Prism
Partnership for Research on Informal and Shared Mobility

Columbia Climate School
Center for Sustainable Urban Development

Missing Mobilities: The Popular Transport Gap in Climate Adaptation

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Executive Summary

Highlights

- In many low- and middle-income countries, "informal" or popular transport systems, from minibus taxis to motorbike services, serve as the backbone of urban mobility and access, providing a lifeline to most residents in underserved communities.
- While much attention in the transportation sector is justifiably focused on decarbonization, the growing severity of climate risks also makes adaptation an urgent priority. In this briefing, we examine how extreme heat and flooding hazards affect popular transport systems and the people who work for and rely on them.
- Based on an initial scan of international agendas and local climate plans in seven cities, we analyze the extent to which these plans address the popular transport sector.
- We identify preliminary research and policy directions. More systematic, but also context-sensitive, data and research are needed to explore how to engage and work with diverse actors in the popular transport sector in different cities and regions.
- Most importantly, popular transport should not be viewed merely from a deficit-based perspective as a climate vulnerability to be managed, but rather as a potentially untapped asset, partner and knowledge-holder in building transport resilience and smart investments.

As climate impacts intensify, so do risks and damage to transportation systems and the people who rely on them, with wide-ranging negative effects on human well-being. In low- and middle-income (LMICs) countries, these extreme events and climate risks are especially concerning for "informal" or popular transport systems. They are often the only kind of transportation service in lower-income communities, many of which are disproportionately affected by climate risks, making this an equity issue. They represent up to 95 percent of motorized trips in sub-Saharan African cities and up to 50% in Latin American cities (Kustar et al., 2023). Yet, these widely used modes of transportation receive little attention in climate adaptation research, planning, and investment at both global and local levels.

This briefing highlights the "missing mobilities" within current climate adaptation work in the transport sector. By "missing mobilities," we refer to "informal" or popular transport systems that are often overlooked in climate discussions despite their integral role. We use the term "popular transport" throughout this paper (See Box 1 for a detailed discussion around this terminology).

When transportation disruptions happen–whether from flooding, heat-induced infrastructure damage, or wildfires, access to critical services is also disrupted causing ripple effects across society (Markolf et al., 2019). Based on a preliminary scan of policy and research work, we explore: (1) how popular transport and their users are being impacted by climate-driven effects like extreme heat and flooding; (2) the extent to which existing climate action plans and adaptation strategies in seven selected sample cities address vulnerabilities in the sector; and (3) how these modes might also contribute to ongoing climate adaptation and mitigation efforts in cities.

This paper is organized into four main sections. The introduction section starts with the conceptual framework by defining terms such as risk, adaptation, mitigation, and popular transport in the context of seven cities: Accra (Ghana), Bangkok (Thailand), Bogotá (Colombia), Cape Town (South Africa), Kumasi (Ghana), Mumbai (India) and San José (Costa Rica). These cities were chosen because of the connections to Urban Living Labs through the Partnership for Research on Informal and Shared Mobility (PRISM) that enabled on the ground insights. Section II presents a literature and policy review examining the gaps in climate policy regarding popular transport with specific attention to heat and flood impacts. Section III provides a scan of local climate action plans across select cities to explore the extent to which popular transport is addressed and, if so, how. Finally, Section IV outlines recommendations and a way forward.

Findings

The popular transport sector remains a missing element in climate resilience, adaptation and action plans. We find that major climate policy frameworks, including the Intergovernmental Panel on Climate Change (IPCC) reports primarily address institutionally supported "formal" transport systems. When popular transport systems are mentioned, they are discussed in the context of reducing greenhouse gas emissions (mitigation) rather than adjusting to climate change effects (adaptation). A review of seven Living Lab cities reveals that Kumasi and San José have not yet developed climate action plans. Among those with plans, Accra, Cape Town, and Mumbai explicitly recognize popular transport services, while Bogotá mentions it only as a statistical reference and Bangkok lacks substantive and clear reference to the transport services.

In the local Climate Action Plans reviewed, we find that transport adaptation receives significantly less attention than mitigation strategies. Reflecting concern with transport's substantial and stubborn contribution to global CO_2 emissions, mitigation dominates the climate agenda for the sector. Historically, the mitigation-adaptation separation reflects both convenience and tradition, with mitigation being driven by global, technical, emissions-centered agendas, while adaptation strategies have developed from local initiatives focused on development needs and risk reduction frameworks (Schwanen, 2019). While there have been more attempted synergies between climate change adaptation and mitigation both in global-level assessment frameworks across different sectors, the integration is relatively slow in the transport sector. Moreover, the preference for transport mitigation over adaptation continues to persist in local Climate Action Plans. We found only one transport-specific adaptation action in the plans we reviewed: "Construction of shaded sidewalks to protect pedestrians" in Accra's Climate Plan (City of Accra, 2020).

When transportation adaptation appears in local climate action plans, it is often categorized under broader urban planning or infrastructure resilience rather than linked to transport-specific measures. This can reduce the visibility of transportation resilience needs. On the other hand, mobility infrastructure can benefit indirectly from urban adaptation initiatives including natural and nature-based solutions. For example, mangrove restoration can reduce flooding risks, creating positive externalities for both formal and popular systems. More direct transportation adaptation measures (such as installing shade structures at bus stops) are also necessary and should be explicitly considered (Abdallah, 2017) including for popular transport modes.

Some important initial work is emerging around flooding and heat impacts on popular transport systems and the people who work for and rely on them in specific cities (Ames et al., 2014; He et al., 2021; Wright et al., 2024). The focus on cities is understandable (although focus must also be on rural areas); like popular transport systems themselves, adaptation is *inherently* local, relying on tailored responses to specific environmental, socioeconomic, and politico-cultural contexts and is ideally participatory, inclusive and co-produced (Rahman et al., 2023; Klopp, 2024). However, it is key to take a closer look at the state of our knowledge and how popular transport can be integrated more systematically into overall research and policy on transportation preparedness in the face of climate change.

Research Implications and Recommendations

A serious popular transport gap exists in climate policy in the transport sector and this gap is a barrier to enhancing climate resilience in a holistic and equitable way. In many cities, the lack of policies addressing popular transport stems from insufficient collection of data, information, and understanding. More systematic, but also context-sensitive, data and research are needed to explore climate impacts and how to engage and work with diverse actors in the transport sector in different cities and regions on addressing these.

Documented heat and flooding impacts on popular transport and its workers and users reviewed in this brief highlight the need for a clearer understanding of several important dynamics (Figures ES-1 and ES-2): 1) how do different and at times compounding and cascading climate hazards disrupt entire intermodal transport ecosystems including both formal and popular modes and their interfaces; 2) how do asymmetric and uneven impacts happen across different transport services; 3) how do different popular transport services adapt? Which bottom-up strategies can be supported within climate action plans and 4) how do current adaptation interventions impact existing inequity across user groups and modes? Answering these questions through further research would help pinpoint whether and how popular transport is especially vulnerable to climate change, and in which specific contexts.

Figure ES-1 | **Extreme Heat Impacts on Users, Service Providers, and Physical Assets across Popular Transport Systems (Non-Exhaustive)**

Extreme Heat

1 Infrastructure and Asset Impacts

1 affects 2

Public infrastructure assets	• Pavement degradation • Melting roads • Exposed and deteriorated stops, shelters, and waiting areas • Weather-damaged signage and information systems • Disrupted and damaged charging infrastructure
Vehicle assets	• Engine overheating • Vehicle shortened lifespan and breakdowns • HVAC system failures • Battery degradation • Increased tire wear and blowouts • Increased fuel/energy consumption

2 Health and Operational Impacts

★ Human-centered experiences	**Buses and Minibuses**	**Two- and Three-Wheelers**
★ **Users** (experience varies by age, gender, socioeconomic conditions)	• Exposure during walking or biking to stops/stations, waiting and in-vehicle • Psychological impacts (stress, anxiety about service) • Avoided trips or modal shifts • Curtailed access and loss of productivity (due to service disruptions) • Heat-related health risks	• Exposure during walking to stops/ stations, waiting and riding • Hot helmet and safety compliance issues • Psychological impacts (stress, anxiety about service) • Avoided trips or modal shifts • Curtailed access and loss of productivity (due to service disruptions) • Heat-related health risks
★ **Service Providers** (Operators, drivers, etc.)	• Exposure during waiting for passengers, in-vehicle • Heat-related health risks • Worker absenteeism during extreme heat • Decreased revenue and increased maintenance costs	• Extensive direct exposure during waiting for passengers, riding • Heat-related health risks • Safety risks when navigating flooded roads • Decreased revenue and increased maintenance costs

