-Aotizonglu Line 6	**6.6**	2013	67	67	Bronze
2013	China	Lanzhou	Lanzhou BRT - Anning Lu	**8.6**	2013	84	84	Silver
2014	China	Lianyungang	Lianyungang BRT - Xingfu-Hailian-Xingangcheng-Gangcheng	**32.0**	2014	64	61	Bronze
2014	China	Urumuqi	Urumuqi BRT - Corridor 1 (Beijinglu-Xibeilu-Yangzijianglu)	**15.5**	2014	70	60	Bronze
2014	China	Xiamen	Xiamen BRT - 0	**51.0**	2014	77	74	Silver
2014	China	Yancheng	Yancheng BRT - Kaifang Dadao - Jiefang Nanlu	**16.0**	2014	58	55	Bronze
2014	China	Yichang	Yichang BRT - Yixing Ave-Dongshan Ave-Jucheng Rd	**23.0**	2015	85	85	Gold
2014	China	Yinchuan	Yinchuan BRT - Huanghe East-Nanxun-Qinghe	**17.0**	2014	62	56	Bronze
2014	China	Zaozhuang	Zaozhuang BRT - B1	**33.5**	2014	60	57	Bronze
2014	China	Zaozhuang	Zaozhuang BRT - B3	**32.2**	2014	57	49	BRT certified
2014	China	Zaozhuang	Zaozhuang BRT - B5	**18.5**	2014	58	50	BRT certified
2014	China	Zhengzhou	Zhengzhou BRT - 0	**30.5**	2014	65	59	Bronze
2014	China	Zhongshan	Zhongshan BRT - Zhongshan 2nd-5th Rd - Jiangling Rd	**13.0**	2014	67	62	Bronze

4. BRT FLEET ELECTRIFICATION:

Lessons and Opportunities from Yinchuan's Experience

4.1 The Rationale for Electrification: From Policy to Economics

Yinchuan's shift to a fully electric bus fleet was initially motivated by national and local environmental policies aimed at decreasing urban air pollution and greenhouse gas emissions. Over time, as the technology advanced and improved, this move also became a financially sound.

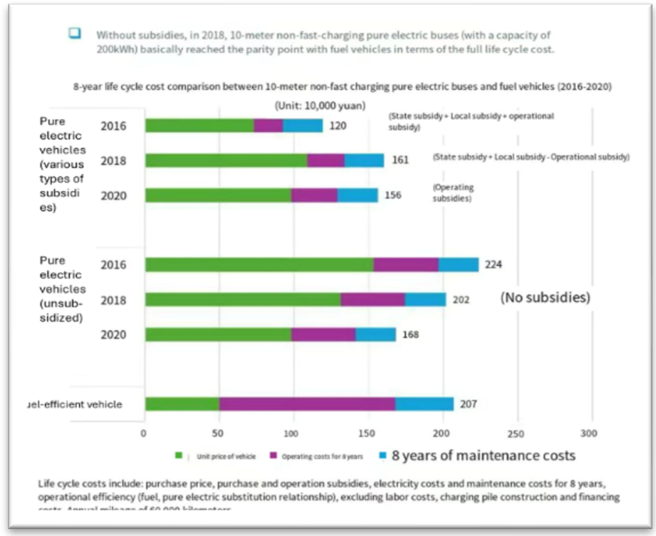
4.2 Economic Viability: Lifecycle Cost and Financing Innovations

Battery Cost Reduction and Market Maturity

Between 2009 and 2018, China's electric bus market experienced significant growth driven by government subsidies that encouraged industry development and technological progress. As a result, technology has improved, and batteries are now competitively priced (battery prices are now only 20% of peak price). This substantial decrease in battery costs made electric buses cost-competitive with, and often less expensive than, traditional fuel-powered buses, even without government subsidies.

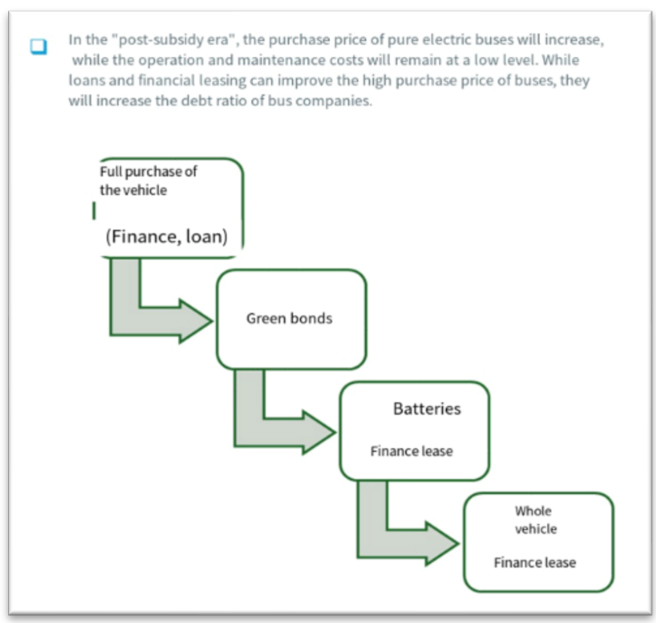
Lifecycle Cost Analysis

A comprehensive eight-year cost comparison—encompassing procurement, maintenance, and operational expenses—revealed that electric buses, despite higher initial investment, now yield lower total costs over their service life. Reduced maintenance (due to fewer moving parts), lower energy costs, and longer vehicle life all contribute to this advantage.



Battery Leasing and Green Finance

Chinese cities have adopted innovative financing options to fund initial investment in electric buses. Battery leasing models are employed to alleviate the requirement for high initial costs. Bus operators rent batteries from third-party providers, paying regular rental fees out of cash generated by operations. This approach amortizes capital costs, improves cash flow, and accelerates fleet upgrades.



