Mobility and Development

INNOVATIONS, POLICIES, AND PRACTICES

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Interview with Riccardo Puliti

In this informal Q&A, Riccardo Puliti answers a few questions, taking the opportunity to update us on his strategic work supporting the Bank's efforts to mitigate the global impacts of climate change. Riccardo approaches this immense, urgent challenge from the 30,000-foot global perspective and also through the more focused lens of infrastructure, specifically how transport and energy sectors can—and must—continue to adapt and adopt advanced technology-based mobility solutions to meet climate-related goals.

Q: Transport had a prominent representation at the recent COP26 proceedings, where you engaged with stakeholders from across the globe as well as the public and private sectors. What can you tell us about the World Bank's progress in driving this critical agenda forward? How is Transport contributing to the climate goals set forth through the Paris Alignment?

We are operating in an era of unprecedented challenges and one of the most pressing ones is indeed the climate crisis. We cannot win the fight against

climate change without taking on the rapidly growing emissions from the transport sector. Greenhouse gas (GHG) emissions from domestic and international transport already contribute 20 percent of global emissions. And transport sector emissions have also grown faster than those of almost any other economic sector over the past 50 years. If no action is taken, substantial additional increase is predicted by as much as 60 percent by 2050.

While developed economies have contributed extensively to the climate challenge, GHG emissions are now growing faster in developing countries than in the developed world, albeit from a very small starting point. This is an opportunity to develop and deploy strategies to help these economies grow in a sustainable way and avoid getting locked into unsustainable modes of transport for future growth. We also need to pay particular attention to global supply chains, which are critical for responding to global shocks, such as vaccine delivery and food security, among others.

At the World Bank, we are guided by our Climate Change Action Plan, which was recently renewed for five years (2021–25). The action plan underpins our commitment to our clients by increasing our climate financing, strengthening climate adaptation, and aligning our efforts with the goals of the Paris Alignment. To facilitate this ambition at the country level, the Bank has developed the Country Climate and Development Report (CCDR) which investigates two overarching concepts:

- How climate change and global decarbonization could impact a country's development path and priorities; and
- Potential areas for country action in resilience, adaptation, and mitigation to improve development outcomes.

In short, the CCDR takes a collaborative and consultative approach whereby teams engage with client governments, the private sector, academia and think tanks, civil society, and development partners to seek technical inputs. It is a deliberate and concerted effort on behalf of our teams who are working together with our clients and international partners to devise solutions to some of the biggest transport-related challenges facing our world today.

In the transport sector, I would like to highlight some examples of our work in action. We have launched the new Global Facility to Decarbonize Transport (GFDT), and we are excited to see the Facility receive new funding at COP26 from several donors. GFDT is the first and only program that takes a truly global and integrated approach to transport decarbonization. It will catalyze innovation toward low-carbon and resilient transport solutions through project financing, knowledge, and capacity building.

Our recent Transport Decarbonization Investment (TDI) Series, where our teams identified concrete ways to unlock more financing for green, resilient transport, offers a great example of an effective partnership. We worked with the government of the Netherlands and the World Resources Institute to deliver actionable recommendations in the series, with a focus on overcoming investment barriers and developing innovative financial instruments to decarbonize transport.

Image Credits: 1. Colin BraderMarch 2012, 2. Gabriel Leonardo Guerrero 2019, 3. Metro de Quito

And, on the project level, our teams are helping client countries change the way they move through active mobility solutions, electrification of transport modes, and public transit. For example:

- In Perú, the Bank developed Lima's new Bicycle Plan, which features more than 1,000 kilometers of protected cycle lanes.
- The World Bank is providing technical advice for the electrification of two and three-wheelers in Bamako and Ouagadougou, two major African cities where these vehicles have emerged as the dominant mode of individual transport for household mobility. The transition towards electric two and three-wheelers will reduce air pollution and fossil energy dependence.
- In the Philippines, the Bank is supporting the construction of bus rapid transit (BRT) corridors in the cities of Cebu and Manila. Once fully operational, the new BRT systems will generate savings of 7,260 and 8,780 tons of GHG emission per annum respectively.
- In Quito, Ecuador, the World Bank has been supporting the construction of the country's first metro line through two successive loans totaling $435 million. By moving passenger traffic from private cars and diesel buses to modern electric trains, the project will save an estimated 65,000 tons of GHG emissions per year.

Q: Transport is one of many sectors being impacted and transformed by advances in technology. How do you foresee these sectors coming together to deliver green and innovative transport solutions?

The convergence of technological innovations in digital connectivity, data platforms, automation, and alternative energy is creating exciting opportunities to make mobility systems more efficient and inclusive through better planning and investment decisions and establishing adaptive policy and regulatory frameworks. These advancements are also opening new opportunities to reduce the climate footprint of the transport sector.

I believe mobility systems will evolve because of the technological innovations we are seeing. However, in many developing countries, a huge gap still exists between technological advancement and deployments on the ground. How we manage and guide technological shifts will have profound consequences on the way mobility services are provided in our client countries. I believe innovation can help address some of the difficult transport issues we have been dealing with for many years, including reducing congestion, increasing access to social and economic opportunities, enhancing livability and livelihoods, and allowing for more efficient delivery of goods and services.

We are already witnessing how technological advances and many innovations are helping developing countries to leapfrog in new service delivery modes and avoid replicating solutions that can be costly in the long term. For example, mobility as a service (MaaS) has been emerging to enable multimodal travel and customer-centric access to transport services. It provides an opportunity to integrate informal transit services and digitally enabled mobility services in emerging economies. This integration, however, also presents a number of challenges—in particular, data integration, service integration and policy integration. A recent World Bank study, *Adapting Mobility-as-a-Service for Developing Cities: A Context-Sensitive Approach*, shows how we can navigate these issues to harness the full potential of MaaS and adapt this new model to the developing country context.

Another example is from the maritime sector. The COVID-19 pandemic upended global trade and supply chains and pushed countries and organizations to speed up the digitalization of critical end-to-end processes. But digitalization is not just a matter of technology. It requires effective change management, data collaboration, and political commitment. While some port communities have been diligent in the development of "smart ports," others still need considerable capacity building and resources to modernize their infrastructure. A recent collaboration between the World Bank Transport Global Practice and the World Ports Sustainability Program (WPSP) of the International Association of Ports and Harbors (IAPH) focuses on promoting critical actions to strengthen the resilience of the maritime supply chain through digitalizing the port sector.

Adapting Mobility-as-a-Service for Developing Cities: A Context-Sensitive Approach

WPSP
WORLD PORTS SUSTAINABILITY PROGRAM
www. sustainableworldports.org

Q: What should the World Bank concentrate on further to galvanize action towards a low-carbon future?

A concerted effort is needed if we are to pursue the path to sustainable mobility without sacrificing growth and development. This calls for a deliberate recognition that each country will have its own path for decarbonizing its transport sector and making it more resilient. Whatever path countries choose, governments need to set clear transport decarbonization targets and adapt their regulatory frameworks accordingly. I see several opportunities here:

FIRST, we need to invest in systems rather than just vehicles. Mobility solutions integrated with urban design and spaces, logistics networks, resilient supply chains, and land management lead to strong, lasting outcomes. For instance, as cities expand, public transport infrastructure, sidewalks, and cycle lanes should be embedded in urban planning right from the inception, offering competitive and relatively low-cost alternatives to private vehicles.

SECOND, we need to use smart policies to incentivize the transition to low-carbon mobility systems. This could mean phasing out fossil fuel subsidies, moving to a distance-based charging system or introducing carbon pricing where appropriate. These policy instruments would not only incentivize governments, businesses, and individuals to adopt low-carbon technologies, but also (1) generate substantial revenues that could be reinvested in low-carbon mobility and resilient infrastructure; (2) induce long-lasting behavioral change; and (3) promote adoption and adaptation of clean and new technologies.

THIRD, investment in renewables for clean transport is crucial and here the topic of e-mobility and new technologies is an important one. Governments need to think about energy and mobility together from the outset, facilitating the transition toward e-mobility, deployment of charging infrastructure, and supporting the transition toward clean and smart electricity grids. Given that e-mobility is a nascent industry, it is critical that scarce fiscal resources be allocated where their largest economic and social impacts will be felt. In many developing countries, for example, electrification of transport means, in the short run, electrification of two and three-wheelers as well as buses.

And **FINALLY**, we need innovative financing. Public and private actors must coordinate to rapidly scale up finance for low-carbon solutions in the transport sector. Development finance institutions can also contribute through their own financing and by helping mobilize private and concessional financing, including by expanding the use of de-risking instruments, through blended financing, credit enhancements, and technical assistance.

Riccardo Puliti

Riccardo Puliti is the vice president for infrastructure at the World Bank. In this position he leads the institution's global efforts to build effective infrastructure in developing and emerging markets and supports the World Bank Group's strategic business priorities, such as the climate change action plan. He oversees the Bank's critical work across the energy and transport sectors, digital development, and efforts to provide access to renewable energy and low-carbon transportation and quality infrastructure services to communities through public-private partnerships. Infrastructure represents around US$75 billion of the Bank's portfolio. Click here to read more.

Binyam Reja
global practice manager for transport,
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A Note from the Editor-in-Chief

As we adjust to the rhythms of a new year, we naturally reflect on the accomplishments of the year gone by, while also embracing the challenges and opportunities ahead. For the World Bank's Transport Global Practice, these accomplishments include the launch of this very periodical, Mobility and Development: Innovations, Policies, and Practices. And looking forward, producing a publication that serves as an inspiration and catalyst for experts working (or simply interested) in transport-related sectors presents us with both a challenge and opportunity for 2022 as well as many years to come.

The inaugural Fall 2021 issue explored solutions for improving low-carbon and resilient mobility in a post-pandemic world. if you haven't already, I encourage you to read through the articles, which cover the evolution of mobility-based services, the role of decarbonizing transport in India's energy policies, the use of geospatial analysis to help mitigate the impacts of climate change on urban transport, how to calculate the health benefits of nonmotorized transport policies, and the importance of integrating and strengthening transport systems in connecting urban centers.

In the Spring 2022 issue, we broaden the range of topics, foregoing a specific theme and instead allowing the submissions to guide the conversation, securely under the expansive umbrella of mobility and development.

To open the issue, we interview **Riccardo Puliti**, the vice president for infrastructure at the World Bank, who discusses his work on global climate change, along with the role of advanced technology in transport, and how sustainable mobility solutions fit into a low-carbon future. It makes for a captivating read and we appreciate Riccardo's generosity of time and insights.

Highlighting the work of World Bank staff, this issue continues with **Jen JungEun Oh, Mathilde Lebrand, Obert Pimhidzai, and Chiyu Niu,** who investigate the links between infrastructure, accessibility, and employment in Vietnam. Despite an impressive achievement in connecting thousands of commune centers with a network of all-weather roads, the country still has pockets of very remote, inaccessible areas. As a result, these remote areas hold limited economic opportunities for residents. In order to understand and quantify the relationship between connectivity and economic outcomes—at both the individual household and commune levels—the team introduced and calculated a "market access index" composite indicator, designed to capture transport costs between consumption and production locations in all potential trading districts. Their analysis shows the improvements in transport infrastructure increased market access, which in turn increases wages and attracts more population. The team also tested the potential impacts of future connectivity improvements on national real income and spatial inequality, with results indicating the national real income would rise, due to improved access to domestic markets and better integration with global trade opportunities.

Pivoting toward Africa, **Vivien Foster** and **Mathilde Lebrand** rely on economic tools and data science to consider the untold story of the wider economic benefits of investing in transport across the continent. Along with the classical focus on the time savings, large transport projects can bring a multitude of much wider and seldom fully accounted for economic benefits. These include

Binyam Reja serves as global practice manager for transport in the Infrastructure Vice Presidency of the World Bank. Dr. Reja oversees the World Bank's Transport Global Unit's knowledge program, analytical studies, technical support to operational units, partnerships, and corporate mandates. He directs an extensive technical assistance program and analytical studies and leads a team of technical professionals and experts in the delivery of the program. Prior to being selected to this position in November 2020, Dr. Reja was the regional practice manager for China, Mongolia, and Central Asia where he oversaw a lending program totaling US$8 billion for China, Mongolia, and Central Asia covering all subsectors, including urban transport, BRT, metros, highways, railways, intermodal freight transportation, and logistics. He holds a Ph.D. in economics from the University of California, Irvine, and attended the Executive Education program at Harvard's Kennedy School of Government.

supporting structural transformation of the economy, increasing the number and quality of jobs, and promoting domestic, regional, and global trade. Drawing on new sources of data and modern econometric techniques, the team presents a significant body of recent economic research covering a wide range of countries in Africa. They then compile a new and compelling evidence base for how transport projects contribute to economic development.

With Latin American cities such as Buenos Aires, Bogotá, and Santiago more than doubling the length of their cycling networks in less than 10 years, the research conducted by World Bank's **Javier Morales Sarriera** and World Resources Institute's **Adriana Jakovcevic** keeps the Spring 2022 issue on a steady pace. Studying the growth of bicycle infrastructure in Latin American cities and how these burgeoning cycling networks benefit the region's urban economies—and armed with a rigorous evaluation framework to inform further network expansions—the team showcases a study of the economic benefits of bicycle lanes and discusses the application of an ex-post cost benefit analysis on two new bicycle lanes in the city of Buenos Aires. The results for Buenos Aires show substantial economic benefits for the two lanes, with a benefit-cost ratio of 5.7 and an economic rate of return of 113 percent resulted from the significant observed increase in cycling on the new lanes.

Next, **Wenyu Jia** and **Edward Andrew Beukes** return our focus to Africa, exploring how the growth and adoption of mobile phone technologies create opportunities for using low-cost, agile data collection and analytics platforms for paratransit diagnostics. The article documents the duo's diagnostic work and key findings on the paratransit sector in the capital cities of two Southern African countries, Lesotho and Botswana. By combining the latest mobile application-based digital platforms for data collection and diagnosis with more traditional transport survey approaches, the work advances the World Bank's understanding of the complexity of the paratransit sector in African cities and sheds light on viable approaches to improving the quality of public transport—especially in the context of smaller urban centers.

In the issue's closing article, **Hongye Fan, Yang Chen,** and **Xuanyi Sheng** examine how the need for decarbonizing the transport sector is driving the rapid development of battery and vehicle technologies as an option to serve the urban transport demand in cities around the world. Globally, the number of electric buses in service is predicted to reach 1.2 million by 2025, more than 40 percent of all buses in circulation. However, the high cost of electric buses presents an obstacle to their wide adoption. The team explores solutions, identifying key elements of the financial viability of bus electrification. In addition, they introduce international experience and lessons learned on capital and ownership structure, financial incentives, and subsidies as well as benefit allocation and risk-sharing schemes. The team also makes recommendations to improve the financial viability of e-buses in developing economies and where multilateral development banks can provide support.

On behalf of the editorial team, I extend my sincerest thanks to everyone who contributed their research to this issue and know that your work will have a positive impact as we continue to strengthen the realm of transport and transition mobility systems into a brighter, more sustainable and resilient future.

Which topics would you like us to explore in future issues? Contact the editorial team with your suggestions at WBGTransport@worldbank.org.

Binyam Reja

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Jen JungEun Oh,
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From Building Roads to Providing Market Access: Reaping the Benefits of Connectivity for Rural Vietnam

Vietnam has made a remarkable achievement in near-universal access to all-weather roads that connect almost all of its more than 10,000 commune centers. However, despite the physical connection, pockets of very remote areas remain with limited economic opportunities—other than subsistence farming—leading to vast spatial disparity across the country. Based on the GSO-WB poverty line, the incidence of poverty in 2016 ranged from approximately 1 percent in the Southeast region to 24 percent in

the Central Highlands region and 28 percent in the Northern Mountainous region. Median household incomes are lower and poverty is more concentrated in the remote and low-density population parts of Vietnam, offering limited productive opportunities. Limited access to off-farm opportunities accounts for much of the income differences across regions, mirroring the spatial variation in the economic structure within the country. Average incomes are significantly lower in high mountain communes—especially in the non-farm wages, household businesses, and remittances categories.

In order to understand and quantify the relationship between connectivity and economic outcomes at both the individual household and commune levels, the team introduced and calculated a "market access index," a composite indicator that captures transport costs between consumption and production locations in all potential trading districts. In all communes around Hanoi and Ho Chi Minh City, the two largest cities, market access is significantly greater; nevertheless, access improved for all communes between 2009 and 2017. The analysis shows that market access is very strongly correlated with access to off-farm opportunities in lagging areas, more strongly than ethnicity. Improved market access also mitigates the disadvantage of low population density and is associated with higher wage-participation for wives than their husbands, highlighting the potential for improved market access to reduce gender disparities in wage-job participation. The analysis shows the improvements in transport infrastructure increased market access, which in turn increases wages and attracts more population.

During the past decade, the travel time and transport costs from most localities of Vietnam to major urban areas and international gateways has reduced significantly, thanks to the expansion of the transport network and improvement of road conditions. Over the period from 2009 to 2017, improvements in connectivity have raised national welfare and real incomes for all communes. For instance, welfare benefits result from increases in domestic trade within the country due to reduction in travel time. Connectivity improvements from 2009

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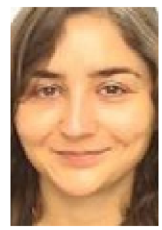

Mathilde Lebrand
is an economist in the World Bank's Transport Global Practice.

to 2017 have slowed the concentration rate of workers in the main two urban poles, benefiting more distant areas in the northwest and along the coastline.

The team also tested the potential impacts of future connectivity improvements on national real income and spatial inequality, under two scenarios: the first focuses on upgrading or rehabilitating national highways mostly in remote areas and near border-crossing points, while the second completes the planned North–South Expressway. The results show the national real income would rise under both scenarios, due to improved access to domestic markets and better integration with global trade opportunities. The income effects would be larger for the North–South Expressway, although such investments could worsen the spatial inequality. Both scenarios estimated inequality would be reduced with no barrier to labor mobility, that is, the unhindered movement of workers to take advantage of better economic opportunities created through connectivity improvement.

In conclusion, the study presents the robust relationship between road building and market access improvement, varying impacts of different types of future infrastructure investments on welfare and equality, and conditions under which physical connectivity can lead to desirable welfare and equality outcomes.

About the Authors

Obert Pimhidzai is a senior economist at the World Bank.

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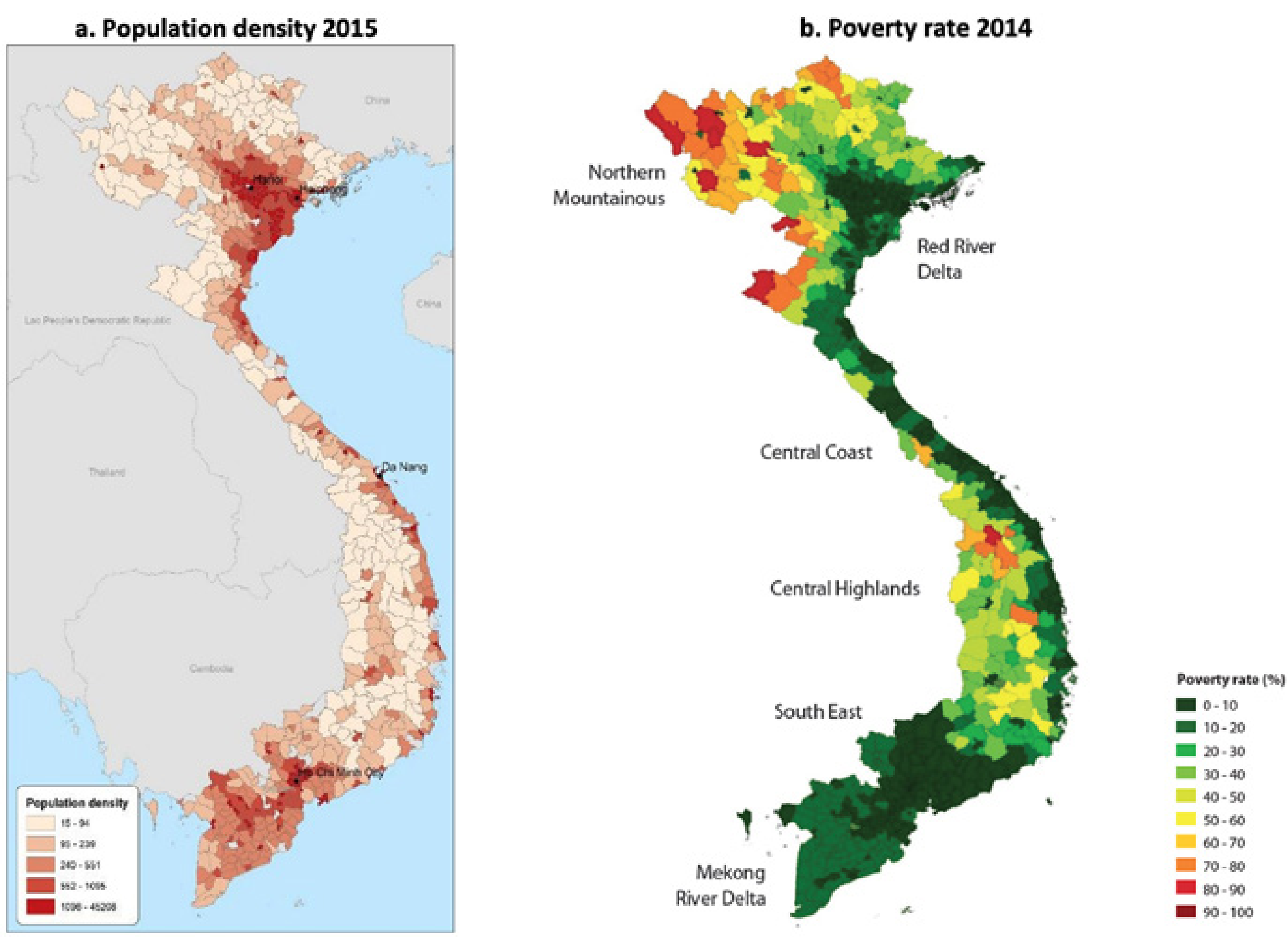
Context: Spatial Disparity of Economic Outcomes in Vietnam

Vietnam has made a remarkable achievement in near-universal access to all-weather roads that connect almost all of its more than 10,000 commune centers. However, despite the physical connection, pockets of very remote areas remain with limited economic opportunities—other than subsistence farming—leading to vast spatial disparity across the country. Based on the General Statistical Office-World Bank (GSO-WB) poverty line, the incidence of poverty in 2016 ranged from approximately 1 percent in the Southeast region to 24 percent in the Central Highlands region and 28 percent in the Northern Mountainous region. Median household incomes are lower and poverty is more concentrated in the remote and low-density population parts of Vietnam offering limited productive opportunities (**figure 1**). Limited access to off-farm opportunities accounts for much of the income differences across regions, mirroring the spatial variation in the economic structure within the country. Average incomes are significantly lower in high mountain communes—especially in the nonfarm wages, household businesses, and remittances categories.

The remote and low-density population parts of Vietnam where productive opportunities are limited show lower median household incomes and more concentrated poverty. The incidence of poverty in coastal and inland delta communes hovers around 4 percent, but is more than 10 times higher in high mountain communes, where 44 percent of people are considered poor. The high mountain communes lie further from economic hubs—with an average distance of 300 kilometers from the nearest major urban center—three times the average distance of inland-delta communes from major urban centers. High mountain communes also have a significantly lower population density, at 34 people per square kilometer compared to 257 people per square kilometer in inland and delta communes. Thus, poverty is much higher in areas with the lowest economic density, presence of firms, and access to nonfarm wage jobs (**table 1**).

Figure 1. Population Concentration and Poverty in Mainland Vietnam



Source: World Bank estimates based on the 2014 Population Inter-Census and the 2014 Vietnam Household Living Standards Survey (VHLSS), both conducted by the General Statistics Office (GSO).

Table 1. Commune Attributes by Topography

Commune attributes	Coastal	Inland delta	Hills	Low mountains	High mountains
Poverty headcount rate (%)	3.9%	4.2%	4.2%	12.9%	44.4%
Share employed in non-agriculture wage jobs	30.7%	41.9%	41.0%	31.8%	18.4%
Share with post-secondary education	17.5%	22.8%	24.4%	23.4%	16.4%
Average distance to major cities (km)	196	108	127	196	301
Has a firm within the commune	89.3%	91.7%	93.3%	83.0%	57.0%
Population density (individual/km²)	214.4	257.1	151.2	84.9	33.8
Share of ethnic minorities	3.2%	1.7%	0.7%	25.2%	68.7%

Source: World Bank calculations from the 2016 VHLSS, conducted by the GSO. See: https://www.gso.gov.vn/en/data-and-statistics/2019/03/result-of-the-vietnam-household-living-standards-survey-2016 (in Vietnamese)

How Connectivity Affects the Location of People and Economic Activities in Vietnam

The uneven distribution of densities is an outcome of geography and economic agglomeration. Greater density areas coincide with greater economic outcomes, such as gross domestic product (GDP), employment, wages, incomes, and overall welfare. Multiple factors explain the concentration of economic activities in some locations, including the geography of the country, the gains from agglomeration, and the access to international gateways. While workers benefit from concentration through better access to jobs and amenities, and firms benefit from access to production services, consumers, and workers, such concentration also brings pollution, congestion, and higher land prices, which can in turn discourage or constrain further concentration. The relative strengths of the agglomeration and dispersion forces underlying these concentrations of economic activity are central to spatial disparity and other related economic issues.

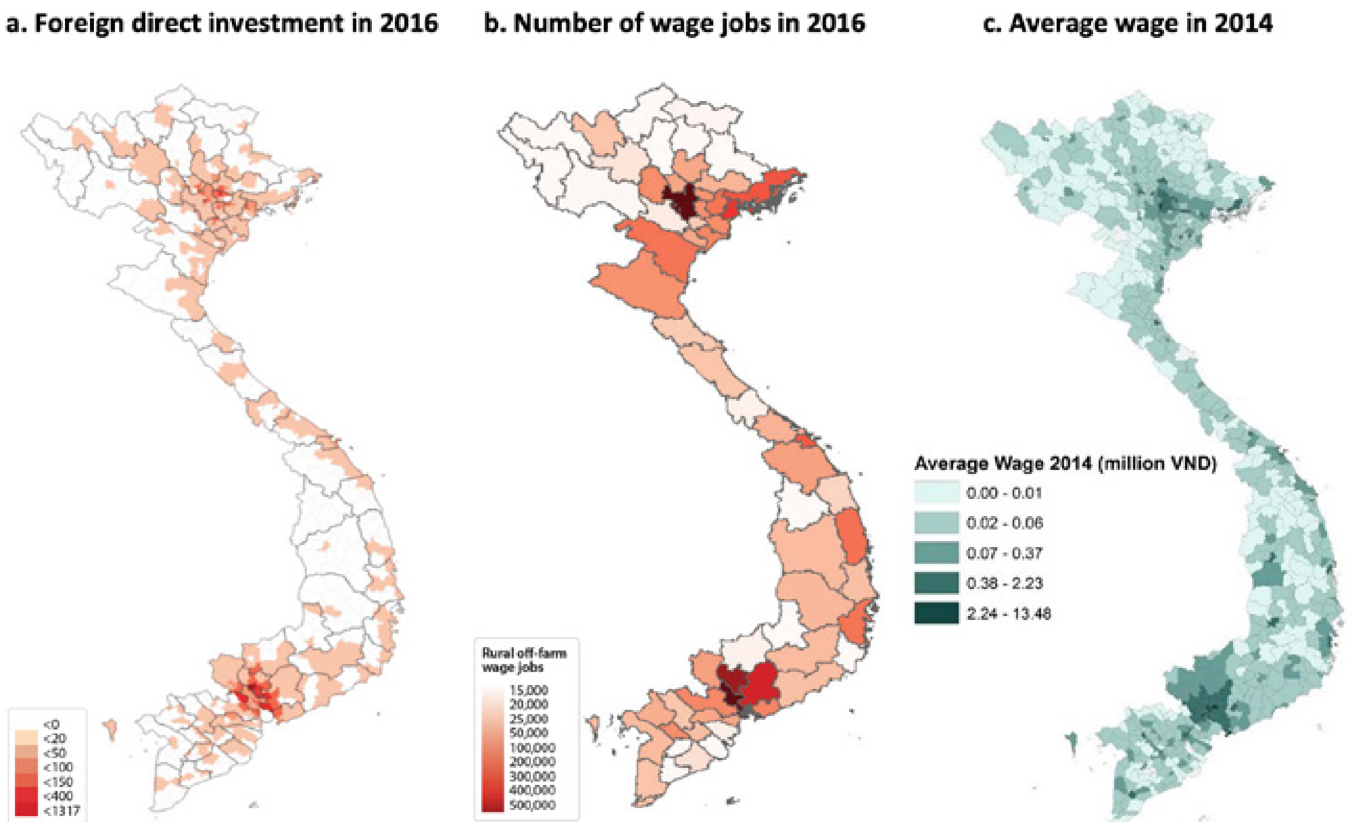
Density and connectivity are closely correlated with firm locations, investments, jobs, and poverty. Data from the 2016 economic census show fewer firms in remote areas. Two-thirds of communes without an enterprise in 2016 are located in mountainous areas. The smaller market means fewer opportunities for easy-to-start household enterprises, most of which concentrate in the retail and trade services sectors. Similarly, foreign direct investment (FDI) in Vietnam is largely concentrated in high density population areas (**figure 2**, **panel a**). As a result, far fewer wage jobs are available in remote areas (**figure 2**, **panel b**). However, some less populated provinces with better market access due to good connectivity or proximity to international gateways (for example, China in the north) have become incipient recipients of FDI.

