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Strengthening the Capacity of Local Governments in Developing Countries to Effectively Manage Infrastructure Assets

Columbia SIPA Capstone | Spring 2023

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List of Abbreviations

AA+	Fitch's global scale rating
Aa1	Moody's global scale rating
AI	Artificial Intelligence
CAPEX	Capital Expenditures
COSIP	Contribuição para o Custeio do Serviço de Iluminação Pública
CPI	Consumer Price Index
DFC	United States International Development Finance Corporation
ESG	Environmental, Social, and Governance
IFC	International Finance Corporation
IAM	Infrastructure Asset Management
IoT	Internet of Things
ITMS	Intelligent Traffic Management System
LDCs	Least Developed Countries
LED	Light Emitting Diodeem
MOOC	Massive Open Online Course
MSRDC	Maharashtra State Road Development Corporation
OPEX	Operating Expenses
PETs	Privacy-Enhancing Technologies
PII	Personally Identifiable Information
PPPs	Public-Private Partnerships
SDGs	Sustainable Development Goals
SPV	Special Purpose Vehicle
UN DESA	UN Department of Economic and Social Affairs

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1. Executive Summary

In developing nations, infrastructure projects may face challenges in sustaining maintenance and effectively managing associated risks due to various factors, hindering long-term success. In response, UN DESA and the UN Capital Development Fund released a Handbook and Massive Open Online Course (MOOC) on Infrastructure Asset Management (IAM) in 2021. To further enhance the handbook's contributions, the Columbia SIPA Capstone research team conducted in-depth research to identify successful and replicable sustainable models for IAM.

The research explored the adoption of technology, financing mechanisms, and procurement in mitigating moral hazard and increasing social and financial returns of existing Public-Private Partnerships (PPPs) at the subnational level, aligned with the Sustainable Development Goals (SDGs). The analysis concentrates on exploring innovative financial and technological strategies to tackle infrastructure asset management (IAM) challenges faced by local governments, especially in Least Developed Countries (LDCs). These challenges include constrained funding, reduced support from central governments, moral hazard in procurement processes, and the absence of sustainable revenue sources.

Four infrastructure asset management projects were chosen as case studies due to their potential for replication, significant financing or technological aspects, and ability to improve essential services: a smart city project in Rio de Janeiro, Brazil; a public-private partnership (PPP) funding for Metro Line 4 in Beijing, China; an intelligent traffic management system for the Pune expressway in India; and a franchising model for waste and fecal disposal in Haikou, China.

The research aimed to identify minimum requirements for LDCs to implement similar projects, providing valuable insights and best practices in technology, procurement, and financing. Local governments in lower- and middle-income countries can apply these insights to promote effective and sustainable IAM strategies.

By analyzing these case studies, the Columbia SIPA Capstone research team explored the hypothesis that understanding the adoption of technology, financing mechanisms, and procurement can mitigate moral hazard and increase social and financial returns of existing PPPs at the subnational level, in alignment with the SDGs.

2. Introduction

2.1. Context and Background

Infrastructure projects in developing countries must anticipate maintenance and risk management costs to ensure their long-term success. To guide national and sub-national governments in efficiently managing their assets, in 2021, the UN Department of Economic and Social Affairs (UN DESA) and the UN Capital Development Fund released the joint publication "Managing Infrastructure Assets for Sustainable Development: A Handbook for Local and National Governments" and the "Massive Open Online Course on Infrastructure Asset Management (MOOC)."

To complement the Handbook, UN DESA has commissioned the Columbia SIPA Capstone research team to investigate successful and replicable sustainable models for infrastructure asset management. This report aims to understand how adopting technology, unique financing mechanisms, and procurement mitigates moral hazard and increases social and financial returns of existing Public-Private Partnerships at the subnational level, in alignment with the SDGs. The report draws upon a range of sources, including existing literature, case studies, and expert interviews, to comprehensively analyze the key factors that contribute to successful and sustainable infrastructure financing models.

Infrastructure Asset Management (IAM) is a critical function for local governments in the Least Developed Countries (LDCs) as they strive to provide essential services and improve the quality of life for their citizens. However, local governments in LDCs often face significant challenges in funding IAM initiatives due to a thinning fiscal base, decreasing financial support from the central government, potential moral hazard in procurement processes, integration of the management of national and subnational assets, interoperability of new technology with legacy IAM operations, and the lack of sustainable revenue streams to manage, maintain, and cover unforeseen risks. To address these challenges, innovative and notable financial and technological solutions have emerged throughout the lifecycle of assets, providing local governments in LDCs with opportunities to overcome these obstacles and effectively manage their infrastructure assets.

Limited financial resources often result in inadequate infrastructure project funding, leading to asset maintenance and replacement delays. A challenge local governments face in LDCs is the decreasing financial support from the central government. Many local governments heavily rely on transfers and grants from the central government to fund their IAM initiatives. However, these transfers may decrease over time due to various factors, such as changing political priorities or budget and fiscal constraints.

Potential moral hazard in procurement processes is a challenge that local governments in LDCs frequently face. Corruption, fraud, and lack of transparency in procurement processes can result in mismanagement of funds, subpar quality assets, and cost overruns. In addition, integrating national and subnational asset management is a hurdle local governments face in LDCs. Different government agencies or levels often manage national and subnational assets, such as roads, bridges, and water supply systems, resulting in siloed and fragmented asset management practices. This situation can lead to inefficiencies, duplication of efforts, and lack of coordination in managing infrastructure assets.

Local governments are encountering a new challenge: ensuring the interoperability of emerging technologies with existing infrastructure asset management (IAM) operations. Emerging technologies, such as the Internet of Things (IoT), Big Data, and Artificial Intelligence (AI), offer significant opportunities for improving IAM practices. However, integrating these new technologies with legacy IAM operations can be complex. Consequently, to address this challenge, strategies such as phased implementation, conducting pilot projects, and enhancing capacity building have been employed.

Asset management plans involve developing long-term asset management strategies, including budgeting for maintenance, repair, and replacement costs. User fees include charging fees to users of infrastructure assets, such as tolls, tariffs, or service charges, to generate revenue for IAM initiatives. In conclusion, profit

and risk-sharing arrangements, which involve collaboration between local government administration with the private sector or insurance companies, help distribute the risks and costs associated with unexpected assets' maintenance or operation related issues. These financial mechanisms are designed to supply local governments with revenue sources for managing, maintaining, and addressing unanticipated asset risks, ultimately ensuring the long-term sustainability of infrastructure asset management initiatives.

This report considers the IAM challenges that local governments face and puts forth innovative and notable financial and technological solutions that can enhance funding, procurement, coordination, interoperability, and revenue generation. The solutions offer opportunities for local governments to effectively manage their infrastructure assets and work towards achieving the SDGs. By leveraging these innovative solutions and prioritizing capacity building, stakeholder engagement, and knowledge sharing, local governments in developing countries can overcome IAM challenges and build resilient, sustainable, and inclusive infrastructure systems that meet the needs of their communities.

2.2. Objectives

This report aims to identify innovative and sustainable financing solutions for municipalities to support IAM throughout its entire lifecycle. The effectiveness of these solutions is assessed through the examination of four infrastructure asset projects:1) Rio de Janeiro, Brazil's enhancing of PPP financing and scope to finance the Smart City project; 2) Beijing, China's PPP funding and sustainable management of Metro Line 4; 3) Pune, India's implementation of the Expressway Intelligent Traffic Management System (ITMS); and 4) Haikou, China's franchising of waste disposal by introducing foreign technology. The research explores similar projects alongside these four case studies to gain valuable insights and best practices in technology, procurement, and financing. The analysis evaluates their success in identifying minimum requirements that lower- and middle-income countries must meet to accomplish comparable results.

Furthermore, this analysis allows local governments to identify good practices that can be replicated and apply the gained insights, streamlining the implementation of similar projects while promoting efficient, sustainable infrastructure asset management strategies.

3. Theoretical Approach

The primary hypothesis guiding this research is: "The adoption of technology, notable financing mechanisms, and procurement will mitigate moral hazard, and increase social and financial returns of existing Public-Private Partnerships at the subnational level, in alignment with the SDGs."

To assess the validity of the stated hypothesis, this paper examines infrastructure projects based on the following criteria:

- Notable financing and/or technological components: Selected case studies incorporate unique financing or technological mechanisms that contribute to the efficiency and sustainability of infrastructure projects, addressing the challenges encountered by local governments in LDCs.
- Potential for replicability in diverse contexts: The case studies exhibit successful implementation of innovative infrastructure asset management approaches that can be replicated in various local

settings, including different socio-economic, political, and cultural contexts.

- Capacity to enhance the provision of essential services: The case studies highlight projects that not only improve the quality and accessibility of essential services, but also positively affect socio-economic development, ultimately contributing to the achievement of the SDGs.

The aforementioned criteria are essential for testing the hypothesis as they tackle the key challenges that local governments face when financing and managing infrastructure projects. If these criteria are not met, local governments may face financial resource constraints and capacity limitations, resulting in difficulties in operating and maintaining infrastructure assets. It is also important to note that effective infrastructure asset management should not adopt a one-size-fits-all approach but should be tailored to local contexts to achieve the SDGs.

To further enhance the analysis, additional infrastructure asset projects with similarities to the selected case studies or relevant technological or financing components were included for comparison. This allows for drawing broader conclusions about effective and innovative approaches to infrastructure asset management that can be applied across various contexts, while also evaluating the extent to which these mechanisms are replicable.

4. Methodology

The authors analyzed the case studies' PPP contracts, government and projects websites, existing literature, financial reports, offering memorandums, and cooperative agreements. Case contexts were developed based on this information, and within each context, key takeaways were highlighted. To complement the information gathered, qualitative interviews were conducted with industry experts which include government officials, project managers, advisors, consultants, scholars and project employees with first-hand experience working with these cases.

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This report focuses on assessing the technological and financing aspects of each case study in relation to the hypothesis, while taking into account the unique characteristics of each country's context. In doing so, the research highlights the importance of replicability as a crucial factor in the analysis. The analysis of replicability took into account factors such as funding, construction and operation costs, outputs related to population levels, and political factors, among others. Additionally, comparable cases were selected based on the selection criteria to showcase the commonalities and differences between them, enabling conclusions to be drawn about their replicability.

The compilation and analysis of this information led to conclusions about efficient and replicable approaches to improving infrastructure asset management in emerging and developing countries. This report subsequently offers lessons learned and recommendations for local governments to more effectively plan, construct, operate, and maintain similar infrastructure assets, providing public goods while striving to achieve the Sustainable Development Goals.

5. Case studies

5.1. Leveraging Blended Finance - The Smart City project in Rio de Janeiro

5.1.1. Overview

Socioeconomic indicators in Rio de Janeiro show a high level of inequality with a Gini coefficient of 0.555, indicating a significant wealth gap between the rich and poor[1]. While the city has made progress in improving infrastructure and services, many residents still lack access to basic necessities such as electricity, clean water, and adequate healthcare, and access to public services in Rio is still a concern. According to a study published by the World Bank, street lighting infrastructure in Brazil accounts for 4.3% of total electricity consumption and commits between 3% and 5% of municipalities' budget[2].

Despite the significant number of streetlights in the city, there are still some areas that are poorly lit, particularly in low-income neighborhoods. In some cases, residents have reported that streetlights are broken or not functioning correctly, which can create safety concerns at night. The city government has implemented various programs to improve street lighting in these areas, including the "Light Up the Future" program, which aims to install LED lighting in all public schools in Rio de Janeiro. The city has also experimented with smart street lighting systems, which use sensors and other technology to adjust lighting levels based on traffic and pedestrians.

The implementation of the Smart City project in Rio de Janeiro holds substantial potential to bring advantages to the city and its inhabitants, as it represents the inaugural municipal Internet of Things network in Brazil.[3] By using technology to optimize urban services and improve the quality of life in the city, the project aims to address some of the key challenges facing Rio de Janeiro. Some of the primary benefits of the Smart City project would be increased efficiency and sustainability; as well as the use of data and analytics to optimize energy and water consumption, reducing environmental impact and saving money in the long run.

The Smart City project increases transparency and participation in city governance. By making data and information more accessible to residents and the community, the project aims to promote greater civic engagement and collaboration. It also includes the development of a digital platform for management. This is important for the city, as it can greatly enhance residents' quality of life, encourage sustainability and efficiency, and foster transparency and civic engagement in city governance. Specifically, it addresses Sustainable Development Goal (SDG) 7 “Affordable and Clean Energy”, 9 “Industry, Innovation and Infrastructure”, 11 “Sustainable Cities and Communities”, and 13 “Climate Action”[4]. Furthermore, as the

[1] Banco Nacional de Desenvolvimento Econômico e Social. "Street Lighting." BNDES Projects Hub. Accessed April 19, 2023. https://projectshub.bndes.gov.br/en/setores/Street-Lighting
[2] Ibid.
[3] Environmental Finance. "Sustainability Project Bond of the Year - Smart Luz." Environmental Finance Bond Awards 2022. Accessed April 19, 2023. https://www.environmental-finance.com/content/awards/environmental-finances-bond-awards-2022/winners/sustainability-project-bond-of-the-year-smart-luz.html
[4] United Nations. "Transforming Our World: The 2030 Agenda for Sustainable Development." 2015. Accessed April 19, 2023. https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf

project continues to develop and expand, it has the potential to become a model for other cities in Brazil and around the world.

The Smart Street Lighting project in Rio de Janeiro is being implemented through a Public-Private Partnership between the city government and the company Smart Luz. The program aimed to replace all of the city's 450,000 light points with LED bulbs, which was completed ahead of schedule in December 2022 leading to savings of approximately 100 million BRL in the municipality's public accounts in the last year[5].

Along with the new LED bulbs, the Smart City project "will install 5,000 Wi-Fi access points, 6,000 smart traffic controllers, 10,000 cameras, and 4,000 storm drains, all of which will collect data to improve security, road safety, and flood prevention. Also part of the concession is a control center to collect and crunch the data"[6]. LED luminaires are energy-efficient and provide better quality lighting. The cameras and wireless sensors provide real-time data on traffic, pedestrian flows, and environmental conditions, allowing for improved asset management and more efficient maintenance of infrastructure. The WiFi access points provide public access to the internet, promoting digital inclusion and enabling the use of smart city applications[7].

The utilization of interconnected technologies leads to enhanced efficiency in governance, as the city can remotely and in real-time monitor and manage public lighting connected to other infrastructures. This reduces the frequency for on-site inspections and allows for proactive maintenance. Furthermore, the data gathered by this network can be examined to analyze patterns and trends, which can then inform policy decisions and resource allocation.

Before 2010, responsibilities and liabilities associated with the provision of street lighting were not clearly defined but the custom was for them to be included in electricity distribution contracts between municipalities and electric power companies[8]. However, in 2010, Federal policy by the Brazilian Electricity Regulatory Agency (Aneel) clearly assigned the responsibility of service provision to municipalities, and mandated all street lighting assets to be transferred to them[9]. Aneel's role is to "regulate supply contracts, energy consumption measurement methodologies and the scope of activities that can use the special public lighting fare"[10]. Nonetheless, each municipal government has the legal authority to determine whether to provide services directly or through third-party contracts like PPPs[11], and to establish quality parameters, technologies, and other operational aspects[12].

[5] LatinFinance. "Financing Brazil." LatinFinance Magazine, 2022 Q4. Accessed April 19, 2023. https://read.nxtbook.com/latinfinance/magazine/2022_q4/financing_brazil.html
[6] Ibid.
[7] Instituto Brasileiro de Geografia e Estatística. "Censo Demográfico 2020." IBGE. Accessed April 19, 2023. https://www.ibge.gov.br/estatisticas/sociais/populacao/9662-censo-demografico-2020.html?=&t=o-que-e
[8] Banco Nacional de Desenvolvimento Econômico e Social. "Street Lighting." BNDES Projects Hub. Accessed April 19, 2023. https://projectshub.bndes.gov.br/en/setores/Street-Lighting
[9] Ibid.
[10] Ibid.
[11] Banco Nacional de Desenvolvimento Econômico e Social. "Street Lighting." BNDES Projects Hub. Accessed April 19, 2023. https://projectshub.bndes.gov.br/en/setores/Street-Lighting
[12] Ibid.