Figure ES-2 | **Flooding Impacts on Users, Service Providers, and Physical Assets across Popular Transport Systems (Non-Exhaustive)**

Flooding

1 affects 2

1 Infrastructure and Asset Impacts

Public infrastructure assets	• Road and pavement degradation from prolonged water exposure • Damaged or clogged drainage systems • Inundated and damaged stops, shelters, and waiting areas • Electrical system failures and damaged signage in flooded areas
Vehicle assets	• Engine, brake and electrical system damage • Vehicle shortened lifespan and breakdowns • Interior damage (for buses/ minibuses) • Battery degradation and corrosion • Increased maintenance requirements • Increased fuel/energy consumption

2 Health and Operational Impacts

★ Human-centered experiences	Buses and Minibuses	Two- and Three-Wheelers
★ **Users** (experience varies by age, gender, socioeconomic conditions)	• Exposure during walking or biking to stops/stations • Extended waiting time at stops and in-vehicle delays • Psychological impacts (stress, anxiety about service • Avoided trips or modal shifts • Curtailed access and economic losses (due to service disruptions) • Health risks from waterborne diseases	• Exposure during walking to stops/ stations • Safety risks during riding in flood conditions • Psychological impacts (stress, anxiety about service) • Travel delays, avoided trips or modal shifts • Curtailed access and loss of economic productivity (due to service disruptions) • Health risks from waterborne diseases
★ **Service Providers** (Operators, drivers, etc.)	• Service disruptions, operational challenges, and suspensions • Safety risks when navigating flooded roads • Health risks from waterborne diseases • Worker absenteeism during severe flooding • Decreased revenue and increased maintenance costs	• Extensive direct exposure to floodwater while operating • Service disruptions, rerouting and suspensions • Safety risks when navigating flooded roads • Health risks from waterborne diseases • Decreased revenue and increased maintenance costs

While our focus on heat and flooding helps identify initial research gaps, more comprehensive studies should focus on how multiple city-specific hazards, including flooding, extreme heat, and air pollution among others, cascade and affect popular transport systems. Moreover, future studies may explore how mitigation and adaptation strategies intersect and might be synergistically co-implemented across the popular transport sector. For instance, the strategic planting of trees along roads and near taxi-ranks or bus stops can serve dual adaptation and mitigation purposes, both reducing heat exposure while potentially sequestering carbon. All these insights are essential to avoid a vicious cycle that undermines a low-carbon future, where declining infrastructure propels shifts toward higher-emitting private vehicles creating a feedback loop that pushes us further towards serious consequences for human well-being (Jain & Singh, 2021).

Research on these dimensions should start with human factors and be grounded in specific people-centered experiences and exposures which are often highly inequitable, while accounting for existing pressing demands—from such issues as making a livelihood to road safety and secure working conditions. Depending on available transport options and the specific hazards in each city, different user groups may shift modes, avoid trips completely, or have no other options but to be exposed to the hazards. These scenarios also impact different popular transport operators differently, many of whom already operate with minimal margins and limited protection within the web of a complex political economy. Working with popular transport users, operators, drivers, conductors, workers, decision-makers and other relevant actors in a complex eco-system is essential; treating them as important knowledge-holders can help address socioeconomic vulnerabilities and improve community resilience.

A key takeaway is that **popular transport should not be viewed merely as a problem to be managed in the face of climate impacts but rather as a potentially untapped asset and partner in building transport and city-wide resilience**. It is critical that the popular transport sector is explicitly recognized and included in climate research, policy, planning and investments. When invested in and engaged with properly, popular transport is likely to be an integral part of the sustainable, resilient, multimodal transport future.

I. Introduction

As the climate crisis unfolds, with increasing threats to cities across the globe, ensuring that transportation systems can adapt and are resilient is a critical task. In many low- and middle-income countries (LMICs), "informal" or popular transport systems, from minibus taxis to motorbike services, form the backbone of urban mobility and access, providing a lifeline to most residents in underserved communities (Tun et al., 2020; Behrens et al., 2021). (See Box 1 for the definition and a detailed discussion.) Yet these transport services appear to remain largely outside of current adaptation efforts, plans and outreach. This not only reduces the effectiveness of adaptation interventions for the integrated transport system but also represents a missed opportunity.

Climate change poses daunting challenges to transportation systems, both through gradual, chronic environmental shifts and acute disruptions caused by increasingly frequent extreme weather events (Markolf et al., 2019). Climate-related disasters are no longer isolated events; rather, they present interconnected challenges whose impacts multiply, compound, and cascade in unexpected ways (United Nations Office for Diaster Risk Reducation [UNDRR], 2020; Kruczkiewicz et al., 2021).

While much attention in the transportation sector is focused on decarbonization through frameworks like Avoid, Shift, and Improve (Bongardt et al., 2019; Dalkmann & Brannigan, 2007), the growing severity of climate impacts makes adaptation an urgent priority. When transportation gets disrupted–whether from flooding, heat-induced infrastructure damage, or wildfires, so does access to services that cause ripple effects across society (Markolf et al., 2019). (See Box 2 for conceptual frameworks on climate risk and transport adaptation.) This reality calls for systemic responses and strategic planning that match the complexity of these layered and interacting threats.

About the Paper

This briefing paper examines the extent to which a gap exists in international and local climate agendas around popular transport, why this oversight matters, and what might be done about it. Popular transport is often the only kind of transportation service in lower-income communities, many of which are disproportionately affected by climate risks making this an equity issue (Klopp & Boateng, Forthcoming). Through an analysis of heat and flood impacts on popular transport across seven cities (Box 1), we identify the sector's vulnerabilities, adaptive strategies, and potential pathways for building resilience.

This briefing is not meant to be comprehensive but rather aims to draw attention to what appears to be a serious policy gap and provide an exploratory landscape overview at the intersection of popular transport and climate adaptation. This serves as an urgent call to action for policymakers, practitioners, and researchers to bridge the disconnect between climate policies and the realities for people who work in and rely on popular transport services.

Box 1 | Popoular Transport Services across Living Lab Cities

Popular transport systems are characterized by some operational flexibility under a spectrum of regulation and informality, from completely unregulated operations to those with basic, lax or more stringent regulation schemes. They often operate without fixed schedules or government-designated stops, frequently adjusting routes based on passenger needs or events (Behrens et al., 2021; Venter et al., 2019; Tun et al., 2021). In many low- and middle-income countries, these services function without direct government subsidies and are provided by small-fleet entrepreneurs using imported vehicles. The sector's union-like organizational structures range from strong associations such as SACCOs in Nairobi, Kenya, to more loosely organized groups among operators, such as in Lilongwe, Malawi (Kerzhner, 2023; Fried et al., 2020).

Terminology varies in academic literature, with services being described as "informal," "paratransit," "semiformal," "indigenous," "artisanal," or "popular" transport (Tun et al., 2020; Behrens et al., 2021; Ames et al., 2014). These technical descriptions often hold little relevance for local users, who might simply perceive these services as public transportation and refer to them by regional terminology: peseros in Mexico City, matatus in Kenya, tro-tros in Accra, while three-wheelers are known as autos, auto-rickshaws, rickshaws throughout South Asia, and tuk-tuks in Southeast Asia. In this briefing, we use the term "popular transport," reflecting their bottom-up origins and ubiquity.

Popular Transport across Regions

Popular transport varies across Partnership for Research in Informal and Shared Mobility (PRISM) Living Lab cities. In **Bogotá**, Colombia, and **San José**, Costa Rica, these services can constitute a smaller modal share (about 4-6% in Bogotá), primarily serving urban peripheries, as feeder services to formal transportation systems, or alongside Metro, BRT, and other city bus services as well as enabling trips of care that the formal system does not acter for adequately (Kimmelman, 2023; City of Bogotá, 2021). In San José specifically, popular transport provides door-to-door services, offers backup options when formal transit faces disruptions or in areas where formal services are non-existent, although they can compete with the latter along shared corridors.