Remoteness and low density contribute to the lack of economic opportunities in Vietnam's lagging areas. Structurally, the lagging areas of Vietnam—further away from economic hubs, yet much more sparsely populated—have low market access. By reducing local potential for job creation and/or reducing household incentives to participate in off-farm activities, the low market access can in turn be a limiting factor to households' access to better jobs. In addition to the impact of access to wage jobs, market access could also explain the variation in real wages across regions (**figure 2**, **panel c**). Lagging provinces, with lower market access, have significantly lower average wages. Average wages are highest in densely populated areas around the Hanoi–Haiphong and Ho Chi Minh City (HCMC) economic corridors. Wages are substantially lower in less populated areas further off these economic corridors or international gateways, thus providing a positive correlation between market access and wages. Firms in locations with greater market access face lower transportation costs, which increases their profitability and ability to pay higher wages while remaining competitive. Invoking this argument, Hering and Poncet (2010) finds market access explains a significant part of the interindividual difference in wages in China—after controlling for skills, living costs, firm types, and provincial fixed effects accounting for other place-specific, non-human endowments present in agglomeration centers with higher market access.

Connectivity is key to both maximizing the benefits of agglomeration and overcoming the challenges of remoteness and low density by reducing economic distances between firms, people, and markets. Transport connectivity is central to understanding how people and firms locate across space and defines how regions can access other domestic and global markets. Better connectivity will reduce frictions hampering growth and improves access for lagging regions to the rest of the country and global markets. Given the above spatial distribution of people and economic activities in Vietnam, the transport network quality will matter in connecting the main growth poles, in connecting the secondary cities to these main growth poles, in connecting lagging regions to growing regions, and in connecting these regions to the main international gateways. Thus, development strategies for low-density economies depend on improved connectivity to link them into the network economy, thus enlarging the external market crucial for generating growth in low-density economies.

With better connectivity and market access, lagging areas could tap into regional and global value chains by attracting maturing industries seeking cost advantages beyond large urban centers. As agglomeration centers evolve into high-value products, some mature industries lose their competitiveness in large urban areas. They then seek to relocate to the periphery, with cheaper labor, rents, and other services. This provides an opportunity for growth in lagging areas, but one that would most likely benefit areas with better connectivity and market access. The shift of garment value chains and other low value-added manufacturing activities have also been biased toward outer provinces with much better access.

Figure 2. Spatial Distribution of Economic Activities in Mainland Vietnam



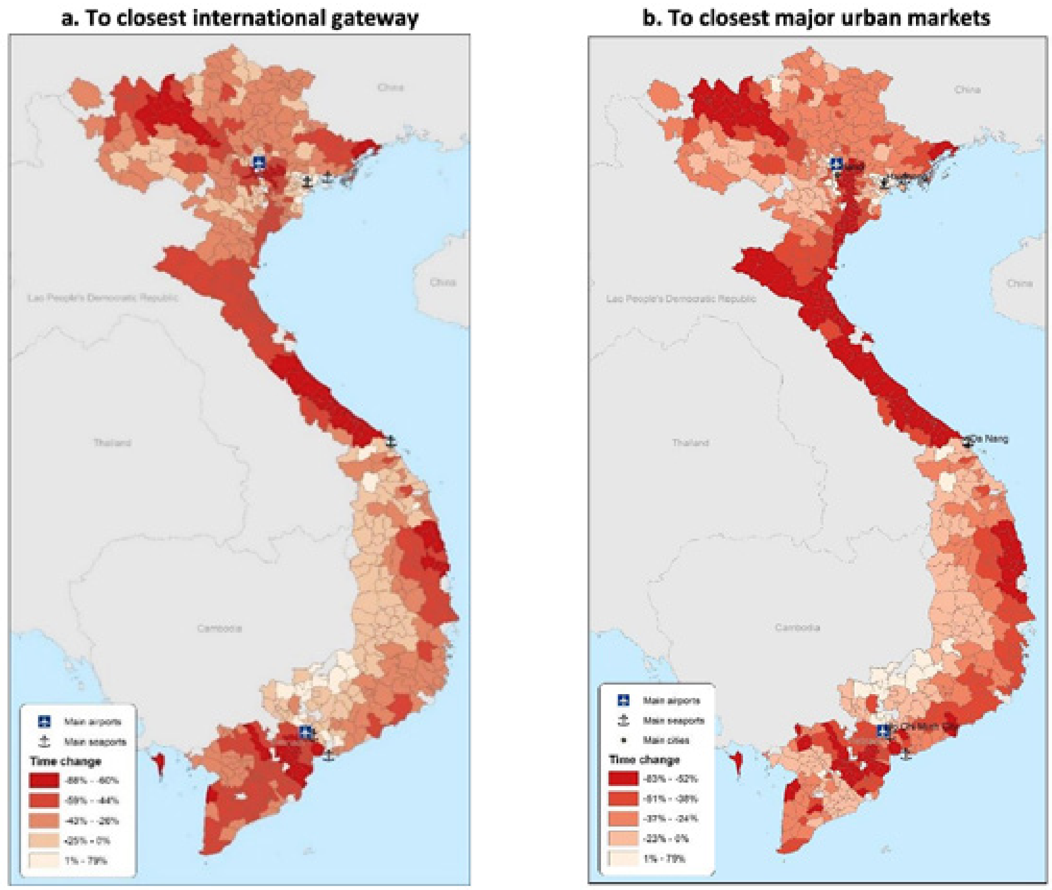
Source: World Bank estimation based on the 2017 Economic Census conducted by the GSO.
See: https://www.gso.gov.vn/en/data-and-statistics/2019/03/results-of-the-2017-economic-census (in Vietnamese).

Changes in Connectivity and Spatial Development in Vietnam

During the past decade, travel time and transport costs from most localities of Vietnam to major urban areas and international gateways have both seen reductions, thanks to expansion of the transport network and improvement of road conditions. Using the transport network of the two time points (2009 and 2017), travel time was calculated from each district to its closest major city and international gateway.[1] As shown in **figure 3**, travel times have improved significantly for districts in the center, north of Da Nang, on the Hanoi–Lao Cai corridor toward China, and south of HCMC. On average, travel time to the closest gateway has decreased by 38 percent between 2009 and 2017 (**figure 3, panel a**), and travel time to the closest main city has decreased by 33 percent (**figure 3, panel b**).

1 For the purpose of the analysis, the main cities include the five most populous cities: Hanoi, HCMC, Haiphong, Cai Tho, and Da Nang. The main international gateways include the main sea ports (HCMC seaport complex, Haiphong seaport, Vung Tau seaport, Tien Sa seaport), the two main airports (Noi Bai airport in Hanoi and Tan Son Nhat airport in HCMC), and the land border at Huu Nghi in Lang Son province, toward China.

Figure 3. Changes in Travel Time to Major Markets in Mainland Vietnam from 2009 to 2017

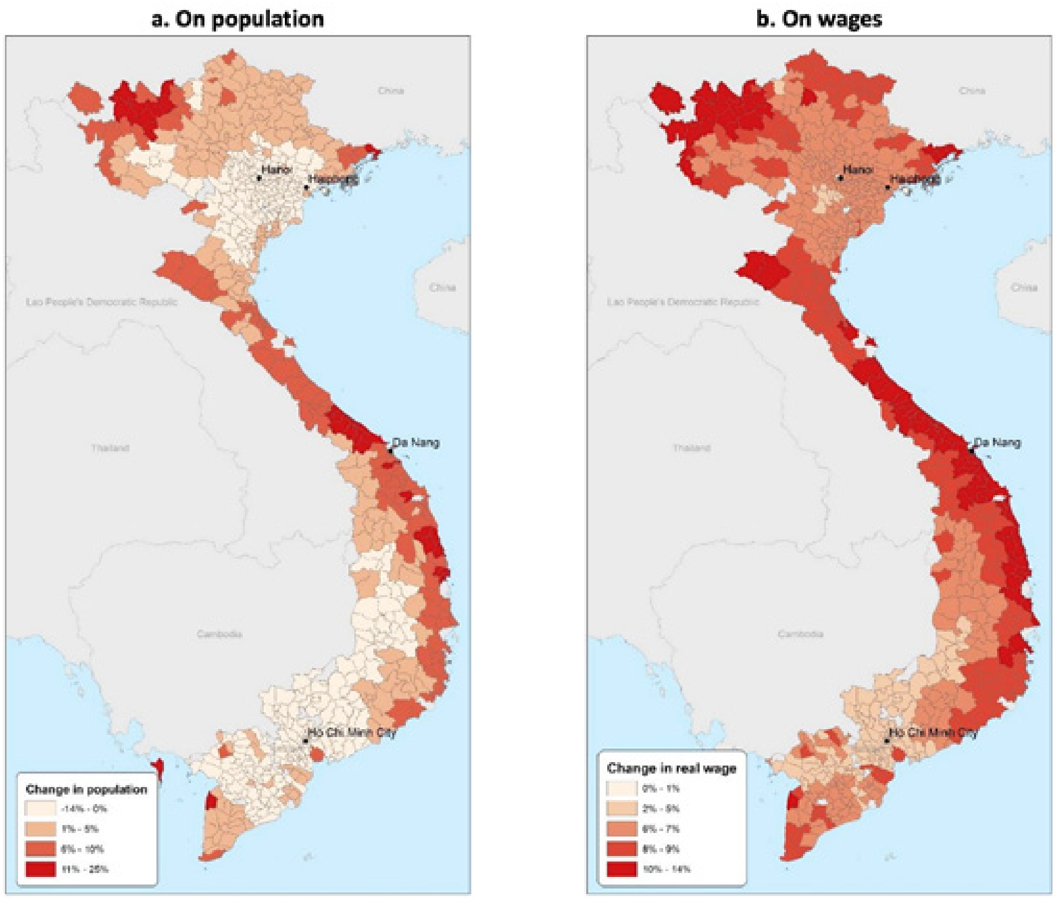


Source: World Bank calculations using the transport network and population data provided by various government of Vietnam sources.

The economic impacts of connectivity improvement can be measured by comparing the actual incomes with a counterfactual, the simulated incomes with no transport improvement over the analysis period. During the period between 2009 and 2017, improvements in connectivity alone have raised real incomes for all communes by 6.7 percent on average.[2] In other words, without the improvements in connectivity, keeping all other factors constant the real income of the country would have been 6.7 percent lower. While incomes in all localities have improved due to better connectivity, such outcomes were unevenly distributed across districts, with an income growth of only 1.1 percent in the district that benefited least from transport investment (Co To district, Quang Ninh province) and a growth of 14.5 percent in the district that benefited most from it (An Minh district, Kien Giang province). Lower transport costs to reach districts in the rest of the country reduces consumption prices and attract more workers in locations with better market access. **Figure 4** shows the simulated effects of the network changes between 2009 and 2017 on population (**figure 4**, **panel a**) and wages (**figure 4**, **panel b**).

2 "Incomes" and "wages" are used interchangeably in this section; even though wage is only a part of total income, given the lack of data, the analysis here focuses on wages.

Figure 4. Simulated Effects of Connectivity Improvement between 2009 and 2017



Source: World Bank calculations using the transport network and population data provided by various government of Vietnam sources.

Quantifying the Link between Market Access and Economic Outcomes

In order to understand and quantify the relationship between connectivity and economic outcomes at both the individual household and commune levels, we introduced and calculated a "market access index" (MAI), a composite indicator that captures transport costs between consumption and production locations in all potential trading districts. As an expansion of the transport network affects all locations and their access to markets, market access of a given commune depends on the quality of the transport network and the size of markets connecting to a commune. Following Donaldson and Hornbeck (2016), market access can be approximated by the following expression:

$$MA_o \equiv \sum_d \tau_{od}{}^{-\theta} N_d$$

With MA_o the market access index at the commune "*o*," τ_{od} the trade cost between two communes, "*o*" and "*d*," N_d is the population of commune "*d*," and θ is the "trade elasticity."[3] Trade costs between the two districts, τ_{od}, are defined by $\tau_{od} = exp\ (\lambda\ time_{od})$, with λ = 0.02 and $time_{od}$ the optimal travel time between the population center of the two communes using the transport networks of 2009 and 2017.[4]

Our analysis of transport network and population data of Vietnam in 2009 and 2017 suggests that market access has improved for all communes during this period, as depicted in **figure 5**, **panel a** and **figure 5**, **panel b**. In 2009, market access index for communes in or very close to Hanoi and HCMC sat just above 2.0 and increased to more than 2.5 in 2017. The communes in and around the cities and their respective ports have the best access to domestic markets. Over the period, the average market access index grew from 1.31 to 2.20, an increase of 88 percent over nearly 10 years. Comparison between the two time points highlights the positive impacts of the agglomeration and development of major transport infrastructure, such as several expressways.[5] Compared to 2009, current access to markets remains higher around the main two cities but has also improved in their larger peripheries. Accessibility has also improved greatly for communes along the coastline as well as along the major transport corridors where investments have been made.

Access to markets depends both on transport costs and the size of the markets that can be reached, and thus, the improvement of market access can be attributed to growing population in neighborhood communes as well as to improvements in the transport network. The analysis shows that the changes in market access in Vietnam over the past decade resulted mostly from the changes in transport costs, rather than from population changes. Disaggregating the change in market access between 2009 and 2017 shows an average 79 percent change in market access due to changes in transport costs, with an average 5 percent change in market access due to population shifts, as illustrated in **figure 5**, panel c and **figure 5**, **panel d**.

Access to markets depends both on transport costs and the size of the markets that can be reached.

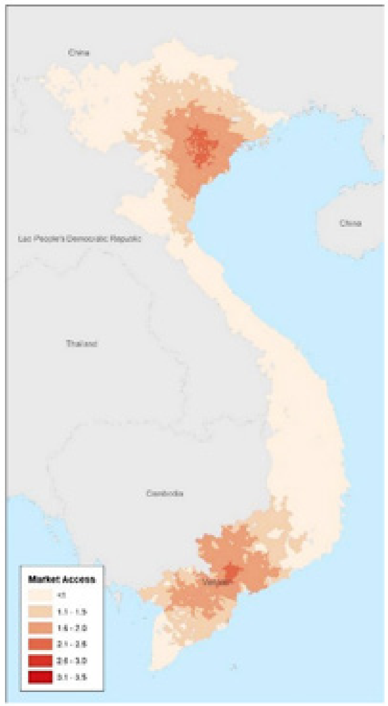
3 N_d is given by population estimates for each commune for 2010 and 2015 using the raster file GPWv4 from United Nations population estimates. The trade elasticity equals 8, following Eaton and Kortum (2002).

4 The optimal time is computed using the ArcGIS network analysis tool. It uses the full transport network and finds the fastest path between two population centers.

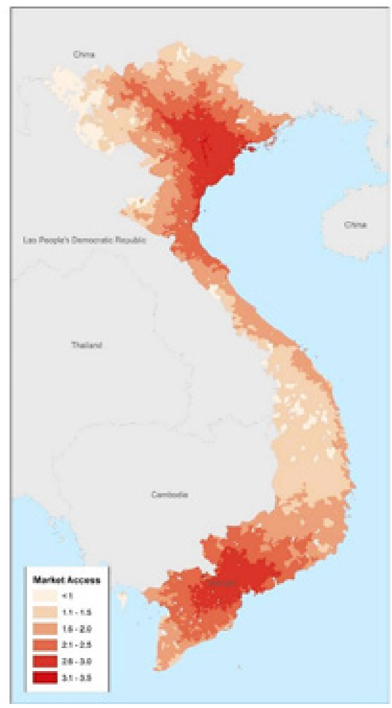
5 The expressway between Cau Gie (south of Hanoi) and Ninh Binh was completed in 2012, the one between Noi Bai (north of Hanoi) and Lao Cai in 2014, and the one connecting HCMC, Long Thanh, and Dau Giay in 2015.

Figure 5. Market Access Index for Communes in Mainland Vietnam

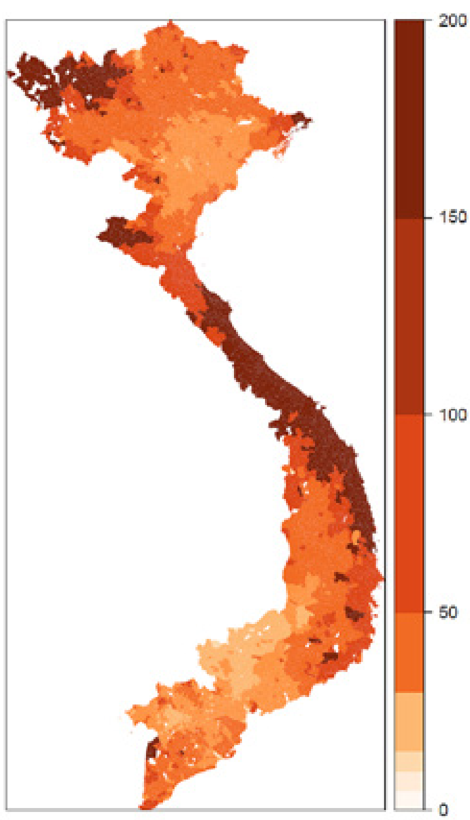
a. In 2009



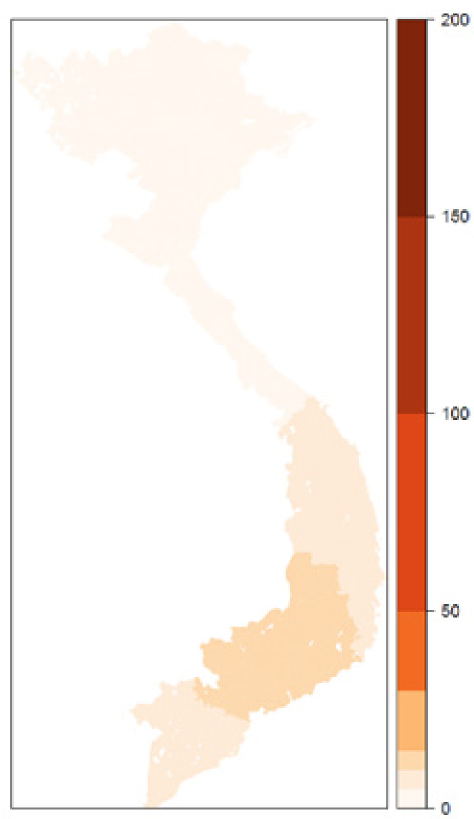
a. In 2017



c. Changes in market access due to transport cost



d. Changes in market access due to population

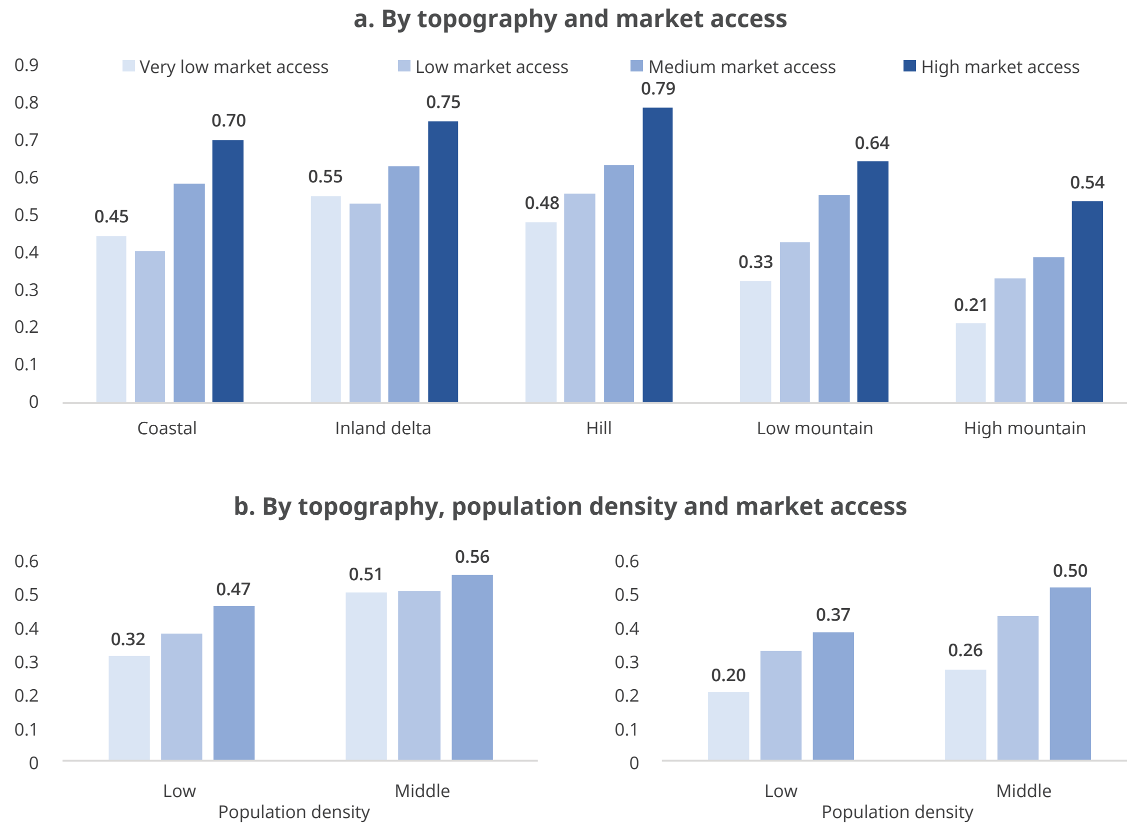


Source: World Bank calculations using the transport network and population data provided by various government of Vietnam sources.

Descriptive evidence suggests a strong correlation between market access and access to off-farm opportunities in Vietnam. As expected, market access is highest in the HCMC and Hanoi–Haiphong corridors, where the highest concentration in access to off-farm jobs is observed. In the northern mountain provinces, access to off-farm jobs is significantly better in Lao Cai, Yen Ban, and Phu To provinces (**figure 6**, **panel a**). Located along the Hanoi–Lao Cai Expressway, these provinces have far better market access indicators compared to surrounding provinces. Contrast this to provinces such as Dien Bien, which are poorly connected and have the lowest number of off-farm wage jobs, at fewer than 15,000 per province. However, descriptive evidence alone is not conclusive due to the presence of confounding factors. Areas with low market access tend to coincide with those populated by an ethnic minority or with lower education attainment, which have been found as important factors (Hoang, Pham, and Ulubaşoğlu 2014; Newman and Kinghan 2015). Road infrastructure investments are also endogenous to economic potential across areas, in that more roads are built in areas with high potential for job creation.

Further breaking down the communes by population density, **figure 6**, **panel b** shows the estimated probability of holding an off-farm wage job at different levels of market access across communes, for young men between 20 and 30 years old, with lower secondary education from the Kinh ethnic group in a rice farming household. In a high mountain commune, that person's prospects of being employed in an off-farm wage job increases from 21 percent among those with the lowest level of market access to 54 percent among those with the highest market access. A 31 percentage-point increase (close to double) is observed in low mountain areas as well. A 20 to 33 percentage-point increase is observed across all types of communes as market access expands from the lowest to highest market access classification category. This pattern suggests that improvements in market access make a larger difference to job access in the remotest and least populated communes than anywhere else.

Figure 6. Probability of Off-Farm Job Participation by Topography and Market Access



Source: World Bank calculations based on data provided by various government of Vietnam sources.

Note: Predicted for a Kinh male aged between 20 and 40 years with lower secondary, from a farming household, and living in a commune with a firm present. Regression controls for the local population density separately from market access calculated using only population and time travel to other communes. The classification of communes into low and medium population density is based on terciles of the national population density. Market access is categorized into four groups based on their standard deviation from the national average: **Very low** – 2 to 1 std. dev. below mean; **Low** – 1 to 0 std. dev. below mean; **Medium** – 0 to 1 std. dev. above mean; and **High** – 1 to 2 std. dev. above mean.

We conducted an econometric analysis to isolate and quantify the contributions of market access to household participation in nonagriculture employment activities. The result suggests that market access explains a considerable amount, but not all, of the variation in access to off-farm opportunities in lagging areas. Statistical decompositions suggest that differences in observable characteristics such as market access, education, farming system, and demographic profile, together account for around 94 percent of the differences in access to wage jobs between inland and delta communes and other communes. About 31 percent of this explained difference—or 29 percent of the overall difference—is due to poorer market access outside inland and delta communes (**table 2**).

6 This uses the Oaxaca-Blinder decomposition (Blinder 1973; Oaxaca 1973), a popular method applied to study differences in an outcome variable among groups, often labor-market outcomes. The method divides the mean outcome differential between two groups into a part "explained" by group differences in endowment characteristics—such as education or work experience—and a residual part that cannot be accounted for by such differences in outcome determinants. The "unexplained" part is often used as a measure for discrimination as well as of the effects of group differential in unobserved variables.

However, gaps in observable characteristics only account for 63 percent of the differences in wage job prospects between ethnic minorities and the majority, of which market access accounts for 34 percent of this explained difference—or 22 percent of the overall gap. A key difference is that minorities seem not to benefit as much from their supposed demographic advantage of having more young people, who generally have the brightest job prospects in Vietnam. This demographic advantage is lower when only comparing locations, meaning that while investment to improve market access can help close the gap in access to off-farm wage jobs between lagging regions and other places, complementary policies are needed to improve access to jobs for ethnic minorities within regions, allowing them to benefit despite their demographic advantage.

Table 2. Decomposition of Access to Off-Farm Wage Jobs

	Ethnic minorities vs. Kinh and Hoa		Inland and delta vs. other communes	
Difference	0.185		–0.143	
Explained gap	0.117	100%	–0.135	100%
Demographic composition	–0.035	–30%	0.018	–13.0%
Education attainment	0.010	8.0%	–0.007	5.0%
Farm characteristics				
Farm activity type	0.008	7.0%	–0.013	10.0%
Agricultural prices	–0.002	–2.0%	0.002	–1.0%
Agriculture wages relative to non-agriculture wages	0.004	4.0%	-0.003	2.0%
Local economic potential				
Market access	**0.040**	**34.0%**	**–0.042**	**31.0%**
Population density	**0.067**	**57.0%**	**–0.064**	**48.0%**
Road in commune	**0.000**	**0.0%**	**0.002**	**–2.0%**
Residual location differences	0.018	15.0%		

Source: World Bank calculations from the 2016 VHLSS, conducted by the GSO. See: https://www.gso.gov.vn/en/data-and-statistics/2019/03/result-of-the-vietnam-household-living-standards-survey-2016 (in Vietnamese).