BNDES, CAIXA, the IFC, and the World Bank came together to develop a national PPP framework to promote replicability and standardization in PPP projects across the country. The framework consists of two phases: the structuring phase and the implementation phase. During the structuring phase, the World Bank provides technical assistance to help governments identify and prioritize potential PPP projects, conduct feasibility studies, and develop business cases. This phase focuses on building capacity and expertise within the government to effectively structure and manage PPP projects. In the implementation phase, it provides financial support to help governments attract private sector partners and implement PPP projects. This includes funding for project preparation, transaction advisory services, and potential guarantees or loans to support the private sector investment. The goal is to facilitate the successful implementation of PPP projects that deliver public services efficiently and effectively[13].

These PPP contracts are awarded through competitive tender processes, to the private party requesting the lowest monthly payment from the public. To ensure performance and accountability, the private party is required to meet modernization schedules, lighting performance standards, and energy efficiency goals audited by an independent third-party verifier. The use of telemanagement technology is also typically mandated for key streets in the city. To guarantee payments to the private sector provider , an escrow account mechanism is established by municipal law, which also explicitly authorizes the delegation of services through PPPs. Finally, to incentivize performance, the private sector provider may earn a fixed percentage of the municipality's energy savings beyond the consumption reduction goal, known as the Energy Bill Bonus. Furthermore, the telemanagement infrastructure may be utilized for additional smart city-related services, subject to municipal approval and a pre-established share of the revenues earned[14].

In the case of Rio de Janeiro, in 1990, the Municipality had incorporated a state-owned entity, Companhia Municipal de Energia e Iluminação - Rio Luz, as a concessionaire for all lighting services. However, as a "result of lower-than-expected revenues and profitability"[15], in 2017, the Municipality pursued a Public-Private Partnership (PPP) for the provision of lighting services previously offered by Rioluz. Rioluz then initiated a public bidding procedure for a sub-concession of these services, which was designed with guidance from the International Finance Corporation (IFC) to comply with the Municipality's PPP framework, federal concessions law, and PPP law. Smart Luz emerged as the winning bidder for the sub-concession and subsequently secured a 20-year agreement with Rioluz as sub-grantor, effective April 28, 2020. Smart Luz is backed by five well-established sponsors that hold the following participations: Green Luce Soluções Energéticas S.A., 27.4% High Trend Brasil Serviços e Participações Ltda., 23% ARC Comércio Construção e Administração de Serviços Ltda., 17.5%; Proteres Participações S.A., 16.4%; and Salberg S.A., 15.7%[16]). These partners hold expertise in the public lighting sector, spanning infrastructure, smart city connectivity, project management, finance, and operations[17].

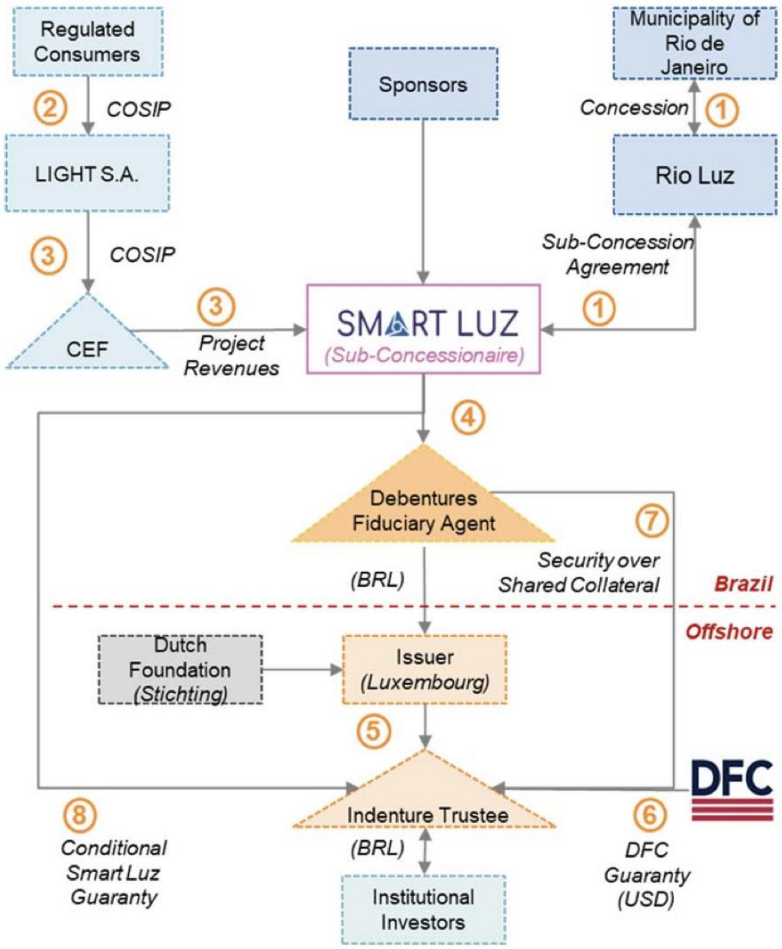
[13] Banco Nacional de Desenvolvimento Econômico e Social. "Street Lighting." BNDES Projects Hub. Accessed April 19, 2023. https://projectshub.bndes.gov.br/en/setores/Street-Lighting
[14] Ibid.
[15] Singapore Exchange. "Rio Smart Lighting - Final Offering Memorandum [Printed 11-3-21]." SGX. Accessed April 19, 2023. https://links.sgx.com/FileOpen/Rio%20Smart%20Lighting%20-%20Final%20Offering%20Memorandum%20%5BPrinted%2011-3-21%5D.ashx?App=Prospectus&FileID=53928
[16] Ibid.
[17] Ibid.

The sub-concession involves financing, developing, improving, operating, and maintaining the Municipality's Smart Public Lighting System and specifies that Smart Luz is tasked with operating and maintaining the Public Lighting System. After the initial planning phase, it began generating revenue in November 2020. Smart Luz was also deemed responsible for replacing high-pressure sodium bulbs with LED bulbs, developing and installing a remote management system, installing an IoT network, and managing the centralized command center. Smart Luz is expected to install 100,000 new lighting fixtures and expand the Public Lighting System as per the Municipality's natural growth during the term of the agreement. According to the Vice President of Business Development and Financing at High Trend Brazil, one of the project's sponsors, in only 24 months, and ahead of schedule, replaced all of the City's 460,000 led lights[18].

Smart Luz is required to invest throughout the life-cycle of the project approximately 1.3 billion BRL (US$239 million) over the 20-year contract period. The majority of the investments will be made during two two-year investment cycles, with the first cycle requiring approximately 820 million BRL (US$151 million) during the first two years of the agreement and the second cycle requiring approximately 348 BRL million (US$64 million) during the thirteenth and fourteenth year of the agreement. The first investment cycle was financed by a combination of proceeds from the sale of the debentures repackaged into Notes, equity contributions, and revenue generated by Smart Luz from receipt of the Smart Luz Contribuição para o Custeio do Serviço de Iluminação Pública (COSIP) Amount[19]. Contribuição para o Custeio do Serviço de Iluminação Pública (COSIP) corresponds to a Public Lighting Contribution collected on electricity bills by the local energy distribution company, Light S.A. on behalf of the municipality for the use of public lighting infrastructure. COSIP is distributed following a waterfall set forth in the COSIP Custody Agreement. Until August 2021, the company had received payments from the Net COSIP amounting to 31.9 million BRL since the beginning of the Sub-Concession[20].

The structure of the PPP transaction and the funding including the concession parties, the funding mechanism, and the revenue streams are presented in Graph 1 below.

[18] Interview with Yan Herreras, Vice President of Business Development and Financing at High Trend Brazil, April 14, 2023.
[19] Interview with Yan Herreras, Vice President of Business Development and Financing at High Trend Brazil, April 14, 2023.
[20] Singapore Exchange. "Rio Smart Lighting - Final Offering Memorandum [Printed 11-3-21]." SGX. Accessed April 19, 2023. https://links.sgx.com/FileOpen/Rio%20Smart%20Lighting%20-%20Final%20Offering%20Memorandum%20%5BPrinted%2011-3-21%5D.ashx?App=Prospectus&FileID=53928



Graph 1. Transaction Structure

As mentioned, on a monthly basis, Light S.A. collects Contribuição para o Custeio do Serviço de Iluminação Pública (COSIP) from users on behalf of the municipality. Those resources are then transferred to a secure escrow account managed by the Caixa Econômica Federal (CEF for its acronym in Portuguese), a state-owned bank that served the purpose of administering public funds. The resources are considered project revenues and serve as collateral to secure the Debentures as they provide certainty regarding the revenue associated with the projects. The certainty associated with these resources was key to the success of the financing structure which will be presented below.

Traditionally, private partners in PPPs obtain their share of financing from commercial banks. In this case, because the contract was signed amid COVID-19 lockdowns, local long-term project financing was unavailable on commercially viable terms. Financing from developing banks and other sources was available but for a shorter term than the one needed.

Furthermore, street lighting was not a well-known asset class at the moment, there was no clear understanding of the risks associated with it, and the deal was of significant size as well as term. Finally, the fact that the deal was to be made with the Municipality instead of the Federal government seemed to

add even more risk facing the banks[21]. This led the consortium to design a notable financing structure which is shown in the second half of Graph 1, where financing was obtained in the international capital market.

Goldman Sachs & Co. LLC served as global coordinator, bookrunner, and structuring agent of the transaction[22]. The structure leveraged an established Infrastructure Debentures sector in Brazil, as well as a U.S. guarantee that would allow investors to book Brazilian bonds with a global appeal[23]. Investors had an appetite either for AAA assets in local currency, or for high yield project bonds in USD. There was no appetite for high yield local currency (BRL) investments. The guarantee allowed for credit enhancement, and for financing above the country investment rate[24]. The company had structured similar transactions for other types and projects in other countries, but only two in Latin America, one in Colombia and one in Ecuador. Furthermore, this is the first of its kind transaction in BRL with DFC, and this structure is now being replicated in other local currencies[25].

Infrastructure Debentures were issued locally, in Brazilian Reais (BRL), by the private partner, Smart RJ Concessionária de Iluminação Pública SPE S.A, or "Smart Rio", in accordance with the provisions of Law # 12,431 of 2011[26]. These debentures, which had 0% withholding tax rate applied on interest payments, were purchased by an offshore SPV located in Luxembourg which was financed by an offshore issuer selling 144A/Reg S Notes. According to the transaction's Offering Memorandum, the Issuer was wholly owned by Stichting Riosmart, a foundation incorporated under the laws of the Netherlands with limited liability and for a specific purpose. Stichting Riosmart is not owned or controlled by any person, derives no benefit from its holding of the shares issued by the Issuer, and any income derived from the transaction will be used only for charitable purposes as decided by the board members.

The 12.25% senior secured notes[27] "were also issued in BRL to avoid currency mismatch between the Debentures and the project cash flows[28]. These notes were guaranteed by the United States International Development Finance Corporation (DFC), and the settling in "US dollars at the Brazilian Central Bank's currency transfer rate … determines the maximum of the DFC's dollar-denominated guaranty[29]". The transaction constitutes the "First-of-its-kind 144A repack issue"[30].

[21] Interview with Yan Herreras, Vice President of Business Development and Financing at High Trend Brazil, April 14, 2023.
[22] Business Wire. "High Trend International Announces R$925 Million (USD 165.5 million) Financing for Rio Smart Lighting Project." Business Wire, November 12, 2021. Accessed April 19, 2023. https://www.businesswire.com/news/home/20211112005765/en/High-Trend-International-Announces-R-925-Million-USD-165.5-million-Financing-for-Rio-Smart-Lighting-Project
[23] Interview with Yan Herreras, Vice President of Business Development and Financing at High Trend Brazil, April 14, 2023.
[24] Interview with experts on the transaction, April 25, 2023.
[25] Interview with experts on the transaction, April 25, 2023.
[26] Ministério da Economia. "Newsletter Infrastructure Debentures - December 2022." Governo do Brasil. Accessed April 19, 2023.https://www.gov.br/economia/pt-br/centrais-de-conteudo/publicacoes/boletins/boletim-de-debentures-incentivadas/2022/newsletter-infrastructure-debentures-december-2022
[27] White & Case. "White & Case Wins Proximo Deal of the Year Awards for PPP, Solar and Mining." White & Case. Accessed April 19, 2023. https://www.whitecase.com/firm/awards-rankings/award/white-case-wins-proximo-deal-year-awards-ppp-solar-and-mining
[28] Interview with an expert on the transaction, April 14, 2023.
[29] Environmental Finance. "Sustainability Project Bond of the Year - Smart Luz." Environmental Finance Bond Awards 2022. Accessed April 19, 2023.
[30] Proximo. "Deals of the Year 2021 Latin America: The winners' podium." Proximo. Accessed April 19, 2023. https://www.proximoinfra.com/articles/8130/Deals-of-the-Year-2021-Latin-America-The-winners-podium

DFC issues its guarantee to the Indenture Trustee for the benefit of the holders of the Notes. Such guarantee will cover the repayment of the principal, and accrued and unpaid interest on the Notes in respect to the outstanding principal amount. In the case of a Guarantor Acceleration Redemption, the payment will be in respect of the outstanding principal amount of the Notes up to the Maximum Guaranteed Principal Amount of such date. As compensation, DFC will be entitled to receive the corresponding fee for the guarantee it provides, as well as reimbursement in the case of a claim and corresponding payment by DFC[31]. Within DFC's purview throughout their due diligence process, to strike a balance between the potential for impact and the ability to mobilize private capital. The Rio Smart City Project merged these two aspects by generating multifaceted outcomes (enhanced energy efficiency, crime mitigation, streamlined traffic, health improvements, and sewage management) while simultaneously securing a reliable revenue stream, thereby making the project financially viable.[32].

There is an additional Conditional Smart Luz Guarantee, which according to an Advisor to the transaction, was included at the end of the negotiation to cover a minimal risk of the Brazilian Real appreciating with respect to the dollar. Only in that case would this guarantee be executed.

The notes' settlement date was November 8, 2022, their maturity date is September 2032[33], and they received a global scale rating AA+ (Fitch) and Aa1 (Moody's)[34]. They did not receive the U.S.'s AAA+ rating because there is some exchange risk[35]. Furthermore, because of the regulation applicable to Regulation S, the notes were offered and sold a) within the United States to Qualified Institutional Buyers (QIBs) and, b) outside the United States to non-U.S. persons (as defined in Regulation S). According to Yan Herreras, Vice President of Business Development and Financing at High Trend Brazil, the Notes were originally purchased by large institutional investors, ESG funds, and other asset managers, there were no pension funds.

As value added to the transaction, Smart Luz established a Sustainability Bond Framework, dated May 2021, and hired Sustainalytics' to provide a Second-Party Opinion on the Framework's environmental and social credentials and its alignment with the Sustainability Bond Guidelines 2021 (SBG), Green Bond Principles 2021 (GBP), and the Social Bond Principles 2021 (SBP)[36]. This Framework made the bond attractive to DFC and its internal policies regarding the sectors to be supported by its guarantees[37].

[31] Singapore Exchange. "Rio Smart Lighting - Final Offering Memorandum [Printed 11-3-21]." SGX. Accessed April 19, 2023. https://links.sgx.com/FileOpen/Rio%20Smart%20Lighting%20-%20Final%20Offering%20Memorandum%20%5BPrinted%2011-3-21%5D.ashx?App=Prospectus&FileID=53928

[32] Interview with experts on the transaction, April 25, 2023.

[33] Ministério da Economia. "Newsletter Infrastructure Debentures - December 2022." Governo do Brasil. Accessed April 19, 2023.https://www.gov.br/economia/pt-br/centrais-de-conteudo/publicacoes/boletins/boletim-de-debentures-incentivadas/2022/newsletter-infrastructure-debentures-december-2022

[34] Business Wire. "High Trend International Announces R$925 Million (USD 165.5 million) Financing for Rio Smart Lighting Project." Business Wire, November 12, 2021. Accessed April 19, 2023. https://www.businesswire.com/news/home/20211112005765/en/High-Trend-International-Announces-R-925-Million-USD-165.5-million-Financing-for-Rio-Smart-Lighting-Project

[35] Interview with Yan Herreras, Vice President of Business Development and Financing at High Trend Brazil, April 14, 2023.