Conversely, in cities like **Accra** and **Kumasi**, Ghana, and **Cape Town**, South Africa, popular transport has been a major component of the urban economy. The motorized modal shares are 62%, 50% and 23% in Accra, Kumasi, and Cape Town, respectively (Behrens et al., 2025). In Ghana's largest urban centers, Accra and Kumasi, tro-tros serve as the primary means for residents' daily mobility needs within a complex ecosystem that now includes two- and three-wheelers and digital platform services. In Cape Town, minibus-taxis have become the dominant public transport mode for over two decades, despite the presence of conventional buses, BRT, and passenger trains (Plano et al., 2020). Residents of peripheral settlements rely almost exclusively on these services for daily mobility needs.

South and Southeast Asian popular transport is dominated by two- and three-wheelers, classified as "intermediate public transport" in India (Jaiswal et al., 2024). In **Mumbai**, these services provide employment opportunities for migrants and low-income households. Many rickshaw drivers live in informal settlements themselves, using this work as both an income source and last-mile transport for their communities and the wider city (Kuttler, 2024; City of Mumbai 2022; Kharodawala, 2025). Beyond mobility, popular transport is a vital part of the economic fabric of these cities, providing livelihoods directly through employment and indirectly by facilitating commercial activities (Klopp 2024; Spooner et al., 2023). In **Bangkok**, tuk-tuks and motorcycle taxis transport both passengers and goods, proving valuable to street vendors who transport fresh ingredients from markets to their stalls (Sopranzetti, 2022; Thaithatkul et al., 2023).

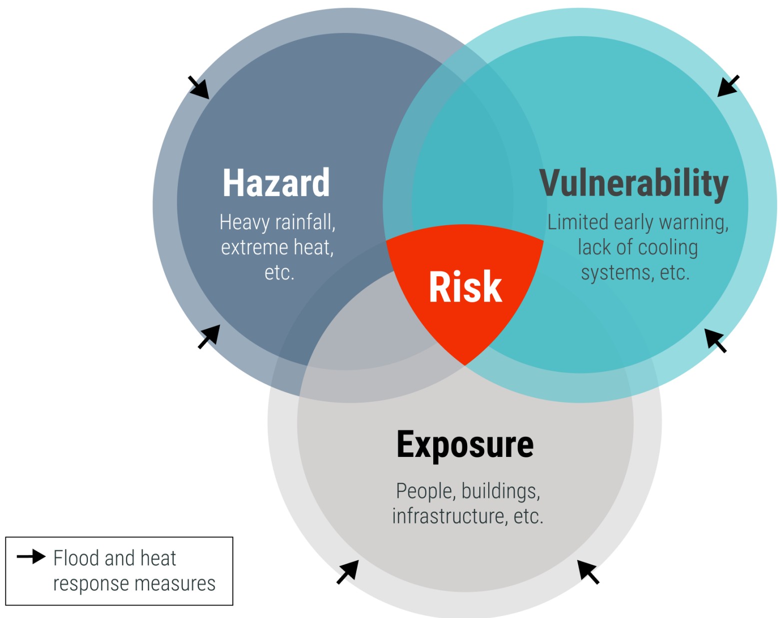
Box 2 | Climate Risk and Adaptation and Transport Adaptation Conceptual Frameworks

Climate Risk Assessment Framework

According to the Intergovernmental Panel on Climate Change (IPCC), **risk** is defined as the "potential for adverse consequences for human or ecological systems" (IPCC, 2022). Conventionally, risk assessments focus on three interacting components: **hazard** (the dangerous event), **exposure** (who or what might be affected), and **vulnerability** (how susceptible they are to the harm), as shown in Figure 1 (IPCC, 2022). Relatedly, **adaptive capacity** is defined as "the ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences" (IPCC, 2022). Recent scholarship suggests that "response" measures, in terms of mitigation and adaptation, should be considered a core component of risk itself, rather than merely external factors that modify risk (Alegría et al., 2024; Simpson et al., 2021).

The IPCC distinguishes between **mitigation**, "human intervention to reduce emissions or enhance greenhouse gas sinks," and **adaptation**, "the process of adjustment to actual or expected climate and its effects" (IPCC, 2022). This division, though useful for analysis, can impede integrated planning approaches important for sustainable cities to yield co-benefits over longer time scales (Dodman, D. et al., 2022). Active transport (such as walking and bicycling) infrastructure is an example of an integrated mitigation-and-adaptation approach. As mitigation, it reduces emissions, air pollution, and health risks; as adaptation, it improves resilience through redundant mobility options during extreme weather and supports green infrastructure that can reduce urban heat (Moosburger et al., 2024; Sofia et al., 2020).

Figure 1 | Risk Assessment Framework



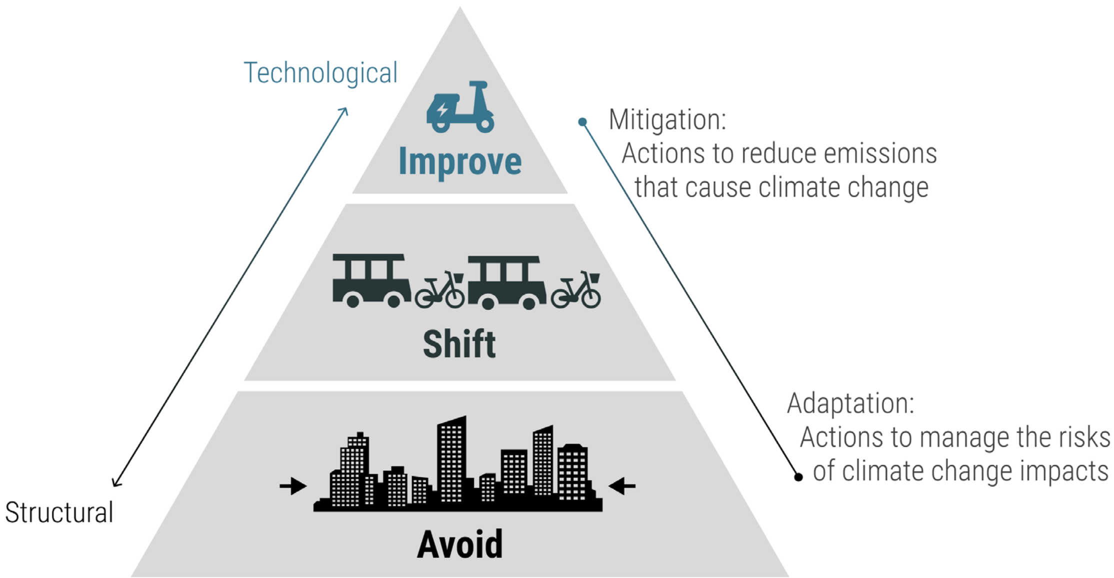
Source: Adapted from IPCC, 2022.

The Avoid-Shift-Improve Framework

Avoid, Shift, Improve (ASI) is a framework for addressing climate change in the transport sector that includes avoiding unnecessary private vehicle travel via compact, mixed-use urban development and travel demand management; shifting to sustainable modes such as public transport, walking and cycling; and improving the efficiency of vehicles and fuels (Bongardt et al., 2019; Dalkmann & Brannigan, 2007). In the context of popular transport, the Avoid strategy relies on integrated land-use planning and operational efficiencies like trip consolidation and reducing empty runs to curb needless vehicle kilometers, while preserving access for vulnerable users and sustaining the livelihoods of the service providers. Under "Shift," popular transport modes such as minibuses already represent a more sustainable alternative to private vehicles. The "Improve" strategy offers potential for both two-/three-wheelers and popular buses through vehicle upgrades, routine maintenance, and electrification.

The framework can be reconceptualized as a pyramid (Figure 2), where the wide base represents both the foundational importance and increased inertia compared to the upper levels (Davidson & Contreras, 2019). It shows "Avoid" strategies as the foundation that require underlying structural and behavioral changes. "Shift" represents an intermediate level of change, and "Improve" targets technological and operational efficiency at the apex. This hierarchy offers an important insight: whereas existing mitigation strategies gravitate toward technology solutions at the top level, building **resilience**, the ability to absorb, recover, and adapt to both anticipated and unanticipated disruptions (Carlson et al., 2012), warrants structural transformations as well as a better understanding of adaptability in the popular transport sector.