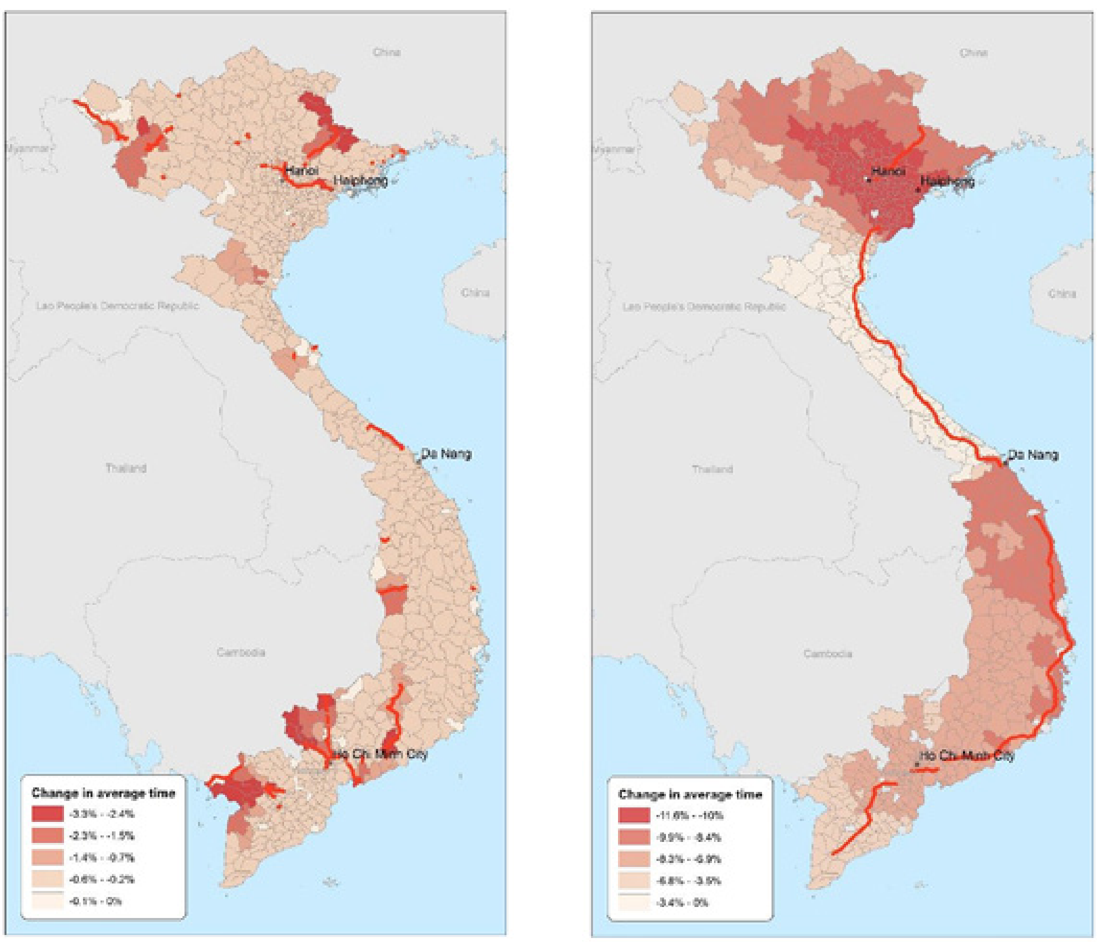
Estimating Welfare Impacts of Connectivity Investment Scenarios

During the past decade, the travel time and transport costs from most localities of Vietnam to major urban areas and international gateways has reduced significantly, thanks to the expansion of the transport network and improvement of road conditions. Over the period from 2009 to 2017, improvements in connectivity raised national welfare and real incomes for all communes. For instance, welfare benefits result from increases in domestic trade within the country due to reduction in travel time. Connectivity improvements from 2009 to 2017 slowed down the concentration rate of workers in the main two urban poles, benefiting more distant areas in the north-west and along the coastline.

We also tested the potential impacts of future connectivity improvements on national real income and spatial inequality, under two scenarios: the first focused on upgrading or rehabilitating national highways mostly in remote areas and near border-crossing points, while the second completed the planned North–South Expressway. We used a quantitative spatial general-equilibrium model[7] to simulate the impacts of two high-priority programs in the government's investment strategy for the transport sector. Analysis results showed both future investment scenarios would bring about notable improvements in average travel time between districts, as depicted in **figure 7**, **panels a** and **b**.

Figure 7. Simulated Travel-Time Changes of Future Transport Investment Scenarios

a. Scenario 1: National highway to boarder gates | **b. Scenario 2: North-south expressways**



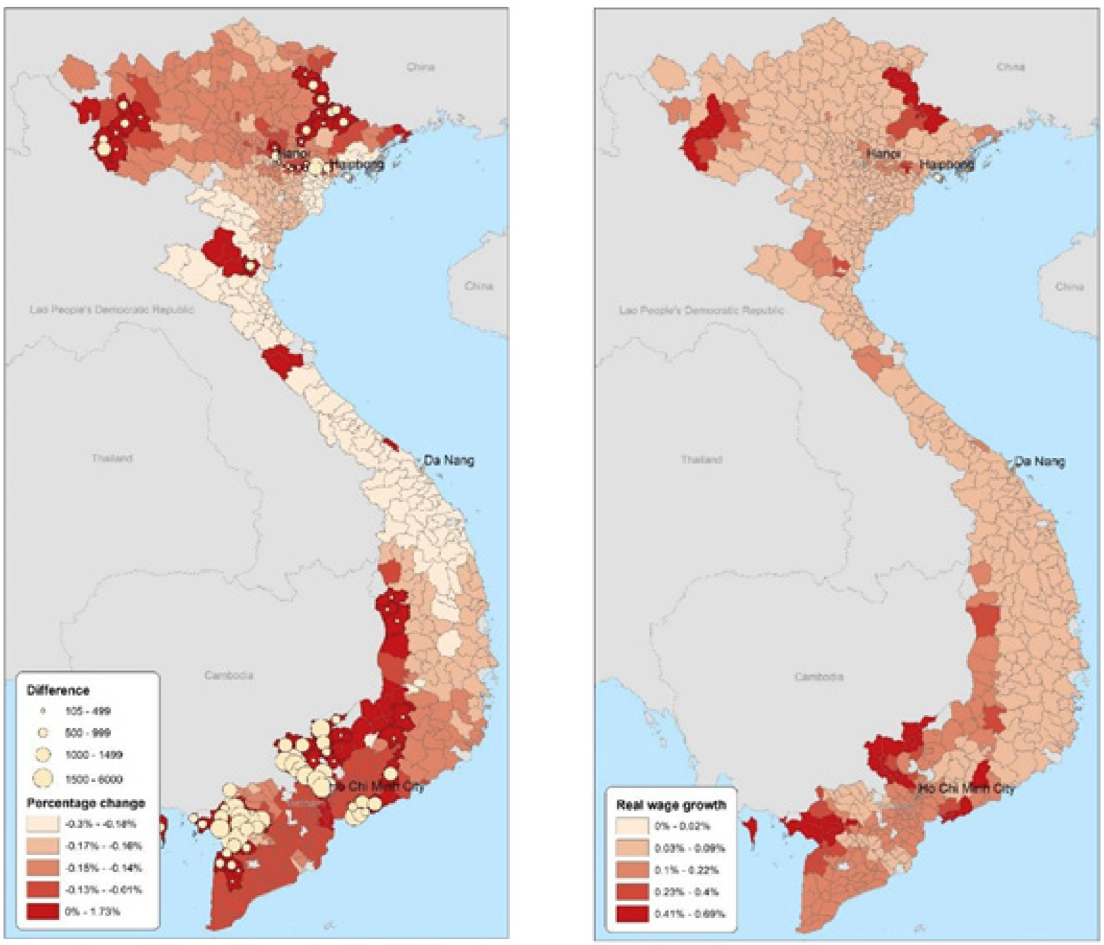
Source: Source: World Bank calculations based on data provided by government of Vietnam sources.
Note: The red lines indicate rehabilitated segments of the transport network.

7 The model is based on Redding (2016) and has been used in other counterfactual simulations, including Lebrand (2021).

The benefits of transport improvements under scenario 1, shown in **figure 8**, would be largest in the northern and southern districts (**figure 10**). In general, this scenario would tend to benefit the richer, more populated, but less centrally located areas throughout Vietnam. Richer regions will become more competitive and attract more workers. Keeping the same country population, a few districts around Hanoi, HCMC, and in some peripheral areas become more attractive for workers as well as those along the borders, which would benefit from the largest reductions in transport costs.

Figure 8. Effects of Future Transport Investment—Scenario 1

a. On population | **b. On real wages**

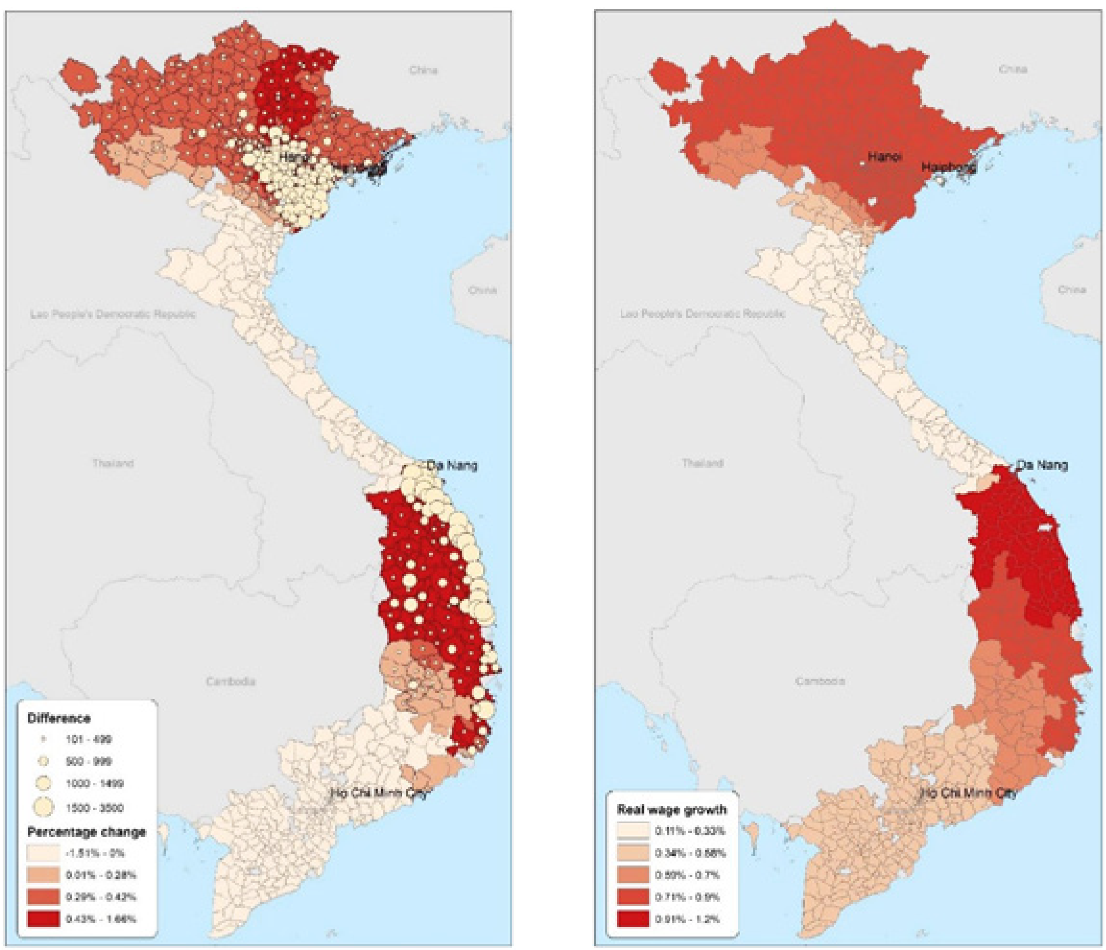


Source: World Bank calculations based on data provided by government of Vietnam sources.

Transport improvements from scenario 2, shown in **figure 9**, would benefit mostly the northern part of the country, including Hanoi and northern provinces, the coastal areas between Da Nang and HCMC, as well as some districts in the central highlands. In general, the investments under scenario 2 would benefit poorer, less populated, and more centrally located areas in Vietnam. Population and real income would grow in the districts with the largest reductions in transport costs. Northern districts and the central districts south of Da Nang would experience the largest increase in real wages. Keeping the same country population, the zone between Hanoi and the coast as well as the central coastal districts would become more attractive for workers. In contrast to scenario 1, transport investments in scenario 2 would not benefit the southern districts.

Figure 9. Effects of Future Transport Investment—Scenario 2

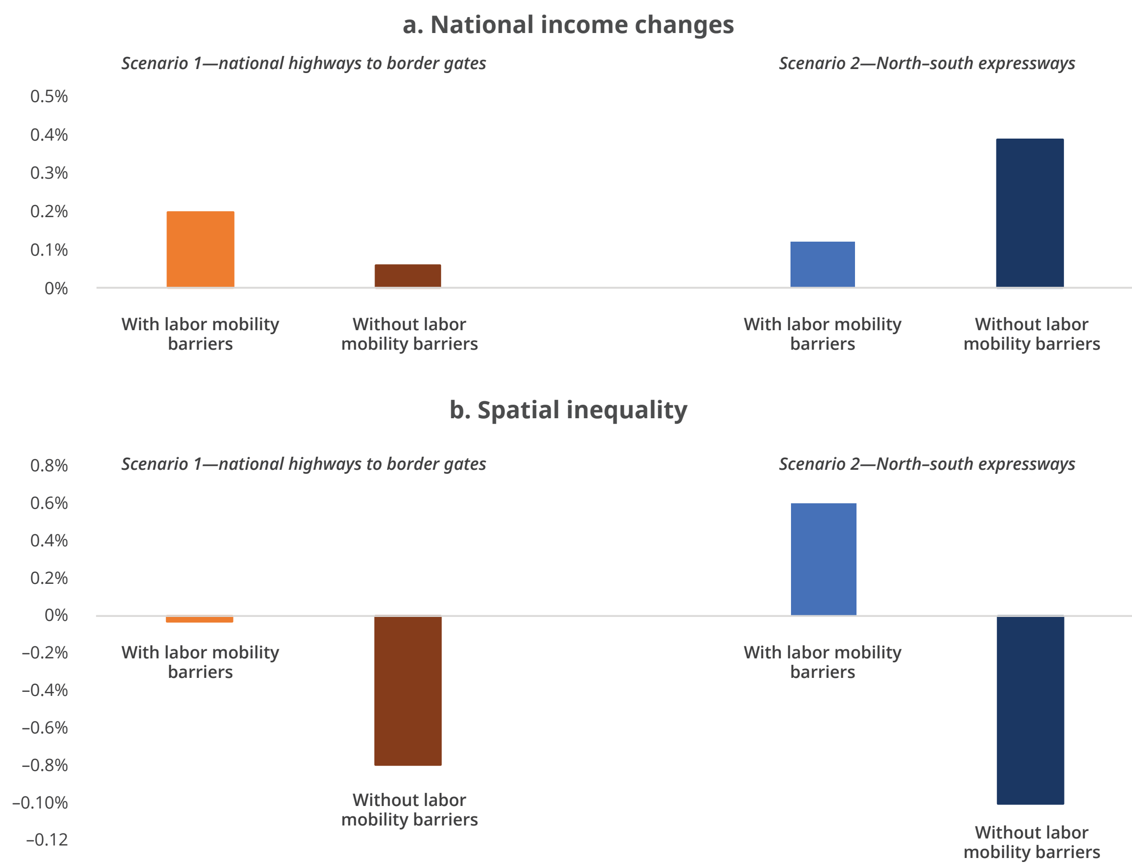
a. On population | **b. On real wages**



Source: World Bank calculations based on data provided by government of Vietnam sources.

While the national real income would rise under both scenarios due to improved access to domestic markets and better integration with global trade opportunities, the real income effects and spatial inequality would be greatly impacted by labor mobility. Assuming no restrictions to labor mobility, the income effects of scenario 1 would be lower than that of scenario 2, as shown in **figure 10**, **panel a**, barriers to the labor mobility would significantly reduce the income effects of scenario 2 (north–south expressways). Transport investments under scenario 1 would not change or marginally improve spatial inequality if labor mobility is restricted but would significantly reduce inequality if labor can move freely for better economic opportunities created by the connectivity improvement. On the other hand, as in **figure 10**, **panel b**, transport investments under scenario 2 would worsen the spatial inequality if the labor cannot relocate freely, but would bring about greater inequality reduction without any restrictions on labor mobility than in the case of scenario 1. This suggests that allowing unrestricted movement of labor is essential to maximize the benefits of transport connectivity on spatial equality.

Figure 10. National Income and Spatial Inequality Effects under Different Labor Mobility Assumptions



Source: World Bank calculations based on data provided by government of Vietnam sources.

Conclusion

Over the past decade, the travel time and transport costs from most localities of Vietnam to major urban areas and international gateways has reduced significantly, thanks to the expansion of the transport network and improvement of road conditions. Over the period from 2009 to 2017, improvements in connectivity raised national welfare and real incomes for all communes.

Quantified in terms of the MAI, empirical analysis provides strong evidence that connectivity plays a significant role in improving job opportunities for the poorer and more remote localities in Vietnam, including through helping them overcome the disadvantages associated with low population density. To maximize the benefits of connectivity improvement, however, complementary policies on education, farming system, and health are needed to improve access to jobs for ethnic minorities within regions.

We also tested the potential impacts of future connectivity improvements on national real income and spatial inequality, under two scenarios: the first focuses on upgrading or rehabilitating national highways mostly in remote areas and near border-crossing points, while the second completes the planned North–South Expressway. The results show that the national real income would rise under both scenarios, due to improved access to domestic markets and better integration with global trade opportunities. The income effects would be larger for the North–South Expressway, although such investments could worsen the spatial inequality. Both scenarios estimated inequality would be reduced with no barrier to labor mobility, that is, the unhindered movement of workers to take advantage of better economic opportunities created through connectivity improvement.

In conclusion, we present the robust relationship between road building and market access improvement, varying impacts of different types of future infrastructure investments on welfare and equality, and conditions under which physical connectivity can lead to desirable welfare and equality outcomes.

References

Additional Resources

Authors:
Vivien Foster and Mathilde Lebrand, **The World Bank**

The Wider Economic Benefits of Transport Investments in Africa

The untold story of the wider economic benefits of transport investments in Africa.

Beyond the classical focus on time savings as the immediate metric for the economic benefit of large transport projects lies a plethora of much wider and seldom fully accounted for economic benefits. These include supporting structural transformation of the economy, increasing the number and quality of jobs, and promoting domestic, regional, and global trade. Drawing on new sources of data and modern econometric techniques, this article presents a significant body of recent economic research covering a wide range of countries in Africa to compile a new and compelling evidence base for how transport projects contribute to economic development.

Introduction

The traditional approach to valuing the benefits of transport investments overlooks their wider economic impacts. Traditional cost-benefit analysis of road projects focuses on estimating the value of time savings that result from upgrading infrastructure to improve the volume and speed of transit. While these benefits are important and have often been enough in and of themselves to justify significant road investments, they overlook the fundamental ways in which transport improvements reshape patterns of economic activity, or in a sense the value of what is moving along any road corridor. In that sense, the traditional approach underestimates the true economic impact of roads.

New spatial data can bring new light on the welfare gains of transport investments for households and firms. The increasing availability of spatial data for infrastructure networks, and household and firm surveys has greatly improved the way we investigate whether infrastructure investments have an impact on prices, jobs, consumption, or productivity.

New modeling tools can help us quantify these wider economic gains of transport investments. The rise of economic geography as a way of thinking about the structure of economies, has led to the rapid diffusion of spatial quantitative general equilibrium models. These are useful tools to model how economic activity is spatially distributed, and hence the impacts of better mobility on workers and firms, and the aggregate consequences for prices, wages, and productivity as well as the migration of workers and firms towards better economic opportunities. Such models have been applied to different geographic contexts to measure the wider economic welfare gains for different transport investment scenarios.

These tools capture how transport investments improve access to jobs and markets. Better transport infrastructures aim at lowering the cost and time of moving goods and people across locations. Workers have a better access to jobs, and employers to potential employees. Workers are therefore more likely to find a job, in particular a job that better fits their qualification

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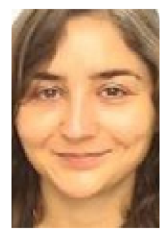


Mathilde Lebrand is an economist in the World Bank's Transport Global Practice.

and preferences. Firms can source cheaper and more diverse intermediate goods and services for their production and be more competitive to sell more to consumers and other firms.

Improved access to jobs and markets has wider impacts on the economy in terms of productivity, prices, wages, and the quality of jobs. Improved mobility for workers and firms can have wider impacts on the economy. Firms improve their productivity thanks to cheaper inputs, and can therefore choose to produce more, reduce their prices, and even increase wages. Workers with more opportunities to find a job and a better job tend to consume more. Ensuing changes in prices, wages, and economic opportunities will then affect how workers choose where and in which sector to work, and how firms choose where and what to produce. All these additional changes can have wider impacts on the economy as a whole.

> While transport helps to improve access to economic opportunities, other types of infrastructure also have important complementary impacts.

Complementary investments in other infrastructures can boost the impacts of transport investments. While transport helps to improve access to economic opportunities, other types of infrastructure also have important complementary impacts. Electrification can boost productivity by permitting the adoption of labor-saving machines. At the same time, access to broadband infrastructure can also contribute to productivity through improved availability of information as well as further facilitating the matching of buyers and sellers in the market. When wider improvements in infrastructure availability are coordinated with transport investments, their economic benefits could be further amplified. In fact, the impacts of bundled investments could turn out to be larger than the sum of the isolated investments.

A new body of emerging research applies these novel techniques to examine the links between roads, complementary infrastructures, and development extensively across many African countries. This article will review the main findings of this new research in a nontechnical format accessible to practitioners, making the emerging evidence readily available to a wider audience. The research has been sponsored by the Chief Economist's Office of the Infrastructure Vice Presidency of the World Bank, in partnership with the Transport Global Practice as well as Infrastructure (INF) and Equitable Growth, Finance and Institutions (EFI) teams in the Africa East and West Regions and the Office of the Director for Regional Integration in Africa.

Infrastructure, Structural Transformation, and Jobs

Development happens through structural transformation that creates increasing numbers of better jobs, as discussed in the *World Development Report 2013: Jobs* (World Bank 2012). At the individual level, people join the labor force and find a job, get better at what they do, and move to better, more productive work. The move to a better situation typically involves moving across economic sectors (from agriculture to manufacturing or service sectors) and employment type (from self-employment to a waged job). These transformations in the work people do show up both across countries at different levels of per capita income and within countries over time. These patterns are strongly in evidence looking across countries at different stages of development. As nations get richer, the share of those employed in agriculture drops steeply (**figure 1**), while the share of those employed in waged jobs rises steeply (**figure 2**). Intuitively, this is because people are more productive and earn higher wages in the manufacturing and services sector than would be possible in low-productivity subsistence agriculture.

Figure 1. Share of Employment in Agriculture Decreases as Countries Grow Richer

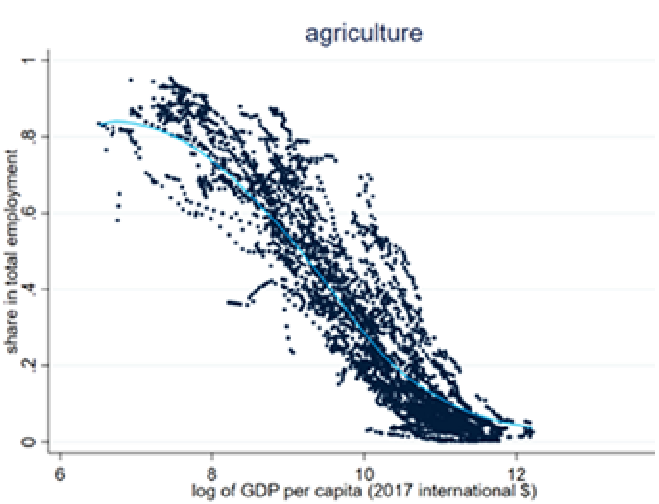
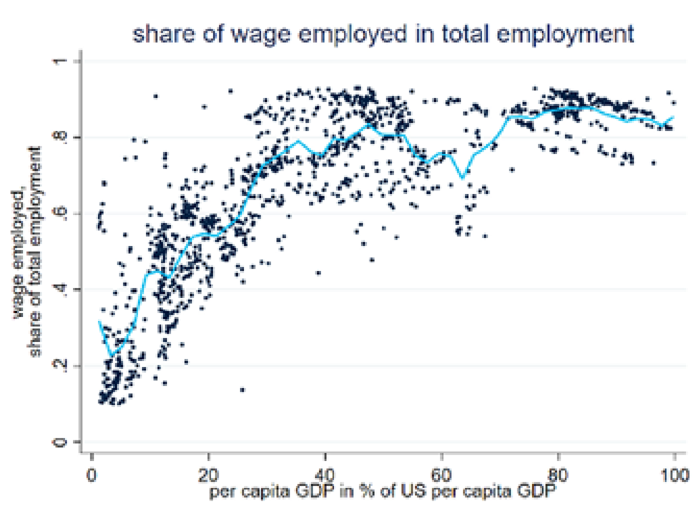


Figure 2. Share of Wage Employed Increases as Countries Grow Richer



Source: Weber and Langbein 2021.

Infrastructure and Structural Transformation

The key question is what role infrastructure (and more specifically transport infrastructure) plays in this process of transformation of economies away from agriculture and towards manufacturing and services? Moreover, to what extent can the benefits associated with roads be amplified through complementary investments in electricity grids and broadband infrastructure?

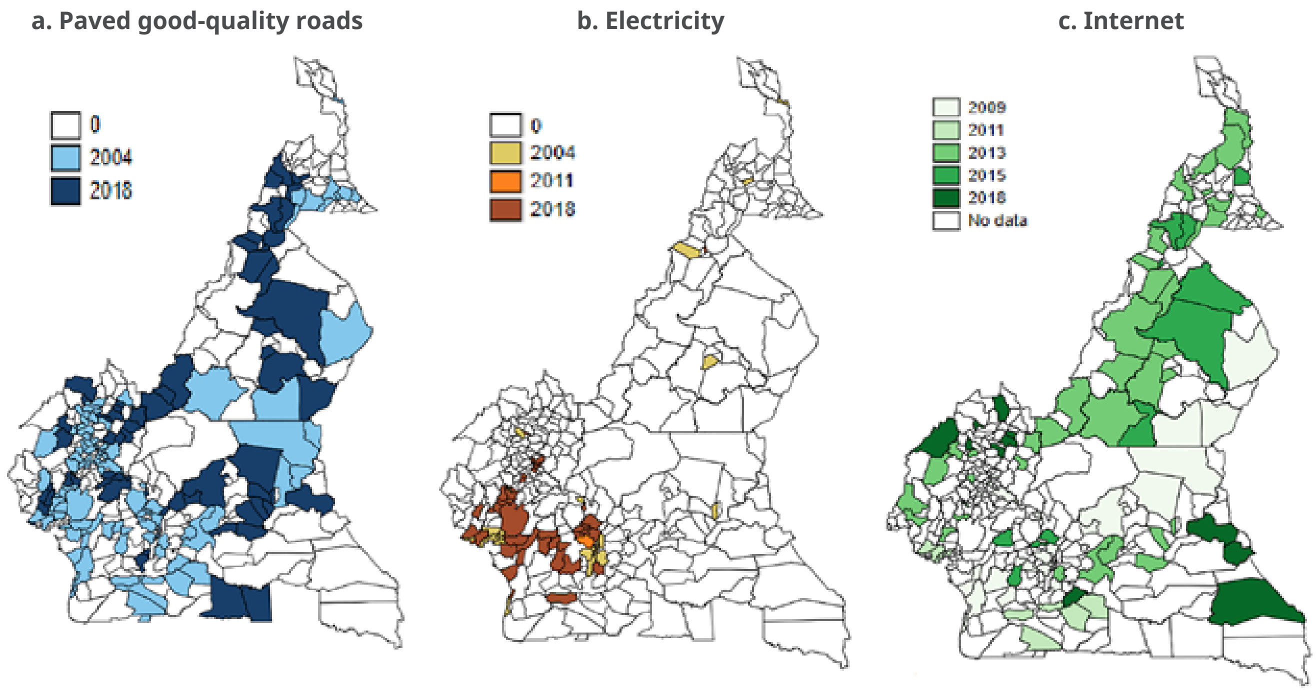
Herrera-Dappe and Lebrand (2021) and Lebrand (2022) investigate the links between investments in electricity, internet, and road infrastructure, in isolation and bundled, and economic development in the Horn of Africa and Lake Chad region, two regions that include countries with varying levels of infrastructure and economic development. Using data on the expansion of the road, electricity, and internet networks over the past two decades, they provide reduced form estimates of the impacts of infrastructure investments on the sectoral composition of employment. As shown in **figure 3** and **figure 4**, there has been a notable expansion in the geographic reach of infrastructure networks across these countries (specifically Ethiopia, Kenya, and Cameroon) during the past 10 to 20 years. By combining spatial information on infrastructure rollout with georeferenced household surveys reporting on employment patterns, it becomes possible to investigate the resulting impact on economic structure.

Figure 3. Expansion of the Paved Road Networks in Ethiopia and Kenya over a 20-Year Period

a. Ethiopia (1996–2016) **b. Kenya (1998–2018)**

Source: Herrera-Dappe and Lebrand 2021.
Note: Data for Ethiopia provided by the Ethiopian Road Authority; data for Kenya provided by the Kenya Road Board.