[36] Margolis, Zach, Hirthik Sharma, Andrew Johnson, and Paramjot Kaur. "Smart Luz Sustainability Bond Framework ." Sustainalytics, July 2, 2021. https://mstar-sustops-cdn-mainwebsite-s3.s3.amazonaws.com/docs/default-source/spos/smart-luz-sustainability-bond-framework-second-party-opinion.pdf?sfvrsn=b43ab7ec_1.

[37] Interview with Yan Herreras, Vice President of Business Development and Financing at High Trend Brasil, April 14, 2023.

Finally, proof of the success and notable character of the financing structure was recognized as in 2022 the project was awarded The Proximo "PPP Deal of the Year Award"[38] and the Latin Finance "Project and Infrastructure Finance Award[39]".

As mentioned above, the availability of DFC's guarantee and the certainty associated with the earmarked COSIP revenue were key factors to the success of the financing structure. However, another key component is that the company has contractual exclusivity to explore and leverage ancillary revenue.

The potential for generating revenue from smart city initiatives, specifically using public lighting infrastructure, was studied in detail by the municipality during the structuring of the PPP. The objective was to leverage technology to improve security, and traffic, and track potential floods, among others. This required the establishment of an interconnected data network, with which it made sense for wifi connectivity as well. These objectives led to the need for a new Command Center where all captured data would be administered. Smart Luz acts as the operator for all data gathered by the technologies, and the municipality as the user[40]. The contract stipulates that while there is potential for monetizing data for ancillary revenue, it must be anonymized and not contain any images. For example, traffic data without car number plates can be utilized to produce revenue. Access to wifi data can also be monetized for both security and advertising purposes. The source of data with a higher potential to be commercialized is that which integrates information from different sources, for example, foot traffic, vehicle traffic, and population aggregation in one source. Privacy legislation for data usage already exists in Brazil and came into effect in 2020, requiring a full review of data operations. There is a legal framework in place to differentiate between data operators and data users[41].

In conclusion, ancillary revenue presents a significant opportunity for this project. The revenue-sharing agreement between the municipality and the private sector companies ensures that all parties benefit from new sources of income, fostering a strong incentive for innovative solutions. entails that new sources of revenue will benefit both parties, creating many incentives for innovation.

5.1.2. Noteworthy Case Characteristics

Funding parties	**Public partner:** The City of Rio de Janeiro via Rio Luz, the state-owned concessionaire for all lighting services. **Private partner:** The Smart Luz Consortium, formed by the companies: Salberg, Proteres Participações, HTI, Arc, and Green Luce.
Type of funding	Municipalities with COSIP revenue, that is, the Public Lighting Contribution collected on electricity bills by the local energy distribution company Lights S.A. on behalf of the municipality for the use of public lighting infrastructure. The Smart Luz Consortium through 925 million BRL (USD 165.5 MN) in resources

[38] Nelthorpe, Tom. "Deals of the Year 2021 Latin America: The Winners Podium." Proximo, March 11, 2022. https://ih.advfn.com/stock-market/stock-news/89210511/latinfinance-has-revealed-the-winners-of-its-2022.
[39] "Infrastructure Financing of the Year – Brazil: Smart Luz Financing." Digital Content Experience Platform, 2022. https://read.nxtbook.com/latinfinance/magazine/2022_q4/financing_brazil.html.
[40] Interview with Yan Herreras, Vice President of Business Development and Financing at High Trend Brazil, April 14, 2023.
[41] Interview with Yan Herreras, Vice President of Business Development and Financing at High Trend Brazil, April 14, 2023.

	obtained from the Capital markets.
Budget	**USD 256 MN** for operation and maintenance over a 20-year period
Revenue	Revenue originated from a combination of proceeds from the sale the debentures repackaged into Notes, equity contributions, and the Smart Luz COSIP Amount. The financial model associated with the PPP balances the CAPEX, OPEX, and a return for the private partner, with a contract duration. Furthermore, this contract in particular allows for multiple types of ancillary revenue which, through a revenue sharing agreement, are distributed between the private entity and the municipality. Finally, it is worth mentioning that for the private partner to have access to the COSIP, they must have provided proof of the delivery of the infrastructure, associated with specific quality conditions.
Innovation component	IoT network that connects 300,000 LED luminaires and 25,000+ others including cameras, wireless sensors, and WiFi access points.
Agency development	The city can more efficiently provide a service that is within its jurisdiction more efficiently through a private partner that has the technological and technical expertise. The fact that "upfront investments are small and operational expenses outweigh capital expenses, leads to lower payback periods and energy-cost reduction with LED technology. Those energy savings allow the private company to be compensated with public expenditure"[42]. Flexibility in the contract allows for innovation both in the private and public, as additional ancillary revenue can be shared among the parties.

Table 1. Noteworthy Case Characteristics

5.1.3. Risk Mitigation

"Structurally, public lighting PPPs are considered exemplary in Brazil, as the costing and expansion of this public service relies on the establishment of an exclusive source of funds, charged directly from electricity consumers… There is a growing private market interested in establishing partnerships with the public sector …, as long as the projects are properly structured, with balanced risks, and financially attractive and with positive externalities"[43].

[42] Marques, Rui Cunha, and R. Richard Geddes. "The use of PPP arrangements in street lighting: A win-win option?." Annals of Public and Cooperative Economics 90, no. 2 (2019): 311-327.
[43] "Public Street Lighting PPP." Accessed April 19, 2023. https://www.globalinfrafacility.org/sites/gif/files/2022-03/PSL%20PPP%20Guide_Executive%20Summary_ENG.pdf.

A principle of PPPs is that risks should be assigned to the party that can best manage or bear them[44]. However, even once liability risks are assigned, PPPs also allow for the determination of special conditions or events that would lead to risks shifting parties or being distributed among the parties. A *risk register* records all associated risks , their classification and the party they are assigned to. According to the World Bank, risks in PPPs can generally be classified as follows: site; design, construction, and commissioning; operation; demand and other commercial risks; regulatory or political; change in the legal or regulatory framework; default; economic or financial; asset ownership; and force majeure[45]. PPP arrangements, therefore, allow for risk to be transferred to the private partner at a reasonable premium to compensate them[46].

For street lighting PPPs, the "PPP operator is considered to have the most risks associated with ownership of the assets i.e. design, finance, maintenance, management.. It is likely that the public… will retain consumption risk as lenders will be unlikely to accept this risk"[47]. Another two relevant risks are future energy costs and technological risks which are generally also borne by the private sector. The former is an exogenous risk that is "however always favorable to a retrofit project (in that it reduces energy consumption), regardless of whether or not the private sector is responsible for paying the energy cost to the electricity company"[48]. The latter issue is not only related to a limited understanding of LED technology, but also to the possibility that superior or more affordable technologies could emerge, rendering LEDs obsolete.[49]. Furthermore, risks out of the private partner's control such as force majeure and political risk, are assigned to the public party[50].

The Rio Smart City Project followed the guidelines of a National Public Street Lighting PPP Model structured by the Brazilian development bank (BNDES), CAIXA, the International Finance Corporation (IFC), and the World Bank. However, during the procurement process, there were multiple stages during which interested private parties could opine and provide feedback regarding, among others, risk assignment[51].

The main risks identified for the project were administrative, operational, political, environmental, and financial. The operational, administrative, and financial risks were assigned to the private partner. The environmental risk was shared among private and public sectors, and the political and regulatory risk was assigned to the public. The latter includes any change in policy, legislation, or delays in the schedule for permits and approvals.

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[44] Marques, Rui Cunha, and R. Richard Geddes. "The use of PPP arrangements in street lighting: A win-win option?." Annals of Public and Cooperative Economics 90, no. 2 (2019): 311-327.
[45] "Identifying Risks." PUBLIC-PRIVATE-PARTNERSHIP LEGAL RESOURCE CENTER. World Bank. Accessed April 19, 2023. https://ppp.worldbank.org/public-private-partnership/identifying-risks.
[46] Marques, Rui Cunha, and R. Richard Geddes. "The use of PPP arrangements in street lighting: A win-win option?." Annals of Public and Cooperative Economics 90, no. 2 (2019): 311-327.
[47] "Toolkits for Public-Private Partnerships." PUBLIC-PRIVATE-PARTNERSHIP LEGAL RESOURCE CENTER, World Bank, March 2013. https://ppp.worldbank.org/public-private-partnership/tools/toolkits-for-public-private-partnerships.
[48] Marques, Rui Cunha, and R. Richard Geddes. "The use of PPP arrangements in street lighting: A win-win option?." Annals of Public and Cooperative Economics 90, no. 2 (2019): 311-327.
[49] Ibid.
[50] Ibid.
[51] Interview with Yan Herreras, Vice President of Business Development and Financing at High Trend Brazil, April 14, 2023.

As for unforeseen risks, in Brazil, these are usually managed with insurance coverage. If insurance coverage is unavailable for a specific risk, it may be classified as an "Act of God" or an unforeseeable risk. The materialization of these types of risks can lead to a contract renegotiation whose conditions are established in the contract. For example, even though this contract did not foresee the appearance of COVID-19, it fell under the category of an “act of God” and renegotiations were carried out, in particular, a grace period was provided. Finally, the contract incorporates dispute resolution mechanisms that establish the conditions and steps to follow in case of an event of this sort[52].

The specifics of this PPP’s funding structure also have risk implications. The issuance of Debentures in Brazilian Reals and their repackaging into Notes also in BRL was strategically done to avoid currency risk or a currency mismatch between the project’s cash flows and the repayment of the Notes. Furthermore, because the guarantee is issued in US dollars, there is a Conditional Smart Luz Guarantee, which according to an Advisor to the transaction, covers the minimal risk of the Brazilian Reals appreciating with respect to the dollar. Only in that case, this guarantee becomes operational to cover that risk. The DFC guarantee played an essential role in mitigating project risk. Despite the project having a stable revenue stream from COSIP, a well-defined cash flow waterfall, an escrow account, structured underlying financing, and financial covenants in place, it was the guarantee that ultimately proved to be the decisive factor in securing financing.[53].

As this was a publicly originated PPP, the government, with support from IFC and the World Bank established how risks were distributed. Despite private parties having the chance to give input throughout the process, the government's adherence to standardized Terms of Reference allowed for a quicker progression of the project. In the case of privately originated PPPs such as the ALO Sur in Bogota, Colombia, risk assignment negotiations can take years given the uniqueness of the project financing structure.

5.1.4. Comparable Case

The funding mechanism for the Puerta de Hierro - Cruz del Viso road project in Colombia involves the issuance of social bonds. In the case of the Puerta de Hierro - Cruz del Viso road project, the social bond framework outlines the use of proceeds for eligible social expenditures related to the project, such as environmental and social mitigation measures, community development programs, and health and safety initiatives[54].

The social bond framework for the Puerta de Hierro - Cruz del Viso road project in Colombia is a set of guidelines and principles that outline the use of proceeds from the issuance of social bonds. It defines the social and environmental objectives that the bond proceeds will be used to achieve, such as promoting road safety, improving connectivity, and supporting local communities. The framework also includes criteria for project selection, monitoring, and reporting on the use of proceeds, as well as an external verification process to ensure transparency and accountability. The social bond framework is aligned with recognized

[52] Interview with Yan Herreras, Vice President of Business Development and Financing at High Trend Brazil, April 14, 2023.
[53] Interview with Yan Herreras, Vice President of Business Development and Financing at High Trend Brasil, April 14, 2023.
[54] “Puerta De Hierro Social Bond Framework,” February 2021. https://www.concesionariavialmontesdemaria.com/documents/35210169/79036585/Puerta+de+Hierro+-+Social+Bond+Framework.pdf/dac3504e-ab66-7c8d-3b54-2b7f4d82924b?version=1.0&t=1621442948094.

sustainability standards and provides a framework for Concesionaria Vial Montes de María to use the proceeds in a manner that aligns with social and environmental objectives, as defined in the framework[55].

The funding mechanism for the Puerta de Hierro - Cruz del Viso road project involves a combination of debt financing, social bonds, guarantees, and equity investment, with a PPP model and a social bond framework that aligns with sustainability objectives. The PPP model is where Sacyr Concesiones, a private company, develops and operates the infrastructure project in partnership with the Colombian National Infrastructure Agency (ANI for its acronym in Spanish), a public agency. The project is funded through debt financing, where Sacyr Concesiones raises funds from financial institutions and/or capital markets to cover the costs of construction and operation of the road. The funding mechanism also includes the issuance of social bonds, where Sacyr Concesiones raises funds by issuing such bonds in the capital markets. The proceeds from the social bonds are earmarked for social and environmental objectives, as defined in the social bond framework, and are used to promote sustainability and social impact. The project also involves guarantees from development finance institutions (DFIs) which provide additional assurance to lenders or investors and help mitigate risks associated with the project, such as political, regulatory, or currency risks.[56]

5.1.5. Lessons Learned and Potential for Replicability

A significant highlight of the Rio Smart City project is the implementation of a financing mechanism that empowers the private party to execute the contract's scope, including designing, financing, maintaining, and managing the infrastructure.

Traditionally, private parties in PPPs secure financing from the commercial banking sector as alternative financing structures are costly or not available to them given the project conditions and companies' track records. In this case, the certainty associated with COSIP revenue reduces financing risk from the start. However, the application of a guarantee from the US Development Finance Corporation sealed the deal for Smart Luz to be able to access international capital market funding. According to an advisor to the transaction, the guarantee served the purpose of transferring project risk to a more legitimate party i.e., DFC.

The presence of a DFC guarantee improved the credit rating of the notes, allowing Qualified Institutional Buyers to invest in Smart Luz, a company that would not otherwise have access to capital market funding. In this instance, the guarantee from DFC, a United States agency, resulted in the note issuance obtaining a higher credit rating than the Brazilian sovereign debt, marking it as the first issue of its kind to achieve such a rating. The repackaging of BRL-denominated debentures (with 0% withholding tax), into 144 Reg A Notes sold under New York State governance law in BRL.

Similar to street lighting PPPs, the Rio Smart City Project has "upfront investments that are small and operational expenses that outweigh capital expenses, leading to lower payback periods and energy-cost

[55] Ibid.
[56] "Puerta De Hierro Social Bond Framework," February 2021. https://www.concesionariavialmontesdemaria.com/documents/35210169/79036585/Puerta+de+Hierro+-+Social+Bond+Framework.pdf/dac3504e-ab66-7c8d-3b54-2b7f4d82924b?version=1.0&t=1621442948094.

reduction with (Light-Emitting Diode) - LED technology[57]". The technology offers "greater energy efficiency and longer service life relative to older street lighting technologies"[58]. They are less harmful to the environment, "offer better quality and lighting-level control, reduce maintenance costs, and incur lower overall economic costs"[59]. These savings, therefore, allow for a cost-efficient model where the private company is compensated with public expenditure, in this case, COSIP revenue[60], and the public can perceive the benefits of these improved infrastructures. "Well-lit streets make people feel safe and reduce accidents while boosting economic and social activity after sunset"[61]. These characteristics make street lighting public-private partnerships (PPPs) highly attractive and replicable in numerous developing countries and cities interested in transitioning towards more sustainable public lighting solutions.

Identifying the project scope and assembling industry experts from legal, financial, and technical domains was a challenging task, but the Rio Smart City Project successfully accomplished it. This achievement can be largely attributed to the municipality's adherence to the National PPP Guidelines, which enabled the formation of a Consortium with extensive expertise and knowledge across multiple sectors.