Figure 2 | **Avoid-Shift-Improve Framework Pyramid showing Hierarchical Relationship**



Note: The diagram shows current practice (technological focus for mitigation in transport) vs. where more attention is needed (structural changes for transport adaptation).

Source: Adapted from Davidson & Contreras, 2019.

Maladaptation

Without understanding mitigation-adaptation synergies and trade-offs, poor planning risks **maladaptation**, actions that may increase climate vulnerability or have negligible impact on risk reduction (Schipper, 2020). Maladaptive outcomes can stem from four mechanisms: (1) shallow and insufficient understanding of vulnerability contexts; (2) inequitable stakeholder participation; (3) retrofitting of adaptation into existing development agendas without proper integration; and (4) inadequate critical engagement with how "adaptation success" is defined (Eriksen et al., 2021). These mechanisms are salient and evident in transport engineering and planning, where standardized interventions often fail to account for local complexities including the presence and workings of popular transport.

Methodology

We reviewed international climate frameworks and selected local climate action plans to assess the extent to which they address popular transport. This review was supplemented by semi-structured interviews with transport experts and practitioners from the Partnership for Research in Informal and Shared Mobility (PRISM) urban Living Labs in Accra (Ghana), Bangkok (Thailand), Bogotá (Colombia), Cape Town (South Africa), Kumasi (Ghana), Mumbai (India) and San José (Costa Rica) (PRISM, n.d.). These inputs helped us bridge global policy discourse with local realities in cities where popular transport plays a key role, especially for lower-income communities. (See Box 1 for information on popular transport typologies across Living Lab cities.)

We focused on heat and flooding and conducted a general literature review on how these climate impacts intersect with transport. This is because both hazards: are globally prevalent with interacting and cascading effects; take place to varying degrees in our study cities; compromise transport infrastructure; and, most importantly, cause everyday disruptions to livelihoods, productivity, access, health, and comfort at the individual level for both users and popular transport service providers.

The analysis begins with a review of international climate policy documents, including the latest Intergovernmental Panel on Climate Change (IPCC) assessment reports, to evaluate the extent to which popular transport systems are considered. As authoritative, global-scale meta-analyses of climate-related topics, the IPCC reports provide an important bird's-eye perspective on mitigation, adaptation, and resilience.

At the other end of the spectrum, we examine local climate action plans from the seven cities to assess whether they address–or overlook–the adaptation needs of popular transport systems. Each plan was analyzed for three elements: climate risks to transport infrastructure, operations and its users and stakeholders; specific references to popular transport systems; and approaches to transport mitigation and adaptation measures. While Nationally Determined Contributions (NDCs) and national transport strategies provide relevant context, city-level plans reflect the scale at which popular transport functions and allow us to gauge how local authorities conceptualize system's resilience within the operational context of popular transport.

The briefing is a preliminary study – we do not aim to be comprehensive but instead identify research and policy gaps that can serve as entry points for future work connecting climate adaptation and transport equity.

II. POLICY AND LITERATURE REVIEW

In this section, we review and analyze existing policy and literature frameworks related to popular transport and climate adaptation. The process includes examination of: (1) primary international climate policy documents, focusing on the IPCC's Sixth Assessment Report; (2) peer-reviewed literature on climate impacts to transportation systems with emphasis on heat and flooding; and (3) both scholarly studies and on-the-ground practitioner documentation on popular transport adaptation. In these documents, we search for key terms such as "informal," "paratransit," "popular," transport with "climate" as well as exploring adaptation vs. mitigation approaches. We prioritize publications from the past five years (2019-2024) while including earlier seminal works where relevant. Rather than attempting to be exhaustive, this scoping-level review provides an initial high-level mapping of policy and research gaps related to climate risks and popular transport.

Gaps in Climate Policy and Popular Transport

The IPCC's Sixth Assessment Report (AR6) Working Group II Chapter 6 ("Cities, Settlements and Key Infrastructure") covers climate impacts and adaptation for cities. When informality is highlighted, however, it focuses on housing and employment and lacks consideration of urban popular transportation (Dodman, D. et al., 2022). The urban mitigation chapter, Working Group III Chapter 8 ("Urban Systems and Other Settlements"), elaborates on the transportation sector's decarbonization role. This makes sense and reflects a broader focus on mitigation, given transport's 23% contribution to global energy-related CO2 emissions, emissions that continue to grow (Dhar et al., 2022). Transport's mitigation agenda is further reinforced by the proliferation of scalable technical solutions like fuel and vehicle technologies and vehicle electrification that attract political support and investments. At the same time, the chapter barely discusses popular transport systems. When popular transport is mentioned in the Working Group III Transport Chapter, such as two- and three-wheelers, it is again unequally framed around mitigation potential rather than adaptation needs (Jaramillo et al., 2022).

The separation between climate change adaptation and mitigation has been gradually institutionalized since the 1990s in both IPCC and national policy structures around the world (Watson et al., 1996). However, the latest IPCC WGII Chapter 13 ("National and Sub-national Policies and Institutions") includes a sub-section that explores synergies among adaptation, mitigation, and sustainable development across different sectors (Dhar et al., 2022). Likewise, there is less imbalance between mitigation and adaptation in the transport literature, given the recent expansion of studies on transport disruptions due to weather events and changing temperatures (e.g., Liu et al., 2024; Markolf et al., 2019; Abad et al., 2020). In the public transport realm, the studies dominantly focus on "formal" transport and climate resiliency. While there is some emerging scholarly work (see below in Extreme Heat Impacts and Flood Impacts sub-sections), popular transport remains an important, understudied area in the transport mitigation-adaptation nexus.

Adaptation challenges in popular transport systems intersect with questions of resilience and fairness. Evidence shows that transposing "best practices" across regions can result in maladaptation when interventions fail to properly account for local vulnerabilities and power dynamics (Rizzo, 2019). While Latin American cities used BRT to restructure their incumbent systems with some success, similar approaches face challenges in African cities where popular transport is deeply embedded in complex socioeconomic networks (Klopp et al., 2019). Building resilience therefore requires transcending technical fixes to engage meaningfully with existing driver-operator-owner-worker networks, local knowledge systems, and community-defined measures of success.

Extreme Heat Impacts

Even if we could keep the global temperature rise to 1.5°C, a scenario that looks increasingly unlikely without more transformation, heatwaves are predicted to become longer, more frequent, and more intense (Masson-Delmotte et al., 2023). By the end of the century, many cities are anticipated to experience temperatures above 35°C for more than 150 days or nearly half the year (Mackres et al., 2023; Wong et al., 2024). In cities this is compounded by the way the built environment, including road infrastructures, traps and re-radiates heat or urban heat island effects. Today, heat-related productivity losses in Chennai total $1.9 billion annually (Jones et al., 2024). In Lucknow and Surat, about 20% of annual working hours for the general workforce exceed safe heat stress levels (Jones et al., 2024). Heat exposures can be heterogenous within a city; surface temperatures in one of Mumbai's slums were found to be on average 6°C warmer than neighboring areas (Mackres et al., 2023). In sub-Saharan Africa, inequitable tree cover distribution, often a result of colonial planning, worsens the temperature differentials (Hosek 2019). In many cases transportation infrastructure projects reduce the tree canopy even further.

Elevated temperatures damage transportation assets, such as bursting tires, melting roads, and buckling rails, as well as transport-adjacent infrastructure like electrical power lines and photovoltaic cells vital for transport electrification (Deuskar et al., 2023). Extreme heat can also cause water scarcity in reservoirs, consequently straining electricity generation and compromising downstream charging infrastructure and electric vehicles (Seitz, 2025; Qiu et al., 2024).

Heat Impacts on Popular Transport Systems

Extreme heat affects public transport users in three situations: walking, waiting, and in-vehicle exposure (Figure 3). Studies show that in urban environments, pedestrians exposed to direct sunlight experience surface temperatures up to 20 degrees Celsius higher than those under tree shade during afternoon hours (Middel et al., 2021). The availability and layout design of transit shelters and waiting areas influences heat exposure as a preventive measure (Fraser & Chester, 2017); yet many rapidly growing cities lack protective infrastructure. In a recent Durban case study, 75% of minibus taxi ranks were found to not have shelters and none provide potable water access (Wright et al., 2024). Moreover, inside enclosed vehicles, temperatures can dramatically rise within minutes, and this can aggravate heat risks for passengers (Zhou et al., 2019). (See Box 3 for heat exposure study for minibus taxis in Durban, South Africa.)