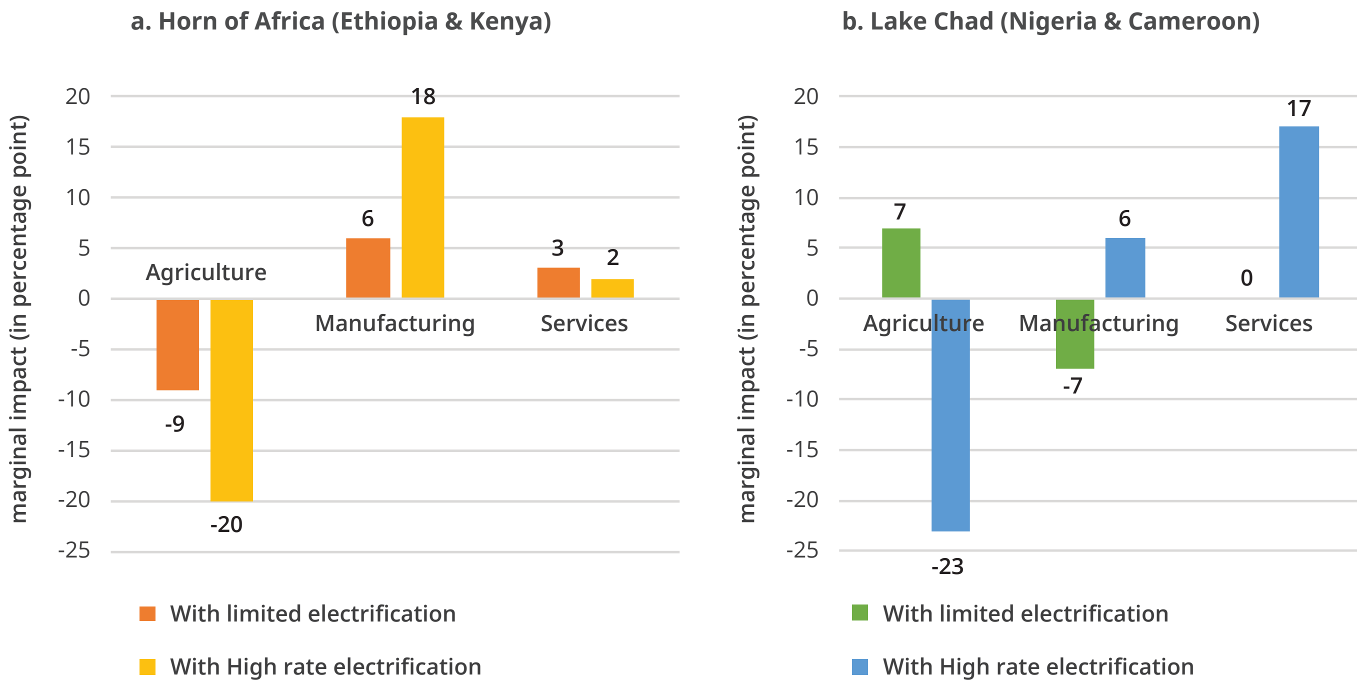
Figure 4. Expansion of the Multiple Infrastructure Networks in Cameroon over a 10- to 20-year Period



Source: Lebrand 2022.
Note: Locations are assumed to have access to electricity if at least 50 percent of their population have access to electricity as measured in Lebrand (2022).

First, the results indicate infrastructure investments play a substantial role in structural transformation. Herrera-Dappe and Lebrand (2021) show access to paved roads by itself has led workers to move out of low-productivity agriculture primarily into manufacturing and services in Kenya andEthiopia. The size of the effect is a reduction of 9 percentage points in the share of the workforce employed in agriculture in the Horn of Africa (see orange bars **figure 5**, panels a). Herrera-Dappe and Lebrand (2021) and Lebrand (2022) also show that access to internet has led workers to move out of low-productivity agriculture into services. The size of the effect is a reduction of 6 percentage points in the share of the workforce employed in agriculture in the Horn of Africa and 3 percentage points in Lake Chad.

Figure 5. Marginal Impact of Having Access to a Paved Road



Source: Herrera-Dappe and Lebrand 2021; Lebrand 2022.

Second, the research finds bundling road investments with access to electricity leads to a much bigger impact. In this case, the share of employment in agriculture falls by as much as 20 percentage points in the Horn of Africa and 23 percentage points in Lake Chad (see yellow and blue bars respectively in **figure 5**, panels a and b). Furthermore, in this case, workers shift mostly into manufacturing in the Horn of Africa (**panel a**) and into the services sector in the Lake Chad (**panel b**).

The policy implications of this research are clear. The spatial coordination of rollout for different types of infrastructure creates important synergies that yield substantially higher benefits. Intuitively, the value of being better connected to markets by roads is greater when firms are able to be more productive thanks to the adoption of electricity.

Infrastructure and Jobs

Both electricity and roads play a central role in economic development, yet evidence for road expansion and electrification as potential drivers of job creation is somewhat mixed and little is known about the potential complementary effects of such investments. On the one hand, electricity can stimulate local production, but the lack of reliable transport infrastructure will reduce the potential gains due to lack of market access, especially in more isolated areas. On the other hand, increased market access from road construction may cause both better access to customers and greater exposure to competition. Without access to modern production technology, the latter effect may outweigh the former and stymie local economic growth.

This leads to several key questions. What are the impacts of infrastructure on jobs? How do the employment impacts of road improvements vary across different segments of the general population? To what extent can the benefits of roads for jobs be amplified through complementary investments in electricity grids and broadband infrastructure?

Empirical evidence on the complementarity between roads and electricity is limited (Moneke 2020). Most existing studies either analyze the effects of infrastructure investments in isolation or estimate the aggregate impact of infrastructure on aggregate, that is the elasticity of output with respect to a synthetic infrastructure index, which includes electricity, transport, and telecommunications (Calderon et al. 2015).

Both electricity and roads play a central role in economic development.

Whether big-push investments in roads and electricity represent a powerful means of creating more and better jobs remains an open question.

To investigate this issue, two sets of georeferenced household survey data for Africa are used, namely the Living Standards Measurement Study (LSMS) surveys for the period 2005–19 and the Demographic and Health Surveys (DHS) for the period 2000–18. These are combined with an extensive array of new data on the spatial patterns of rollout for road and electricity networks across 27 African countries (**figure 6**). Proximity to the nearest main road and the nearest electricity transmission lines vary across households, and this is shown to affect patterns of employment, as illustrated in **figure 7**.

However, the high costs and potentially large benefits of infrastructure investments mean that the placement of electrification projects and new roads are typically correlated with both economic and political characteristics of locations and this affects where projects are placed. To address this potential spatial endogeneity of infrastructure investment, the study team uses an instrumental variable (IV) approach.

Figure 6. Change in Africa's Main Roads between 1971 and 2003

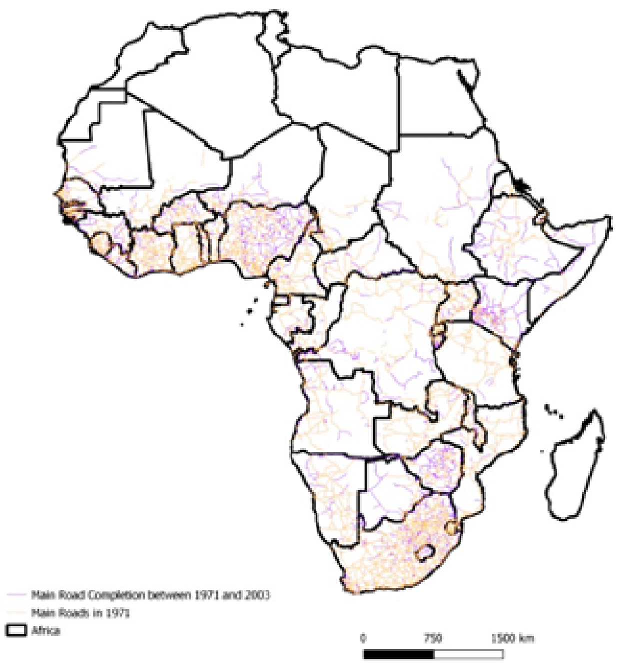
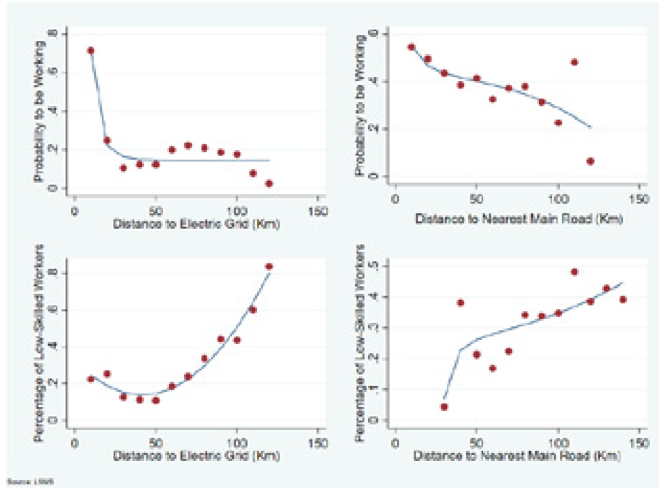


Figure 7. Simple Correlation between Distance to Infrastructure and Employment Patterns



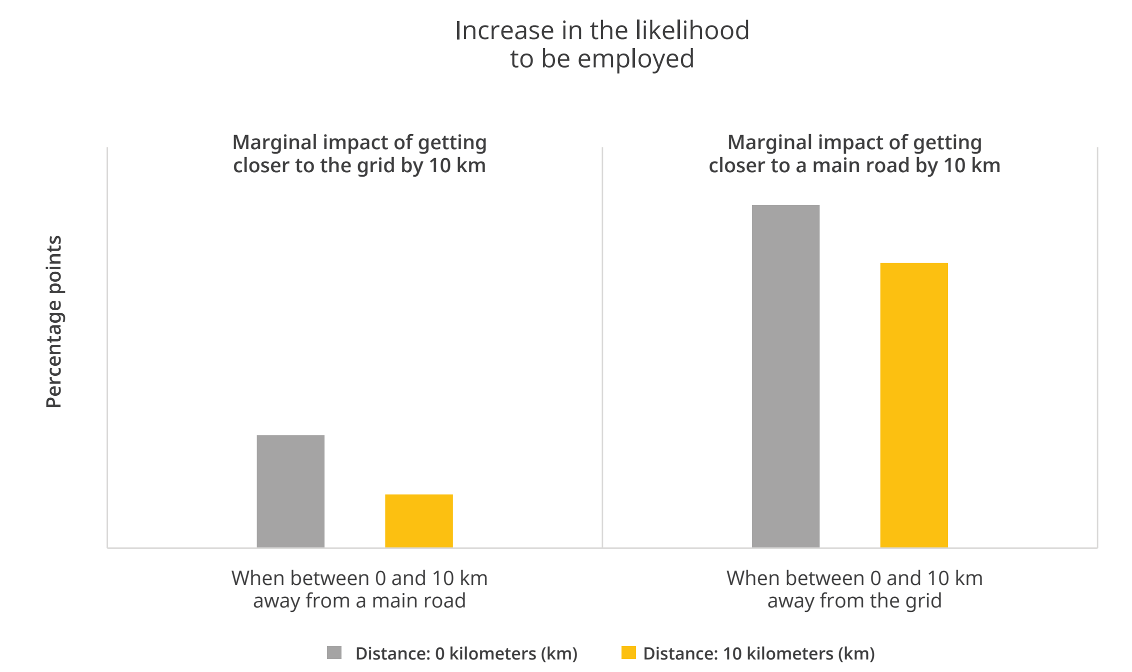
Source: Abbasi et al. forthcoming.
Note: To generate these figures, we compute the probability of employment for each givendistance to an infrastructure, where distance is measured in bins of 10 kilometers. We then compute the prediction of employment on distance.

The results of this new research (Abbasi et al. forthcoming) show proximity to infrastructure substantially increases the probability for workers to find a job and work a higher number of hours across all 27 African countries over the past two decades. These effects are quite large, since every kilometer of greater proximity to a road raises the probability of having a job by 2.13 to 2.57 percentage points, while every kilometer of greater proximity to the power grid raises the probability of having a job by 0.40 to 0.84 percentage points (**figure 7**). At the same time, the number of hours of employment increases by approximately one hour per week for every kilometer of proximity to the power grid and every 10 kilometers of proximity to a road (**figure 7**).

Abbasi et al. (forthcoming) also show how the positive effect of proximity to a main road on the probability to be employed is amplified for households located closer to the electricity grid, and vice-versa. Roads and electricity are therefore complementary investments. Using the DHS sample of survey data, getting 10 kilometers closer to the electric grid increases the probability of working by more than 8.4 percentage points when located next to the road, but only by 4 percentage points when located 10 kilometers away from the main road network (**figure 8**). Similarly, getting 10 kilometers closer to the main road network increases the probability of working by more than 25 percentage points when located next to the power grid, but only by 21 percentage points when located 10 kilometers away from the electric grid (**figure 8**). When it comes to the number of hours worked per week, getting 10 kilometers closer to the electric grid increases the number of hours by more than 12 percentage points when located next to the road, but only by 7 percentage points when located 10 kilometers away from the main road network (**figure 9**). Getting 10 kilometers closer to the main road network increases the number of hours by more than 1 percentage point when located next to the power grid, but decreases the number of hours when located 10 kilometers away from the grid (**figure 9**). The results suggest that, on average, road and electricity expansions play a complementary role in job creation for countries in the sample.

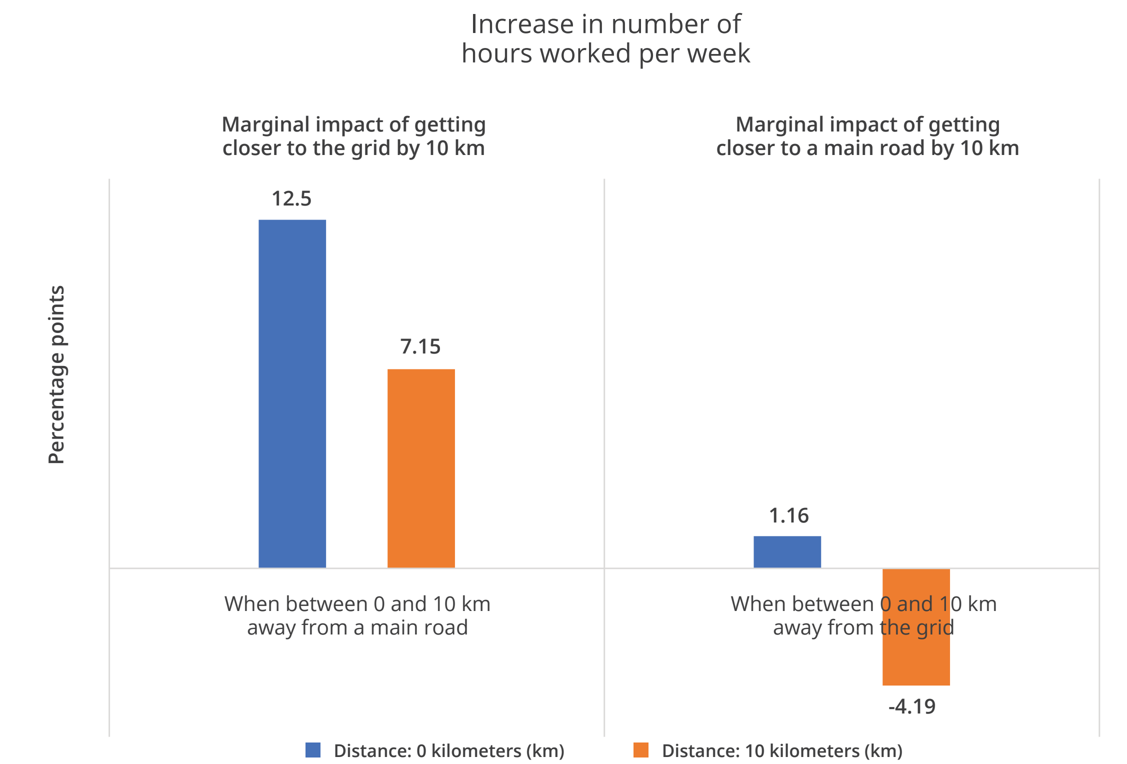
Moreover, these impacts differ between men and women, across age categories, and urban and rural areas. Being closer to a main road has a larger marginal impact on increasing the probability to have a skilled job rather than an unskilled job in rural than in urban locations. In addition, the employment gains due to infrastructure investment appear to accrue more to men than to women in the LSMS sample, suggesting that other constraints might be more binding for women than for men in certain countries. The results suggest young and middle-age individuals benefit more from infrastructure investment.

Figure 8. Complementary Effects between Road Expansion and Electrification on the Probability of Having a Job



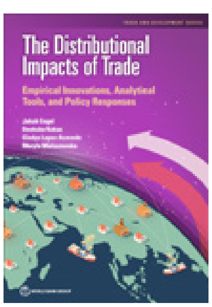
Source: Abbasi et al (forthcoming).

Figure 9. Complementary Effects between Road Expansion and Electrification on the Number of Hours Worked



Source: Abbasi et al (forthcoming)

Infrastructure and the Gains from Trade



The Distributional Impacts of Trade: Empirical Innovations, Analytical Tools, and Policy Responses

The rapid increase in global trade has been a key engine of growth and poverty reduction in developing countries, as shared in a World Bank press release announcing the release of a 2021 report, *The Distributional Impacts of Trade: Empirical Innovations, Analytical Tools, and Policy Responses* (Engel et al. 2021). From 1990 to 2017, global poverty fell from 36 percent to 9 percent as developing countries increased their share of global exports from 16 percent to 30 percent. Countries open to international trade tend to grow faster, innovate, improve productivity, and provide higher income and more opportunities to their people. Open trade also benefits lower-income households by offering consumers more affordable goods and services.

However, while trade agreements and liberalization through the reduction of tariffs are necessary to boost trade, they are not necessarily sufficient if more fundamental conditions—such as infrastructure connectivity—are lacking. For example, Africa has seen massive trade liberalization in the past three decades. But the success of translating reduced tariffs into increased international trade has been limited and geographically unbalanced. One of the main reasons for this is the high cost of moving goods within countries and poor infrastructures.

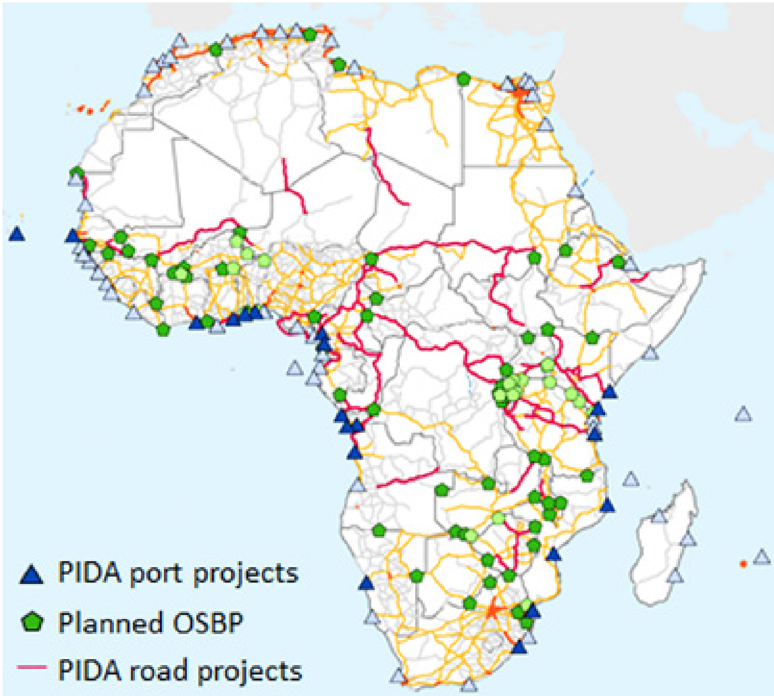
In this context, the new agreement on the African Continental Free Trade Area (AfCFTA) offers a unique opportunity to boost growth and job creation through the intensification of trade between countries across the continent. The potential of regional trade in Africa remains largely underexploited. To date, trade between African countries represents only 12 percent of total trade—against 60 percent between countries in Europe and 40 percent in Asia. These figures can be explained by high internal transport costs, as well as other factors such as the structure of the productive base, a high rate of informality, and the rise of conflicts across the continent. An important policy question, then, is how do regional road corridors contribute to the development of trade both within the African continent and between Africa and the rest of the world?

Given recent advances with the long-awaited AfCFTA agreement, it would be damaging for the resulting economic benefits not to materialize due to high internal transport costs. Fontagne et al. (forthcoming) investigate the economic benefits from both pillars of continental integration: massive investments in infrastructure and the signing of the Pan-African Trade Agreement. Both reduce trade frictions, but infrastructure development has potentially complex effects on trade and income gains as it reduces both domestic transport times, transport times between African countries, and those between African countries and third countries.

Fontagne et al. (forthcoming) first undertake a large data collection effort to map the different Program Infrastructure Development for Africa (PIDA) projects related to road, port, and border investments (**figure 10**). They use a network analysis to compute the travel time between major African cities and cities in the rest of the world before and after the PIDA investments listed in **figure 10**. **Table 1** reports the change in shipping times under four scenarios. Overall, the average transport times for all pairs of countries will decrease by 0.4 percent in the first scenario, by 7 percent in the second, by 6 percent in the third, and by 11 percent in the last and most complete scenario. The large reduction in average transport time associated to port investments and the new one-stop border posts (OSBPs) indicates the importance of sea and land border delays for connectivity in Africa and highlights the complementarity between transport infrastructure and trade facilitation reforms.

The rapid increase in global trade has been a key engine of growth and poverty reduction in developing countries.

Figure 10. New Investments in Roads, Ports, and Border Posts



Source: Fontagne et al. (forthcoming).
Note: PIDA = Program Infrastructure Development for Africa; OSBP = one-stop border post.

Table 1. Change in Transport Times between African Countries and the World

Scenario		Average change in transport times to Africa	Average change in transport times to the rest of the World, not excluding Africa	Average change in transport times to the World
1	Only road improvements	−1%	−0.2%	−0.4%
2	Road improvements and new ports	−10%	−6%	−7%
3	Road improvements and new OSBPs	−14%	−3%	−6%
4	Road improvements, new OSBPs and port investments	−20%	−7%	−11%

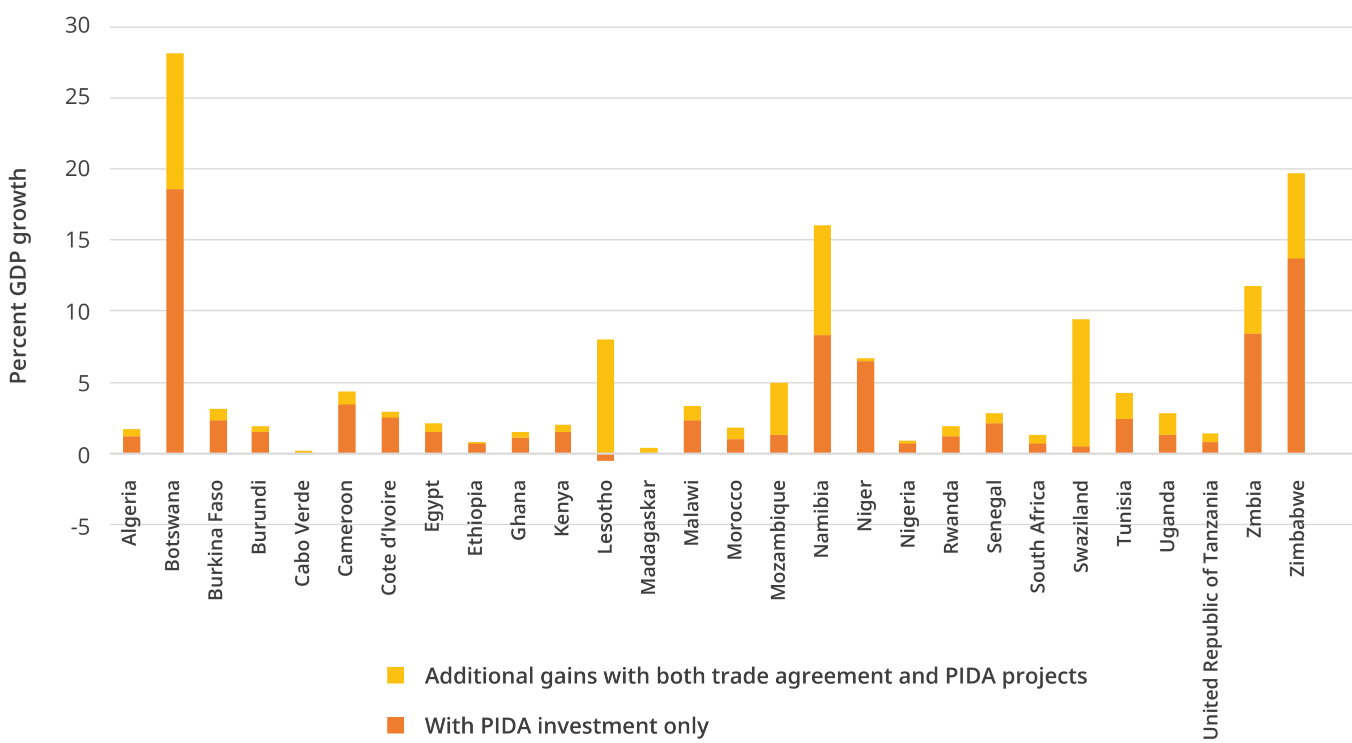
Source: Fontagne et al. (forthcoming).
Note: OSBP = one-stop border post.

The analysis relies on a general equilibrium model to quantify the trade and welfare impacts of counterfactual scenarios of trade and transport reforms. Specifically, the research investigates three scenarios: (1) signing of a deep trade agreement, the AfCFTA, linking all African countries; (2) completion of the PIDA transport infrastructure and border posts projects (**figure 11**); and (3) combination of these two trade and infrastructure/trade facilitation reforms. This quantification exercise helps to identify priorities for reform to improve connectivity and integration prospects for countries in Africa.

Fontagne et al. (forthcoming) show the growth of exports and gross domestic product (GDP) could be up to 5 times higher if the AfCFTA was accompanied by substantial investments in transport infrastructure—mainly roads and ports—as well as a substantial reduction in border crossing times. Signing a deep trade agreement linking all African countries without removing the important gaps in terms of infrastructure and the large trade facilitation bottlenecks would lead to an increase in trade integration and GDP, but these gains would be limited. A combination of deeper trade agreements, improvements in transport infrastructure and of trade facilitation reforms would lead to a boost in exports for African countries by 12.2 percent and GDP by 2.2 percent per year relative to the baseline.

In addition, Fontagne et al. (forthcoming) show the impacts on trade and welfare differ across countries, depending on the level of new infrastructure investments and the comparative advantage of countries in trading with others. While all African countries have positive trade and welfare effects from trade and transport reforms, these gains are not uniformly distributed. Countries such as the Bostwana, Nambia, Swaziland, Zambia, and Zimbabwe have the largest percentage improvements in GDP (**figure 11**).

Figure 11. GDP Gains from PIDA Investments and the Signing of a Deep Trade Agreement



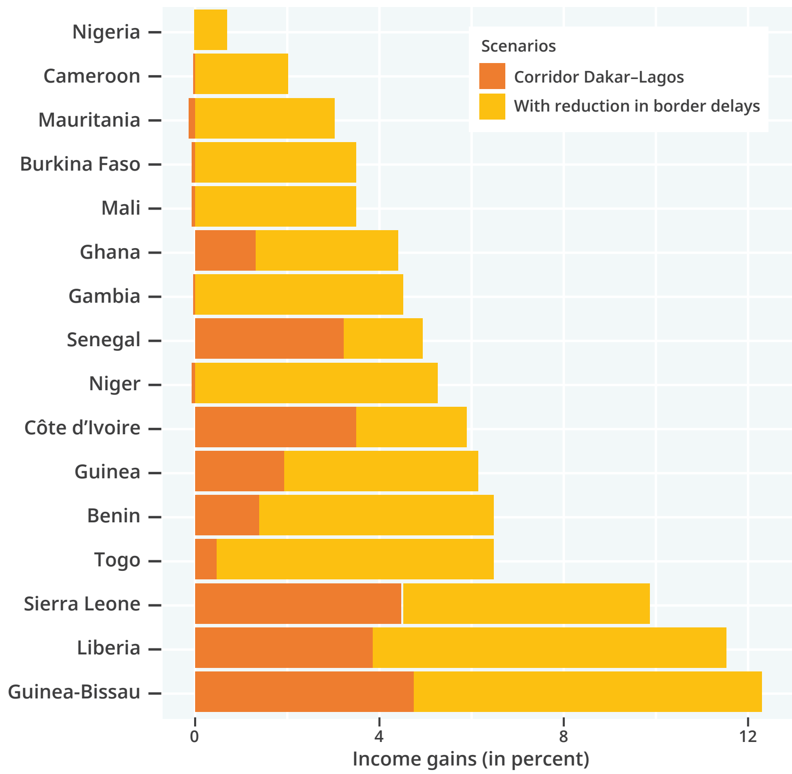
Source: Fontagne et al. (forthcoming).
Note: PIDA = Program Infrastructure Development for Africa.