To replicate this World Bank led public-private partnership (PPP) such as the Smart City project in Rio, it is crucial to have widespread infrastructure around the City. This facilitates the expansion and integration of additional smart technologies and solutions into the design and implementation of the project: incorporating digital infrastructure, Internet of Things (IoT) devices, data analytics, and other smart city technologies. It also requires the public and private sectors to work in concert to enhance urban services, improve citizen engagement, and achieve sustainable development goals. Proper planning, stakeholder engagement, and strategic use of technology helped transform a traditional PPP into a Smart City project with enhanced efficiency, innovation, and sustainability.[62]

5.2. Risk Mitigation Structures In Public Transportation - The Beijing No. 4 Metro line project

5.2.1. Overview

Beijing has been the country's political, cultural, and educational center for over 800 years. However, in its history, the city's population has never seen such unprecedented demographic growth, particularly after 1978, a result of the relaxation of domestic migration controls in China. The rapid economic development in Beijing was driven by the massive migration of rural workers to the city, combined with a transition to a market-oriented economy[63].

[57] Marques, Rui Cunha, and R. Richard Geddes. "The use of PPP arrangements in street lighting: A win-win option?." Annals of Public and Cooperative Economics 90, no. 2 (2019): 311-327.
[58] Ibid.
[59] Ibid.
[60] Ibid.
[61] Food waste disposal stations at Dongzhou government canteen in Fushun, China. Gaoxinquliang, July 28, 2019. https://www.meipian.cn/2a7pohnz?first_share_uid=5872395&share_depth=6&share_source=timeline&share_user_mpuuid=949ed654c6e8ed05b00bd2bed3986ee8&sharer_id=&user_id=&v=5.0.1.
[62] "Street Lighting." Projects Hub. BNDES,Accessed April 18, 2023. https://projectshub.bndes.gov.br/en/setores/Street-Lighting.
[63] Yi, Peng, Zhe Sun, and Yiwen Bu. 2021. "A Systematic Review and Meta-Analysis on the Effectiveness of Exercise on Cognitive Function in Older Adults with Mild Cognitive Impairment." Aging & Mental Health 25, no. 7: 1145-1154. Accessed April 20, 2023. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8351535/

To adapt to the population density increase, the Beijing government put in motion urban and industrial plans to expand beyond the Central City toward outlying areas[64]. The policy aimed to extend existing subway lines to facilitate commuting to different parts of the City. In 2001, Beijing won the right to host the 2008 Olympic Games[65]. At that time, Beijing's mass transit system needed to be developed with only two metro lines covering 54 kilometers, less advanced than other major cities in Asia, such as Seoul, Hong Kong, and Shanghai[66]. The absence of public transportation networks was primarily due to fiscal constraints for the local government. To finance transportation infrastructure development while limiting the burden on public finances in preparation for the Olympics, the Beijing and Shenzhen governments adopted a PPP (Public-Private Partnership) model for metro development in 2006 and 2004, respectively.

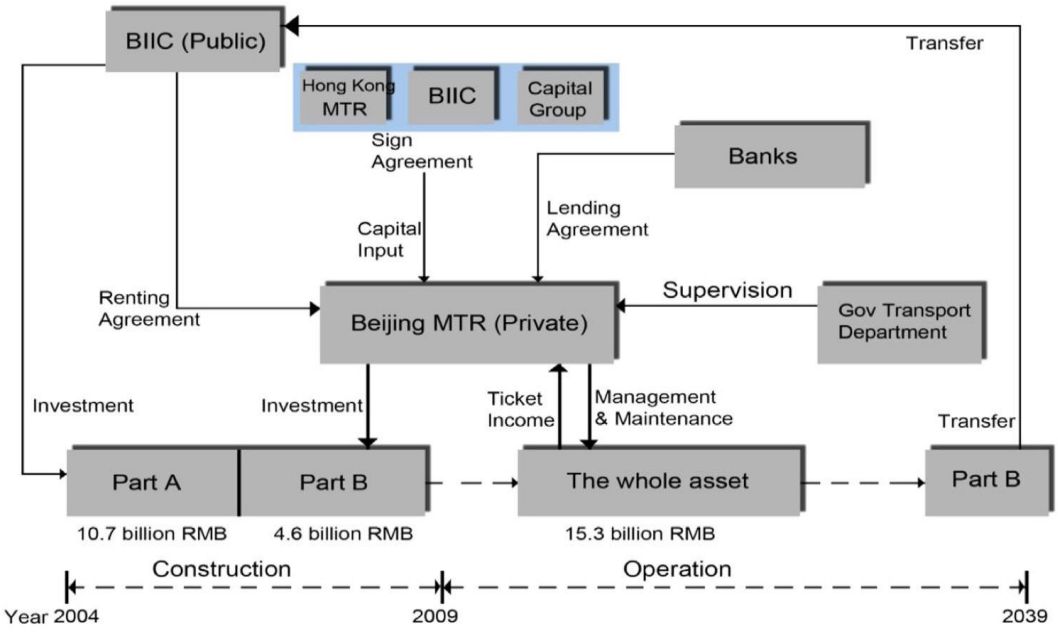
In 2004, the Hong Kong MTR Corporation was selected as the partner for the Beijing No. 4 Metro line project through a public tender process. Chinese foreign investment regulations stipulate that foreign investors cannot hold more than 50% stake in a joint venture company for urban infrastructure projects. Hence, the PPP corporate structure for the Beijing No. 4 Metro line project was devised as follows: Hong Kong MTR, the private partner, holds a 49% stake in the joint venture, while the China Capital Group and the BIIC, both Chinese state-owned enterprises, own 49% and 2% stakes, respectively[67].

The Beijing No. 4 Metro Line, which began operating in September 2009, was constructed with a total investment of 15.3 billion RMB (2.2 billion USD)[68]. Spanning 28.2 km (17.5 miles), this line connects the Anheqiao North neighborhood in Haidian District to Gongyi Xiqiao in Fengtai District. It includes 24 high-traffic stations[69]. Metro Line 4 is considered one of China's most successful and impactful PPP projects due to its reduced construction and operational costs, as well as its efficient management and operations. This Metro line PPP model has since been replicated in over four other cities in China.

In 2011, the Chinese government announced its plan to invest approximately 1.27 trillion RMB (199 billion USD) in the construction of subways and light rail lines by 2015[70]. Between 2016 and 2020, the investment has increased by an estimated 262 billion USD and 303 billion USD. The Beijing Metro Line 4 PPP model will likely continue to be replicated in other parts of the country.

[64] Dixon, Roland B. 1907. "Maidu Myths." The Journal of American Folklore 20, no. 76: 37-45. Accessed April 20, 2023. https://www.jstor.org/stable/215557
[65] "Olympic Games Beijing 2008" https://olympics.com/en/olympic-games/beijing-2008
[66] "Bureau, Beijing Statistical. "Beijing statistical yearbook." (2013)." http://tjj.beijing.gov.cn/EnglishSite/OC/
[67] Beijing MTR Corporation Limited. 2016. "公司简介" [Company Profile]. Archived December 31, 2016. Accessed April 20, 2023. https://web.archive.org/web/20161231092333/http://www.mtr.bj.cn/about/profile.html
[68] South China Morning Post. 2012. "Business Digest November 7, 2012." South China Morning Post, November 7. Accessed April 20, 2023. https://www.scmp.com/business/china-business/article/1076612/business-digest-november-7-2012
[69] Ibid.
[70] Reuters. 2011. "China Invests $199 Billion for Urban Rail through 2015: Report." Reuters, August 26. Accessed April 20, 2023.https://www.reuters.com/article/us-china-investment-metro/china-invests-199-billion-for-urban-rail-through-2015-report-idUSTRE77P06J20110826

5.2.2. Noteworthy Case Characteristics



Graph 2. Funding, Asset Share & Revenue Streams[71]

Funding Parties

The financing for Beijing Metro Line 4 was divided into two distinct parts. Part A focused on infrastructure construction and was entirely funded by the Beijing Infrastructure Investment Corporation, with a total estimated investment of 10.7 billion RMB (1.55 billion USD)[72]. In 2003, the Beijing government restructured its metro department into three independent corporations: the Beijing Infrastructure Investment Corporation (BIIC), the Beijing Metro Construction & Management Corporation (BMCC), and the Beijing Metro Operation Corporation (BMOC)[73]. Within this new public agency framework, BIIC is responsible for financing metro projects. Part B of the financing focused on the purchase of rolling stock and was financed by the joint venture, Beijing MTR, with an estimated investment of 4.6 billion RMB (0.67 billion USD). The role of Hong Kong MTR (HK MTR), a private partner, was limited to financing and did not involve participation in the construction process[74].

[71] Wang, H. "Chengshi Guidao Jiaotong Tourongzi Wenti Yanjiu (studies on urban mass transit issues)." (2005).https://scholar.google.com/scholar_lookup?title=Chengshi%20Guidao%20Jiaotong%20Tourongzi%20Wenti%20Yanjiu%20%28studies%20on%20urban%20mass%20transit%20issues%29&publication_year=2005&author=Wang%2CH

[72] National Development and Reform Commission. 2015. "2015年全国经济社会发展计划执行情况与2016年全国经济社会发展计划草案的报告" [Report on the Implementation of the National Economic and Social Development Plan for 2015 and the Draft National Economic and Social Development Plan for 2016]. Accessed April 20, 2023. http://tzs.ndrc.gov.cn/zttp/PPPxmk/pppxmal/201507/P020150721602804672682.pdf

[73] Zhao,H. Ren,B. Wang,T. "Analysis and Evaluation of the Beijing Metro Project Financing Reforms," Advances in Social Science, Education and Humanities Research, volume 291. Page 5-16. https://www.atlantis-press.com/article/55910747.pdf

[74] Ibid.

Ownership of the Assets

Under the terms of the contract, The government reserves its right to price the ticket fares uniformly with the rest of the metro line network, while the joint venture company has exclusive rights to operate the Beijing Metro Line 4 for 30 years[75]. At the end of this period, the state-owned enterprise BIIC will take over the ownership of Part B, which accounts for 30% of the total investment, at no additional cost[76]. Consequently, BIIC will gain full ownership of the entire metro system, encompassing both infrastructure and rolling stock, once the operating period concludes.

The contract also provides an exit clause for the private sector partner, HK MTR. If the private sector wishes to exit the project due to poor financial management, unpredicted events, etc, then the Beijing Municipal Government entity, BIIC, will have the right to acquire Part B at a discounted price[77].

Contractual Agreement on Cost Sharing

The contract stipulates that the joint venture is entitled to the total revenue generated from ticket fares and advertisements. However, the Beijing government retains the authority to determine and standardize ticket fare pricing. If the government decides to set artificially low fares resulting in financial losses for the joint venture company, it will be compensated. The contract also specifies that the joint venture company is responsible for the following costs: investment in rolling stock (30% of which is equity from the private sector and 70% is loans from Chinese commercial banks), operational costs and capital improvements, an annual rental fee for Part A paid to the public sector (with the rental fee adjusted every three years), and corporate taxes paid to the public. In 2010, the rental fee was 42.5 million RMB (6.17 million USD)[78].

Subsidy and Revenue Distribution Mechanism [Conflicitng Interests]

The contract sets up a subsidy and revenue distribution mechanism that relies on "shadow pricing" and "shadow ridership."[79] Shadow pricing is a technique used to mitigate conflicting interests between the government social policy decisions and the private partners. In this case, it ensures that each passenger's benefits are independent of the price charged and, therefore, not connected to the revenue collected. For example, in 2006, based on passenger ridership, the estimated fares for the Beijing Metro had to be between 3 to 7 RMB (0.5-1 USD). Ultimately, both parties agreed on a shadow price of 3.34 RMB (0.49 USD) for Line 4; and a fare change every three years based on the adjusted Consumer Price Index (CPI)[80].

If the actual fare is lower than the shadow price, the Beijing Municipal Government will compensate the private sector for the difference. If the basic fare is higher than the shadow price, extra profits will be divided, with 70% going to the public sector and 30% going to the private sector. Shadow patronage serves

[75] Ibid.
[76] Ibid.
[77] Interview with Beijing Municipal Government officials, March 27th, 2023.
[78] Interview with BJ MTR, April 5th, 2023.
[79] National Development and Reform Commission. 2015. "2015年全国经济社会发展计划执行情况与2016年全国经济社会发展计划草案的报告" [Report on the Implementation of the National Economic and Social Development Plan for 2015 and the Draft National Economic and Social Development Plan for 2016]. Accessed April 20, 2023. http://tzs.ndrc.gov.cn/zttp/PPPxmk/pppxmal/201507/P020150721602804672682.pdf
[80] Ibid.

as a method to compensate the private partner for the risk of lower ridership than projected. Revenues are guaranteed even if the actual number of passengers deviates from the forecast, whether due to government policy or exogenous changes. In the case of Beijing Metro Line 4, MVA Transport Consulting was hired to forecast shadow patronage. The projected daily shadow patronage in 2010 was 564,000. In 2019, the average daily ridership had increased to 700,000.

From the above, we can define the shadow revenue as the shadow price multiplied by the shadow patronage. The revenue and subsidy-sharing plan would be as follows, with Table 2 illustrating the initial profit-sharing scheme.

If the actual patronage is less than 80% of the shadow level, the public sector will guarantee the private sector a revenue floor of 80% of shadow revenue. If the actual patronage is between 80% and 100% of the shadow level, the public sector will provide a subsidy equal to the difference between the actual patronage and the shadow level, multiplied by the shadow price. If the actual patronage is between 100% and 120% of the shadow level, the public sector will subsidize an amount equal to the difference between the shadow revenue and the actual price of shadow patronage. In contrast, any additional revenue from excess passengers will be credited to the private sector. Finally, if the actual patronage is above 120% of the shadow level, the public sector will provide the same subsidy as in the previous scenario, but will also share half of the revenue generated above 120% of shadow patronage with the private sector.

Summary of public subsidy and revenue sharing scheme: original.

R (ratio of actual patronage to shadow patronage)	Public subsidy	Public revenue sharing
$R \leq 80\%$	80% Shadow revenue−actual revenue	0
$80\% < R \leq 100\%$	(Shadow price − actual price) × actual patronage	0
$100\% < R \leq 120\%$	Shadow revenue − actual price × shadow patronage	0
$R > 120\%$	Shadow revenue − actual price × shadow patronage	50% × Actual price × (R − 120%) × shadow patronage

Table 2. Original Summary of Public Subsidy and Revenue Sharing Scheme[81]

In 2007, the Beijing local government lowered metro fares to a fixed rate of 2 RMB (0.3 USD) per trip. Since passengers usually take more than one line per trip, the actual fare for Beijing Metro Line 4 was 1.04 RMB (0.15 USD) in 2010[82]. That year, given a shadow price of 4 RMB (0.6 USD), the public sector subsidized 2.96 RMB (0.45 USD) per passenger trip to the joint venture company[83]. Generally, initial patronage would be low and grow over time; however, the passenger count exceeded both the public and private sectors' expectations. In 2010, the daily shadow patronage averaged 564,000 passengers, while the actual number of passengers was 687,600, or 122% of the shadow level[84]. The public sector attributed the excess patronage to the fare reduction, which was not factored into the original contract. As a result, the government and the Hong Kong MTR signed a supplementary agreement in 2010 to reflect the change. Table XX presents the revised subsidy and revenue-sharing scheme. In the updated contract, the public

[81] Zheng, C. "Public–Private Partnerships in China: A Case of the Beijing No.4 Metro Line." Transport Policy, Volume 30, 2013. Pages 153-160,
ISSN 0967-070X, https://doi.org/10.1016/j.tranpol.2013.09.011.
[82] Interview with BJ MTR, April 5th, 2023
[83] Ibid.
[84] Interview with BJ MTR, April 5th, 2023.

sector begins sharing revenue when the patronage reaches 100% of the projected figure, instead of 120%. If the actual patronage falls between 100% and 110% of the projected ridership, the public entity will receive half of the revenue. If the patronage surpasses 110%, the public entity will obtain 60% of the revenue.

Summary of public subsidy and revenue sharing scheme: revised.