4.3 Operational Advantages and Grid Integration

Depot Infrastructure and Charging Management

Yinchuan's electric depots are equipped with 120 kW fast chargers, enabling a full charge within 3–4 hours. In colder months, a 20kW heating system maintains battery performance, using only 3–4 kWh for 15–20 minutes. These technical solutions ensure reliability and operational continuity, even in challenging climates.

Electricity Pricing and Cost Savings

Yinchuan's tiered electricity pricing—RMB 0.72/kWh during valley hours and RMB 1.16/kWh during peak—means that electric buses cost RMB 43.2–69.6 per 100 km to operate, compared to RMB 68.67–85.02 per 100 km for LNG buses. By scheduling charging during off-peak hours, operators maximize cost savings and help stabilize the grid, making electric buses "the grid's best large customer." For Maceió, collaborating with local utilities to secure favorable electricity rates and optimize charging schedules could further enhance the economic case for electrification.

Photo: Delegation's Visit to Yinchuan's Bus Depots

4.4 Integrating Micro-Mobility: The "Last Mile" Solution

Yinchuan's green mobility strategy extends beyond buses to include a robust shared e-bike system, branded as "Micro-Bus." With 16,200 e-bikes operated by multiple providers, the system achieves 3–4 rides per bike per day, with trip lengths of 3–5 km. Intelligent redeployment ensures high utilization: bikes unused for 12 hours are flagged for relocation, and a single vehicle can rebalance 16–20 bikes at a time. Monthly revenues from e-bikes rival those of the bus network, illustrating the financial and operational synergy of integrated, layered mobility.

4.5 International Best Practices: The Santiago Example

Santiago, Chile, provides a compelling international reference. By partnering with the national grid, the city co-financed charging infrastructure and deployed 600 electric buses, earning the 2020 Global Green Finance Innovation Award. This demonstrates that large-scale electrification is feasible when supported by innovative finance and strong utility partnerships—an approach Maceió can adapt to its own context.

Chile's capital worked with the national grid to co-finance charging infrastructure and 600 electric buses—the largest fleet outside China—and won the 2020 Global Green Finance Innovation Award.

4.6 Recommendations for Maceió

Based on Yinchuan's experience and global best practices, the following steps are recommended for Maceió for determining the bus fleet between electric buses vs. combustion engine buses:

- **Conduct a Detailed Lifecycle Cost Analysis:**
  Assess the long-term financial benefits of electric buses compared to diesel or LNG alternatives, factoring in local energy prices and operational patterns.

- **Explore Battery Leasing and Green Finance:**
  Partner with financial institutions and energy providers to develop battery leasing or pay-as-you-save models, reducing upfront capital barriers.

- **Collaborate with Utilities:**
  Negotiate preferential electricity rates for off-peak

charging and explore opportunities for grid-friendly charging management.

- **Pilot and Scale:**
  Start with a pilot project on high-ridership BRT corridors to validate operational feasibility and cost savings before scaling up citywide.

- **Integrate Micro-Mobility:**
  Explore shared e-bike or e-scooter services to complement the BRT network, enhancing accessibility and system efficiency.

In Summary:

China's successful transition to a fully electric bus fleet, driven by innovative financing, comprehensive technical planning, and integrated micro-mobility, provide a clear model for Maceió to develop a sustainable, cost-effective, and modern BRT system. By applying these lessons and tailoring them to local conditions, Maceió has the potential to become a leader in green urban mobility in Latin America, generating long-term economic, environmental, and social benefits for the city and its residents.

5. PRELIMINARY TECHNICAL RECOMMENDATIONS FOR MACEIÓ'S BRT PROJECT

During technical discussions, the NDB consultant provided the following preliminary recommendations, subject to further appraisal and refinement:

- Align with the municipality's vision for road space allocation: 30% for buses, 30% for cars, and 40% for bicycles and pedestrians.

- Preserve the center-running bike lanes and explore technical enhancements to the current staggered-offset platform design.

- Avoid operating curbside conventional bus services along the corridor to minimize competition with the BRT and protect its ridership base.

- Implement a staggered center-side platform configuration: co-locate bus and bike lanes in the center of the corridor, stagger the platforms to optimize flow, eliminate curbside stops and bus bays, and consolidate all services within the BRT corridor to promote system integration and ensure passenger uptake.

Workshop Participants

- **DELEGATION FROM MUNICIPALITY OF MACEIÓ**

Fernando José Cavalcante da Silva

Executive Coordinator of UGP (Project Implementing Unit) – Municipal Secretariat for Strategic Actions and Metropolitan Area Integration (SEMAEMI)

Fabrício de Almeida Fernandes

Undersecretary for Municipal Treasury – Municipal Secretariat of Finance (SEFAZ)

José Glauco de Oliveira Andrade

Technical Director for the Maceió Municipal Urban Transportation System – Municipal Department of Transport and Traffic (DMTT)

Victor Correia Vasconcellos

Undersecretary – Municipal Secretariat for Infrastructure (SEMINFRA)

- **NEW DEVELOPMENT BANK**

Yang Ji (Aimee)

Project Team Leader, Public Sector Department

Zhengyu Yang

Senior Professional, Public Sector Department

Charmaine Kazamula

Senior Professional, Public Sector Department

Jiechao Nie

Professional, Public Sector Department

Ludmila Vidigal Silva

Senior Professional, Americas Regional Office

Guilherme Macedo Favoretto

Professional, Americas Regional Office

Daizong Liu

NDB Technical Consultant (BRT)

Yujing Xie

Intern, Public Sector Department