Complementing the previous study, Lebrand (2021) zooms in on one particularly important regional trade corridor—the Dakar–Lagos motorway corridor—which will serve the capitals of The Gambia, Guinea-Bissau, Guinea, Sierra Leone, Liberia, Côte d'Ivoire, Ghana, Togo, and Benin. This project, which aims to support trade among the coastal economies of West Africa, is inspired by the successful development of the priority corridors of the Trans-European Road Network, which have made it possible to create a genuine single European market and to develop cross-border value chains. As of today, it is generally cheaper to trade goods from coastal nations in West Africa with China, than it is to exchange goods within West Africa itself (World Bank's Trade Cost Database for 2017). The reason for this is not only poor-quality road infrastructure, but also lengthy border delays. This leads to a further important question: To what extent can the benefits of regional road corridors be amplified through complementary measures aimed at reducing border delays?

New agreement on the African Continental Free Trade Area offers a unique opportunity to boost growth and job creation through the intensification of trade between countries across the continent.

Lebrand (2021) shows the modernization of the Dakar–Lagos regional road corridor brings considerable economic benefits in relation to the investment costs, with a benefit-cost ratio estimated at around 3. However, this corridor traverses as many as 11 border crossings over a distance of 4,560 kilometers, introducing delays per border that range from several hours to several days, due to the remarkably slow and inefficient border arrangements. As a result, the economic benefits of the road corridor improvements would be both doubled overall and more equitably spread across the region, if such investments were combined with measures to reduce current border crossing times. As illustrated in **figure 12**, the associated gain in income for the regional population are expected to be greater for countries at the western end of the corridor (+ 10 to 20 percent) than for countries at the eastern end of the corridor (+5 to 10 percent). This is due to the fact that countries at the eastern end of the corridor (such as Benin and Togo) are already proximate to the largest market in the region to be found in Nigeria, whereas countries towards the western end of the corridor (such as Guinea-Bissau, Liberia, Sierra Leone) are typically smaller, more fragile, and more remote from economic centers and as such have more to gain from the investment. An important policy implication is that road corridor projects need to be combined with soft measures targeted at reducing border delays.

Figure 12. Income Gains from Upgrading the Dakar–Lagos Corridor with and without Major Reduction in Border Delays



Source: Lebrand 2021.

Boxes 1 and **2** present the aggregate and subnational welfare impacts of the large transport investments complemented with electrification and trade facilitation programs. Herrera-Dappe and Lebrand (2021) and Lebrand (2022) show the impacts on welfare differ across countries.

The Abidjan–Lagos corridor illustrates how the benefits of regional corridors may be distributed differently across and within countries. Simulations from Herrera-Dappe and Lebrand (2021) and Lebrand (2022) quantify the subnational and aggregate gains from new corridors of interest for the World Bank: a series of regional corridors in the Horn of Africa (**figure B1.1**) and the road and rail corridors in Chad and Cameroon (**figure B2.1**). These shed further insight on the spatial distribution of investments in regional transport corridors.

In the Horn of Africa, Somalia will benefit the most from the transport as well as combined energy and transport investments as the new road corridors will largely increase its access to bigger regional markets and lead to important reduction in prices for goods exchanged in the region (**table B1.1**). However, the effects differ across locations within country. The road investments will primarily benefit the border locations that gain the most in terms of market access. While some regions do not benefit from road investments alone, all regions gain when infrastructure investments are combines with trade facilitation measures, as these help to amplify the affected area (**figure B1.2**).

Around Lake Chad, the gains from transport investments will mainly benefit Chad whose domestic integration and access to larger markets in Cameroon and overseas are greatly improved. However, those gains would be larger when complemented by an electrification program and trade facilitation policies. The locations near the lake at the intersection of Nigeria, Cameroon, and Niger will benefit the most from a better access to bigger markets and lower prices (**table B2.1** and **figure B2.2**), while the southern area around Douala and Yaoundé in Cameroon will gain a lot from its existing advantage in the manufacturing sector.

Box 1. The Benefits from New Corridor Investments and Complementary Policies in The Horn of Africa

Table B1.1. Counterfactual Increases in Real Income in Horn of Africa, by Country (Percentage)

Scenarios	Total	Ethiopia	Djibouti	Somalia	Kenya
Electrification only	3.5	4.8	1.7	3.5	0.9
Roads only	1	1.3	0	1.4	0.7
Roads and trade facilitation	4.3	3.9	5.3	6.3	4.9
Roads and electrification	2.1	2.6	7.6	6.2	0.3
Roads, trade facilitation and electrification	7.8	9	8.6	10.1	5.1

Figure B1.1. Proposed Road Corridors in the Horn of Africa

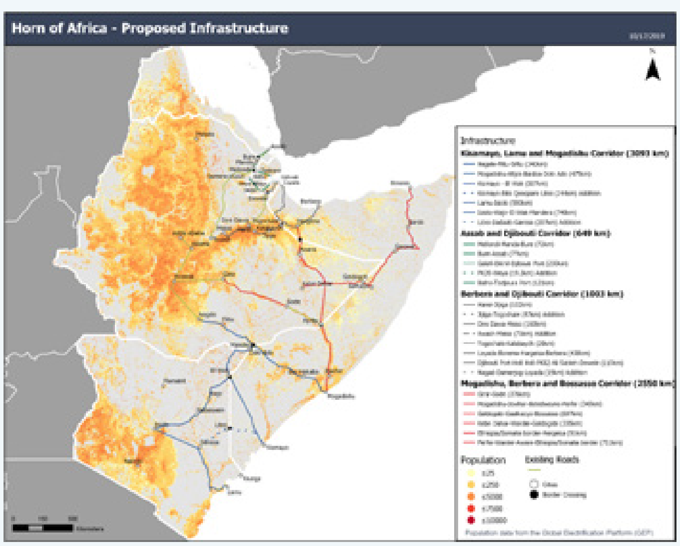
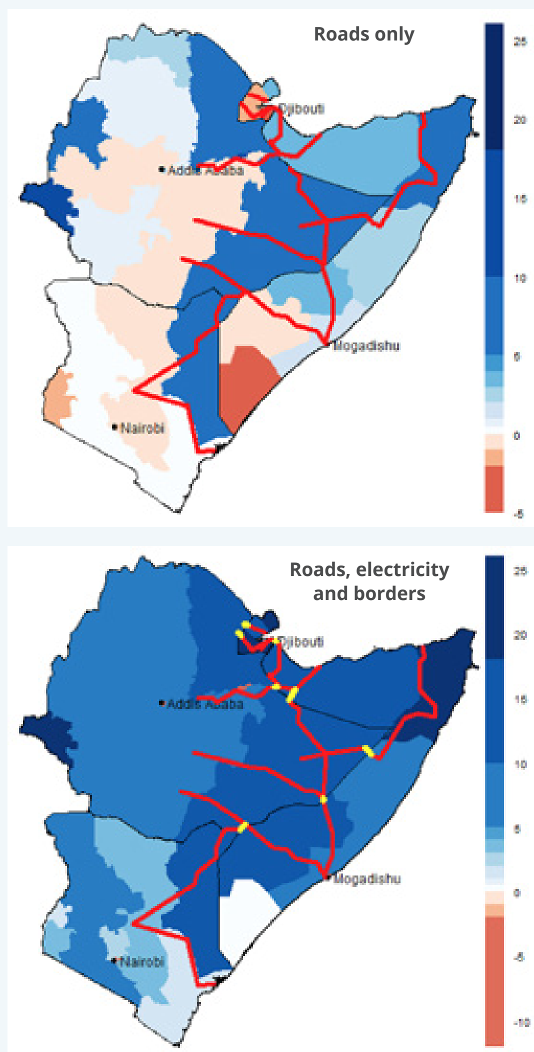


Figure B1.2. Subnational Impacts of Proposed and Complementary Investments in the Horn of Africa



Source: Herrera-Dappe and Lebrand 2021.

Box 2. The Benefits from New Corridor Investments and Complementary Policies in Lake Chad

Table B2.1. Change in Welfare in Counterfactual Scenarios in Lake Chad Countries (Percentage)

Scenarios	Total	Ethiopia	Djibouti	Somalia	Kenya
Road (Chad)	0.03	0.0	0.23	0.02	0.1
Road and rail	0.13	0.5	0.7	0.03	0.8
Electrification	4.4	5.7	5.2	4.2	5.6
Electrification + road and rail	4.6	6.1	6	4.3	6.3
Road and rail + border	2.5	2.8	3.7	2.3	4.8
Electrification + road and rail + border	7.1	8.7	9	6.8	10.7

Figure B2.1. Proposed Cameroon–Chad Road and Rail Corridors

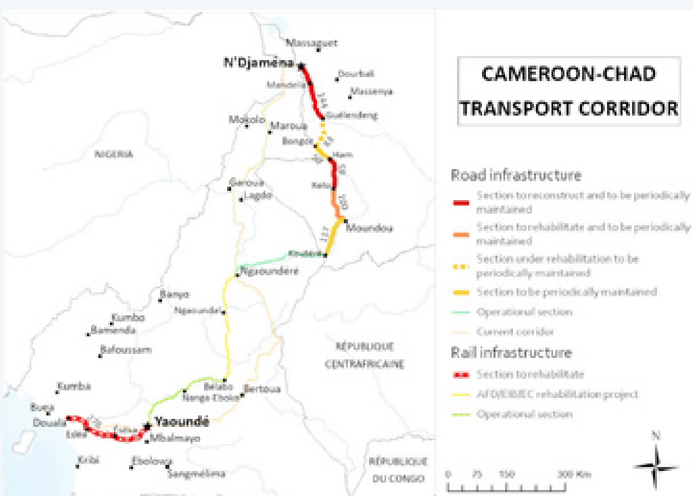
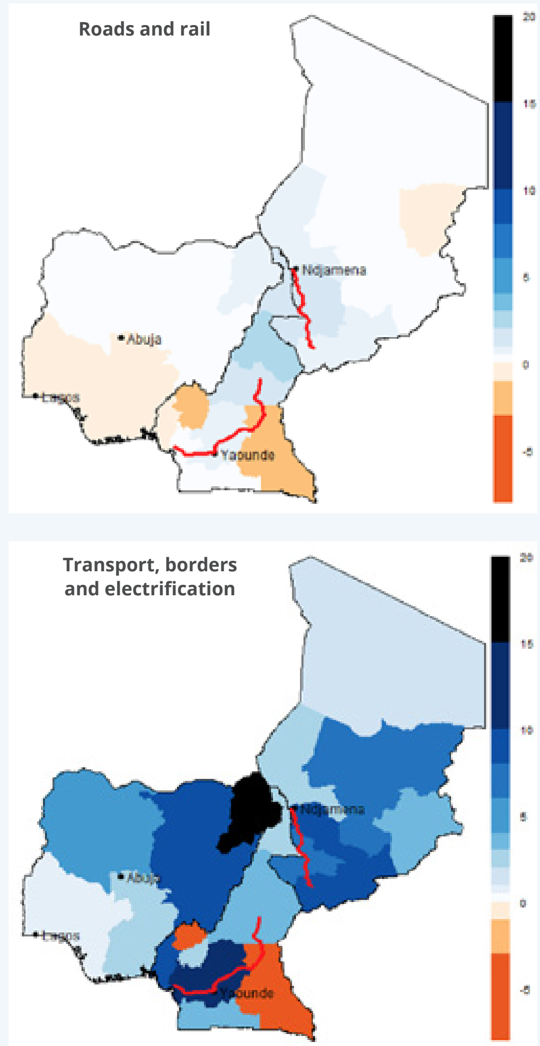


Figure B2.2. Subnational Impacts of Proposed and Complementary Investments in Lake Chad Countries



Source: Lebrand 2022.

Conclusion

Emerging findings from the application of such new analytical tools will hopefully enable a more comprehensive and meaningful appraisal of investments in transport infrastructure in the future. These results provide rigorous evidence for the wider economic impacts and allow a more realistic and comprehensive estimation of the economic benefits of transport investments. At the same time, they can inform project design by shedding light on key complementary areas of investment and policy reform that may further amplify the economic impact of transport investments as well as clarifying which locations are best placed to benefit from different interventions. In addition, the same tools can be adapted to answer a wider range of questions regarding the impact of transport investments on food security, poverty reduction, conflict, and climate change.

References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Identifying and Quantifying the Economic Benefits of Bicycle Lanes

Bicycle infrastructure in Latin American cities has grown rapidly over the past decade. Cities such as Buenos Aires, Bogotá, and Santiago have more than doubled the length of their cycling networks in less than 10 years. In Buenos Aires, daily bicycle trips grew from approximately 176,000 in 2013 to more than 405,000 in 2020, and the bicycle lane network has grown from approximately 35 kilometers in 2010 to more than 260 kilometers in 2020. Aiming to provide a rigorous evaluation framework to inform further network expansions, this article showcases a study of the economic benefits of bicycle lanes and discusses the application of an ex-post cost benefit analysis on two new bicycle lanes in the city of Buenos Aires, in Avenida Corrientes and Avenida Córdoba.

Economic evaluations of bicycle infrastructure are scarce, but they in general consider at least four types of benefits: (1) health benefits from physical activity estimated as a reduction in the mortality rate, (2) travel time savings for cyclists and travelers switching to cycling, (3) reduction of road crashes, and (4) reduction of air pollution and greenhouse gas (GHG) emissions due to the shift from motorized modes of transportation to cycling. Bicycle infrastructure brings additional, seldom monetized benefits, most notably enjoyment, noise reduction, option value—as the willingness to pay for having access to a cycling lane, even without the likelihood of an individual using it—and more compact and accessible land use, among others.

The results for Buenos Aires show substantial economic benefits for the two bicycle lanes analyzed, with health benefits accounting for 60 percent and travel time benefits accounting for 28 percent of total benefits estimated. A benefit-cost ratio of 5.7 and an economic rate of return of 113 percent resulted from the significant observed increase in cycling on the two new bicycle lanes.

Introduction

Bicycle use as a mode of transportation is associated to multiple health and environmental benefits, as it promotes physical activity, does not generate emissions, imposes less severe injury risk to third parties in traffic, and improves the livability of cities.

To promote these benefits along with tackling traffic congestion problems, many cities around the world started to support bicycle use as a sustainable transport solution. One of the main actions to promote cycling is the construction of dedicated cycling infrastructure.

During the past decade, Buenos Aires has been one of the Latin American cities to consistently invest in bicycle lane infrastructure, as it started the construction of a protected lane network in 2009 (OMSV 2021a). This network is physically

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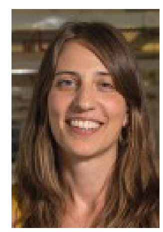

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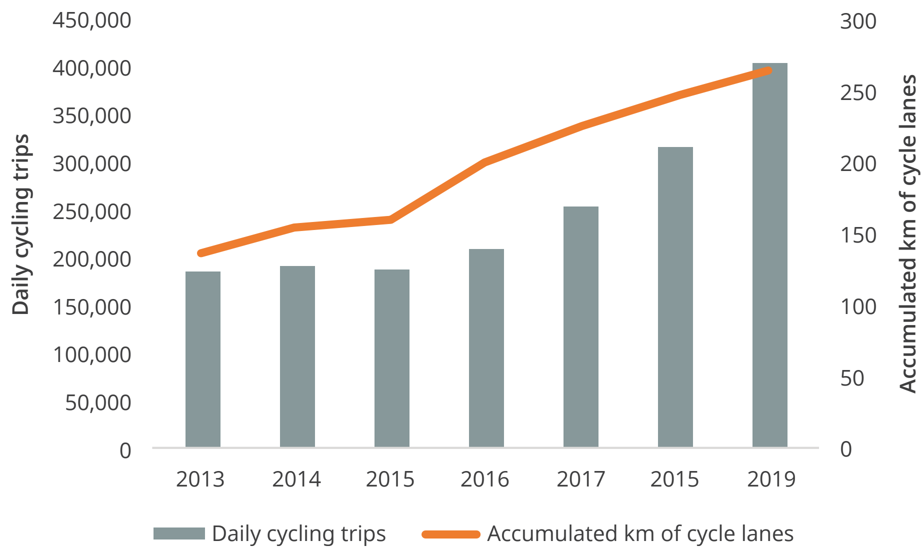
separated from traffic, bidirectional, and mainly placed in secondary roads. This network grew from the administrative and commercial area of the city to the residential zones, connecting different strategic city points such as transport hubs, universities, schools, and hospitals. In 2020, the network reached 265 kilometers of bicycle lanes (OMSV 2021a; also see **figure 1**). This action, together with the implementation of a shared bicycle system as well as with multiple cycling promotion programs (GCBA 2018), led to a significant increase in the number of cycling trips. While in 2013 riders completed approximately 175,000 daily bicycle trips, in 2020 trips totaled more than 405,000, representing a 131 percent increase in bicycle use (OMSV 2021a; also see **figure 2**).

Figure 1. Map of Buenos Aires Cycling Network

Source: Secretary of Transport, GCBA 2018.
Note: Yellow lines: Buenos Aires cycling network; violet lines: Avenida Córdoba and Avenida Corrientes lanes.

Figure 2. Number of Daily Cycling Trips and Accumulated Kilometers of Cycle Lanes, Autonomous City of Buenos Aires, 2013 to 2020



Source: OMSV 2021a.

In 2020, to face the mobility challenges associated with the COVID-19 pandemic, Buenos Aires built 17 kilometers of new bicycle lanes, that, as opposed to most other existing lanes, were placed in two of the main avenues of the city: Avenida Córdoba and Avenida Corrientes (see **figure 1**). To achieve a rapid implementation, these lanes were constructed with tactical urbanism, which implies the use of paint markings and plastic bollards to separate cyclists from traffic. Moreover, these lanes have several characteristics that distinguish them from the previous ones and align them with international recommendations for bicycle lane construction (WRI 2021): Each is 3 meters wide, allowing comfortable turns and physical distancing; unidirectional, increasing safety; more direct, contributing to a 10 percent travel time reduction for cyclists; and, importantly, well connected with the network as well as with main city attractions (see design details in **figure 3**).

Figure 3. Design Details of Corrientes Avenue Cycling Lane, Buenos Aires, Argentina

Source: Secretary of Transport, GCBA 2018.

As a consequence of the new patterns of mobility during the COVID-19 pandemic, the city of Buenos Aires registered a 28 percent increase in the number of cycling trips in comparison to 2019. This increase was greater in the intervened avenues, on average 107 percent—while bicycle traffic in parallel streets increased 8 percent. An estimation based on Buenos Aires cyclists' counts indicated the new lanes generated at least an additional 3,752 new daily cycling trips, controlling the number of trips that could have be reassigned from other routes. This means that in Avenida Córdoba and Avenida Corrientes, 221 new cycling trips per kilometer of bike lane were observed after the implementation.

Also, a greater growth in the number of cycling trips by women compared to men, especially on Avenida Córdoba and Avenida Corrientes, where the share of women cyclists increased from 18 percent to 26 percent, on average. In turn, on parallel streets the variations in the flow of female cyclists were similar to male cyclists. Importantly, in terms of road safety, while the number of cyclists at the city level increased, their mortality rate per million cycling trips decreased 71 percent—partly due to lower traffic—and no cyclists' fatalities were registered on the new lanes.

Although the new infrastructure seems to have had a significant impact on the number of cyclists and on their safety, what are the economic benefits of this investment? To answer this question, the study team performed an ex-post evaluation of the costs and benefits associated with the implementation of the bicycle lanes on Avenida Córdoba and Avenida Corrientes in the city of Buenos Aires.

The first step was to identify methodologies and models used to evaluate the benefits associated with the implementation of bicycle lanes. To accomplish this, the study team performed a literature review aimed to identify parameters internationally used for the evaluation of benefits.

Benefits of Bicycle Lane Infrastructure

The study team analyzed a set of 16 studies aimed at identifying and measuring the socioeconomic benefits of cycling infrastructure. From those studies, 9 analyzed benefits associated with road safety, 8 to health benefits, 7 analyzed benefits related to decreasing greenhouse gas emissions (GHG) with another 5 analyzing benefits related to decreasing other pollutant emissions, 4 analyzed travel time savings, 3 work absenteeism, and 2 noise reduction and fuel savings. Additionally, one study each addressed benefits related to operational costs and travel quality. A brief description of the methodologies employed to calculate each type of benefit is provided below.

Road safety benefits

Road safety benefits are generally valued in terms of changes to the number of road crashes involving cyclists, and in particular considering changes to the number of cyclist fatalities. One of the most known approaches to estimate the benefits associated with changes to the number of road crashes involving cyclists is the health economic assessment tool (HEAT) for walking and cycling (Götschi et al. 2020; Kahlmeier et al. 2017). This methodology estimates the number of cyclists' fatalities as a function of the volume of cycling (measured in cycled kilometers) and a risk factor based on national statistics. The risk factor could be modified to consider safety improvements resulting from cycling infrastructure. The benefits are evaluated using the statistical value of life. Also, the Transport Analysis Guidance or TAG (DfT 2020b), estimated the benefits in crash reduction based on the definition of crash rates and the valuation of associated costs according to injury severeness (fatal, serious, or minor). Crash rate functions can be defined using data for infrastructure of similar characteristics implemented in other areas. For instance, Jacobsen (2003) estimated a crash rate function that suggests doubling of the cyclists' flow due to a new bicycle lane would imply a 32 percent increase in the number of crashes. In the Economic Evaluation Manual

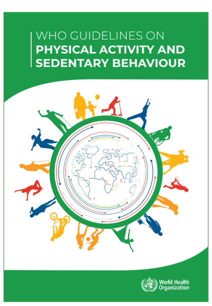
Health economic assessment tool for walking and for cycling

Economic Evaluation Manual

prepared by the New Zealand Transport Agency (2018), the benefits associated with crash reduction were estimated based on historical crash data (minimum five years) and crash reduction factors. The manual defines crash reduction factors associated with the implementation of a new bicycle lane, which vary between 10 percent and 20 percent. The savings are estimated based on crash costs, which vary according to the type of injury and the speed limit of the area where the bicycle lanes are located. Additionally, the methodology employed to evaluate the bicycle lane master plan for Chile (Steer Davies Gleave 2013) considered road safety benefits in terms of the reduction in the crash rate (crash rate to kilometers traveled per year) for scenarios with and without bicycle lanes. Crashes were distributed by type of injury (fatal, serious, or minor) and the expected crash reduction rate was defined according to the type of bicycle lane. Benefits were estimated as a function of the difference in injuries between the situation with and without bicycle lanes, and monetary valuations including the statistical value of life. Finally, a study implemented in the city of Lima (Decisio 2020) estimated the road safety benefits in terms of the reduction in the crash rate per kilometer and the cost of crashes by type of injury. A crash reduction rate of 50 percent due to the new bicycle lanes was assumed.

In sum, road safety benefits of bicycle lanes are estimated based on changes to the number of road crashes involving cyclists. The calculation of benefits is based on the costs associated with each crash and most methodologies estimate costs by type of injury (fatal, serious, or minor). Changes in the rate of road crashes involving cyclists could be positive or negative, depending on the expected change to the volume of cycling and whether the risks of cycling are reduced by the infrastructure.

Health benefits



WHO Guidelines on Physical Activity and Sedentary Behaviour

Several studies showed a relationship between physical activity and improved health (WHO 2020). Comparing people with a sedentary lifestyle with those who perform some level of physical activity per week, it is observed that the latter, in general, are healthier (Kahlmeier et al. 2017). It is estimated that if a person performs between 100 and 150 minutes of physical activity per week, this reduces the risk of dying from any disease by 10 percent. Most of the methodologies reviewed estimated health benefits based on one of two approaches (Chiabai, Spadaro, and Neumann 2018; Roy 2015): (1) from the reduction in the mortality rate due to any disease resulting from improvements in health, by using a statistical value of life; (2) from the reduction in years of life lost due to improvements in health, by using a value of a life year.

Health benefits are estimated from the reduction in the mortality rate of the population because of the increase in the physical activity of cyclists. It is estimated that an increase in physical activity implies a reduction in the probability of dying from certain diseases.

Reduction of polluting emissions

The methodologies reviewed generally measure pollutant reduction benefits through two approaches: (1) The most widely used approach corresponds to the estimation of benefits from the reduction of GHG, which are largely responsible for the effects of climate change and have a global effect on people's health; (2) A complementary approach, used in some methodologies, estimates the benefits associated with the reduction in the emission of atmospheric pollutants, which generate negative effects on people's health as they are one of the main causes of disease of the cardiorespiratory system and also have a local effect.

GREENHOUSE GASES

To evaluate the impact of bicycle lanes on the reduction of GHG, the reviewed methodologies, in general, involved three steps: (1) Estimate the modal shift from motor vehicles to cycling because of the new bicycle lanes; (2) Estimate the quantity of emissions no longer emitted due to modal shift; (3) Estimate the economic benefits of GHG reduction by defining a social value for carbon dioxide (CO_2).

LOCAL POLLUTANTS

Some studies, such as DfT (2020a) and New Zealand Transport Agency (2018) used a methodology similar to the one used to estimate GHG reduction benefits, thus quantifying and valuing the changes in the concentration of these pollutants due to the implementation of a new bicycle lane. The HEAT tool also measures the impact of air pollution; however, the benefits are estimated differently. This tool assumes if people start cycling more in congested urban conditions, they could be more exposed to particulate matter, which poses a health risk. A risk factor is calculated to represent this effect on the mortality rate of the affected people. The risk factor is calculated as a function of (1) the level of exposure to air pollution, which varies depending on whether the bicycle path or route used by a cyclist is located near a roadway with motorized traffic or passes through a park or areas away from vehicular traffic, and (2) The purpose of the bicycle trip, where the basis for comparison of the level of exposure to air pollution is, for a recreational trip, the alternative of staying at home and, for a city trip, the alternative of using a car. An increase of 10 $\mu g/m^3$ (micrograms per cubic meter) in the concentration of particulate matter 2.5 in the air implies a 7 percent increase in the probability of dying (Kahlmeier et al. 2017). This increase is not immediate, with a five-year time lag between the increase in pollutant concentration and the negative effects on people's health.

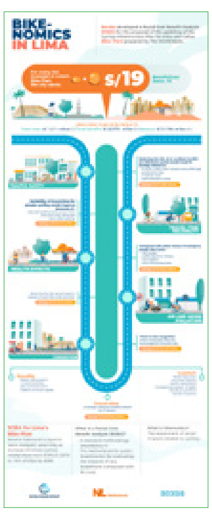
Economic Evaluation Manual

Travel time savings

The impacts on travel times of both cyclists and motor vehicles are considered in several of the methodologies reviewed, however, the approach to estimating benefits varies.

The 2013 Steer Davies Gleave study measures the benefits associated with reduced travel times for bicycles and motorized vehicles due to flow segregation were measured. The methodology for motorized modes measured the differences in vehicle flow and speed in the situation with and without bicycle lane and estimated the benefits in terms of travel time savings due to increased speed. The methodology for nonmotorized modes estimated travel time savings due to the shift from walking to cycling by defining capture rates for a certain area of influence around the bicycle lane. For both modes, the benefits were estimated based on the social value of time. In the case of the New Zealand Transport Agency (2018), benefits were estimated by reducing travel times for motorized and active modes due to modal shift. Time savings were defined according to trip purpose, vehicle type, and the level of congestion. The value of travel time is also defined as a function of these three variables.

The speed of cyclists tends to increase with new bicycle lanes due to flow segregation, more direct trips, and less interference with other traffic. Also, the time savings of people who switch from walking to cycling can be considered. With regards to the effect of bicycle lane implementation on traffic congestion and travel time reliability for automobiles, the overall impact could be ambiguous. On the one hand, mode shift from motor vehicle travel will alleviate traffic congestion, generate travel time savings, and improve travel time reliability for motorists. On the other hand, a reduction in road space allocated for motorized traffic means lower capacity for motor vehicles, which could lead to increased congestion and higher volatility in travel time. The overall effect could vary for each intervention, depending on the expected mode shift and in the reallocation of road space.



Health economic assessment tool for walking and for cycling

Other benefits

ABSENTEEISM

Some studies estimated the benefits associated with reduced absenteeism due to increased physical activity from cycling and improvements in people's health. The TAG estimates the benefits in terms of the number of new cyclists due to the new cycleway, spending time daily on physical activity, average work absenteeism, and associated costs. It is considered that 30 minutes of physical activity per day can reduce absenteeism by 25 percent (DfT 2020b). Garrett (2019) found that the main benefits of new cycling infrastructure in Denmark were associated with health, including reduced medical costs and added value at work due to reduced absenteeism. According to a study conducted by Decisio (2020), regular physical activity (for example, daily cycling) produces benefits in people's physical and mental health. These improvements in health decrease the risk of getting sick and, in turn, reduce absenteeism from work. The study concluded that regular cycling to work would mean an average of 1.3 fewer days of absence from work per year.