R (ratio of actual patronage to shadow patronage)	Public subsidy	Public revenue sharing
$R \leq 80\%$	80% Shadow revenue − actual revenue	0
$80\% < R \leq 100\%$	(Shadow price − actual price) × actual patronage	0
$100\% < R \leq 110\%$	Shadow revenue − actual price × shadow patronage	50% × Actual price × (R − 100%) × shadow patronage
$R > 110\%$	Shadow revenue − actual priceShadow patronage	50% × Actual price × 10% × shadow patronage + 60% × actual price × (R − 110%) × shadow patronage

Table 3. Revised Summary of Public Subsidy and Revenue Sharing Scheme[85]

Regarding taxation, the Beijing municipal government categorizes joint venture companies as foreign-invested enterprises and, in compliance with Chinese tax laws, grants them exemptions from local income taxes and offers preferential policies for corporate income taxes.

Funding Parties	Public Partner: Beijing Infrastructure Investment Company (10.7 BN CNY), the subnational government owned entity Private Partner: BJMTR (4.6 BN CNY), a joint venture company formed by Beijing Infrastructure Investment Company (BIIC), Beijing Capital Group (BCG) and Hong Kong MTR (HK MTR)
Type of funding	Mix of Public and Private funds BIIC provide funding for the construction process of the asset (Public funding) The joint venture company of BJMTR will input 30% of the equity to acquire rolling stock and equipments, the rest 70% comes from loans provided by Chinese commercial banks (Private funding)
Total Project cost	15.3 BN CNY (Equivalent to 2.2B USD) for the completion of the asset
Ticket Fare Mechanism	Ticket fare is determined by Beijing Municipal Government The government agency will adjust the ticket fare every 3 years depending on CPI, citizen income and operational cost
Agency development	Private party (HK MTR) coach the high-competent talent on experience of operating and maintaining the asset Adaptation of the smart metro system "1+3+N", using cutting edge technologies to

[85] Zheng, C. "Public–Private Partnerships in China: A Case of the Beijing No.4 Metro Line." Transport Policy, Volume 30, 2013. Pages 153-160, ISSN 0967-070X, https://doi.org/10.1016/j.tranpol.2013.09.011.

	manage and operate the asset[86]

Table 4. Noteworthy Characteristics of the project

5.2.3. Risk Mitigation

Risk Mitigation for Public Sector

Board Structure

The joint venture company's board of directors consists of five members, one appointed by BIIC, two by Capital Group, and two by HK MTR Corporation. The director appointed by Beijing Infrastructure Investment Company serves as the chairman, the director appointed by Capital Group serves as the vice chairman, and the two directors named by the MTR Corporation serve as directors[87].

Responsibilities and Authority of the Beijing Municipal Government

The Beijing Municipal Government acts as the primary initiator for the project, without having legal ownership or control over the asset. Under the franchise agreement, the government holds regulatory oversight, ticket pricing authority, the responsibility to manage unusual or extraordinary circumstances that may arise during the course of a project, and contract termination rights. Oversight involves the government's supervision of the civil engineering aspects of the Metro Line 4 project during construction to ensure timely and high-quality completion. Additionally, the government monitors the franchise company's structure, specifically with regard to mechanical and electrical equipment components.

Ticket pricing rights involve the government controlling Line 4's operational fares through official pricing management. Throughout the franchise period, the government formulates and announces Line 4 fares and policies in accordance with relevant legislation and regulations, adhering to the principle of equal pricing for the same network and adjusting fares based on socio-economic developments.

Special situation management rights indicate that the government supervises the franchise company according to operation and safety standards during the operational period. In public safety emergencies or other extraordinary circumstances, the government reserves the right to intervene to safeguard public interests. Contract termination rights under the franchise agreement allow the government to take actions, including revoking the franchise if the franchise company breaches the obligations outlined by the agreement. The Beijing municipal government is responsible for bearing expenses under the form of subsidies that arise from policy changes.

[86] Beijing MTR Corporation Limited. 2020-2021. "Sustainability Report 2020-2021." Accessed April 20, 2023. http://cdnwww.mtr.bj.cn/bjmtr/attachments/hbdjY5vkYiCPoHI-k-Eax.pdf
[87] Interviewed with BJ MTR, April 5th, 2023.

Mechanism for Adjusting Subway Fares

When a discrepancy arises between the public welfare-focused government pricing scheme and the profit-oriented market pricing, the Beijing government, which holds authority over subway line pricing, addresses the issue in accordance with the franchise agreement. As per this agreement, the fare levels for Beijing Subway Line 4 are revised every three years, taking into account both the Consumer Price Index (CPI) and the average number of passengers[88].

Risk Bearing for Public Sector

If the actual patronage falls 20% below the projected numbers for three consecutive years, the joint venture company can request subsidies from the government[89]. If an agreement on subsidy amounts cannot be reached within two years, the franchise company reserves the right to terminate the contract and the government will acquire Part B assets at market value.

Cost Management in Rolling Stock Acquisition Process

In the rolling stock acquisition process, the private sector assumes minimal risk related to revenue due to the contract's protective mechanisms. By efficiently managing costs, the private sector can lessen the likelihood of government intervention in funding infrastructure assets and the need for associated subsidy expenses. Table 5 below displays the budgeted and actual costs involved in acquiring rolling stock. It reveals that the prices for most rolling stock are below the budgeted amount[90]. One reason is that the joint venture company initially selected the US dollar as the reference currency for procurement to mitigate currency risk associated with the import of infrastructure material and equipment[91]. Conversely, the actual costs in the "others" and "preparation fees" categories exceed the budgeted amounts. These categories are ambiguously defined and prone to inflation. Furthermore, the private sector may have faced unforeseen constraints, and increased costs due to changes in laws and policies.

Cost of rolling stock (in Millions of RMB)	Budgetary Cost	Actual Cost
Communication devices	197	182
Signal system	371	324
Cars	1704	1290
Power system	948	1183
Depot	287	317
Preparation fees	193	394

[88] Interview with BJ MTR, March 22nd, 2023.
[89] Ibid.
[90] Interview with BJ MTR, March 22nd, 2023.
[91] Ibid.

FAS, AFC	340	214
Debt repayment during construction process	273	94
Others	264	605
Total	4577	4603

Table 5. Budgeted and Actual costs involved in acquiring rolling stock

Cost Control During Operation

Beijing MTR, the private partner, managed to reduce operational and maintenance costs for cars and signal systems by training its employees and negotiating with suppliers to cover 80% of the maintenance costs for the first couple of years. As a result, in 2010, the actual maintenance costs amounted to 33 million RMB (5.8 million USD) instead of the expected average cost of 90 million RMB (13.8 million USD) per year. Moreover, they implemented a "Smart Metro " System, which operates with big data, the Internet of Things (IoT), and artificial intelligence (AI) to monitor the rail transit system in real time and determine when maintenance or replacement of components is necessary. This system helped BJMTR improve safety, cost-effectiveness, and increase the value of the assets.

Talent Training

As part of the cooperative agreement, HK MTR will assist Beijing MTR by sharing their experience in operation and maintenance, as well as training Beijing MTR employees and operation engineers. This collaboration ensures a smooth transition and process when the exclusive operation period ends. If the agreement is not extended, the entire asset (Part A and Part B) is contractually transferred to the BIIC. However, it is expected that onward, the metro line asset will continue to operate efficiently and maintain the same level of service.

5.2.4. Comparable Cases:

Beijing Metro Line 14, Hangzhou Metro Line 1, and Shenzhen Metro Line 4 have adopted the exact PPP mechanism dividing the asset into two entities. First, the private company is responsible for procuring rolling stock, operating and managing the asset, and implementing a Build-Operate-Transfer mechanism once a certain operational period expires. After this period, the joint venture company transfers ownership and operating rights to a government-designated entity.

Nanjing Metro Line 5 also utilized the Build-Operate-Transfer mechanism with a different approach. In this instance, the Private Party is still accountable for constructing the asset (Part A), asset operation, and transfer back to a government-designated entity but it is also granted commercial real estate development rights to increase revenues and provide services to the public.

5.2.5. Lessons Learned and Potential for Replicability

Implementing the PPP model for the Beijing No. 4 Metro line has brought three significant social benefits for the public. First, significant resource savings have been achieved due to the cost control by the private sector, indirectly helping manage subnational government expenses. Second, operating costs for trains are lower than anticipated, while service quality exceeds projections. According to BJ MTR's 2020-2021 sustainability report, train punctuality and service delivery rates reached 99.99%. Furthermore, the passenger satisfaction rate was 95.43% based on 980 million total passenger trips, with an average daily ridership of 1.544 million. Lastly, the joint venture company has expanded Beijing's metro line network. By the end of 2021, Beijing MTR covered 148.5 km, or approximately 20% of the Beijing metro network.

The Beijing Metro Line 4 project was procured through a transparent open market bidding process selecting the most qualified bidder, private partner, in the public's best interest. The process only included bidders with a reputable track record to participate, allowing the government to select the best-qualified bidder to carry out the project. This competitive bidding process is crucial to guarantee transparency and the cost efficiency of the public-private partnership.

The cooperative agreement provided a comprehensive mechanism delineating the allocation of benefits and risk mitigation measures between the public and private sectors. This mechanism ensured that both parties were apprised of their respective obligations and responsibilities, eliminating ambiguities during the operational process and extending beyond the operating period. The well-defined apportionment of roles and responsibilities has been employed in other PPP agreements, suggesting replicability for additional projects aiming to align the interests of all stakeholders toward a common objective of delivering sustainable infrastructure assets.

Adjustable fare prices aiming to provide social and economic benefits while balancing public interest and profitability for private sectors is an approach that fosters the sustainability of managing and operating the asset throughout its life cycle.

Franchise rights can be beneficial in facilitating the transformation of government functions within a market economy. The separation between government and enterprises, promote the sustainability of public utilities, and empower local governments to manage the assets in concert with private sector professionals. By transitioning from a public transportation operator to a regulatory role, the government can improve the operation and efficiency of private enterprises while improving the management of public transportation. This transition also fosters the use of emerging technologies to manage infrastructure assets. Throughout this process, government-related laws and regulations can be adapted to maximize public interests.

Technical personnel who have received training from the private sector provide specialized support for the operation and management of infrastructure assets. Their expertise is expected to have a positive impact throughout the entire life cycle of the assets, while also cultivating a talent pool that can be utilized for both present and future infrastructure projects. This talent pool possesses the necessary qualifications to uphold high service standards, ensuring seamless operations, and delivering dependable public services for these public infrastructure assets.

5.3. Integrating New Technologies into IAM - The Mumbai-Pune Expressway Intelligent Traffic Management System (ITMS)

5.3.1. Overview

The Mumbai-Pune Expressway Intelligent Traffic Management System (ITMS) project is being implemented as a public-private partnership project to improve the safety and efficiency of the Mumbai-Pune Expressway, and it involves the installation of various advanced technologies such as automatic traffic counters and classifiers, vehicle tracking and classification systems, variable message signs, CCTV cameras, and emergency telephones, among others, which will be integrated into the existing infrastructure of the expressway; the project is expected to benefit a large population, including both residents and visitors, and contribute to the economic, social, and environmental development of the region. The asset management of the project is expected to be carried out by the Maharashtra State Road Development Corporation (MSRDC).

The Mumbai-Pune Expressway Intelligent Traffic Management System (ITMS) has several objectives. To improve road safety by monitoring and controlling vehicle speeds, detecting incidents and accidents, and providing real-time information to drivers. To reduce congestion and travel times by optimizing traffic flow and minimizing incidents. ITMS also has the objective of enhancing incident response by providing accurate information to emergency services and facilitating quicker response times. Additionally, ITMS aims to mitigate environmental impacts by improving traffic flow, thus reducing emissions and fuel consumption. Overall, the ITMS is a comprehensive system specifically designed to enhance road transportation, benefiting drivers, local populations, and the environment.

Such factors positively impact the community, benefiting residents of Pune and its visitors. In addition, the system will contribute to the region's economic, social, and environmental development. Ultimately, the enhanced economic growth in the area could generate job opportunities across various sectors, including transportation, logistics, and tourism.

The asset management of the Mumbai-Pune ITMS project is expected to be carried out by the Maharashtra State Road Development Corporation (MSRDC), which is the public agency responsible for the development and management of road infrastructure in the state of Maharashtra, India. The project is being executed as a public-private partnership (PPP), where the private partner assumes responsibility for the design, installation, and maintenance of the ITMS infrastructure. On the other hand, the Maharashtra State Road Development Corporation (MSRDC) is accountable for the project's financing, monitoring, and oversight in accordance with the PPP agreement.

Under this agreement, the private partner is responsible for operating and maintaining the ITMS infrastructure for ten years, after which asset ownership will be transferred to the MSRDC. During this period, the private partner shall be obligated to adequately maintain the ITMS infrastructure and ensure its compliance with the performance standards and service level agreements stipulated in the project agreement.

By connecting Mumbai, a significant economic and cultural hub, with Pune, a major educational and business center, the Mumbai-Pune Expressway is one of the busiest highways in India, with a combined

population of over 40 million people, the expressway has an average daily traffic volume of over 50,000 vehicles, including passenger cars, buses, trucks, and other commercial vehicles. The expressway also serves as a major transit route for out of state travelers.

As of February 2023, the ITMS project is still in progress and being actively implemented. The project was awarded to a consortium of companies in August 2019, and the implementation work started in November 2019. The project involves the installation of various advanced technologies such as automatic traffic counters and classifiers, vehicle tracking and classification systems, variable message signs, CCTV cameras, and emergency telephones, among others. These systems are being integrated into the existing infrastructure of the Mumbai-Pune Expressway.

According to the latest update from the Maharashtra State Road Development Corporation (MSRDC), the ITMS project is progressing well and is on track for completion in 2024. However, the COVID-19 pandemic and related lockdowns have caused some delays in the implementation work.

5.3.2. Noteworthy Case Characteristics

Funding parties	Consortium of private companies, banks, and financial institutions
Type of funding	Equity from a consortium of private companies and financial institutions loans
Budget	**178 Million INR** (25 Million USD) for the operation and maintenance over 10 year period
Revenue	It is estimated to receive revenue from toll collection and for the acquisition of the toll collection rights of ITMS (unofficial source).[92] The estimated revenue-to-cost ratio for the next 10 years is 87:1 [93]
Innovation component	AI applications linked with traffic management systems. Using data efficiently to reduce costs.
Agency development	The government does not have to pay upfront, pay installments , less pressure on the government. Maintenance cost will be covered by private parties in the duration of the PPP which is 10 years, and thereafter the government will have the ownership of the project.

[92] Chittaranjan, T. "Toll Collection on Mumbai-Pune Expressway: MSRDC Receives Cheque of Rs 6,500 Crore from IRB: Mumbai News - Times of India." TOI, June 18, 2020. https://timesofindia.indiatimes.com/city/mumbai/toll-collection-on-mumbai-pune-expressway-msrdc-receives-a-cheque-of-rs-6500-crs-from-irb/articleshow/76450941.cms.
[93] Makarand, G. "MSRDC Gets Rs 9,000 CR from Sale of Mumbai-Pune Expressway Toll Rights." Mumbai Mirror, September 4, 2018. https://mumbaimirror.indiatimes.com/mumbai/civic/msrdc-gets-rs-9000-cr-from-sale-of-mum-pune-expressway-toll-rights/articleshow/65663644.cms.

5.3.3. Risk Mitigation[94]

The ITMS project encompasses various financial, technical, operational, and political risks. To mitigate these risks, the project has implemented several measures, including risk allocation between the public and private partners, performance guarantees, insurance coverage, and dispute resolution mechanisms. The project also has a comprehensive risk management plan in place identifying potential risks while evaluating their probability and potential impact, to outline risk mitigation strategies.

However, a significant concern arises regarding the presence of data management risks in the Mumbai-Pune Expressway ITMS, raising questions about their potential impact and suitable risk mitigation strategies. While there is limited information available to directly address this concern, we have examined adopted principles and best practices from other sources. As a result, we have identified four major risks that should be considered for projects integrating AI into IAM: data ownership, privacy and confidentiality, data security and unauthorized access, and data quality, bias, and misuse.

Data Ownership

Data ownership is a crucial aspect of managing the Mumbai-Pune Expressway ITMS, particularly concerning the potential transition of the system between private and public stakeholders. The ownership, usage, storage, and management of data collected by the ITMS have implications for privacy, security, and long-term system sustainability.