Extreme heat poses greater health concerns for women than men, especially pregnant women or those traveling with children, given their more complex trip chains related to mobility of care (Porath & Galilea, 2025; Adrienne Arsht-Rockefeller Foundation Resilience Center [Arsht-Rock], 2023). While waiting at stops and in crowded popular transportation, women can also face exacerbated risk of gender-based violence, for example, as a result of wearing lighter or shorter clothing due to heat – an unfortunate situation that becomes reinforced and normalized as extreme heat events become more frequent (Arsht-Rock, 2023; Woods & Agoncillo, 2024).

Extended exposure to high temperature disrupts our body's thermoregulation, and heat stress happens at a threshold of wet-bulb temperatures 30-31 degrees Celsius in humid environments (Vecellio et al., 2022).

Two- and three-wheeler operators face challenges with prolonged direct exposure to solar radiation and reflected heat from road surfaces, which can increase felt temperatures by 10-20°C (Turner et al., 2023). In Delhi's scorching summer, auto-rickshaw drivers in their open vehicles experience symptoms such as headaches, cramps and eye pain from the intense heat and sunlight (Soofi, 2024; Ghosh, 2024). Heat can also exacerbate already severe air pollution exposure in any cities (de Bont et al., 2025). In addition to physiological and health impacts, extreme heat can reduce overall demand for the auto-rickshaw services, as less price-sensitive passengers might shift to other options such as air-conditioned cabs or platform-based rideshares (Ghosh, 2024; Hossain, 2024). Summer heat might also cause more involuntary vehicle downtime as frequent power cuts affect access to charging infrastructure, thus further cutting the operators' revenue.

Figure 3 | **Extreme Heat Impacts on Users, Service Providers, and Physical Assets across Popular Transport Systems (Non-Exhaustive)**

Extreme Heat

1 Infrastructure and Asset Impacts

Public infrastructure assets	• Pavement degradation • Melting roads • Exposed and deteriorated stops, shelters, and waiting areas • Weather-damaged signage and information systems • Disrupted and damaged charging infrastructure
Vehicle assets	• Engine overheating • Vehicle shortened lifespan and breakdowns • HVAC system failures • Battery degradation • Increased tire wear and blowouts • Increased fuel/energy consumption

1 affects 2

2 Health and Operational Impacts

★ Human-centered experiences	Buses and Minibuses	Two- and Three-Wheelers
★ **Users** (experience varies by age, gender, socioeconomic conditions)	• Exposure during walking or biking to stops/stations, waiting and in-vehicle • Psychological impacts (stress, anxiety about service) • Avoided trips or modal shifts • Curtailed access and loss of productivity (due to service disruptions) • Heat-related health risks	• Exposure during walking to stops/ stations, waiting and riding • Hot helmet and safety compliance issues • Psychological impacts (stress, anxiety about service) • Avoided trips or modal shifts • Curtailed access and loss of productivity (due to service disruptions) • Heat-related health risks
★ **Service Providers** (Operators, drivers, etc.)	• Exposure during waiting for passengers, in-vehicle • Heat-related health risks • Worker absenteeism during extreme heat • Decreased revenue and increased maintenance costs	• Extensive direct exposure during waiting for passengers, riding • Heat-related health risks • Safety risks when navigating flooded roads • Decreased revenue and increased maintenance costs

Box 3 | **Minibus Taxi Heat Exposure Study in Durban, South Africa**

South Africa's minibus taxis (MBTs) are the backbone of public transport, with an estimated 2,600 taxi ranks and 283,000 taxis operating across the country. One of the first ever studies to investigate heat exposure and heat-related health risks in the popular transport sector was conducted for these MBTs in Durban, South Africa's third most populous city with 4.2 million residents.

This study was conducted by the team at the South African Medical Research Council and focused on the Chesterville Taxi Association. The research measured hourly temperature and relative humidity levels inside 16 minibuses across 12 different ranks for five days (Wright et al., 2024). The measurements were complemented by questionnaires administered to taxi drivers. Taxi drivers in South Africa often work up to 12 hours daily, spending their time either sitting inside the taxi, driving on the road, or "binding" - waiting to load queuing passengers at taxi ranks.

The study found that temperatures inside minibuses reached up to 39 degrees Celsius and were on average about 3-4 degrees Celsius higher than outside. The most common minibuses are fifth-generation Toyota HiAces that have six regular windows and one panoramic window. The design has limited ventilation capabilities and increased exposure to direct sunlight. This placed minibus taxi drivers at increased risk of dehydration and heat-related health issues.

Based on these findings, the study recommends raising awareness about the importance of hydration, creating more shaded areas for parked taxis, improving ventilation and adding window tinting inside HiAce vehicles, and conducting future research on this critical yet understudied topic. This also points to the need for redesigning and vehicle upgrading.

Heat vulnerability studies have conventionally focused on children and elderly populations (Margolis, 2021). But a recent study from Mexico shows that people under 35 comprised three-fourths of health-related fatalities, and this occurs at moderately warm temperatures rather than during extreme heat events and is linked to occupational exposure for prolonger time periods (Wilson et al., 2024). The study's finding has implications for popular transport drivers, operators and workers who fall within this age group and engage in physically demanding work during hot conditions.

When extreme heat causes transport infrastructure damage, this can result in more waiting, mode shifts or avoided trips for users. Heat also undermines vehicle reliability, ranging from engine overheating to battery degradation for electric vehicles (Figure 3). These infrastructure and asset challenges create a compounding effect for operators. As they lose passengers during extreme heat, they at the same time experience service disruptions and increased operating and maintenance costs, threatening the viability of services that already tread on thin profit margins (Hosek, 2019). Stranded passengers may also be subject to prolonged heat exposure.

Flood Impacts

Floods are a primary cause of weather-related transport system disruptions around the world (UNDRR, 2020). Urban flooding takes many forms, from fluvial (river-based) and pluvial (rainfall) to coastal and flash floods (Ferguson et al., 2023). For example, among sub-Saharan African cities, Accra and Cape Town experience pluvial flooding as the dominant type of flood risk, while Dar es Salaam and Luanda are more exposed to coastal flooding risk (Gonzalez Reguero et al., 2023). Flood hazards can happen independently or concurrently and emerge from the cascading effects of extreme climate events (Ferguson et al., 2023). A low-lying coastal city may experience pluvial flooding from heavy rainfall that becomes exacerbated when combined with high sea levels during spring tides. As such, the variety of flood hazards warrants localized flood risk analysis for effective interventions.

Given the trend of urbanization and climate change, the severity and frequency of urban flood damage are projected to increase in coming decades (Rentschler et al., 2023; de Abreu et al., 2023). When roads are flooded repeatedly, and for an extended period, water can become trapped because of limited or poor drainage. The excessive water can weaken and reduce the roads' load-bearing capacity, and negatively affect their durability (Mushtaq, Corradi, & Sikdar, 2024; Ntakiyimana et al., 2022). Moreover, analysis of over 14 million kilometers of global urban roads shows that even minor flood events trigger cascading disruptions

(He et al., 2022). A 5-year flood event that inundates 3.64% of road networks can cause 11.58% of overall routes to fail, causing regional congestion beyond initially affected areas.

Floods can have serious human tolls. Many flood fatalities happen during transportation or evacuation attempts. In addition to vehicle-related deaths, fatalities also result from pedestrians crossing flooded areas, structural collapses, and electrocution, as victims are often unaware of flood dangers (Agonafir et al., 2023).

Flood Impacts on Popular Transport Systems

Flood impacts in LMICs are often worsened by inadequate urban planning, drainage infrastructure, and technical and financial resources, all compounded by many unplanned settlements (Bloch et al., 2012). Recent news highlights how heavy rains in East African cities like Nairobi and Kigali render popular transport impassable – with minibuses (matatus) sometimes swept away in floods or motorcycle taxis (boda bodas) forced to reroute to avoid flooded areas (Muia, 2024; Ndushabandi, 2019; Ntakiyimana et al., 2022). These situations cause disruptions and inconvenience, ranging to potentially life-threatening situations for commuters and service providers (Figure 4). One study in Kinshasa, Democratic Republic of Congo, notes that the city's only formal bus service, Transco, suspends operations during floods (He et al., 2021). Popular transport modes like Esprit de Mort (large, shared taxis), although continuing to operate, suffer 41.9% longer waiting times; travel delays cost users an estimated $1.2 million daily (He et al., 2021).