NOISE

New Zealand Transport Agency (2018) and Decisio (2020) evaluated the benefits of noise reduction due to the reduction of motorized vehicle flow resulting from modal shift to bicycles. In both cases the benefits were measured in terms of vehicle flow and noise valuation.

FUEL SAVINGS

Potentially, two mechanisms could generate reduced fuel consumption: (1) modal shift from motorized vehicles to cycling; (2) greater engine efficiency due to the increased speed of motorized vehicles when cycling flows are segregated (Steer Davies Gleave 2013; New Zealand Transport Agency 2018).

OPERATIONAL COSTS

The calculation of this benefit involved modeling the costs of transport including investment costs (buying a bicycle), payment of public transport fares, and maintenance costs, among other types of cost (New Zealand Transport Agency 2018).

QUALITY OF TRAVEL

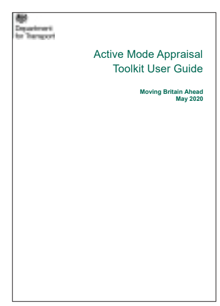
The TAG (DfT 2020a; DfT 2021) measured benefits to the quality of travel for cyclists due to the implementation of a new bike lane and included valuations specific to the time spent on different types of bicycle lane and also to other cycling infrastructure such as secure parking or cyclists' facilities. The methodology measures the benefits perceived by the user along the trip.

Social Cost-Benefit Analysis

To conduct an evaluation of the bicycle lane interventions in Avenida Corrientes and Avenida Córdoba in the City of Buenos Aires, a social cost-benefit analysis was developed drawing from the list of above-mentioned benefits. The model was based on the HEAT methodology (Götschi et al. 2020; Kahlmeier et al. 2017) and adapted to the local context after calibrating key model parameters for the City of Buenos Aires. The parameters include assumptions on value of time, value of a statistical life, mode split, traffic counts, shadow price of carbon emissions, and local pollutants, among others.

Health economic assessment tool for walking and for cycling

Since the literature review showed most benefits of bicycle lane interventions that can be monetized are related to modal shift from motorized modes to active modes, the following—which derive from modal shift—were calculated: (1) health benefits associated with increased physical activity; (2) changes in the rate of road crashes involving cyclists; (3) reduction in GHG emissions; and (4) travel time savings. To estimate the expected modal shift from automobile travel to cycling, capture probabilities were applied to expected demand. In the Buenos Aires model, different scenarios were generated based on secondary data and sensitivity analysis. In other cases where data from stated preference surveys is available, the probabilities of switching to active modes could be estimated with discrete choice models. The input parameters are as shown in **table 1**.



Active Mode Appraisal Toolkit User Guide

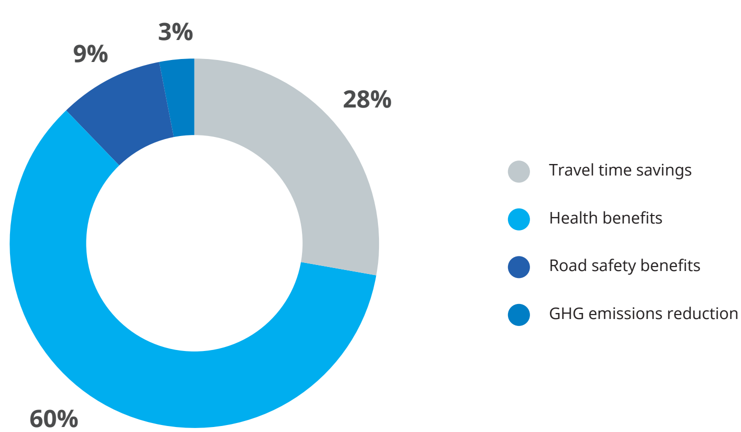
Table 1. Parameters to Evaluate the Avenida Córdoba and Avenida Corrientes Bicycle Lanes

Variable	Value
Length of the bicycle lane network before project implementation	247.4 km
Length of the bicycle lane intervention	17.0 km
Total investment	US$177,000
Annual maintenance cost (share of capital cost)	10%
Year of implementation	2020
Horizon of cost-benefit analysis	2040
Additional daily cycling trips	4,690
Proportion of cycling trips reallocated from other routes	20%
Discount rate	10%
Annualization factor (days to year)	300

Source: Original calculations produced for this publication.

The results of the cost-benefit analysis reveal a sizeable economic rate of return of 113 percent, with total benefit of US$1,880,000 and an associated cost of US$330,000 for the implementation and maintenance of the evaluated bicycle lanes—calculated in net present value. With a large benefit cost ratio of 5.7, the socio-economic benefits are in reality smaller compared to a similar study of bicycle lane interventions in Lima, Peru (Decisio 2020), which resulted in a cost-benefit ratio of 19.0. Health benefits from travelers shifting to bicycles from automobile travel represented 60 percent of the total benefits, followed by travel time savings (28 percent), road safety benefits (9 percent) and GHG emissions reductions (3 percent) as shown in **figure 4**.

Figure 4. Share of the Benefits of the Avenida Córdoba and Avenida Corrientes Bicycle Lanes, in Net Present Value



Source: Original figure produced for this publication.

A sensitivity analysis was carried out by assessing different assumptions on: (1) cycling demand generated by the new bicycle lanes; (2) proportion of demand reassigned from other routes; (3) value of a statistical life; (4) value of time; and (5) diversion factor for demand switching to cycling from walking. Results show that total benefits are more sensitive to the changing the expected cycling demand triggered by the project. In all sensitivity scenarios, the economic rate of return was above the discount rate. A stress analysis was also carried out to understand how parameters should change so that the economic feasibility of the project reaches a breakeven point, with a benefit-cost ratio of one. This would require all five parameters listed above to simultaneously decrease or increase by 55 percent toward more adverse values. Therefore, Avenida Córdoba and Avenida Corrientes bicycle lanes are almost certainly socially profitable even in the most adverse scenarios estimated with the model.

Discussion

Bicycle lane infrastructure plays an important role in urban mobility, in support of an efficient, equitable and gender inclusive transport system. Cycling provides benefits in terms of accessibility, physical fitness, transportation safety, and environmental benefits, among others. Expanding and improving bicycle lane infrastructure benefits existing cyclists, encourages mode shift toward cycling, and improves the overall transport system, including travelers in automobiles and public transport.

In the city of Buenos Aires, cycling as a means of transport has increased significantly over the past decade, aligned with a significant expansion of the bicycle lane infrastructure. In particular, in 2020 during the COVID-19 pandemic, bicycle mode share increased to an estimated 10 percent (OMSV 2021b), up from 4 percent in the prepandemic period.

Most urban areas have been recently expanding the network of bicycle lanes; however, very few investment decisions are based on rigorous socioeconomic evaluation. To understand the social and economic benefits of cycling infrastructure, a methodology was developed and applied to the recent bicycle lane interventions in Avenida Córdoba and Avenida Corrientes in Buenos Aires. This comprehensive evaluation assessed benefits in terms of health, travel time, road safety, and emissions reductions. The results indicated very large rates of economic return, consistent with the range of values obtained for the cost-benefit analysis of cycling infrastructure in other countries (Davis 2014; DfT 2015; Decisio 2020).

It is important to highlight that even for the calculation of benefits with broadly accepted methodologies, there are often limitations associated with data availability. For example, data to support the calculation of parameters for cost-benefit analysis—such as mode shift based on discrete choice models and demand data based on reliable traffic counts on the corridor of the bicycle lane—on the area of influence of the bicycle lanes, and in control areas. It is recommended that in preparation for cost-benefit analysis, data gaps must be assessed and new data must be collected to validate and estimate key parameters.

While some benefits of cycling interventions are relatively easy to monetize, other benefits that include quality of travel and user enjoyment, noise reduction and—more broadly—labor market outcomes, option value, support toward equity objectives, and more compact and accessible land use, are more challenging to quantify though do require a qualitative presentation. Altogether, the benefits are multiple and synergistic, and support the justification of much needed expansion of bicycle infrastructure.

Acknowledgments

This article was prepared with inputs from a World Bank study developed by the Steer Group in September 2021, *Social Cost-Benefit Analysis and Evaluation Framework for Active Mobility and Road Safety in Buenos Aires, Argentina*, written by Alex Mitrani and Ester Villavicencio. The authors are grateful for the inputs and guidance received from Mariana Sanguinetti (government of the City of Buenos Aires), Verónica Raffo, Liljana Sekerinska and Felipe Targa (World Bank), and Claudia Adriazola-Steil (World Resources Institute).

References

Authors: Wenyu Jia and Edward Andrew Beukes, **The World Bank**

Transit Reform in Small Southern African Cities: Using Mobile Technologies to Identify Potential Improvements for Paratransit Services

The rise and widespread adoption of mobile phone technologies have opened the opportunity for using low-cost, agile data collection and analytics platforms for paratransit diagnostics. This article documents a World Bank transport team's diagnostic work and key findings on the paratransit sector in two small Southern African capital cities, Maseru, Lesotho, and Gaborone, Botswana. By combining the latest mobile application-based digital platforms for data collection and diagnosis with more traditional transport survey approaches, the work advances the World Bank's understanding of the complexity of the paratransit sector in African cities and sheds light on viable approaches to improving the quality of public transport in these small city contexts.

The diagnostics revealed the extensive minibus and 4+1 sedan taxi (4+1) networks in both cities are operated at the cost of limited operating hours, poor accessibility, low service quality, and higher road safety and personal security risks. In the absence of network and operations planning, the lack of a clear hierarchy for network routes between modes results in excessive service overlaps and destructive competitive behaviors. Minibuses in both cities and sedan taxi in Maseru are well past typical service life—in excess of 16 years—poorly maintained and generate large quantities of pollutants. Paratransit terminals lack amenities, security, and basic operations management, leading to the unsafe mix of passengers, pedestrians, vendors, and constant vehicle flows. Female riders are disproportionately impacted by the lack of security when traveling in the evening (3 p.m. and later), which impedes their accessibility to various opportunities. Based on the assessment, the study identified short-term opportunities that would help the government and the sector make meaningful incremental improvements in the sector and in the quality of urban mobility.

Completed via mobile-phone apps, data collection over the four key study aspects—operations, vehicles, facilities, and users—was largely conducted in February and March 2021, after the governments of Botswana and Lesotho eased COVID-19 lockdowns. Prior engagement with the city councils and paratransist associations greatly

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facilitated the field work, and even allowed the team to include associations members as part of paid survey enumerators, effectively transferring skills and knowledge on the ground.

The analytics assess the current strengths and weaknesses of the status quo in the paratransit sector in these cities through the lens of four key stakeholders: the public authority, the operator, the driver, and public transport passengers.

The authors thank Justin Coetzee, Philip Van Ryneveld, and Donna Schulenburg for their critical contribution on field work and diagnostics, the Digital Development Partnership (DDP), and the Public-Private Infrastructure Advisory Facility (PPIAF) for funding the project, and Maria Marcela Silva, World Bank practice manager for transport, for the Ethiopia and Southern Africa region, along with country representatives in Botswana and Lesotho for their support and advice.

Context and Rationale

Sub-Saharan Africa (SSA) is the world's most rapidly urbanizing region. The urban population is approaching 500 million and is expected to double over the next 20 years. In 2000, one in three Africans lived in cities and by 2030, an estimated one in two Africans will live in urban areas. This growth is not only driven by the lure of burgeoning urban economies, but often also by poor employment, social, environmental and deteriorating security conditions in rural areas. Meanwhile, the region faces unprecedented climate stress, and is anticipated to warm 1.5 times faster than the global average. African cities are set to expand even faster, as declines in rural productivity including lower crop yields stemming from climate change will further accelerate urbanization—especially among the poor and unless urgent actions are taken—African cities and city dwellers will suffer disproportionately from climate change.

Paratransit has developed largely organically in SSA cities, driven by local entrepreneurial responses to local needs and conditions. While the United Nation's 2030 Sustainable Development Goals (SDGs) and climate goals call for the development of public transport systems that are "safe, affordable, accessible, and sustainable . . . for all," the quality of urban transport infrastructure and services in the region have lagged behind the fast-growing mobility demand driven by the global trend of urbanization. In response to the dire need for transport services amidst a lack of formal transit options, various forms of paratransit services have proliferated in the SSA cities, including the traditional minibus taxi (MBT) and more recently also the "4+1" sedan taxi, and motorcycle taxi. The term "paratransit" generally refers to a flexible transportation mode that does not follow fixed schedules and operates to a large extent in the informal economy, as opposed to formal public transport (which, in many cities in the region, is nonexistent) that operate as registered, well-regulated businesses. **Figure 1** shows typical examples of MBT and 4+1 sedan taxi's (4+1) and **figure 2** shows that in most SSA cities paratransit comprises the bulk of the public transport mode share.

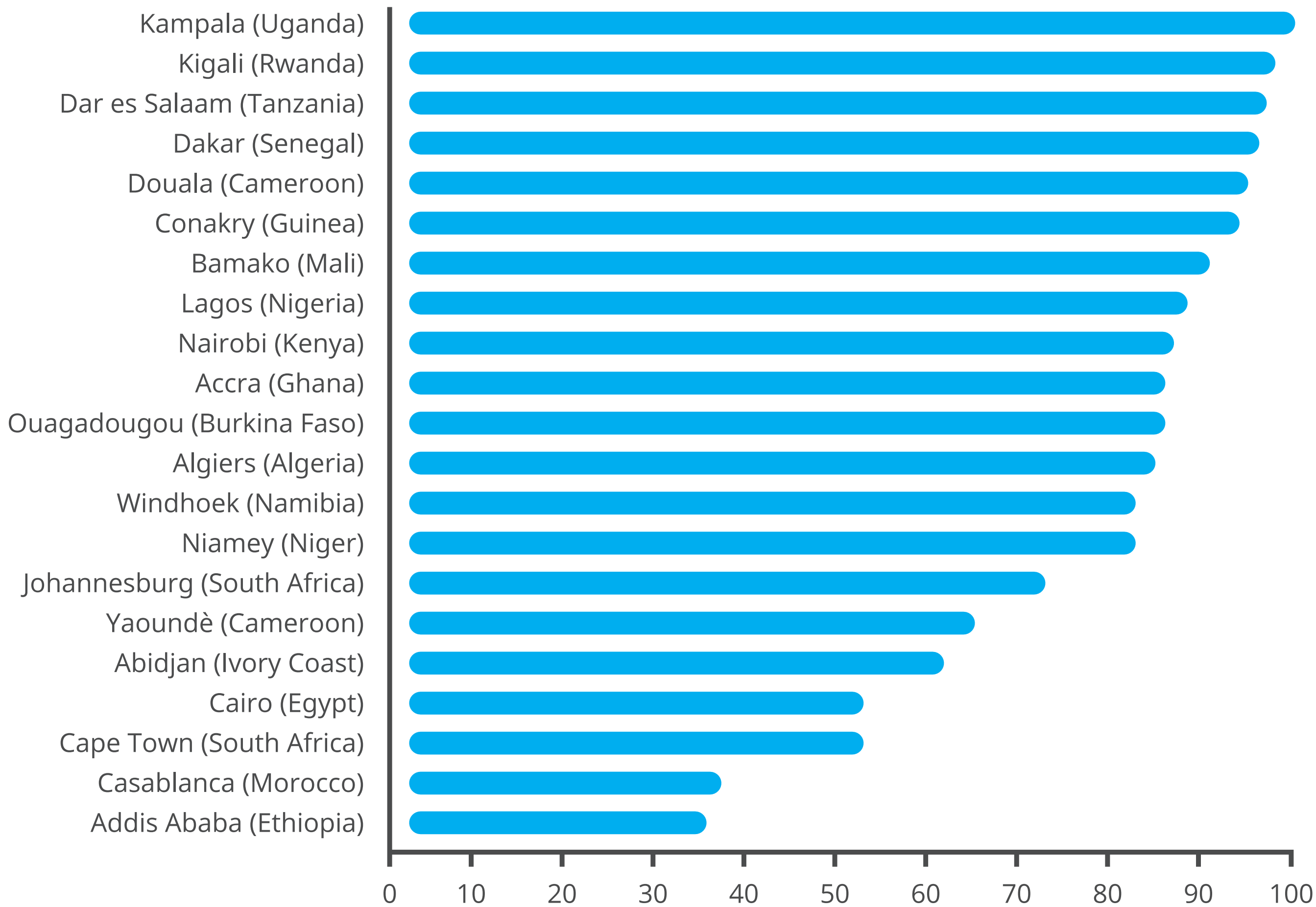
Figure 1. Minibus Taxis and 4+1 Sedan Taxis in Gaborone and Maseru

Gaborone

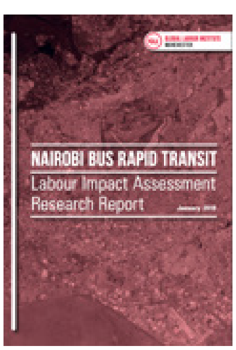
Maseru

Source: Original photos produced for this publication.

Figure 2. Paratransit Mode Share in Sub-Saharan African Cities



Source: Bruun and Behrens 2016.



Nairobi Bus Rapid Transit Labor Assessment Study

The popularity of paratransit stems from its demand-responsive business model; however, this success comes at the cost of societal externalities. Paratransit businesses are informal, fragmented, and unregulated, leading to outcomes that do not always serve passenger needs and interests, the development of the work force, or promote long-term sustainable urban transport imperatives. Vehicles tend to wait at terminals until full before departing, forcing long wait times especially in interpeak periods, touting for passengers at terminals and along routes—which increases congestion—and imposing safety hazards. Pervasive inequality is rampant in the paratransit sector; as per the *Nairobi Bus Rapid Transit Labor Assessment Study* (ITF 2018), while profitability is acceptable for owners, drivers and supporting crews earn very low wages, work long hours, and are largely untrained.

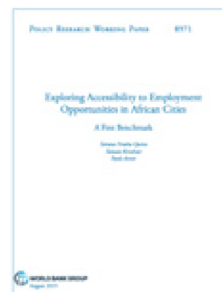
Previous attempts at formalization have achieved limited success. Over the past decade or more various development institutions have recommended the implementation of formal mass transit systems to replace paratransit in some SSA cities, usually some form of bus rapid transit (BRT). However, according to a 2020 working paper produced by World Bank Transport, "Synopsis of Bank-Funded Bus Rapid Transit Projects" (Jia et al. 2020), success has been limited. This is partly because decision makers and planners largely focused on the technical aspects of the new systems such as vehicles and infrastructure, but insufficiently understood the context in which they work, including market dynamics, and the institutional, financial, and managerial challenges. Many hold overly simplistic views as to how transformation might be achieved, often stating the paratransit sector must be "formalized" to address its shortcomings. This could be a result of the change, but it is not easily achieved, and a poorly executed process of formalization could lead to a worsening, rather than an improvement, of the quality of services.

Building incrementally by improving the existing paratransit system has the potential to reduce the risk of transport system development failures through capital-intensive initiatives. It also offers greater scope for existing operators to build skills and develop as participants in a new system rather than be replaced and displaced by a new supersystem. This incremental approach requires first developing partnerships with existing operators to build an understanding of the forces that drive them before making recommendations for improvement. To do this, however, requires data to develop a thorough understanding by the government and the paratransit sector of the trengths and weaknesses of the prevailing business model, and the potential opportunities to improve for the benefit of all. However, the lack of data on paratransit in SSA hampers efforts on these important conversations and steps. In the World Bank working paper, "Exploring Accessibility to Employment Opportunities in African Cities," researchers found the largest obstacle faced by the study was the lack of data on urban transport (Peralta-Quiros, Kerzhner, and Avner 2019).

Paratransit data brings important benefits to city authorities and transport operators. With better information on the mobility patterns of people, city authorities have more opportunities to act on mobility improvements that generate social and economic benefits and to make informed decisions in terms of urban transport infrastructure and service planning to better serve citizens and businesses. Understanding the extent and operations of the paratransit network is especially important for cities where people rely on these modes to reach jobs, education, and other opportunities.

The popularity of paratransit stems from its demand-responsive business model; however, this success comes at the cost of societal externalities.

Synopsis of Bank-Funded Bus Rapid Transit Projects



Exploring Accessibility to Employment Opportunities in African Cities

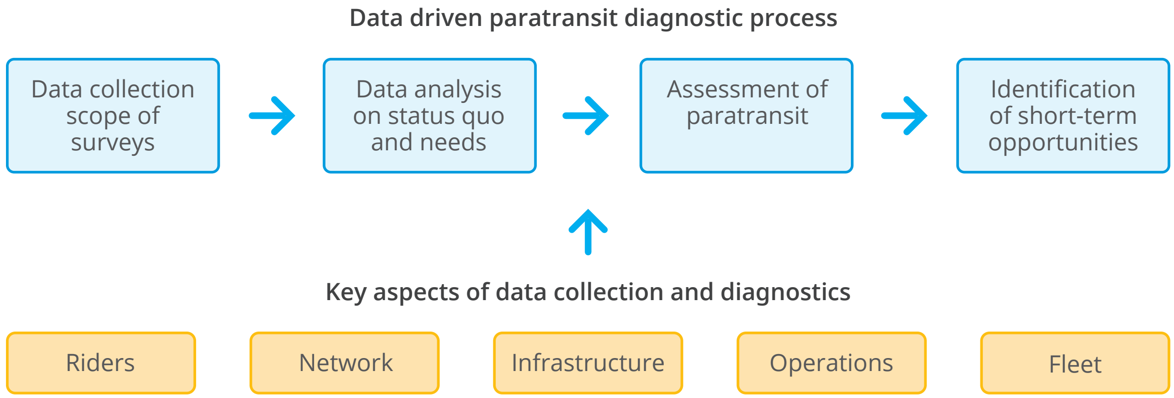
Approach and Methodology

App-based mapping technologies. In the past five to seven years, mapping projects have emerged in various African cities, such as the Digital Matatus and Mapping Accra projects. Companies and services have emerged, producing General Transit Feed Specifications data that describe the paratransit network of a city. At a basic level, mapping includes collecting spatial data on routes and stops and building a record of stop names, stop infrastructure, interchanges, and route pricing. A more advanced level of mapping includes temporal data on service frequencies and operating times, and the creation of estimated timetables incorporating expected trip durations.

Advancing mapping into operations diagnostics. While these digital mapping projects have tended to make an impact on raising the awareness and create visual representations of paratransit networks, they have not necessarily led to any significant direct changes in paratransit operations, improved mobility, or in providing real value to the users of paratransit systems. What is needed, rather, is to combine advanced mapping with proven public transport data collection practices and methods as well as a profiling of operations and the structures governing them to provide a diagnostic review of a paratransit service. Paratransit data collection and analysis is not novel in terms of its assessment of the familiar parts of a public transport system—the vehicle, the route, the stop and the passenger—but it is more challenging due to the fragmented and largely unpredictable behavior of the elements within the system. Using conventional analysis alone is therefore inherently limiting.

The study team formulated an approach that combines mobile app-based collection technologies and conventional transport data categories, such as rider satisfaction, waiting time and stated preference surveys. As shown in **figure 3**, the data collection and diagnosis methodology follow a logical progression of steps. The methodology starts with data collection, followed by an analysis of both the data and on-the-ground experience, and culminating in an assessment of key features that constitute important levers for paratransit reform in the city. These are carried out for five key areas of operations—the network, infrastructure, operations, fleet, and rider. In the case of mobile app-based data collection, an enumerator with a hand-held device interviews a rider waiting for a vehicle, even allowing her to enter her address on the device or point to her destination on a digital map. This data is immediately uploaded and available for assessment and analysis in the project back-office. This technique is low-cost, agile, and allowing for wide distribution in African cities—facilitating the collation of conventional baseline data other markets assume will be systematically collected. Additionally, the team invited paratransit association members to join the field data collection, effectively transferring this knowledge to the sector.

Figure 3. Study Approach to Paratransit Diagnostics



Source: Original figure produced for this publication.

Diagnostic Summary

The approach and the resultant diagnostic findings serve as a starting point for providing the relevant stakeholders with information on the operational characteristics—including strengths and shortcomings—of their paratransit system. By deploying the low-cost, agile mobile-app data collection and transport diagnostics, this study provides the relevant stakeholders, such as the different tiers of government and paratransit operators with information on the demand, supply, and operational characteristics of the paratransit system, over five broad areas: network, infrastructure, operations, fleet, and riders, as shown in **figure 3**. This diagnostic summary advances sector knowledge, deepens the understanding of the sector status and potential improvement needs, and demonstrates how innovative data techniques and diagnostics can be used to develop approaches that support any attempts at reform with detailed, empirical data.

City overviews

The project was conducted in two small capital cities in the SSA region, namely Gaborone, capital city of Botswana, and Maseru, the capital of Lesotho. The work focused on these two cities in particular because very little was known about the state of public transport in these cities and ongoing operations had already established a relationship between the World Bank and the ministries of transport in each country. Additionally, the team was interested in exploring the developmental options for smaller and secondary African cities, and despite Gaborone and Maseru both being capital cities, they are representative of many small African cities—with Gaborone being comparatively prosperous, and Maseru being poor.

Maseru is the capital city of Lesotho and Gaborone is the capital city of Botswana; both cities, shown in **figure 4**, are also the economic powerhouses of their respective countries. The city of Gaborone has a population of 234,775 (2017) and Maseru 330,760 (2016 census). While both cities have low levels of motorization, as measured by registered vehicles per capita, congestion is already disproportionately problematic (for cities of this size) with long queues at key intersections at peak times of the day. This congestion stems from a lack of effective traffic management and a road network that offers few alternatives to key chokepoints on the network. Both cities have road networks and already oversaturated infrastructure in peak hours, too constrained by the urban form as well as resources—and in Maseru's case, the topography—to allow for extensive upgrading of the existing road network.

Figure 4. Skylines of Gaborone and Maseru

Gaborone

Maseru

Source: Just a Brazilian man

Source: John Hogg/World Bank

Governance and regulation

The public sector institutional environment is fragmented in both cities, with no clear responsibility for public transport in either case. At the local level in both cities the urban footprint spills over into neighboring districts. Additionally, in both cases municipalities largely lack relevant powers, with key responsibilities for public transport spread across a number of national-level ministries or departments. For instance, the departments in charge of planning and licensing within the ministries have no functions for network planning, operations design, or service monitoring. This lack of effective regulatory controls has contributed to the proliferation of operators and excessive competition among operators, which helps explain some of the challenges presented by the sector in these cities. It also leads to the pernicious culture of viewing transit primarily as a source of taxes, with control over aspects of the service representing valuable revenue streams for authorities.

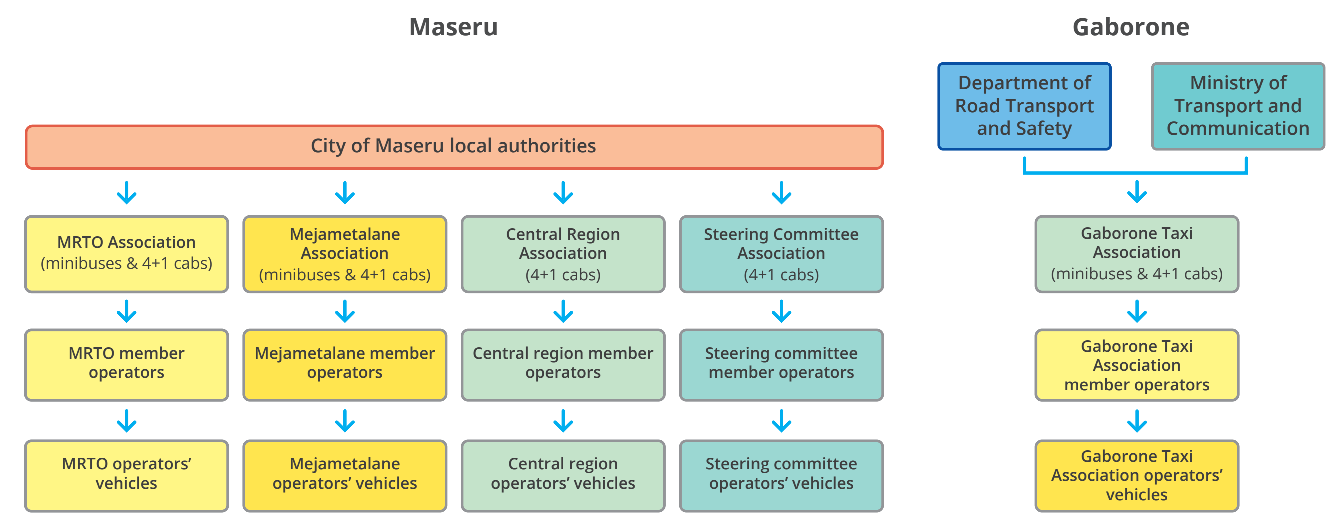
Paratransit regulatory oversight and budgeting for transport development is situated at the national level for both countries. The national departments of transport for both Lesotho and Botswana oversee policy for the public transport sector as well as managing the funding for projects and initiatives. The city governments have smaller roles in implementing regulations or in managing permitting and do not have the necessary funding streams local authorities would usually need to have an impact—and so city governments are often incapable of fulfilling their planning and developmental responsibilities as local authorities.