To address data management risks, it is crucial to understand the data management lifecycle, which includes:

Data creation: Collection of data from various sources, such as automatic traffic counters, classifiers, vehicle tracking and classification systems, variable message signs, and CCTV cameras.
Data storage: Storing of data in similar projects will likely be in situ and cloud-based systems to meet industry good practices for security and accessibility. Projects like the Sydney Coordinated Adaptive Traffic System (SCATS) centralize the data in a single location /central server.[95]
Data sharing/usage: The sharing of data with stakeholders, including the Maharashtra State Road Development Corporation (MSRDC), private partners, and emergency services, is undertaken to optimize traffic flow, mitigate incidents, and expedite incident response times. In the case of SCATS, it adheres to the Transport Privacy Policy, which outlines its approach to handling personal information in accordance with applicable legal requirements. By adhering to these privacy standards and regulations, the government fosters trust and transparency with its partners.[96]
Data archival: The retention of stored data that may have future relevance for reference, analysis, or compliance purposes is of utmost importance. In the context of the ITMS project, data archiving is crucial for maintaining historical records and monitoring long-term trends in traffic patterns and infrastructure performance and maintenance**.**

[94] Cameron F., K. "Protecting Privacy in an AI-Driven World." Brookings, February 10, 2020. https://www.brookings.edu/research/protecting-privacy-in-an-ai-driven-world/.
[95] Sydney Coordinated Adaptive Traffic System (SCATS) For today's and tomorrow's challenges, move smarter with SCATS.
[96] "Transport Privacy." Transport for NSW, July 18, 2017. https://www.transport.nsw.gov.au/about-us/transport-privacy.

Data Deletion: The deletion of data that is no longer necessary, obsolete, or irrelevant is necessary to ensure optimal storage and compliance with data retention policies and regulatory requirements.

In the event of the withdrawal of a private party from the ITMS project, it is crucial to establish a robust data ownership framework that delineates the ownership rights, roles, and responsibilities of each party, including provisions for the transfer of ownership upon a party's exit from the project, thus safeguarding the ultimate control of the data by the government entity responsible for IAM and ensuring uninterrupted availability and service and protecting the interests of the users of the infrastructure asset.

The collaborative administration of data generated by ITMS necessitates a well-defined governance framework delineating the rights, duties, and obligations of public and private partners with respect to the access, storage, and control of said data. The framework must also incorporate data protection and security protocols, warranting the safeguarding of confidential information and its utilization strictly for legitimate objectives.

The consideration of the data's lifecycle management is crucial for the enduring viability of the ITMS, including data acquisition, preservation, employment, and ultimate disposition. Privacy and security safeguards must persist throughout the lifecycle of the asset, with consistent audits and evaluations to ascertain potential opportunities for enhancement. Moreover, as the ITMS advances and novel technologies materialize, data management methodologies must be revised to guarantee the continued significance of data as a IAM resource.

In summary, the Expressway ITMS necessitates the formulation of unambiguous ownership architectures, governance configurations, and lifecycle administration protocols. These provisions will warrant the responsible utilization of ITMS-derived data, defense against privacy and security breaches and leverage the data ownership effectively to improve traffic management and infrastructure planning throughout the asset’s life cycle.

Data Management Risks

a) **Privacy and Confidentiality:**

Guaranteeing the protection of privacy and confidentiality of sensitive user data (unauthorized access, identity theft, or other privacy breaches) is paramount. If infrastructure assets employing AI fail to ensure privacy, confidentiality, and protection against misappropriation, both private and public entities managing these assets may face legal consequences and reputational risks, ultimately undermining the trust of the public and users. Furthermore, apprehensions regarding privacy violations could influence users' readiness to disclose their data usage, potentially impeding the long-term efficacy of the IAM.

To mitigate privacy and confidentiality risks, organizations should adopt measures such as anonymizing or de-identifying user-generated data to safeguard privacy. These precautions may entail the removal of personally identifiable information (PII) and other sensitive data from datasets prior to utilization in AI systems. Implementing stringent access controls and permissions also enables restricting data exposure, ensuring that solely authorized personnel have access to sensitive information. Lastly, employing privacy-

enhancing technologies (PETs) can further diminish the risk of re-identification, fostering confidence in users of the infrastructure asset that their data is being managed in a responsible manner.

b) Data Security and Unauthorized Access:

Potential vulnerabilities in the storage, transfer, and processing of sensitive information are data risks that can be exploited by malicious actors gaining unauthorized access to valuable and sensitive data, including intellectual property, personal information, or trade secrets.

IAM should employ stringent security measures, utilizing data encryption and storage solutions with intrusion detection systems to bolster the security and integrity of user and infrastructure data. Continuous monitoring, security protocol updates, and routine security audits can aid in pinpointing and addressing potential vulnerabilities before exploitation occurs.

c) Data Quality, Bias, and Misuse:

Data quality, bias, and misuse risks linked to AI-driven IAM can result in inaccuracies, prejudices, or malicious data usage. Subpar data quality or inherent biases in training data may yield suboptimal or harmful AI-enabled IAM, adversely impacting its performance and reliability. This can lead to detrimental consequences for users and both private and public providers of public goods.

To address data quality, bias, and misuse risks, IAM must ensure training data is curated, pre-processed, and diverse. This involves verifying data source accuracy and relevance, addressing potential biases within datasets, and employing methods to reduce biases in training data and model outputs, ultimately fostering equitable and reliable AI systems.

5.3.4. Comparable Cases

Highway 407 ETR (Electronic Toll Route), Ontario, Canada:

Project Description[97]:

Highway 407 ETR is a tolled expressway in Ontario, Canada, which utilizes an open-road electronic toll collection system. It integrates various ITS components like traffic cameras, dynamic message signs, and traffic sensors to monitor and manage traffic.

Risk Mitigators, Strengths, and Challenges:

This project incorporates multi-level redundancy in communication systems, routine maintenance and upgrades to tolling infrastructure. Government and private partners collaborate closely to mitigate risks. The strengths of Highway 407 ETR can largely be attributed to an efficient and accurate electronic toll collection system, congestion reduction through dynamic pricing, and real-time traffic monitoring and incident management. However, the project faces challenges such as reliance on private partners, which

[97] "Background Information." 407 ETR. Accessed April 18, 2023. https://www.407etr.com/en/highway/corporate/background-information.html.

could result in profit-driven decisions and elevated implementation costs misaligned with the public interest.

Sydney Coordinated Adaptive Traffic System (SCATS), Australia:

Project Description[98]:

SCATS is an adaptive traffic management system used to optimize traffic signal timings, in real-time, based on traffic demand. The System is implemented across various cities in Australia and has been exported to over 27 countries.

Risk Mitigators, Strengths, and Challenges:

Risk mitigators for SCATS include continuous development and updates to the software, collaboration with local traffic authorities for implementation, and periodic evaluation and recalibration of traffic models. Strengths of the SCATS system are its ability to reduce congestion and travel time, adapt to real-time traffic conditions, and scalability for use in other cities. However, the system depends on accurate data from traffic sensors. It is less effective in rural areas with lower traffic volumes, which require continuous evaluation and optimization.

Singapore Intelligent Transport System (ITS):

Project Description[99]:

Singapore's ITS combines various smart technologies that optimize road usage, reduce congestion, and improve traffic flow. Key components include the Electronic Road Pricing (ERP) system, the Green Link Determining System (GLDS), and the Expressway Monitoring and Advisory System (EMAS).

Risk Mitigators, Strengths, and Challenges:

Risk mitigators for the Singapore ITS involve public-private partnerships for technology development, which have a strong track record of reducing incident response times for system failures, as well as rigorous testing and evaluation of new technologies before rollout. The strengths of Singapore's ITS lie in its comprehensive integration of multiple ITS components, effective congestion management through the ERP system, and real-time traffic monitoring and incident management. However, the system faces challenges such as the high cost of implementation, maintenance, and public acceptance of toll systems and other technologies.

Key factors effectively mitigating risks, are common to these projects and the Mumbai-Pune Expressway ITMS. These projects strongly focus on traffic management, congestion reduction, and incident response. They also emphasize collaboration between public and private partners involved in the IAM. Common vulnerabilities of these ITS include: high costs, reliance on (difficult to verify) accurate data, and public

[98] "Home." SCATS. Accessed April 18, 2023. https://www.scats.nsw.gov.au/home.
[99] "Intelligent Transport Systems." LTA. Accessed April 18, 2023. https://www.lta.gov.sg/content/ltagov/en/getting_around/driving_in_singapore/intelligent_transport_systems.html.

adoption of new technologies. Risk mitigators generally involve redundancy, regular maintenance, and strong collaborations.

5.3.5. Lessons Learned and Potential for Replicability

The Mumbai-Pune Expressway Intelligent Traffic Management System (ITMS) project is a notable example of how public-private partnerships can be leveraged to enhance the safety and efficiency of road infrastructure while serving a large population. Several lessons learned from this ongoing project can be applied to other similar projects.

One key success factor of the project is it's strong governance. The success of the Mumbai-Pune Expressway ITMS project and its resilience to Covid-19 can be attributed, in part, to the robust governance framework that was put in place. The project agreement included provisions for transparency, accountability, and governance and provided a dispute resolution mechanism between the public and private partners. The project also involved regular monitoring and reporting ensuring compliance with project milestones and deliverables. This governance framework enabled the project to be delivered on time, within budget, and to the required quality standards.

Another factor was the competitive bidding process. The Mumbai-Pune Expressway ITMS project was awarded through a competitive bidding process, which ensured that the best-qualified bidder was ultimately selected to deliver the project. The bidding process was designed to ensure that only qualified and experienced bidders were invited to participate in the process and that the best-qualified bidder was ultimately selected to deliver the infrastructure. A competitive bidding process can be replicated with other infrastructure assets to ensure that procurement is awarded to the bidder who provides the best value proposition for the public. Clear roles and responsibilities were also essential for the project's success and were assigned to both the public and private partners involved; this approach ensures that each partner is aware of the scope of their legal obligations and liabilities, which is essential for the project's success in working towards a shared objective.

The Mumbai-Pune Expressway ITMS project can be replicated in other regions where road safety and sustainable IAM are primary concerns. However, certain minimum conditions must be met to ensure the viability of the investment.

- First, political support at the national and regional levels are essential to ensure the necessary approvals and regulatory frameworks are in place.

- Second, the project must be financially viable with a clear financing plan and revenue-sharing mechanism to ensure the private partner can recoup their investment.

- Third, the private partner must have the technical knowledge, experience and track record to design, install, and maintain an ITMS infrastructure.

- Finally, a powerful project governance framework must be in place to ensure that the project is delivered on time, within budget to meet the required quality standards.

In summary, the Mumbai-Pune Expressway ITMS project serves as a prime illustration of how public-private partnerships can enhance road safety, efficiency, and the delivery of public services, benefiting a sizable population. By applying the lessons learned from this project and ensuring that the minimum necessary conditions for viability are in place, similar projects can be successfully implemented in other regions.

5.4. Outsourcing Eco-friendly Infrastructure - The Haikou Food Waste Disposal Project

5.4.1. Overview

The Haikou food waste and feces disposal facility aims to provide sustainable and environmentally responsible services to the 2 million residents of Haikou. Utilizing advanced waste treatment methods and efficient management practices, the facility converts food waste and feces into biogas and fertilizer, intended to be sold to the local public transportation system and local farmers in the Haikou region.

The facility was established through a public-private partnership (PPP) project, which underwent a transparent and competitive bidding process.The Haikou City government fully outsourced this project to Hainan Shenzhou, a subsidiary of the German private company ALBA Group, through a comprehensive procurement process.

Under their agreement, all costs of construction, operation, and maintenance are directly borne by Hainan Shenzhou.The Haikou City government remits a fee for waste disposal services in accordance with the fee structure stipulated in the PPP agreement with Hainan Shenzhou, subject to adjustments every three years, based on the prevailing price levels. Hainan Shenzhou bears the responsibility for collecting, transporting, and recycling the waste while adhering to the quantitative and qualitative requirements delineated in the service contract.[100]

Economic and Social Impact

The primary objective of this waste disposal facility is to establish environmentally responsible solutions for managing food waste and feces in Haikou City at their source. Achieving these goals is in alignment with achieving the Sustainable Development Goals (SDGs).

The facility employs anaerobic fermentation technology to repurpose organic waste for comprehensive use, which reduces environmental pollution resulting from inadequate treatment of such waste and protects public health. By converting waste into clean energy and eco-friendly organic fertilizer, this waste management infrastructure asset contributes to the sustainable economic development of Haikou City. The Haikou City government views this project as an integral component of its efforts to transform Haikou into a modern tourist destination.

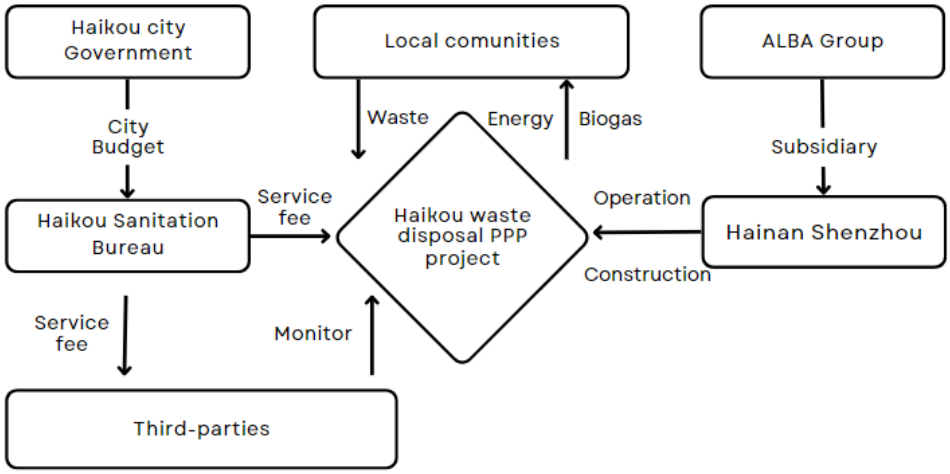
[100] Service Contract, Haikou food waste disposal PPP project.

In addition to processing and repurposing waste, the Haikou Food Waste Disposal Project creates recycling jobs in safe working conditions, in contrast to traditional waste recycling plants that expose workers to toxic hazardous waste from incineration or in landfills.

Government Decision-Making Process

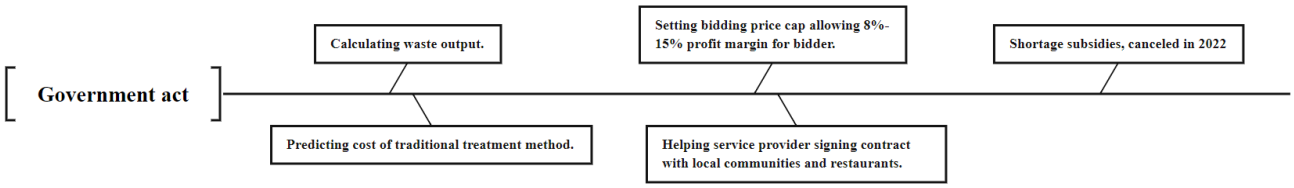
Waste management is a core municipal service budgeted and provided by the city of Haikou. The city became interested in managing the sustainability of its waste management in 2016. To reduce the related costs, the city government conducted a cost/benefit analysis for outsourcing the food waste and feces disposal process to private companies. Based on their analysis, the Haikou City government determined that the procurement agreements for waste management should be a PPP targeting a stable 8-15% profit margin, to incentivize private companies' investment in advanced waste management technology [101]

Following the awarding of the PPP contract through an open bidding process, the Haikou City government assumed the role of guarantor to (1) assist Haikou communities, schools, and restaurants in signing contracts with the facility, and (2) commit to subsidizing the facility if the waste output amount did not meet the contractually agreed minimum, i.e., a shortage subsidy. Conversely, if the facility failed to meet the disposal amount or quality, it would be obligated to pay fines to the city government. In 2022, when the government expanded the service agreement with the facility, it eliminated the shortage subsidy commitment in response to the economic recession and the city budget stress it was facing. The actual waste output level established in the contract, has been within range of the disposal amount and quality, so the shortage subsidy has not yet been triggered[102].