In Mumbai, tropical monsoons regularly flood streets. Like heat, floods can degrade vehicles and reduce the useful lifespan of transport assets. When Mumbai floods force auto-rickshaw operators to reroute and/or delay operations, they not only face higher fuel consumption and operating expenses but also incur additional maintenance costs, often with neither insurance nor formal financing options (Khatua, 2017). For users dependent on shared auto-rickshaws connecting to the suburban rail network, waterlogging adversely affects their livelihoods. During floods, the Brihanmumbai Electricity Supply and Transport Undertaking (BEST), the city-run bus operator in Mumbai, deploys buses in affected areas to ferry commuters to the nearest railway station, though severe flooding can also leave buses themselves inoperable and stranded (Ahmed, 2021; Press Trust of India, 2017). Unlike in Kinshasa where popular buses persist through flood conditions, Mumbai's municipal buses might substitute for rickshaw trips. (See Box 4 for adaptation-mitigation challenges in flood-prone Bangkok's popular transport system).

More troubling maladaptive and preferential flood management interventions can redistribute rather than resolve problems. In Manila, when infrastructure projects prioritize protecting arterial roads used by wealthy car owners, the outcome is aggravated flooding in low-income neighborhoods that are served by jeepney routes (Plyushteva and Schwanen, 2024). Another Metro Manila study found that only one-third of public transit users (including jeepneys) reportedly had alternate routes during floods, while the remaining two-thirds without alternate ways perceived their current route was either "the only route available" or the "most convenient" route for them. Despite having limited alternatives, lower-income commuters had to adjust their travel behavior to meet work commitments (Abad et al., 2020).

These cases highlight the need for a clearer understanding of: how hazards can cause disruptions to the entire transport ecosystem due to its inter-modal nature; asymmetric impacts on different transport services; the varying adaptive capacity of different popular transport modalities; potential modal shifts during emergencies, which highly depend on available transport options in each city; and how interventions can reinforce inequity across user groups and modes. These understandings are essential to avoid a vicious cycle of aggravating climate impacts, where declining infrastructure propels shifts toward higher-emitting private vehicles and undermines a low-carbon future (Jain & Singh, 2021).

Figure 4 | **Flooding Impacts on Users, Service Providers, and Physical Assets across Popular Transport Systems (Non-Exhaustive)**

Flooding

1 Infrastructure and Asset Impacts

1 affects 2

Public infrastructure assets	• Road and pavement degradation from prolonged water exposure • Damaged or clogged drainage systems • Inundated and damaged stops, shelters, and waiting areas • Electrical system failures and damaged signage in flooded areas
Vehicle assets	• Engine, brake and electrical system damage • Vehicle shortened lifespan and breakdowns • Interior damage (for buses/ minibuses) • Battery degradation and corrosion • Increased maintenance requirements • Increased fuel/energy consumption

2 Health and Operational Impacts

★ Human-centered experiences	Buses and Minibuses	Two- and Three-Wheelers
★ **Users** (experience varies by age, gender, socioeconomic conditions)	• Exposure during walking or biking to stops/stations • Extended waiting time at stops and in-vehicle delays • Psychological impacts (stress, anxiety about service • Avoided trips or modal shifts • Curtailed access and economic losses (due to service disruptions) • Health risks from waterborne diseases	• Exposure during walking to stops/ stations • Safety risks during riding in flood conditions • Psychological impacts (stress, anxiety about service) • Travel delays, avoided trips or modal shifts • Curtailed access and loss of economic productivity (due to service disruptions) • Health risks from waterborne diseases
★ **Service Providers** (Operators, drivers, etc.)	• Service disruptions, operational challenges, and suspensions • Safety risks when navigating flooded roads • Health risks from waterborne diseases • Worker absenteeism during severe flooding • Decreased revenue and increased maintenance costs	• Extensive direct exposure to floodwater while operating • Service disruptions, rerouting and suspensions • Safety risks when navigating flooded roads • Health risks from waterborne diseases • Decreased revenue and increased maintenance costs

Box 4 | Adaptation-Mitigation Challenges in Bangkok's Popular Transport System

In Thailand, Bangkok's popular transport system, composed of motorcycle taxis, tuk-tuks, and minibuses (songthaews), provides first- and last-mile connectivity beyond the "formal" networks. Though labelled as part of the informal economy, the system operates within a structured regulatory framework. Drivers, for instance, must register, wear uniforms, and follow safety protocols (Sopranzetti, 2022; Theerakosonphong & Amornsiriphong, 2022). The services not only transport passengers but also bolster the informal economy through goods delivery and supply chain services for street vendors and small businesses (Sopranzetti, 2022; Thaithatkul et al., 2023).

During flood events, Bangkok's popular transport modes often continue to offer mobility services. Although they are typically the first to be impacted by flooded roads, experts we interviewed noted that these modes also adeptly navigate through narrow streets and reach areas inaccessible to formal transport, though driver and user safety remains an important consideration.

As Thailand has one of the largest two- and three-wheeler fleets in Southeast Asia, electrifying them has become a trendy transport decarbonization goal (Kim et al., 2025). Climate mitigation and adaptation challenges are closely intertwined in Bangkok's case. While electric transition can serve as a strategy to reduce greenhouse gas emissions, the low-carbon future of electric motorcycles hinges on effective adaptation considerations. Without flood resilience, the vehicles struggle to operate in Bangkok's flood-prone conditions, incurring costs, reducing access, and rendering the services less safe.

Research on how Bangkok's popular transport systems could integrate with sustainable, climate-resilient mobility networks is limited. According to expert interviews, there is also a lack of detailed data on how climate change impacts the socioeconomic conditions of drivers and operators. While some government initiatives are exploring better synergy between formal and popular transport systems as part of the city's flood planning, they currently lack comprehensive support.

III. CLIMATE ACTION PLANS IN LIVING LAB CITIES: A BRIEF ANALYSIS

We review local Climate Action Plans of the Living Lab cities to align the research with the scale at which popular transport systems operate. The results are complemented by PRISM expert interviews. For each Plan, we consider: (1) climate hazards and vulnerabilities that may affect transport systems and its users and relevant stakeholders; (2) approaches to transport mitigation and adaptation measures, and; (3) mentions and/or descriptions of popular transport where available. Through this review, we explore whether popular transport operators and users appear to be engaged with and represented in climate planning processes. We also look for opportunities that serve as possible entry points for future work connecting climate adaptation and transport equity.

The Climate Action Plans in our reviewed cities are created through iterative, multi-stakeholder processes involving workshops, technical analyses, and cross-sector consultations. Environmental or climate-focused departments tend to lead the drafting process (See Table 1 for main stakeholders involved). Most Plans were developed with technical assistance from the C40 Cities and align with the Paris Agreement. Bangkok, Thailand is the only one receiving technical support from JICA. For Bangkok, we could only obtain the Executive Summary of the Master Plan on Climate Change, not the full plan. San José (Costa Rica) and Kumasi (Ghana) did not have published climate action plans at the time of writing this, while Bogotá's plan is available in in Spanish.

Plans often follow a consistent and comparable template, likely due to the common technical partner C40 Cities. They begin with introductory chapters that explain the participatory development process, followed by city context, geography, and climate hazards, before diving into sectoral CO_2 emissions. Later chapters explore priority action areas (sometimes grouped by sector) and may include sections on cross-cutting themes, concluding with monitoring and progress tracking mechanisms.