Paratransit ownership and organization

The fragmented authority over modes and ownership of vehicles in both cities results in individualistic operators and compromises the creation of an organized system. Operators typically have one or two permits, which could be operated by the owner and/or by a family members or close friends. The 4+1 sedan taxis are typically owner-drivers with owners as the registered operator on the permit. In Maseru, of the permits issued to MBT operators, 61 percent are issued to individual operators who have no more than two permits. For 4+1 sedan taxis, 93 percent of all permits are issued to individual operators, while in Gaborone, more than half (56 percent) of all permits issued to paratransit operators are to minibus-taxis, 37 percent to 4+1 sedan taxis, and the remaining 7 percent to bus operators.

As shown in **figure 5**, Maseru has developed separate industry structures for minibus and 4+1 sedan taxis. In contrast, the Gaborone Taxi Association is the only taxi association in the city of Gaborone. Membership is voluntary since no legislated requirements exist for operators to belong to associations. Institutionally, no distinction is made between a MBT operator or a 4+1 sedan taxi operator in both cities' member associations. Operationally and practically, though, the two modes do operate separately.

Figure 5. Organization of Paratransit Systems in Maseru and Gaborone



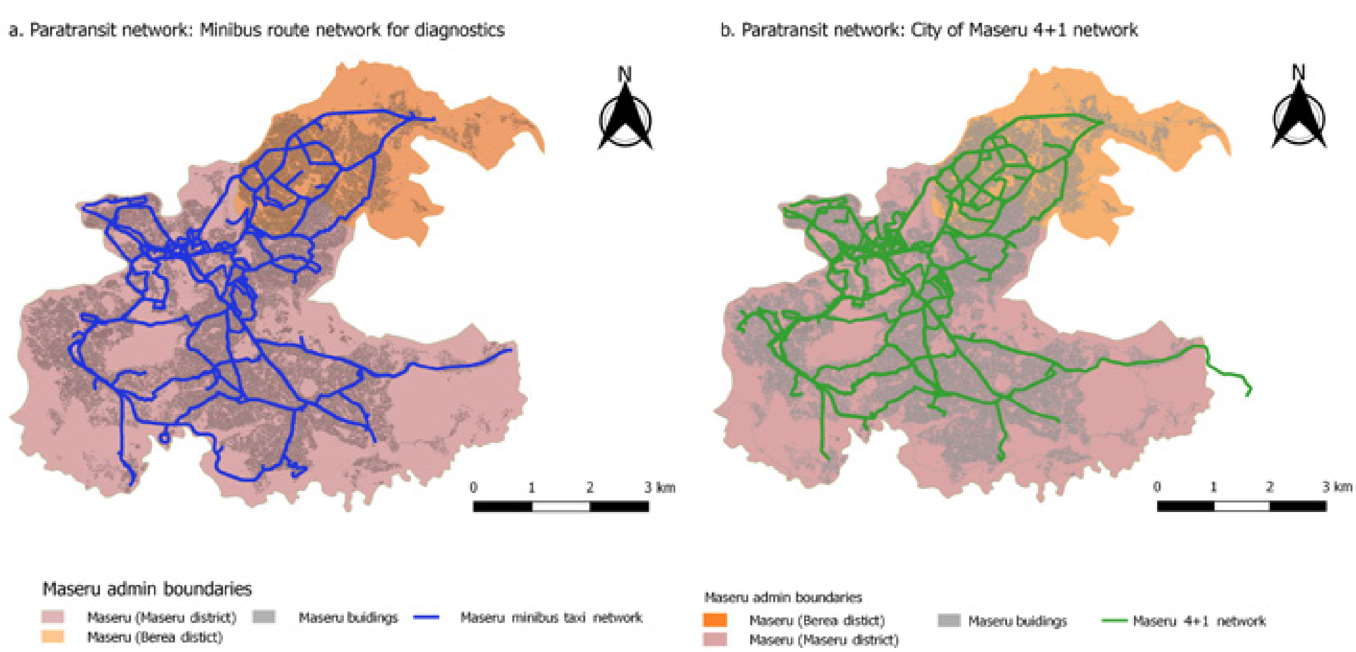
Source: Original figure produced for this publication.

Paratransit network

With no clear hierarchy of network routes or the determination of fares for minibus and 4+1, excessive service overlaps and destructive competitive behaviors often result. In both cities, minibus and 4+1 cabs operate on the same popular routes, compete for the same customers, and erode efficiency and profitability, more so in Maseru than Gaborone. Minibuses in Maseru continue to lose market share to the 4+1 sedan taxis because passengers have to wait less time to get into 4+1s and reach their destination. This drives a vicious cycle of declining service quality on the minibus operators, who compete with an expanding pool of operators, forcing them to abandon marginal routes and operating times in favor of more profitable routes and peak hours only, which in turn makes 4+1 sedan taxis the only viable option for many origin-destination (OD) configurations. Both the Gaborone and Maseru minibus networks are very poor in terms of frequency of services throughout the day, and both cities offer very infrequent services for most suburbs and regions. This destructive competition exemplifies the so-called, "race to the bottom," and ultimately leads to worsening conditions for passengers and the operation of the road network. **Figure 6** depicts the route overlap between MBT (panel a) and 4+1s (panel b) in Maseru.

In Maseru, the ongoing steady growth for 4+1 cabs erode the MBT market share, without any structured intervention by the transport authority. The mid-day frequency can go as much as 1 to 2 hours for minibus passengers along certain routes. This gap in services has been filled by the 4+1 sedan taxis who can offer relatively frequent and direct services, furthering reducing service quality of the MBT and driving the uptake of the 4+1 taxi in Maseru.

Figure 6. MBT and 4+1 Taxi Networks in Maseru



Source: Original figure produced for this publication.

In Gaborone, 4+1 sedan taxis are not yet considered a threat to the MBT industry; however, it is expected that competition will intensify as more 4+1 newer fleet sedan taxis enter the market. A major reason why 4+1s are not threatening the MBT market share in Gaborone is the unique "sleeping" arrangement of minibuses in villages to support a daily commute from village to capital that would not be economically possible with a fleet of 4+1 sedan taxis. This has preserved the MBT market share in Gaborone, but it is not an indefinitely defensible beachhead. As more 4+1 sedan taxis enter the market, competition for passengers will inevitably drive further erosion of market share.

Transit terminals

As the source of much customer dissatisfaction, paratransit facilities stand in dire need of improvements (see **figure 7**). In Maseru, all 4+1 sedan taxi terminal facilities are unpaved and informally organized, with crumbling, potholed surfaces. MBT terminals are paved with brick and concrete blocks but are in a poor condition due to a lack of maintenance. In addition, none of the facilities offer any public amenities, such as washrooms. While all facilities have informal trading within and around the periphery of the facility, only two facilities have dedicated shelters and lockup space for informal traders. At Metro terminal, the city's centrally located MBT facility, one single entrance and exit point is shared by vehicles and pedestrians. This poses a road safety risk to pedestrians and paratransit operations. The road infrastructure needs in Maseru are even more pressing, with the city's feeder roads remaining largely unsurfaced. This has a significant impact on operating costs since high rates of wear and tear are experienced by vehicles operating in those conditions. In addition, given the high costs of providing services for operators, some outlying areas are not served by informal paratransit, leaving many communities without easy or reliable access to

Figure 7. Transit Facility Conditions in Gaborone and Maseru

Gaborone | **Maseru**

Source: Original photos produced for this publication.

motorized transport. In Gaborone, while infrastructure conditions are better, with paved surfaces and vendor stalls, maintenance is neglected and sanitary conditions are poor. The BBS Mall area facility is an open earthen space devoid of any facilities whatsoever. During the rainy season, the facility is usually flooded, impeding easy navigation by both operators and passengers. With no platforms of any kind, the facility has only a surfaced apron, and while there are sidewalks, these are crowded with informal trading stalls, forcing pedestrians into the carriageways which slows down vehicles entering and leaving the facility and affects its operating efficiency. Approximately 90 percent of roads used by informal paratransit vehicles in Gaborone are unsurfaced and inadequately maintained.

Operation model

Most MBT operations consist of no more than two vehicles owned by a family and are typically driven by family members. Vehicles not driven by owners typically operate on either a commission or target-based business model. In the commission model, drivers are remunerated a percentage of the daily vehicle revenue; in the target-based model, drivers are given a daily target by the vehicle owner and earn the difference between the daily target and daily vehicle earnings.

With tight operating margins, many operators can't afford regular preventative maintenance on vehicles.

In Maseru, the commission model dominates, while in Gaborone the target-based model dominates. Since paratransit services are cash-based, with no tickets being issued, owners have no way of verifying revenue generation each day, increasing the risk of drivers under reporting revenue.

During peak periods, MBTs operate fixed-route services, traveling between two terminals. The MBT and 4+1 sedan taxi operators follow the market practice of queuing in the designated traffic terminals and touting for customers along the allocated route. During off-peak periods, many operators deviate from their primary route to serve neighboring suburbs along their route. MBT vehicle capacities range from 10 to 18 passengers.

Given the informal, fragmented nature of MBT and 4+1 cab operations, most operators do not keep records of their operating expenditures. Further, in the absence of regulated operating permits, competition between drivers is high, making it very difficult for operators to turn a profit. MBTs do, however, generate higher earnings per kilometer than sedan taxis, since sedan taxis run far more circuitous routes and carry fewer passengers, making them less efficient. With tight operating margins, many operators can't afford regular preventative maintenance on vehicles. As a result, repairs might only be performed when components fail to the extent that the vehicle cannot be driven. This not only results in vehicles being out of service for longer periods, losing revenue, but also leads to greater damage to the vehicle and higher maintenance costs over the long term.

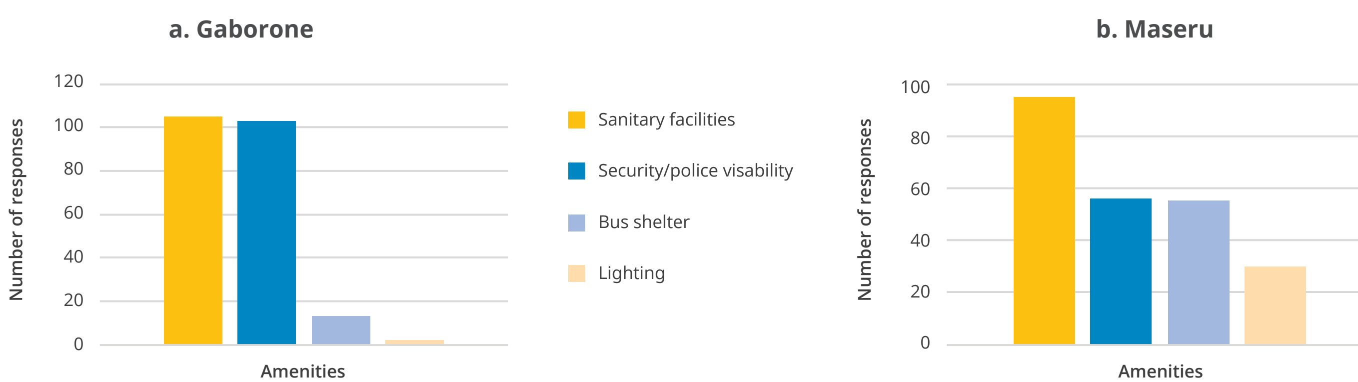
Old fleet

The average age of the fleet is high, with minibus vehicles well beyond their typical service life in both Maseru (18 years) and Gaborone (16 years), and also poorly maintained and highly polluting—posing road safety hazards, and contributing to air quality degradation. In both cities, the most popular MBT vehicle model is the older generation Toyota HiAce, generally sourced used from South Africa and the Japanese second-hand markets. These vehicles tend to have high mileage and are kept on the road with minimal ad-hoc maintenance. Most minibus models are not aligned with modern safety and emission standards. The 4+1 sedan fleet in Maseru is also very old (more than 15 years for many models) and imported as second-hand cars from markets such as Japan. These vehicles also do not adhere to modern safety and emission standards. Upon arrival they are already almost 10 years old, with high mileage, and are then driven hard until they have fallen apart completely and the cost of repair exceeds the benefits of continued operation.

User experience and gender issues

Paratransit users in Maseru and Gaborone are generally low-income individuals with no other means of transport. In Maseru, 26 percent of respondents are formally employed, 47 percent earn less than US$230 a month and 63 percent do not own cars. In Gaborone, the socioeconomic profile is similar: 64.8 percent of respondents are formally employed, 54.2 percent earn less than US$290 a month and 35.2 percent have no cars. Work is the dominant trip purpose, followed by education and personal trips. During the morning peak period, 70 percent of passengers using paratransit in Gaborone are traveling to work, while in Maseru the figure is 47 percent. Riders in both cities showed dissatisfaction with the comfort and condition of the vehicles and terminals, as shown in **figure 8**, panels a and b. Improving the comfort and conditions of the public transport terminals and interventions to improve the quality of the fleet would not only benefit the sampled users, but could also attract other choice users in both cities.

Figure 8. Facility Experience in Maseru and Gaborone



Source: Original figure produced for this publication.

Female riders are disproportionately impacted by the lack of security. In Maseru, the majority of riders are female (57 percent) and don't feel safe (71 percent) when traveling in the evening peak. They prefer to travel during midday when more people are on the roads and there is a lower chance of being harassed or intimidated. In Gaborone, slightly more than half of paratransit passengers (51 percent) are female riders and of these, 84 percent of do not feel safe traveling in the evening.

Short-Term Opportunities

The outcomes of the diagnostic summary in Gaborone and Maseru demonstrate the practicality of the diagnostics, reveal strengths, weaknesses, and identify short-term opportunities, which can serve as the foundation for meaningful dialogue among key stakeholders. Highlighted opportunities identified from the diagnostics include:

Institutional improvements and readiness. The implementation of any initiatives requires better organization within the paratransit sector and improved institutional capabilities in the public sector for both cities. One problem faced by cities all around the world is the fragmentation of authority over the key factors required for successful urban public transport governance. Both Gaborone and Maseru have multiple local authorities responsible for different areas of the city. They also face fragmentation between local and national government and through the proliferation of departments responsible for the various aspects of public transport.

Both Gaborone and Maseru demonstrate a need to define the key locus of responsibility for public transport. Ideally this should be placed with the city government, which is largely responsible for local roads and land-use planning. Wherever such locus of responsibility is located, strong relationships should then be built with any other public sector agents that have responsibilities affecting public transport, such as development control and traffic police. This key locus of responsibility should be where strategy is developed; permitting and revenue and investment management is centralized and leadership can be exercised in the improvement of public transport, supported by the various other agencies. The key initiatives presented in this article should be driven from here, wherever feasible.

Regulatory reform requires an efficient and up-to-date database of vehicles, permits, and owners designed to counter unlicensed operation and fraud and be used effectively both for supporting the paratransit sector as well as enforcement. Greater attention needs to be given to the regulation with regard to safety, security, and comfort across a range of indicators, along with a better matching of supply with demand. The latter will require gathering good information on an ongoing basis on operations, especially including waiting times at different times of the day. A methodology will need to be developed to calibrate the issuing of licenses based on supply and demand statistics. Where sufficiently short headways can be achieved by MBTs, the presence of 4+1 taxis should be limited by regulation, enforcement, and pricing. The need to balance supply and demand also underpins the need to centralize permitting within the authority that manages urban development.

Business model reform. Once a more structured dialogue is established with and within the paratransit sector, and better information is available on an ongoing basis about the match of supply and demand, the issue of more substantial business model reforms can be brought onto the agenda in each of the cities. Such change will require leadership from the paratransit industry and facilitation from the authorities. The creation of companies to support the collective purchase of inputs or to capitalize on opportunities elsewhere in the value chain—other than the provision of the services themselves—can assist in building the skills required for more substantial business model reform. These initiatives should be undertaken by paratransit leadership supported by authorities.

Paratransit infrastructure improvements. A tarred road network expansion plan can be developed in conjunction with the definition of an official paratransit route network in Maseru, to enable paratransit services to access terminal areas more easily and efficiently. While paratransit will tend to stop along the route according to rider requirements, locations of frequent boarding and alighting should be identified, and infrastructure provided to enable safer pulling over and protection of users against the elements. Pedestrian facilities inside terminals and on the roads leading to terminals should be provided to ensure clear separation between vehicles and pedestrians, passengers, and vendors. In Gaborone, a proposed paratransit route network expansion plan would be developed in conjunction with a road network infrastructure maintenance plan. Notably, bus priority lanes and a centrally managed signaling system have been recently developed to mitigate against deteriorating congestion. However, Gaborone is yet to develop a bus lane access policy and has made no progress on its plans for introducing formal public transport services. It is not clear how these bus lanes will be managed in the interim.

Fleet renewal. If the public resources are available, authorities in both Gaborone and Maseru could consider the introduction of a capital subsidy, such as through a scrapping program, to assist in fleet renewal in exchange for certain operating concessions by the industry, for the public good. Capital subsidies should be granted only in conjunction with the scrapping of old vehicles and should be designed with conditions that help improve the efficiency of the sector, such as evidence of a valid operating permit.

Cleaner paratransit for cleaner air. Since the fuel available is already able to support EURO 4 emissions standards, EURO 4 emissions compliance should be the minimum permitted for all new and used imported vehicles. Within the sector, lower emissions are achievable through better vehicle technologies and by means of recapitalizing the fleet with newer, less polluting vehicles. Another most important factor for air quality improvement: an improved paratransit service can help slow down the pace of people shifting from public to private transport, as urbanization and motorization pick up pace in SSA cities.

References

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Financing and Funding Bus Electrification: How to Address the Viability Gap?

Driven by the need for decarbonizing the transport sector, the emergence and fast development of battery and vehicle technologies make electric buses (e-buses) an option to serve the urban transport demand. Globally, the electric bus market is projected to grow from 81,000 units in 2021 to 704,000 units by 2027, at a compound annual growth of 43.1 percent, and reflecting the fastest-growing part of the electric vehicle market. However, the purchase cost of an e-bus can be double or triple of that of a diesel bus depending on jurisdictions. High capital costs for electric buses, charging infrastructures, and ancillary facilities in comparison with traditional combustion engine buses indicate the necessity to explore viable financing

This article identifies the key elements of the financial viability of bus electrification and explore the solutions to address the viability gap.

and funding mechanisms for the adoption of e-bus, particularly for the cities in developing economies facing fiscal constraints, fast-growing mobility demand, environmental and climate change challenges, and insufficient readiness for private participation.

This article identifies the key elements of the financial viability of bus electrification and explore the solutions to address the viability gap. The first section of the article summarizes the existing financing and funding mechanisms of e-bus services in different cities, analyzing sources and conditions of financing and associated institutional and contractual arrangements. The article also introduces international experience and lessons learned on capital and ownership structure, financial incentives, and subsidies as well as benefit allocation and risk-sharing schemes.

The second section of the article makes recommendations to improve the financial viability of e-buses in developing economies and on how multilateral development banks (MDBs) can help. Based on the first part and the feedback from public and private stakeholders—the study team maintains a list of interview/survey respondents with experience and potential interest to participate in this work—such as public authorities, banks, leasing companies, bus and battery manufacturers, and charging infrastructure service providers and operators, this section will explore how government policies and typical instruments of MDBs can assist cities and the private sector in de-risking bus electrification, optimizing life-cycle cost and benefit, and making e-buses more financially viable and sustainable.

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Introduction

The number of electric buses (e-buses) in service has grown quickly in cities with various development stages, sizes and geographies. The global electric bus market is projected to grow from 81,000 units in 2021 to 704,000 units by 2027, at a compound annual growth of 43.1 percent (Bloomberg 2021).

Multiple factors are driving the deployment of e-buses, mainly policy shifts and technology advances. Motivated by low carbon development and reducing air pollution, many countries have been shifting policies from supporting private vehicles with internal combustion engines (ICE) to electrification and public transport. On the other hand, advancements in battery technologies and innovations in electric powertrains are bringing down battery prices and boosting vehicle performance. While the total cost of ownership (TCO) is highly sensitive to local circumstances, e-buses are approaching TCO parity with diesel buses in some cases, thanks to government subsidies, declining battery prices, and lower operation and maintenance costs of the e-buses.

The global electric bus market is projected to grow from 81,000 units in 2021 to 704,000 units by 2027, at a compound annual growth of 43.1 percent.

However, financing and funding e-bus projects in emerging economies remain challenging. Compared to their ICE counterparts, e-buses cost one to two times more to purchase, and the charging infrastructure and battery also impose additional capital expenditure (CAPEX), bringing extra stress to the constrained fiscal space in developing economies. The stability and availability of energy supply of e-buses are also often questioned by financiers, especially in developing economies. In addition, e-bus operation is relatively new for many traditional bus operators, which also leads to hesitation from financial institutions who typically provide credit for business as usual.

While challenges exist, opportunities also present themselves. Bus electrification is not just about bus operation and the bus operator, it also links to the whole urban mobility ecosystem and the e-mobility industry. Financing and funding of bus electrification, therefore, can involve more diverse players and there is space for innovation. While public financing prevails as the primary source for bus electrification, some commercial financings have been channeled through various mechanisms to address the gap between the cost and available fiscal budget, transferring certain risks from the government to parties better equipped to manage these risks. This article summarizes the experiences of these commercial financing models to provide recommendations to relevant stakeholders.

Comparison of Bus Electrification Financing Mechanisms

The global practices present five types of commercial financing models for the capital investment of bus electrification categorized by who are the major financiers bearing the financing risk transferred from the government. In practice, different approaches can be blended. In these commercial financing models, as analyzed in more detail in **table 1** and the subsequent sections, financing risks and asset ownerships are reallocated among the different stakeholders.

Table 1. Analysis of Bus Electrification Financing Models

<table>
<tr><th colspan="3">Model</th><th>Bus (excluding battery)</th><th>Battery</th><th>Charging infrastructure</th><th>Bus depot retrofit</th><th>Energy grid connection</th></tr>
<tr><td colspan="2" rowspan="2">1. Bus operator + charging service company financing model (London, UK)</td><td>Financing</td><td>Private bus operator</td><td colspan="3">Charging service company</td><td>Energy utility company</td></tr>
<tr><td>Funding</td><td>• Mileage-based payment from government
• Subsidy from national and subnational government</td><td colspan="3">• Charging payment and charging infrastructure lease fee from operator
• Grid-to-gate funding from transport authority</td><td>Payment from operator</td></tr>
<tr><td rowspan="4">2. Financial leasing company + charging service provider financing model (Shenzhen, China; Dalian, China)</td><td rowspan="2">2.1 Bus-battery separation leasing</td><td>Financing</td><td>Financial leasing company</td><td colspan="4">Charging service provider</td></tr>
<tr><td>Funding</td><td>• Lease payment from state-owned operator (guaranteed by charging service provider)
• Vehicle sale or production subsidy from governments</td><td>Lease payment from operator on battery</td><td colspan="3">• Charging fee paid by operator
• Charging subsidy from government</td></tr>
<tr><td rowspan="2">2.2 Bus outright leasing</td><td>Financing</td><td colspan="2">Financial leasing company</td><td colspan="3">Charging service provider</td></tr>
<tr><td>Funding</td><td colspan="2">• Lease payment from state-owned operator
• Vehicle sale or production subsidy from governments</td><td colspan="3">• Charging fee paid by operator
• Charging subsidy from government</td></tr>
<tr><td colspan="2" rowspan="2">3. OEM financing model (Kolkata, India)</td><td>Financing</td><td colspan="4">Original equipment manufacturer (OEM)</td><td>Energy utility company</td></tr>
<tr><td>Funding</td><td colspan="4">• Mileage-based payment from government
• Subsidy from government</td><td>Charging fee from OEM</td></tr>
<tr><td colspan="2" rowspan="2">4. Energy utility company financing model (Santiago, Chile)</td><td>Financing</td><td colspan="5">Energy utility company</td></tr>
<tr><td>Funding</td><td colspan="5">• Periodical payment for buses and charging infrastructure from system financial manager guaranteed by city transport authority
• Payment for energy from private bus operator</td></tr>
<tr><td>5. Other financing mechanisms</td><td colspan="7">(1) OEM installment: OEM sells e-bus equipment with zero or discounted upfront cost and amortizes the cost payment from buyers through yearly installment during operation, for example, Proterra (United States); BYD (China).
(2) Green financing facility as an aggregator for e-bus uptake: bus operators obtain financing at preferential rates and sourced through a capital pool by green financing facilities, for example, Tianjin, China; Gujarat, India.</td></tr>
</table>

Source: Original table produced for this publication.

1. Bus Operator + Charging Service Company Financing Model

Under this model, the bus body (without battery) is financed and owned by the bus operator, the charging service provider finances and owns the battery and charging infrastructure. The charging infrastructure provider also finances bus depot retrofit to facilitate charging and in many cases such depot is owned by the bus operator or the government. The energy grid connection could need upgrades due to the e-bus charging. The utility company finances the grid upgrades and is often paid by the operator through a direct payment, or as part of the charging fee allocated to the utility company from the charging service provider.

Decision makers could consider this model when the charging service provider has strong financing capacity and better technical capacity than the operator in managing the battery technology, and the operator has sufficient financing capacity to cover the capital cost of the bus vehicle. With capital investment in bus vehicles, the operator might prefer cost-recovery and investment return through mileage-based payment and additional subsidy from the government rather than fare revenue to avoid taking the demand risk. Similarly, the charging service provider requires dedicated funding from the government for their capital investment return, in addition to the charging payment and battery lease fee from the operator.

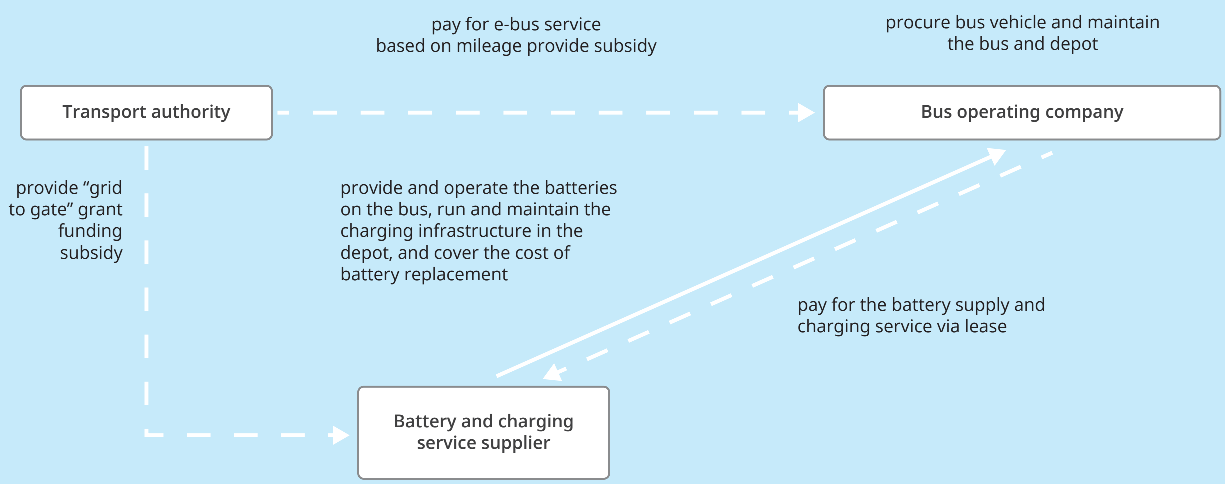
Box 1 presents an example of bus operator + charging service company financing model in London, United Kingdom.

Benefits	Disadvantages
• The cost of battery and vehicle body are split and shared by multiple parties • Direct involvement of charging service company can lower the cost of battery and charging service provision • The upfront cost of battery is converted to operation cost for operator • Lease payment for battery offsets taxable profits	• Bespoke requirements and technological compatibility issues between vehicle and battery • Ownership separation could add contracting complexity and transactional cost • This model could increase the entry threshold for small operators and charging service provider which have relatively weak financing capacity. • Operators could lack incentive to improve bus service, as their financial return is not directly linked to the bus ridership

Box 1. The Bus Operator + Charging Service Company Financing Model in London, United Kingdom

In London, Zenobē Energy, a charging service company, provides battery-on-bus financing to jointly roll out e-buses with the operator. This financing model splits the ownership of an e-bus between the operator Abellio, which owns the vehicle's body, and the charging service company Zenobē, which owns the battery, runs, and maintains the charging infrastructure in the depot for Abellio (Zenobē Energy 2020). **Figure B1.1** details the model.