Graph 3. Decision Flows of the Haikou Waste Disposal PPP Project

[101] Planning document, 2015. Haikou food waste disposal PPP project.
[102] Appendix 1, Haikou food waste disposal PPP project.



Graph 4. Process of Setting the Waste Disposal Project

Facility Operating Process

The funder, builder, and operator of this facility, Hainan Shenzhou, is a Chinese subsidiary of the German company the ALBA Group, specializing in waste and water disposal services. Hainan Shenzhou previously was the agriculture waste treatment provider for Haikou City, before it won the open bid for the Haikou food waste and feces disposal project in 2015.[103]

Hainan Shenzhou is responsible for the investment and construction of the waste management infrastructure. The land for the infrastructure asset is owned by the company. The construction and operation costs are 100% financed by the company itself through commercial banking, without any government intervention on their behalf.[104]

The company is also responsible for the collection, transportation, and entire treatment process of the food waste and feces, which are collected directly from the Haikou's communities. The capacity of the treatment facility is about 200 tons/day for the food waste, and 100 tons/day for the feces. Other than the communities' waste, ALBA is responsible for the collection and disposal of all restaurant food waste, providing services that include sending trucks and haulers.[105]

In 2022, the city government and ALBA Group expanded the existing facility to add treatment capacity for food and kitchen waste.

[103] From an interview with the development manager of the facility, April 6, 2023.
[104] Ibid.
[105] Ibid.

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Graph 5. The Disposal System and Recycling Process

5.4.2. Noteworthy Case Characteristics

Funding parties	ALBA Group, who acts as the project funder, builder, and operator
Type of funding	100% private funding (ALBA Group) Government subsidizes in rare conditions
Budget	The construction cost is $10 million USD. The company covers the construction, operation, and maintenance costs. The Haikou City government pays for the service based on disposal quantities. On average, they pay $6 million US a year, and the price is reset every 3 years depending on market conditions
Revenue	$4 million USD annually
Innovation component	Tech to convert feces and food waste into fertilizer and biogas, improving sustainability and demonstrating a commitment to protecting the environment
Agency development	The Haikou City Government designed a stable and profitable municipal project that attracted private investment, contributed to the SDGs, reduced costs and increased waste recycling.

Table 7. Noteworthy Case Characteristics

[106] "The disposal system and recycling process." ALBA Group. Accessed April 18, 2023. http://hainanshenzhou2016.cluster10.mfdns.com/about/?17.html.

5.4.3. Risk Mitigation

Contractual Risk Mitigation with Service Provider

The risk mitigation process is established pursuant to the service agreement between the government and the service provider, which delineates the measures to be undertaken by both parties to identify, assess, and manage potential risks associated with the performance of the contractual obligations.[107]First, the Haikou City government imposes fines on the disposal facility if it does not meet the treatment quality and quantity benchmark of 200 tons per day established in the contract. Furthermore, the government subsidizes the disposal facility if the city waste output fails to meet the contractually agreed minimum. Second, service prices are determined based on the Hainan Price Index, which is largely correlated to the cost of fuel. Third, if the facility causes negative environmental and social externalities, the Haikou City government will impose fines. Fourth, the Haikou City government reserves the right to stop the activities of the disposal facility in case of an emergency, with the obligation to compensate the business for damages unless caused by a force majeure.

Risk Monitoring by the Government

The city budget for this waste management operation is utilized in strict compliance with financial city budget regulations. In accordance with municipal waste disposal management requirements, the city government entrusts third-party professional institutions (e.g., the manufacturer of the waste weighing systems) to oversee the food waste treatment plant operations. These institutions supervise and assess quality and quantity of the output, producing a supervision report on behalf of the government.[108]

The city government hires a third-party accounting firm to audit and monitor the quantity of food waste and feces collected and disposed of. This firm is responsible for assessing and evaluating the performance of the infrastructure, and the auditing reports are used as the basis for the city's payment of operating expenses.[109]

The Hainan Shenzhou development manager states that the facility's waste weighing system is supplied by a government contractor, to “vet” the measurement accuracy of the waste managed by the facility. Additionally, the government regularly dispatches supervisors to the plant to confirm its proper operation and generate monthly regulatory reports.

Operating Analysis by the Haikou City Government

The budget for this PPP project in 2021 was 46.8 million RMB ($7.2 million), and it was fully funded by the city budget. As of December 31, 2021, the total project expenditure was 45 million RMB ($6.92 million) distributed as follows: 33.2 million RMB ($5.1 million) for food collection and treatment services carried out from January to December 2021; and 11.8 million RMB ($1.8 million) for feces collection and treatment

[107] Service Contract, Haikou food waste disposal PPP project.
[108] Fiscal Expenditure Report 2021, Haikou food waste disposal PPP project.
[109] From an interview with the development manager of the facility, April 6, 2023.

services carried out from January to December 2021. The project expenditures are within the assigned budget control[110].

As for output, according to the 2021 Fiscal Expenditure Report, 109,318.24 tons of food waste and 73,399.61 tons of feces were collected and treated from January to December 2021. One hundred percent of the waste processed at the facility is 100% harmless to the environment and the health of residents.

Replicability

To generate profit, complex waste management facilities such as Haikou require a minimum quantity of waste output per citizen. The volume of waste collected necessary for profitability corresponds to the waste produced by at least half a million urban dwellers living in close proximity. The replicability of the waste disposal service for smaller communities is analyzed using comparable waste management infrastructure as follows.

5.4.4. Comparable Cases

1. Waste Management System in Alexandria, Egypt: A Progressive and Sustainable PPP for Enhancing the Living Environment in a Rapidly Developing Urban Area

To improve the inefficiency of the waste management system, the Governorate of Alexandria, as the ruling public authority, and Veolia, the selected private provider of environmental services, signed a PPP contract in September 2000. The contract started in 2001, for a term of 15 years. Total investment on the start-up phase of the project was €50m ($54.8 million), for a global contract worth €295m ($323.7 million) over the 15-year term[111].

This waste management initiative caters to over 5 million inhabitants, handling one million tons of waste annually. The project encompasses waste collection, cleansing, processing, end-of-life recycling, and sustainable agronomic initiatives. Additionally, the project includes the restoration of two aging dumpsites and the collection and treatment of medical waste[112].

Three primary factors contributed to the project's success. First, an initial screening stage identifying challenges. In this phase, two entities collaborated to evaluate the former waste management system's inadequacies, pinpointing key issues such as: 1) insufficient readiness to provide modern mechanical equipment; 2) excessive reliance on manual labor; 3) decreased productivity due to availability of alternative stable and high income employment opportunities offered by the government; 4) an aging

[110] Fiscal Expenditure Report 2021, Haikou food waste disposal PPP project.
[111] Veolia Environment. "Waste Management System in Alexandria, Egypt: An Innovative and Sustainable Public-Private Partnership to Improve the Living Environment in a Large, Developing City," August 13, 2006. https://staging.unhabitat.org/downloads/docs/032-Waste%20Management%20System%20in%20Alexandria%20%28Egypt%29.doc.
[112] Ibid.

workforce; 5) difficulties in maintaining equipment; 6) management processes needing improvement; and 7) inadequate waste disposal practices[113].

Second, the government's traditional role as project manager was amplified in this case. The PPP project was implemented in accordance with local and national regulatory frameworks, ensuring maximum oversight. After conducting an initial evaluation, the Alexandria government followed legal procedures to appoint a large, specialized international firm to carry out a reliable and efficient waste management operation. Additionally, the government established an organizational framework and specialized training program for employees to monitor the private party's fulfillment of their commitments[114].

Third and last, the private entity is involved in an ongoing campaign to raise environmental awareness across the region. The public was encouraged to participate in the decision-making process and trained on how to manage their waste.

The infrastructure waste management of Alexandria shares several success factors with Haikou's: strong government control, collaboration with private entities, and community involvement. However, there are some differences between the two cases. For instance, Alexandria's operations do not have clearly defined risk mitigation measures like Haikou's. Also, Alexandria's plant improves waste management objectives through increased cooperation with foreign private entities. On the other hand, Haikou's waste management infrastructure has a greater impact on the SDGs, as it is more economically and environmentally friendly by recycling waste and converting it into usable resources that generate revenues.

2. Wastewater treatment BOT project (WWTP) in Miluo, China: Risk sharing and transfer for smaller PPP projects

Due to limited financial resources, the Miluo Wastewater Treatment Plant (WWTP) project is implemented through the Build-Operate-Transfer (BOT) model to attract private operators to invest in a wastewater treatment plant. BOT is a PPP model that allows the project company to secure financing, design and build the project facilities, and be liable for the long-term operation and maintenance of the project until the infrastructure ownership is reversed to the government at the end of the concession period. Changsha Guozhen Water Treatment Co. Ltd is the private partner who invested 6.15 million RMB ($0.94 million), financing the acquisition with 30% in equity and 70% through commercial banking loans. The plant's treatment capacity is 25,000 cubic meters of wastewater per day, for a contract duration of 28 years[115].

Three main reasons contribute to the project's success. First, employing competitive negotiation strategies attracted private investment. Initially, the Miluo BOT project failed to garner private sector interest, with

[113] Fahim, Rasha, Rania El-Gazzar, and Mohamed Elgohary. "Understanding the Dilemma of the Municipal Solid Waste Management in Alexandria, Egypt: Could ICT Improve the System?" IFIP Advances in Information and Communication Technology, May 2017. https://www.researchgate.net/publication/317179225_Understanding_the_Dilemma_of_the_Municipal_Solid_Waste_Management_System_in_Alexandria_Egypt_Could_ICT_Improve_the_System.

[114] Veolia Environment. "Waste Management System in Alexandria, Egypt: An Innovative and Sustainable Public-Private Partnership to Improve the Living Environment in a Large, Developing City," August 13, 2006. https://staging.unhabitat.org/downloads/docs/032-Waste%20Management%20System%20in%20Alexandria%20%28Egypt%29.doc.

[115] Shrestha, Asheem, Toong-Khuan Chan, Ajibade A. Aibinu, and Chuan Chen. "Efficient Risk Transfer in PPP Wastewater Treatment Projects." Utilities Policy, 2017. https://doi.org/10.1016/j.jup.2017.03.003.

only three companies participating. To increase competition, the government shifted the tendering strategy to competitive negotiations. Government consultants reached out to over 60 private companies, identifying their interests, and ensuring rational negotiations. This approach successfully attracted more experienced private companies to the wastewater treatment infrastructure[116].

Second, robust ex-post monitoring. The Miluo government supervised the WWTP construction, implementing measures to monitor the project comprehensively, including monthly progress reports, random inspections, and detailed financial reporting. These actions ensured adherence to all standards.[117].

Third, employing positive and negative incentives to transfer and share risk through an allocation structure. The Miluo government specified risk sharing responsibilities, price adjustment mechanisms, and dispute resolution including termination arrangements. It imposed heavy penalties on performance bonds when non-performing. Additionally, Guozhen Co. must cover 30% of project costs with equity. Higher equity involvement reduces the risk of PPP failure by transferring more risks to the private sector.[118].

The Miluo case shares similarities with Haikou's, in terms of risk transfer, monitoring, and incentives. It serves as a model for small PPP projects, attracting experienced private investors through competitive negotiations.

3. Food Waste Disposal Stations at Dongzhou Government Canteen in Fushun, China: Building Waste Disposal Station at the Community Level

In response to the Chinese central government's directive to improve African swine fever prevention, which bans feeding swine with kitchen waste, the Fushun City's Dongzhou district government invested $70,000 in two food waste processors and high-tech district canteens, serving 5,000 people.[119].
Jingshi Environmental, a private provider of environmental technology, produces the food waste processors used in this project[120]. The processors, featuring low noise, odorless operation, and energy efficiency, have simple installation requirements, needing only a site and power source. In the Dongzhou government canteen, the machine breaks down kitchen waste using internal microbial populations, converting waste into non-toxic composite fertilizer within 24 hours.[121]

During the negotiation stage, Jingshi Environmental assisted the government in estimating daily kitchen waste per capita and provided processors with corresponding capacity. According to Jingshi Environmental project manager, daily kitchen waste per person ranges from 0.1 to 0.5 kg, based on urban development levels. Using government data, Jingshi Environmental effectively modeled the optimal treatment required

[116] Ibid.
[117] Shrestha, Asheem, Toong-Khuan Chan, Ajibade A. Aibinu, and Chuan Chen. "Efficient Risk Transfer in PPP Wastewater Treatment Projects." Utilities Policy, 2017. https://doi.org/10.1016/j.jup.2017.03.003.
[118] Ibid.
[119] Food waste disposal stations at Dongzhou government canteen in Fushun, China. Gaoxinquliang, July 28, 2019. https://www.meipian.cn/2a7pohnz?first_share_uid=5872395&share_depth=6&share_source=timeline&share_user_mpuuid=949ed654c6e8ed05b00bd2bed3986ee8&sharer_id=&user_id=&v=5.0.1.
[120] Jingshi Environmental Products. Accessed April 18, 2023. https://www.jsjshb88.com/product/37/.
[121] Food waste disposal stations at Dongzhou government canteen in Fushun, China. Gaoxinquliang, July 28, 2019. https://www.meipian.cn/2a7pohnz?first_share_uid=5872395&share_depth=6&share_source=timeline&share_user_mpuuid=949ed654c6e8ed05b00bd2bed3986ee8&sharer_id=&user_id=&v=5.0.1.

based on waste amount, to maximize economic benefits. The waste treatment per person per year is estimated to be, on average, 10 USD[122].

Localized waste treatment has greater economic benefits for rural areas and low-density urban areas due to a lower cost of transportation and waste collection. In Haikou, a densely populated city, it is more suitable to build centralized food waste treatment plants in suburban areas as the collection process is easier and may cost less due to the scale effect. As a government, in the decision-making stage, it should consider the population density and estimated per capita waste production to determine whether to build centralized waste treatment plants or localized ones.

5.4.5. Lessons Learned and Potential for Replicability

The Haikou food waste and feces disposal infrastructure, along with the comparable waste infrastructure assets reviewed, demonstrates how governments can finance and manage waste treatment infrastructure within local contexts by employing rigorous due diligence and comprehensive risk mitigation strategies.

The Haikou waste facility, initiated and overseen by the government but financed and operated by private enterprises through a PPP framework, effectively navigates the government's initial lack of relevant technology and funding, as well as issues arising in subsequent operation and asset management. In this model, the government's regulatory role is maximized, starting from due diligence in the decision-making phase, meticulous screening during the bidding phase, contract drafting in the project initiation stage, and onto the division of responsibilities, risk management, and continuous operation, management, and expansion phases. In this development, the government succeeded in building a mutually beneficial relationship with the private sector while delivering to its citizens an innovative waste management service.

Additionally, the Egypt case showcases the feasibility of PPP projects, emphasizing the value added of government control of the PPP terms, while fostering synergies between collaborating public and private entities, ensuring that the IAM serves the public interest.

The Miluo case highlights strategies for promoting projects and achieving risk transfer and sharing in scenarios for smaller scale infrastructures that without government support would not attract private investment.

The Fushun case focuses on localized and community-based waste disposal, with the government purchasing integrated equipment from private companies using minimal funding to reduce transportation costs and process food waste on-site.

Food waste disposal infrastructure requires the government to raise public awareness through education and appropriate incentives for proper waste sorting. During the construction phase, the government needs to take into consideration urban planning and population densities to provide suitable waste management methods and corresponding IAM. In densely populated cities with populations above half a million, centralized waste processing infrastructure may offer greater economic benefits, while in rural areas and suburbs, using integrated equipment for local disposal might be more economically viable. Consequently,

[122] Interview with Project Manager, April 19, 2023.

combining centralized waste disposal with community-based approaches can maximize social, economic, and environmental benefits.

6. Prospects for the Projects

Drawing insights from the above IAM case studies and examining the notable practices in each case, this section delves deeper into the future prospects of each specific project. The key factors that contributed to the success of each project are outlined below, along with how they will be integrated into the functioning of each project to maximize their potential.