Preliminary Findings

Coastal cities like Mumbai and Accra face compound risks from sea-level rise and intense rainfall, whereas Cape Town experienced severe drought (2015-18) alongside flooding in low-lying areas with high water tables. Bogotá reports minimal extreme heat or flooding events, noting changes in seasonal

Table 1 | **Climate Action Plan Stakeholders in Living Lab Cities**

CITY	CLIMATE ACTION PLAN DEVELOPMENT SUMMARY
Accra, Ghana	▪ **Plan**: Accra Climate Action Plan: First Five-Year Plan (2020-2025) ▪ **Published Year**: 2020 ▪ **Lead Agency and Technical Partners**: Accra Metropolitan Assembly (AMA) Resilience and Sustainability Unit, with C40 Cities support ▪ **Stakeholders and Collaborators**: AMA Officials and Departments; Government Ministries including Ministry of Environment, Science, Technology and Innovation (MESTI) and Transport; Environmental Protection Agency (EPA-Ghana) and Greater Accra Private Transport Executive (GAPTE); Private sector operators in waste, transport and energy; Community groups with emphasis on informal settlements and informal waste collectors
Bangkok, Thailand	▪ **Plan**: Executive Summary: Bangkok Master Plan on Climate Change (2021-2030) ▪ **Published Year**: 2022 ▪ **Lead Agency and Technical Partners**: Bangkok Metropolitan Administration (BMA), with Japan International Cooperation Agency (JICA) technical support ▪ **Stakeholders and Collaborators**: Department of Environment (lead coordinator); Traffic and Transportation Department; Department of Drainage and Sewerage; Department of City Planning and Urban Development; Public Works Department; District Offices; The Krungthep Thanakom Co., Ltd; Department of Alternative Energy Development and Efficiency (DEDE)
Bogotá, Colombia	▪ **Plan**: Plan de Acción Climática de Bogotá 2020-2050 ▪ **Published Year**: 2021 ▪ **Lead Agency and Technical Partners**: Secretary of Environment, with support from C40 Cities and Global Green Growth Institute (GGGI) ▪ **Stakeholders and Collaborators**: IDIGER (Instituto Distrital de Gestión de Riesgos y Cambio Climático); District Secretariats; TransMilenio; Public service companies (metro, water, energy, waste management); Private sector; Academia; Civil society organizations
Cape Town, South Africa	▪ **Plan**: City of Cape Town: Climate Action Plan ▪ **Published Year**: 2021 ▪ **Lead Agency and Technical Partners**: City's Energy and Climate Change Directorate, with C40 Cities support ▪ **Stakeholders and Collaborators**: Mayor and councilors; Sustainable Energy Africa; Ricardo Energy and Environment; AfD; Western Cape Economic Development Partnership; Civil society, academic, business, residents
Mumbai, India	▪ **Plan**: Climate Action Plan 2022: Towards a Climate Resilient Mumbai ▪ **Published Year**: 2022 ▪ **Lead Agency and Technical Partners**: Ministry of Environment and Climate Change, Tourism and Protocol; Brihanmumbai Municipal Corporation (BMC), with C40 Cities and WRI India support ▪ **Stakeholders and Collaborators**: Maharashtra Pollution Control Board; Energy, Water, and Transport Departments; Municipal Commissioners and Deputy Municipal Commissioners across city and suburban divisions; Community-based organizations (CBOs) and NGOs; Industry players including Tata Power, Adani Electricity, and private consultants; Residents, local advocacy groups, and citizen forums actively contributing to participatory processes
Kumasi, Ghana	▪ The Climate Action Plan does not exist or was not available for the city.
San José, Costa Rica	▪ The Climate Action Plan does not exist or was not available for the city.

Source: Compiled by the authors.

weather patterns partly due to its high altitude (City of Bogotá, 2021). Nevertheless, urban flooding is an almost universal challenge across the reviewed cities, though it varies from monsoon-driven disruptions in Mumbai and Bangkok to flash floods in Bogotá. Heat stress is another well-recognized hazard in Climate Action Plans, though it is almost never discussed directly under the Transport action area but instead under a different thematic title. Based on interviews, some cities like Mumbai and Bangkok experience a double-jeopardy risk of both heat and flooding, meteorologically, with one sometimes causing another or vice versa, while occasionally enduring both hazards in the span of a single day (Singh & Marghidan, 2025). Summary of climate risks and vulnerabilities, general transport patterns and specific descriptions of popular transport systems, where available can be found in Appendix.

Popular Transport Recognition

All Plans include a transport sector and describe its priority actions. However, the degree to which the popular transport sector is recognized varies (see Table 2). Accra, Cape Town, and Mumbai explicitly mention the popular transport sector. The Accra Plan aims to renew all tro-tro fleets in the city by 2040 (City of Accra, 2020). The Cape Town Plan notes how the city's minibus taxis, a fleet of 8,000 vehicles operating on licensed routes under an unscheduled cash-based system, form a crucial part of Cape Town, despite decades of formal transit investments (City of Cape Town, 2018).

In contrast, Bogotá mentions popular transport only in statistical reporting. The city restructured its public transport network through the introduction of the Transmilenio BRT system in early 2000 and the establishment of the Integrated Public Transport System (SITP) - leaving its semi-formal transport at about 4 to 6% of the mode share (City of Bogotá, 2021; Rodriguez-Valencia, et al., 2023; Kimmelman 2023; Hidalgo, et al., 2013). For Bangkok, while tuk-tuks are not mentioned, there are measures on electrifying delivery motorcycles. The general lack of popular transport references might be because we only have access to the Executive Summary of the Plan (City of Bangkok, 2022).

The human dimension of transportation users and service operators is also missing in the Plans that mentioned popular transport. In Accra, where 98% of transport services are provided by private operators (City of Accra, 2020), the Climate Action Plan misses explicit discussion of the user-operator ecosystems. This contrasts with other sectors: the document identifies the People's Dialogue on Human Settlement as a targeted engagement group and emphasizes the priority of job security for informal waste collection operators. This asymmetry reflects varying degrees of acknowledgment and progress in different informal sectors. Transport authorities envision eventually shifting to a more formal system, as described in the 2050 vision for an "integrated hub [and] spoke mass transit network," where tro-tros would play the feeder role to the BRT backbone. However, the transition has been slow, and interim adaptation measures focusing on tro-tros could be arranged during the gradual transition.

In many Plans, popular transport associations and workers' organizations are absent from primary stakeholder lists. The exception is Mumbai, where the auto-rickshaw drivers' union was mentioned as a supporting stakeholder for medium- and long-term priority actions under the Sustainable Transport sector (City of Mumbai, 2022). The major limitation here is the Plan's boundary does not consider the full urban extent of the Mumbai Metropolitan Region, leaving out the peripheries where most auto-rickshaws operate. (See Box 5 for a closer look at Mumbai's Climate Action Plan.)

Balance Between Mitigation and Adaptation

Transport-related actions in local Climate Plans overwhelmingly focus on and favor mitigation (Table 2). Mitigation has historically been shaped by global, technical, and emissions-centered agendas, whereas adaptation has emerged from localized, developmental, and risk management frameworks (Schwanen, 2019). These contrasting origins have brought about fragmented governance, metrics, and funding pathways that marginalize integrated, place-based interventions. The imbalance is also a result of adaptation falling behind mitigation in climate negotiations – for which an important milestone was reached as late as the Paris Agreement in 2015 (Seo, 2017; Hussein et al., 2025). Though the latest IPCC seeks synergies and integration between climate change mitigation and adaptation (Schipper et al., 2022), the separation and imbalance persist in local Climate Action Plans, especially in the transport sector. Despite the uneven attention, transport mitigation efforts can, in addition to decarbonization, provide localized co-benefits such as improved air quality, reduced noise pollution, and potential cost savings (Fried et al., 2021; Dalkmann & Brannigan, 2007).