Figure B1.1. Bus Operator + Charging Service Company Financing Model



Source: Original figure produced for this publication.
Note: The solid line refers to the provision of physical asset; the dashed line refers to the capital flows of funding, subsidy and payment.

2. Financial Leasing Company + Charging Service Provider Financing Model

Under this model, financial leasing companies and charging service providers jointly provide commercial financing. Two types of derivate schemes offer different asset ownership arrangements: (1) bus-battery separation leasing, and (2) bus outright leasing.

2.1. Bus-battery separation leasing

The bus-battery separation leasing model is similar to the bus operator + charging service company financing model described previously, but with the introduction of a financial leasing company to take ownership of the vehicle instead of the operator.

While bus bodies (excluding batteries) are financed and owned by the financial leasing company, batteries and charging infrastructure are financed and owned by the charging service provider. These assets are leased to the operator. This model transfers the risks of e-bus financing to the financial leasing company and the charging service provider. It can be considered when the operator tends to avoid bearing the upfront cost of the e-bus but still controls the technical specifications of the vehicle—by advising the financial leasing company on the procurement. When the battery technology is nascent, and performance is unreliable, separating the provision of battery from the bus vehicle could be a solution to allow the charging service provider to manage the battery failure risks given its better technical capacity in charging and maintaining batteries.

Box 2 describes the bus operator + charging service company financing model as implemented in the phase 1 of e-buses rollout Shenzhen, China.

Benefits	Disadvantages
• The capital cost of battery and vehicle is converted to operation cost could reduce the upfront financial pressure to the operator/government • Charging service provider bearing the battery failure risk when technology is not mature makes the electrification transition feasible • Lease payments could offset taxable profits	• Battery maintenance could increase the cost of the charging service provider • Ownership separation could add contracting complexity and transactional cost • Operators could face additional cashflow pressure during the operation due to the payment obligation to lease • Operation disruption in case of battery failures might be longer because of interface risk of battery management and bus management

Box 2. Bus-Battery Separation Leasing in Shenzhen, China

The first phase of bus electrification of the Shenzhen Bus Group (SBG) rolled out when the battery performance and charging technical risks were high at the technology nascent stage. The Shenzhen government negotiated a concession deal that designated Potevio Group Corporation (PGC), a state-owned enterprise (SOE), as the only authorized charging service provider, who also bought and took charge of the batteries. PGC also offered guarantees to the financial leasing company, the financial leasing division of the Bank of Communications, who purchased the bus body without batteries and then leased the buses to the operator, SBG. SBG receives government subsidy and collects fare revenue. This approach overcame upfront financial constraints by moving financing risks to charging service providers and financiers and lowering the financial leasing costs with the guarantee provided by the state-owned charging service provider. **Figure B2.1** illustrates the model. In the Shenzhen case, the e-buses' ownership will be transferred to the operators after the lease period. Given the operators have control over the e-bus maintenance, the residual value risk can be mitigated to some extent.

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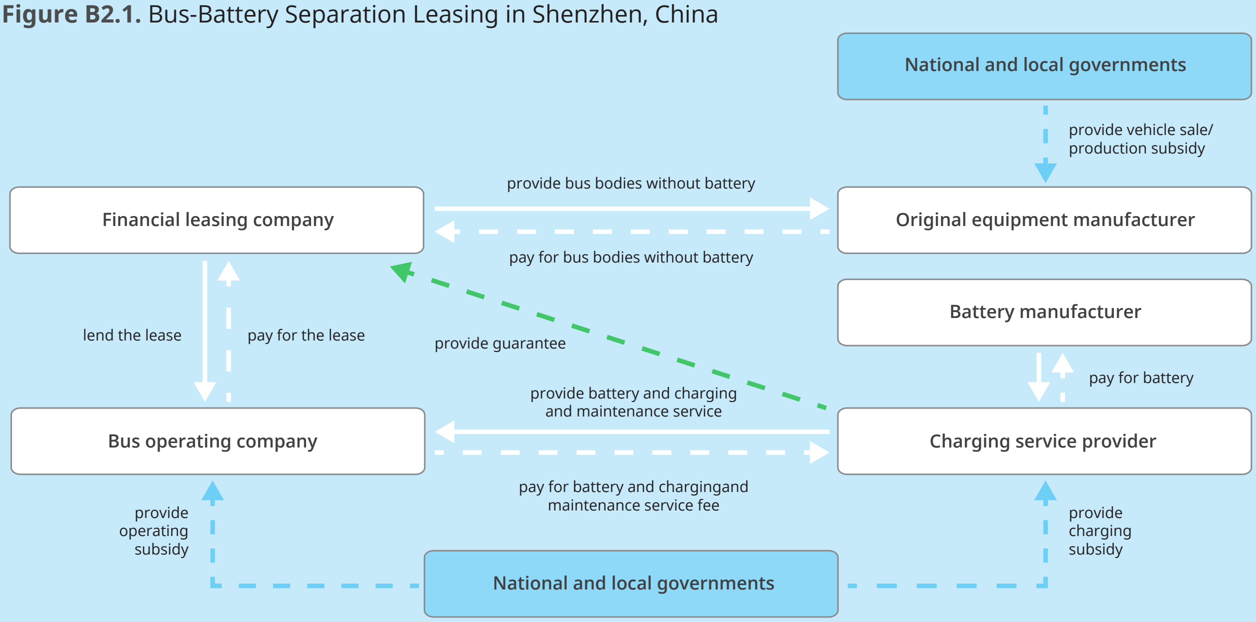
Figure B2.1. Bus-Battery Separation Leasing in Shenzhen, China



Source: Adapted from World Bank 2021.
Note: The solid line refers to the provision of physical asset; the dashed line refers to the capital flows of funding, subsidy, and payment; the green dashed line refers to the guarantee for leasing.

2.2. Bus outright leasing

In the bus outright leasing scheme, the operator takes major e-bus financing risk, with ownership of the whole bus vehicle including battery. This model has similar advantages as the bus-battery separation leasing model, and it can be applied when battery reliability is no longer a major deterring factor, and the operators and financial leasing companies are technically and financially strong enough to take the lead.

Box 3 describes the outright leasing model as implemented in the phase 2 of e-bus rollout in Shenzhen, China.

Benefits

- The upfront cost of e-bus is converted to operation cost, which lowers the financial pressure of the operator/government
- Lease payment for bus and charging could offset taxable profits
- Compared with the bus-battery separation scheme, this model allows more efficient bus operation with whole vehicle lease, also making direct involvement of OEM (e.g., in forms of warranty of major components including batteries) easier, which can lower the e-bus maintenance cost

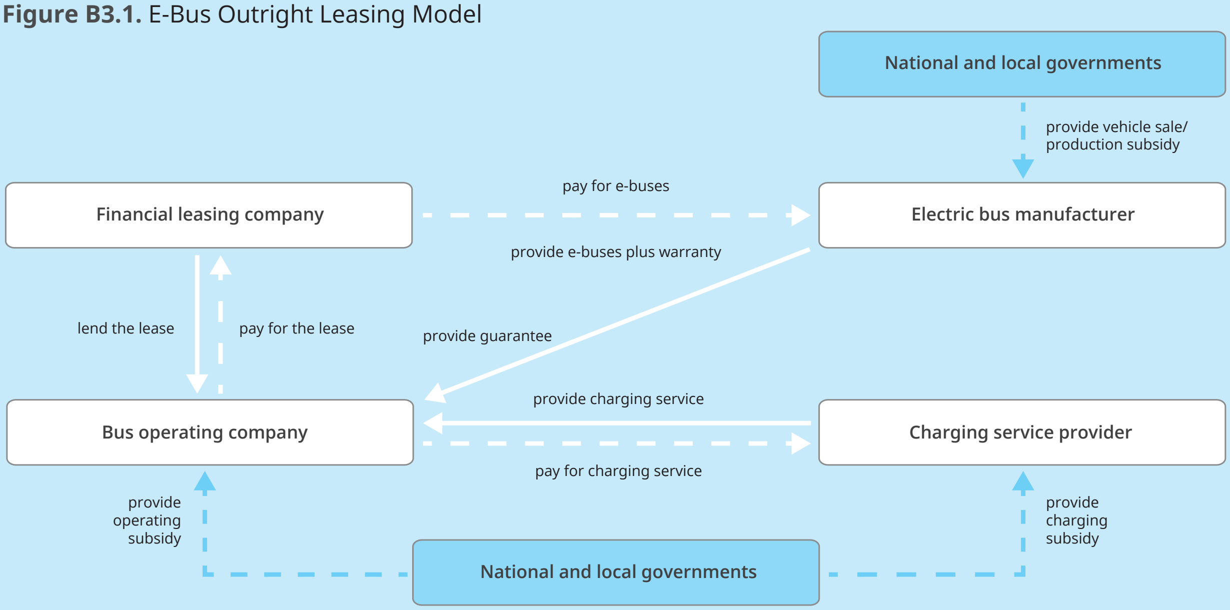
Disadvantages

- Ownership separation could add contracting complexity and transactional cost
- Operators could face additional cashflow pressure during the operation due to the lease payment obligations
- High requirement for the operator’s balance sheet to qualify for using lease

Box 3. The E-Bus Outright Leasing in Shenzhen, China.

The second phase of SBG's bus electrification used a whole bus lease model. While a financing leasing company buys and owns the buses including batteries, the operator pays the lease to the financing leasing company on a seasonal basis, with an annual interest rate of around 4 percent during the buses' eight-year lifespan. At the same time, the bus manufacturer provides a lifetime warranty for the key components of the e-bus, for example, battery, electric motor, and controller. The charging service provider constructs and operates the charging facilities while the bus operator pays the charging service fee. SBG receives government subsidy and collects fare revenue. This model is more efficient than the bus–battery separation model because fewer parties are involved with lower transaction costs. **Figure B3.1** shows the model in detail.

Figure B3.1. E-Bus Outright Leasing Model



Source: Adapted from World Bank 2021.
Note: The solid line refers to the provision of physical asset; the dashed line refers to the capital flows of funding, subsidy, and payment.

3. Original Equipment Manufacturer Financing Model

In this model, the original equipment manufacturer (OEM) takes major e-bus financing risk from the government, owns e-bus assets, and operates the bus fleets. Meanwhile, the risks of capital cost, technology, and management capacity are transferred to the OEM. This model can be applied when the manufacturers have local e-bus production, installation, and maintenance capacity, with sufficient competition among the manufacturers to provide value for money for e-bus service.

Box 4 takes a closer look at the OEM financing model as applied in Kolkata, India.

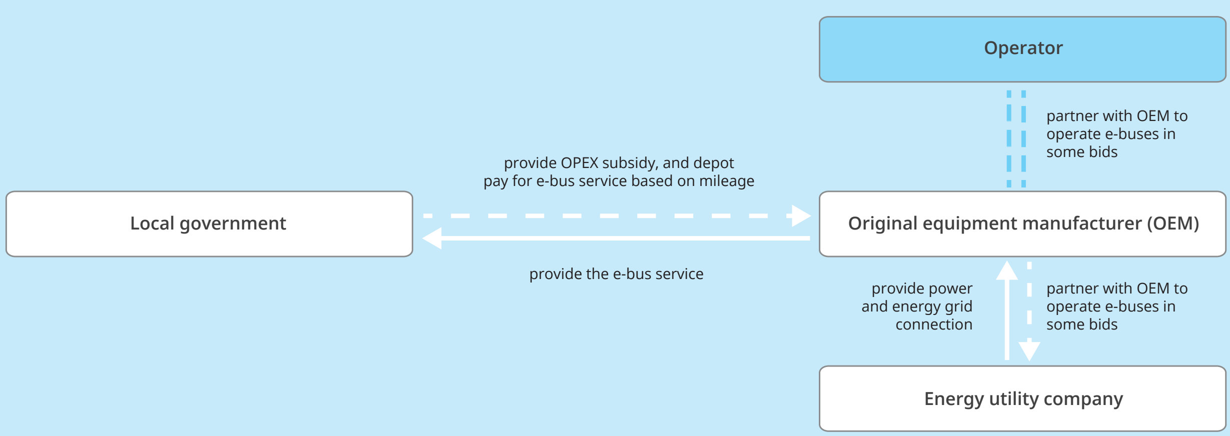
Benefits	Disadvantages
• Integrated ownership and operation of e-bus could lower contracting complexity • Could provide more opportunities for operators with relatively limited financing capacity to join the e-bus service	• High financing, technological and operational capacity requirements for OEMs • Potential risk on operation service quality given OEMs could lack operation experiences

Box 4. The OEM Financing Model in Kolkata, India

In Kolkata, the national and state governments provide capital and operation and maintenance subsidies for the e-bus provision and operation led by PMI-Foton, a leading Indian e-bus OEM. The consortium led by PMI-Foton was awarded the gross cost contract for operating and maintaining 50 e-buses in New Town Kolkata at a rate (in Indian rupees) of Rs86 per kilometer (TERI 2020; Gupta et al. 2021).

The most common approach in India has been for state transportation undertakings (STUs) to own, operate, and repair the buses themselves. As a result, only a few operators have a sufficient presence and track record, making it difficult for operators to obtain financing for bus electrification. As a result, the involvement of OEMs could provide additional guarantees on behalf of bus operators. **Figure B4.1** illustrates the OEM model. There are also other measures to improve the bankability of the bus e-bus project when the involvement of OEM is optional under such gross cost contract model, for instance, allowing non-OEM bidders/consortium led by financiers and operators to participate by submitting an undertaking from (one or more) OEMs or procuring from empaneled list of OEMs.

Figure B4.1. OEM Financing Model



Source: Original figure produced for this publication.
Note: The solid line refers to the provision of physical asset; the dashed line refers to the capital flows of funding, subsidy, and payment.

Other contract types under the OEM financing model feature unbundled bus bodies and batteries. The operators purchase bus bodies and lease the batteries from OEMs over the lifetime of buses. For example, as the OEM, Volvo excludes the batteries from the bus purchase price and leases batteries for up to 12 years in Bogotá, Colombia (Moon-Miklaucic et al. 2019), and Proterra sells bus bodies and leases batteries to the operator in Park City, Utah, United States (Proterra 2019a).

4. Energy Utility Company Financing Model

In the energy utility company financing model, the energy utility owns e-buses, leases them to the operator, provides charging service, and supplies energy. Meanwhile, the risks of e-bus procurement and charging infrastructure construction are transferred to the energy utility company who can assume the investment costs of charging infrastructure either through the loan, its own capital, or with the support of government grants and recuperate their investment by charging the fleet operators for service provision. This model can be applied when the energy utility companies have a strong financing capacity and can integrate the resources of other players such as OEMs and operators.

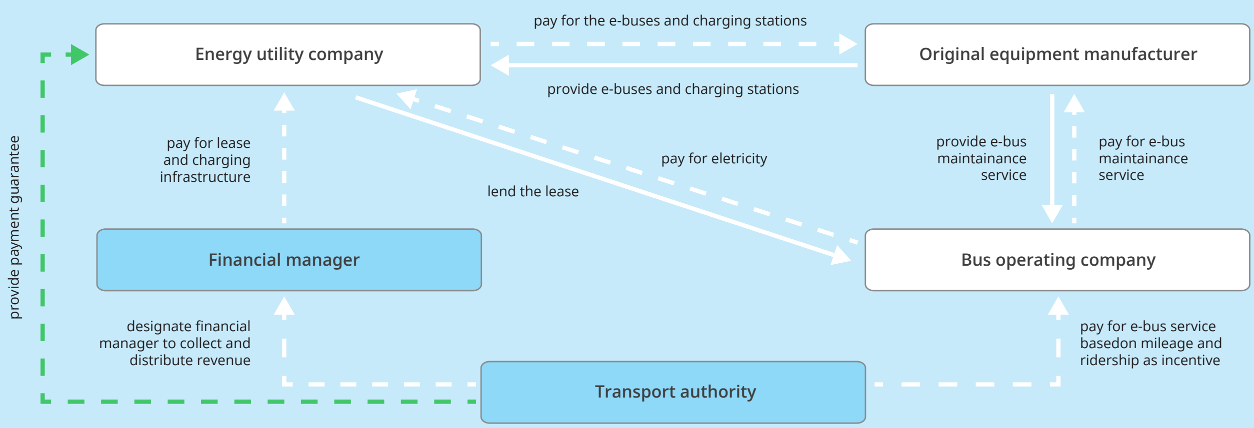
Box 5 provides an example of the energy utility company financing model as rolled out in Santiago, Chile.

Benefits	Disadvantages
• Energy utility company could modify the energy grid and provide charging infrastructure and service at a lower cost • Energy utility company with strong financial profile could have more negotiation power on the interest rate of commercial bank loans	• High entry bar for bidding could result in insufficient competition • Traffic risk could affect the payment to the lease

Box 5. The Energy Utility Company Financing Model in Santiago, Chile

The city of Santiago utilizes the energy utility company financing model where the energy utility company cooperates with OEM and private operator for bus electrification. The key enabling factors include the fleet and charging infrastructure investment from the energy utility company and direct pass-through payments on fleet and energy from authority to fleet provider. Enel, an energy utility company, finances the buses and leases them to the operator, Metrobus, for ten years, after which ownership is transferred to Metrobus. In addition, Enel is also involved in the installation and power provision for the charging infrastructure as well as the depots. The manufacturer, BYD, sells the buses and charging infrastructure and provides maintenance services, including battery packs and electric drivetrains for a fixed-rate payment. AFT (a private enterprise procured by the city's transport authority to manage the system's finances) collects the system's revenue, including from the fareboxes, and distributes it to pay for charging infrastructure and the bus operator based on ridership and mileage. Meanwhile, the AFT subtracts from the payment to the operator the amount corresponding to the leasing contract it has with the energy utility company and pays that sum directly to the energy utility company. This key feature allows energy utility company to lower the risk of investment. Contracts with operators and fleet providers stipulate the buses remain in the system until the debt is paid, which allows for longer debt tenures than operating contracts and results in lower operating costs (World Bank 2020). **Figure B5.1** illustrates the model.

Figure B5.1. Energy Utility Company Financing Model



Source: World Bank 2020; figure adapted from Jattin 2019.
Note: The solid line refers to the provision of physical asset; the dashed line refers to the capital flows of funding, subsidy, and payment.

Another case under the energy utility company financing model is the bus electrification project in Oregon, United States, whereby the energy company provides financing for the transit agency TriMet to purchase e-buses and install charging stations. In other cases, the energy utility companies will waive some tariffs and provide an affordable rate structure for e-bus operation, for example, e-bus rollout in northern Los Angeles County, California, United States (Casale and Mahoney 2018).

5. Other Financing Mechanisms

Other financing mechanisms are also being explored, including OEM installment and green financing facility. Bus manufacturers with strong financial capacity offer installments for scaling up e-bus purchase with a less upfront cost for the buyers. For example, BYD and China Development Bank partner to launch the "Zero Vehicle Purchase Price" program (CAAM 2012) whereby bus operators can choose to replace upfront payments with installment payments through a **financial lease**, **operating lease**, or **buyer's credit**.[1] The U.S.-based manufacturer Proterra offers a number of battery leasing options, including low-cost financing as well as an operating lease (Proterra 2019b). The operating lease allows cities to pay for the use of the bus over time with an option to purchase the bus at the end of the lease period.

Green financing options such as green bonds, green-tagged loans, green investment funds and climate funds could also be considered for financing bus electrification as they can help the investors raise capital from more diverse sources at a lower cost and also provide some financial incentives (for instance, tax benefits). For example, the Shanghai Pudong Development Bank (SPDB) raised capital by issuing a green bond and provided a low-interest loan to support Tianjin Bus Group purchasing e-buses with the guarantee provided by the subsidiary financial leasing company of SPDB (Transport Scotland 2021).

Key Findings on Financing Bus Electricfication

Based on the case studies and interviews with private stakeholders conducted by the authors, the key findings on designing financing bus electrification are summarized as below:

FINANCING

- Commercial financing can be channeled through industrial players with strong financial capacity such as operators, charging service providers, OEMs, and energy utility companies.
- Leasing can mitigate the impact of high upfront capital cost by converting it to operating cost over the lease period. Nonetheless, it is important to carefully assess the cost of leases as they could increase lessees' liability during the operational period.

1 A **financial lease** is a type of commercial lease agreement in which a finance company is the legal owner of an asset, and the lessee rents the asset for an agreed-upon period of time. The lessee makes a series of payments for the use of the asset and has an option to make a residual payment and acquire the ownership of the asset at the end of lease contract.

An **operating lease** is also a commercial lease agreement, similar to a financial lease except without an ownership transfer at the end of the lease period.

Buyer's credit is a short-term loan facility provides by a lender such as a bank or financial institution to finance the purchase of capital goods and services.The buyer owns the assets and pays installments to the financial institutions.

- Long-term maintenance provided by OEM in the forms of warranty or concession contract could reduce technology risks, battery maintenance and replacement risks, and better support residual value capture.

- Government payment guarantees could help reduce the risks perceived by the financiers and improve the bankability of the project. Yet, the contingent liability from the guarantee needs to be carefully managed in the government fiscal system.

FUNDING

- Capital and operational subsidies might be needed when the project revenue (fare and non-fare revenue) cannot meet the return demand from the financiers.

- The funding for CAPEX should consider the cost of the buses, batteries, charging infrastructure, energy grid connections including necessary capacity upgrade and depot retrofits, etc. Where local governments have tax-raising powers, tax income such as part of the payroll tax could be used to fund the electrification of public transport systems.

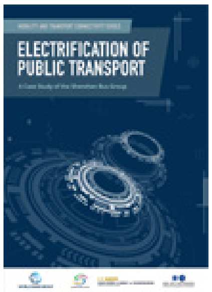
- The funding for operating expenses (OPEX) should be prepared based on the estimation of operating cost and deficits, peak hour capacity, excess of costs over passenger fares, periodic refurbishment of buses and other equipment, periodic replacement of batteries, ongoing power price, and length of operation contracts.

- Traditional funding sources for OPEX are mileage payment, fare revenue, subsidies and incentives provided by the government. Alternative funding sources that can be explored include land monetization, carbon tax, fuel levy, additional revenue generated from assets (including charging, data, maintenance workshops, advertisement), congestion charge, and bus scrappage.

OTHER ASPECTS

- Monetary and non-monetary incentives can be provided by the government to channel commercial financing further. The incentives include government guarantee and subsidies, preferential pricing for tariffs and concessional and blended finance, exemption of value-added tax and import tax and corporate tax, designation of low emission zones, and land provision for charging infrastructure and depot.

Addressing the Viability Gap of Financing Bus Electrification



Electrification of Public Transport: A Case Study of the Shenzhen Bus Group.

To address the viability gap of financing bus electrification, it is important to reduce the cost, increase revenue, and de-risk projects. Stakeholders need to target sensitive cost components, including the price of electric battery bus, subsidy, bus lifetime, annual distance, electricity tariff, warranty, residual value, and operation penalty, to reduce the TCO of bus electrification (World Bank 2021).[2] On the revenue side, government subsidy at an appropriate level and monetizing the residual value of bus and charging infrastructure will help increase the revenue. **Table 1.2** provides some pragmatic recommendations to bridge the viability gaps of bus electrification from the perspective of cost reduction and revenue generation.

Table 2. Recommendations for Enhancing Bus Electrification Viability

Cost reduction and/or revenue generation measures	
Cost items	
Cost of e-bus	• Optimize battery capacity based on operation needs • Optimize fleet size based on the bus operation capacity and local demand • Introduce competition among manufacturers to lower the price of e-buses • Take advantages of tax incentives such as value-added, import, and corporate profit tax breaks to lower the price of e-bus
Construction of the charging station	• Collaborate with the energy utility companies to lower the price of transmitting electricity to the charging station • Involve original equipment manufacturers (OEMs) in the construction of charging stations or installation of chargers to ensure their compatibility with the e-buses • Take advantage of public land provision incentive for charging stations
Land availability and rental for the charging station	• Utilize existing depots for building charging stations • Government collaborates with other stakeholders to utilize the land and charging infrastructure outside depots to improve land availability and reduce the rental cost • Decentralize chargers to reduce the cost of land acquisition for the charging station construction when the land is unavailable, or cost is high
Warranty	• Negotiate with the manufacturer to extend the warranty of key parts especially batteries to reduce the maintenance, repair and replacement cost

2 Bus electrification was also discussed during an August 2021 virtual workshop on e-bus deployment arranged by the World Bank with support from Institute for Transportation and Development Policy (ITDP). See ITDP (2021) for more details about the workshop.

Cost reduction and/or revenue generation measures	
Electricity cost	• Coordinate operation and charging time to take advantage of lower/valley rates (usually at night time) • Negotiate discounted tariff with utility companies • Optimize battery performance during operation, such as preset vehicle temperature and replace low state-of-charge buses with high state-of-charge buses during cold, hot, and other extreme weathers
Bus lifetime	• Closely monitor vehicle and battery status during operations and keep regular maintenance and repairs • Train drivers, charging staff, and maintenance staff for better maintenance of the buses • Optimize software interoperability between the charger and e-bus to charge and maintain the bus battery in a safer and more efficient way
Annual distance	• Optimize route planning and rationalization, timetable preparation, frequency scheduling, and bus fleet monitoring system to improve operational efficiency and reduce per kilometer cost
Revenue items	
Subsidy	• Potential alternative revenue sources from carbon tax, land value, congestion charge, and bus scrappage could be explored to widen the revenue sources • Additional revenues can be generated by assets (for example, charging infrastructure, data collected from vehicles, maintenance workshops and skilled electricians, commercial activities during charging time)
Residual value of e-bus and charging infrastructure	• Develop secondary markets for buses and batteries to capture the residual value • Buyback guarantees from OEMs • Recycle and reuse use batteries for home energy storage, bus station reserve batteries, and energy storage elsewhere in the grid to obtain additional revenue

Source: Original table produced for this publication.

In addition, since bus electrification is still new to many developing countries, overall risks are perceived high by financiers and investors. It is helpful to mitigate the risk by leveraging expertise and financing from multilateral development banks (MDBs). **Table 1.3** summarizes the risk mitigation measures provided by MDBs.

Table 3. Multilateral Development Bank De-Risking Measures for Bus Electrification

Risk type	Mitigation instruments of MDBs
Technical risk	• Technical assistance in improving policy and regulatory environment • Technical assistance in prefeasibility and feasibility analyses with robust ridership forecast • Technical assistance in improving bus system design and network integration • Technical assistance in technical specifications (vehicle and battery, charging infrastructure and depot retrofit, fleet management system and passenger information system, and grid capacity) based on local context • Technical assistance in operator transition including staff training • Technical assistance in financing options, market analysis, and public-private partnership (PPP) options • Technical assistance in tendering, including standard tendering documents
Financial risk	• Provide concessional lending to public entities for bus electrification • Provide oversight and guarantee of public fund subsidies • Provide support on local currency financing to manage foreign exchange risk support expansion of bus electrification funding mechanisms, including (1) the development of ring-fenced funds with the capital raised from green and climate bonds, among others, dedicated to bus electrification project funding, and (2) the establishment of debt and contingent liability management systems to cope with the risks of demand change, operation default and force majeure events such as pandemic • Provide underwriting first-loss insurance to a local currency instrument to help mitigate risk associated with the convertibility of local currency • Support leasing solutions by providing financial contribution to financial lease companies, operators, original equipment manufacturers (OEMs) and charging service companies • Support aggregator and financing facility through intermediary financial loan • Provide advice on risk transfer and associated cost to help the governments and private stakeholders coordinate the risk allocation, align different objectives, and optimize the overall financing cost
Political risk	• Provide political insurance and guarantee to mitigate political risks

Source: Original table produced for this publication.

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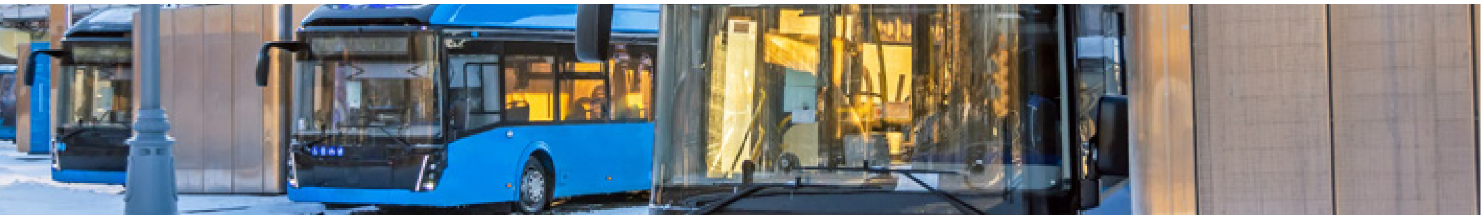

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