Rio de Janeiro:

Leveraging the existing National PPP framework and legislation, the Rio Smart City project effectively combined technology and blended finance to successfully implement the country's first Street Lighting PPP in record time.[123]

The PPP contract was structured to allow flexibility in the case of unforeseen circumstances or Acts of God, ensuring the project's resilience and adaptability to changing conditions while mitigating risks, as experienced during the COVID-19 pandemic. The contract also provides exclusivity and expandability for generating ancillary revenue sources, enabling significant opportunities for operating the infrastructure . The revenue-sharing agreement between the municipality and the private party ensures that new revenue sources benefit both parties. The agreement provides incentives for innovation throughout the asset's lifecycle. Additional ancillary revenue can be generated by leveraging new technology (IoT) and potentially monetizing infrastructure and user-related data. The contract is flexible enough to accommodate multiple new sources of innovation.[124]

Yan Herreras Yambanis, the Vice President of Business Development and Financing at High Trend Brazil stated that the project aims to, in the near future, provide 100% of its power through renewable sources of energy. In this regard, work has already begun to install solar panels that will be integrated into the Public Street Lighting System. Apart from environmental and sustainability reasons, the objective behind transitioning to renewable energy sources is to reduce the long-term running costs of the infrastructure.[125]

Beijing:

The successful implementation of the PPP model in the Beijing Metro Line 4 project has the potential to encourage the adoption of PPPs in the transportation sector in other cities.[126]

The open market bidding process used in the Beijing Metro Line 4 project could serve as a model for other projects, promoting transparency and competition among potential bidders. The emphasis on cost control and service quality in the Beijing Metro Line 4 project offers valuable insights for future infrastructure projects, leading to more efficient resource utilization and improved public services.

The emphasis on emerging technologies in infrastructure asset management is a trend that should continue for future development, resulting in increased efficiency and effectiveness. Private sector involvement in

[123] Interview with Yan Herreras, Vice President of Business Development and Financing at High Trend Brasil, April 14, 2023.
[124] Interview with Yan Herreras, Vice President of Business Development and Financing at High Trend Brasil, April 14, 2023.
[125] Ibid.
[126] Interview with National Development and Reform Commission, April 12, 2023

technical training contributes to the development of a skilled talent pool and can provide high IAM standards, as well as the consistent delivery of reliable public services.[127]

In summary, the insights gleaned from the Beijing Metro Line 4 project could be replicated in other cities, thereby enhancing urban sustainability through improved connectivity and reduced congestion and air pollution. The replication of this successful model is anticipated to lead to more efficient public services and increased benefits for the public.[128]

Pune:

The Mumbai-Pune Expressway ITMS, incorporates lessons from the successes and challenges of similar systems like the Highway 407 ETR in Ontario, Canada,[129] SCATS in Sydney, Australia,[130] and Singapore's Intelligent Transport System.[131] It is set to bring significant improvements to traffic management in India. By incorporating the strengths and addressing the weaknesses of these existing systems, the future outlook of the Mumbai-Pune Expressway ITMS appears promising.

The SCATS system in Sydney is known for its adaptive traffic signal control that optimizes signal timings based on real-time traffic conditions.[132] This technology can be leveraged to enhance traffic flow on the Mumbai-Pune Expressway, reducing congestion and travel times. However, the Mumbai-Pune Expressway ITMS should also consider potential weaknesses, such as adapting the SCATS approach to the region's legacy traffic patterns and infrastructure.

Singapore's Intelligent Transport System (ITS) showcases the successful integration of various advanced technologies, including real-time traffic information, incident detection, and smart city infrastructure.[133]

This comprehensive approach can be a model for the Mumbai-Pune Expressway ITMS, allowing it to adapt to emerging transportation technologies like autonomous vehicles and connected systems. However, the ITMS must also tackle challenges such as substantial infrastructure investments, ongoing maintenance, and ensuring data privacy and security.

In conclusion, the future outlook of the Mumbai-Pune Expressway ITMS is promising, with opportunities to learn from and build upon the strengths and experiences of established systems like the 407 ETR, SCATS, and Singapore's ITS. By addressing potential weaknesses and incorporating the most effective elements of these systems, the Mumbai-Pune Expressway ITMS can significantly improve traffic management, safety, and overall transportation efficiency in the region.

Haikou:

The Haikou government will monitor the private entity to make sure they fulfill the contractual obligations at all times. In the future, if there is a need to increase or decrease food waste processing, the Haikou

[127] Interview with National Development and Reform Commission, April 12, 2023
[128] Ibid.
[129] "Background Information." 407 ETR. Accessed April 18, 2023. https://www.407etr.com/en/highway/corporate/background-information.html.
[130] "Home." SCATS. Accessed April 18, 2023. https://www.scats.nsw.gov.au/home.
[131] "Intelligent Transport Systems." LTA. Accessed April 18, 2023. https://www.lta.gov.sg/content/ltagov/en/getting_around/driving_in_singapore/intelligent_transport_systems.html.
[132] "Home." SCATS. Accessed April 18, 2023. https://www.scats.nsw.gov.au/home.
[133] "Intelligent Transport Systems." LTA. Accessed April 18, 2023. https://www.lta.gov.sg/content/ltagov/en/getting_around/driving_in_singapore/intelligent_transport_systems.html.

government will promptly negotiate contract modifications with the private enterprise to ensure the smooth operation of the infrastructure.[134]

In 2022, thanks to the Haikou government's efforts in cultivating public awareness of garbage classification and recycling, they signed an expansion agreement with Hainan Shenzhou, as the demand for food waste disposal increased. The distribution of responsibilities and risk mitigation will continue to follow previous procedures. The waste treatment infrastructure expansion will create new job opportunities and increase the scope for food waste processing. However, the project manager noted that some street restaurants are still not cooperating with the collection of kitchen waste.[135] The government gradually outsourced all kitchen waste collection to Hainan Shenzhou, rather than third parties.[136] This standardizes the collection of kitchen waste and scales up waste recycling.

7. Conclusions and Recommendations

Infrastructure Asset Management is a crucial function provided by local governments in Emerging and Less Developed Countries (LDCs) as they strive to deliver essential services. These governments often face funding constraints and challenges such as limited institutional capacity, moral hazard in procurement processes, the need to integrate the management of national and subnational assets, difficulties in making new technology interoperability with existing operations, and the lack of sustainable revenue streams to manage and maintain assets and address unforeseen risks. The four case studies analyzed showcase innovative financial and technological approaches that have an impact at various stages of the assets' lifecycles. These solutions, as highlighted in this research, aim to enable local governments in emerging and developing countries to effectively manage their infrastructure assets in the interest of the public while managing financial constraints.

A thorough examination of the case studies from Rio de Janeiro, Beijing, Pune, and Haikou highlights the need to consider a supportive political environment and potential impact from the start of the structuring phase. Taking into account critical aspects, such as population density like in the Haikou case, is key to ensuring the project's potential for development and obtaining financing. The analysis reveals several vital lessons and recommendations applicable in various contexts. First and foremost, transparency and governance are essential elements for sustainable projects. Establishing transparent contractual agreements, decision-making processes, and maintaining open communication channels fosters trust among a wide range of entities that are directly or indirectly involved in the project, facilitates smooth project execution, and minimizes litigation. A robust governance framework, encompassing transparency, accountability, and dispute-resolution mechanisms, serves to protect projects from unforeseen events such as regulatory changes, labor disputes, and political instability, contributing to their overall success.

Risk mitigation and management strategies play a crucial role in ensuring project success. Comprehensive risk identification, mitigation, and management measures involve thorough due diligence, multilateral risk-sharing mechanisms, meticulous contract drafting, clear divisions of responsibility, and continuous monitoring and reassessment throughout the project lifecycle. By implementing these measures, an infrastructure project PPP's resilience and adaptability are significantly enhanced, allowing it to effectively

[134] From an interview with the project manager, April 6, 2023.
[135] From an interview with the development manager of the facility, April 6, 2023.
[136] Ibid.

address issues such as disputes, delays, and cost overruns. Additionally, including revenue-sharing agreements regulated by the contract can incentivize innovation on the part of the private partner.

Innovative financing structures are instrumental in funding IAM throughout the assets' lifecycle. By accessing new sources of financing and employing innovative financial mechanisms, such as the use of the U.S. Development Finance Corporation (DFC) guarantee and debentures repackaging (The Smart City project in Rio de Janeiro), private partners gain access to additional funding and new investors from capital markets. This diversification of financing sources makes infrastructure projects more attractive to investors including institutional asset managers. The increased investor interest can mobilize the required capital, bridge financing gaps, and ensure the long-term financial sustainability of infrastructure asset management.

A transparent competitive bidding process is vital for ensuring project efficiency and effectiveness. By utilizing this approach, the selection of highly qualified and reputable bidders is facilitated, enabling the assignment of clearly defined roles and responsibilities for all project stakeholders. This approach promotes accountability, fosters a sense of ownership, and enhances the overall effectiveness and success of the management of the infrastructure assets. The adoption of replicable frameworks, such as the one developed by the Brazilian Government, the World Bank, and the International Finance Corporation, adds credibility to the conditions that ensure competitive bidding processes following established best practices. Standardizing processes through these frameworks also mitigates the risk of favoritism in procurement, strengthens the technical capacity of local governments, and enables the selection of the most suitable private partner.

By implementing auditable cost control mechanisms, project expenses can be closely monitored and managed, minimizing the risk of budget overruns. Additionally, establishing predictable revenue sources provides stability and financial sustainability to the project, ensuring a steady flow of income to cover operational costs and debt service obligations. Implementing effective cost control measures and establishing reliable revenue streams are critical factors for ensuring sustainable IAM and delivering public goods and services.

By incorporating these actionable recommendations into future infrastructure asset operations, stakeholders can establish synergies that lead to the efficient delivery of public goods to citizens. This collaborative and sustainable environment, fostered by local governments, regulatory bodies, private partners, and investors, will enhance Infrastructure Asset Management (IAM) practices and create lasting value in diverse contexts. Ultimately, these efforts will benefit local governments in emerging and developing countries as they strive to deliver public value and provide essential services to their constituents.

Lastly, this research emphasizes that incorporating the mentioned practices can greatly increase the probability of achieving financial and operational sustainability in Infrastructure Asset Management (IAM), while also mitigating unforeseen risks. The assessed innovations in IAM financial and PPP agreements facilitate improvement, enhance informed decision-making of sub-national governments, and contribute to the long-term management of infrastructure assets, throughout their lifecycle. This research review of infrastructure asset management demonstrates that local governments, private partners, and other stakeholders can replicate or adapt the analyzed strategies to effectively manage their infrastructure assets in alignment with the Sustainable Development Goals (SDGs).

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9. Appendices

9.1. Sustainable Development Goals (SDGs) for Each Case Study[137]

The table below presents a matrix listing the Sustainable Development Goals (SDGs) and their associated targets achieved by the four case studies: Rio de Janeiro, Beijing, Pune, and Haikou. The table only includes the goals and targets that have been achieved by at least one of the case studies.

SDG Goals	Targets	Rio de Janeiro	Beijing	Pune	Haikou
Goal 3: Good Health and Well-being	**Target 3.6:** By 2020, halve the number of global deaths and injuries from road traffic accidents.		✓		
	Target 3.9: By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water, and soil pollution and contamination.				✓
Goal 6: Clean Water and Sanitation	**Target 6.a:** By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programs.				✓
	Target 6.b: Support and strengthen the participation of local communities in improving water and sanitation management.				✓

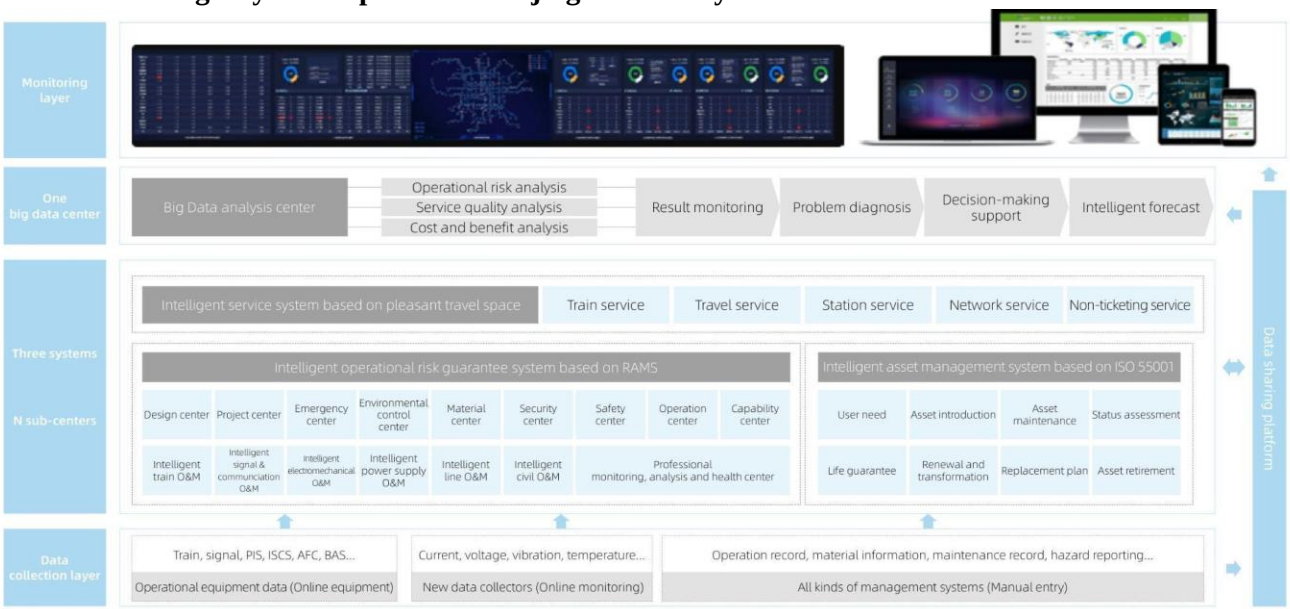
[137] "The 2030 Agenda for Sustainable Development - United Nations." Accessed April 18, 2023. https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf.

	Target 6.3: By 2030, improve water quality by reducing pollution, eliminating dumping, and minimizing the release of hazardous chemicals and materials.				✓
Goal 7: Affordable and Clean Energy	**Target 7.b:** By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries.				✓
	Target 7.3: By 2030, double the global rate of improvement in energy efficiency.	✓			
	Target 7.4: By 2030, promote access to research, technology, and investment in clean energy.			✓	
Goal 9: Industry, Innovation, and Infrastructure	**Target 9.1:** By 2030, develop sustainable, resilient, and inclusive infrastructure.		✓	✓	
	Target 9.4: By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes.	✓	✓		✓

	Target 9.5: Enhance research and upgrade industrial technologies.			✓	
	Target 9.6: Facilitate sustainable infrastructure development for developing countries.		✓	✓	
Goal 11: Sustainable Cities and Communities	**Target 11.a:** Support positive economic, social, and environmental links between urban, per-urban, and rural areas.				✓
	Target 11.2: By 2030, provide access to safe, affordable, accessible, and sustainable transport systems for all.	✓	✓	✓	
	Target 11.6: By 2030, reduce the adverse per capita environmental impact of cities.				✓
	Target 11.8: Strong national and regional development planning.			✓	
Goal 12: Responsible Consumption and Production	**Target 12.3:** By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains.				✓
	Target 12.4: By 2020, achieve the environmentally sound management of chemicals and all				✓

	wastes.				
	Target 12.8: By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature.				✓
Goal 13: Climate Action	**Target 13.2:** Integrate climate change measures into national policies, strategies, and planning.	✓		✓	
Goal 16: Peace and Justice Strong Institutions	**Target 16.6:** Develop effective, accountable, and transparent institutions at all levels.	✓			
Goal 17: Partnerships to achieve the Goal	**Target 17.17:** Encourage and promote effective public, public-private, and civil society partnerships, building on the experience and resourcing strategies of partnerships.				✓

9.2. Agency Development for Beijing Case Study



Overall architecture of "1+3+N" smart metro

The "1+3+N Smart Metro" system of Beijing Metro Line 4