Table 2 | **Climate Action Plan Stakeholders in Living Lab Cities**

CITY	TRANSPORT IN CLIMATE PLANS	POPULAR TRANSPORT RECOGNITION
Accra, Ghana	▪ **Mitigation**: Included in Transportation, a Priority Climate Action sector. Specifically, under: "Transition to a low-emission bus rapid transit system" (Action 10) and "Accra Low Emission Travel Strategy" (Action 12). ▪ **Adaptation**: Explicitly included in Transportation sector under Action 11, "Construction of shaded sidewalks to protect pedestrians," facilitating green infrastructure. A sub-action under Action 12 includes "Creat[ing] Transport Analysis Zones (TAZs) to serve as spatial units for transport modelling and incorporate climate risks to build resilience to flood and heat (2022)."	▪ Quasi-regulated minibus tro-tros represent 62% of modal share – largest public transport mode in Accra. ▪ Motorcycle taxis are banned in the city. ▪ Plan aims for renewal of all tro-tro fleets by 2040. ▪ A hub-and-spoke transport system is envisioned for 2050, where tro-tros would serve as feeder services. The Plan acknowledges the slow progress and difficulty professionalizing the sector.
Bangkok, Thailand	▪ **Mitigation**: Transportation sector is included under "Mitigation Measures." ▪ **Adaptation**: Briefly mentioned as part of "Water resources management" under "Adaptation Measures" - to optimize drainage system to prevent road surface flooding.	▪ Minimal mention – only references to electrification of delivery motorcycles as part of the Mitigation Measures.
Bogotá, Colombia	▪ **Mitigation**: Transport sector is included as part of "Mitigation Actions." The actions are organized under "Sustainable Transit-oriented Development" (DOTS in Spanish), "Sustainable Mobility: Modal Shift," and "Sustainable Mobility: Fuel Substitution." ▪ **Adaptation**: Transport adaptation is not mentioned in any sectors under "Adaptation Actions." However, under "Cross-Cutting Actions," there is one brief reference to public transport services in relation to coverage of vegetated infrastructure in public space.	▪ Minimal mention as a statistic: popular transport represents 4-6% of trips in Bogotá.
Cape Town, South Africa	▪ **Mitigation**: Mainly under Strategic Focus Area (SFA) 9, "Mobility for quality of life and livelihoods" but also discussed under SFA 6, "Spatial and Resource Inclusivity," SFA 7, "Clean energy for work creation and economic development," and SFA 8, "Zero-emission buildings and precincts." ▪ **Adaptation**: Transport department is listed as a "Supporting department" in several adaptation-focused goals and actions, although no specific transport-related heat or flooding adaptation is mentioned.	▪ The transport sector is dominated by minibus taxis (MBTs), which operate licensed routes in a cash-based unscheduled fashion. ▪ Plan aims to fast-track integration of MBTs and other public transport modes. ▪ Plan promotes transition to electric vehicles of minibus taxis.
Mumbai, India	▪ **Mitigation**: Mostly under "Sustainable Mobility" as a sector priority. ▪ **Adaptation**: Interspersed in other sectors, such as "Energy and Buildings," "Urban Greening and Biodiversity," and "Urban Flooding and Water Resource Management."	▪ About 200,000 auto-rickshaws provide door-to-door service and last-mile connectivity. Most run on CNG and face longer fueling time given limited CNG filling stations. ▪ Plan aims for transition to electric two-wheelers and auto-rickshaws by 2050. ▪ Mumbai auto-rickshaw drivers' union designated as stakeholders for medium- and long-term actions under "Sustainable Mobility" sector priority.
Kumasi, Ghana	▪ The Climate Action Plan does not exist.	
San José, Costa Rica	▪ The Climate Action Plan does not exist.	

Source: Compiled by the authors.

Transport adaptation in local Plans appears through cross-cutting actions in non-transport sectors, such as water resources management in Bangkok's Plan and urban cooling initiatives in Cape Town's Plan. Both these adaptation examples could indirectly benefit transport services and infrastructure; however, this also means transport-specific climate resilience receives limited visibility. Furthermore, longer-term infrastructure-based adaptation might overlook the daily adaptive needs of users and transport operators experiencing "smaller" but frequent floods. A notable exception is Accra's Climate Plan, which explicitly includes a transport adaptation action: "Construction of shaded sidewalks to protect pedestrians" (City of Accra, 2020).

Implementation Challenges

Another challenge of climate action plans is implementation hurdles. Accra's Climate Action Plan, for example, is hindered by institutional coordination, funding mechanisms, and monitoring frameworks (Adjaison & Amoah, 2024). Similar challenges appear in Thailand, where low-carbon urban mobility initiatives are hampered by fragmented responsibilities among agencies and frictional coordination mechanisms (Chalermpong et al., Forthcoming). The challenge is relevant in issue-specific areas as well. Despite emerging awareness of heat hazards to transport systems, cities and countries struggle to implement adaptation measures due to funding issues, limited technical capacity, and coordination challenges (Ukkusuri et al., 2024; Hussein et al., 2025). Climate impacts on transport may also be under-examined or poorly understood, as found by Greenham et al. (2022) in their review of National Adaptation Plans from South Asian and sub-Saharan African countries. Heat, for example, is dubbed as a "silent killer" that does not cause the visible damage of other climate hazards, leading to lower prioritization, especially when funding is limited (Win & Dash, 2017).

The gap is more pronounced in the popular transport sector, where operators and users face multiple competing priorities that can overshadow climate considerations. For users, simply being able to get from point A to point B takes priority; for minibus operators, drivers, and transport workers, being able to maintain or maximize daily revenues, sustain their livelihoods, resolve intra-association conflicts, and manage the impact of law enforcement on their businesses may supersede longer-term climate resilience planning. Importantly, these livelihood concerns directly affect community resilience, which is foundational to climate resilience, though this relationship requires deeper understanding. In Cape Town, integration between minibus taxis and formal transit (BRT and train) has focused on cost moderation and modal integration through professionalization of the minibus industry (Schalekamp & Klopp, 2018) – though these important foundational steps will need to incorporate the climate dimensions as more urgency emerges. One example is the successful integration of upgraded minibuses- Mikrotrans services- with A/C- as feeders for the Transjakarta BRT (Institute for Transportation & Development Policy, 2021; Berita Jakarta, 2023).

The role of two- and three-wheelers remains uncertain, especially in sub-Saharan Africa, where many governments outright ban them (Owino et al., 2024; Porter et al., 2020). In Accra, while motorcycle taxis are technically banned, users still rely on them as an affordable and flexible solution to access the central area amid the congested, sprawling city, while perceived and/or actual safety concerns warrant more practical regulation (Owino et al., 2024; Martin et al., 2023). Climate adaptation, while increasingly relevant, must therefore work in concert with pressing day-to-day operational concerns that popular transport stakeholders perceive as within their sphere of influence.

At the same time, this does not mean that the various popular transport stakeholders are not adapting to heat and flooding issues or perhaps they are adaptive and resilient by necessity, though the literature on this is scarce. For example, app-based two-wheeler operators in the sub-Saharan Africa, when navigation software is imprecise and unreliable, develop alternative navigation approaches: sharing information through hand-signals, WhatsApp groups and notifications from multiple applications to learn about road conditions during flood and other hazards (Barquero & San Gil León, 2024). In fact, beyond adaptation, there is also ongoing data and evidence paucity regarding climate change mitigation, emission reduction potential, and electrification strategies of popular transport sectors despite some recent attempts (Abraham et al., 2023; Giliomee et al., 2023; Trouvé et al., 2023; Moawad et al., 2024).

Box 5 | A Closer Look at the Mumbai Climate Action Plan

The Mumbai Climate Action Plan (MCAP) outlines six sectoral priorities along with respective action tracks, as seen in Figure 5 (City of Mumbai, 2022). The "Sustainable Mobility" sector comprises four action tracks: enhancing public transport ridership, improving non-motorized transport (NMT) access, and two tracks on zero-emission action items for passenger vehicles, buses and freight. Transport infrastructure resilience is discussed under the "Build flood resilient systems and infrastructure" track within the "Urban Flooding and Water Resource Management" sector. Transport-related urban heat concerns appear interspersedly within the "Urban Greening & Biodiversity" and "Air Quality" priority sectors.

The action tracks, "Enhance public transport ridership" and "Improve access to NMT transport and infrastructure" facilitate both mitigation and adaptation. Some adaptation-oriented elements appear in this section, such as developing "walking corridors with climate-resilient components." However, like other Climate Action Plans, the MCAP's overall "Sustainable Mobility" section, emphasizes emissions reduction over adaptation through various indicators targeting zero-emission vehicles, freights, and EV charging infrastructure.The study found that temperatures inside minibuses reached up to 39 degrees Celsius and were on average about 3-4 degrees Celsius higher than outside. The most common minibuses are fifth-generation Toyota HiAces that have six regular windows and one panoramic window. The design has limited ventilation capabilities and increased exposure to direct sunlight. This placed minibus taxi drivers at increased risk of dehydration and heat-related health issues.

Figure 5 | A Closer Look at the Mumbai Climate Action Plan

Sectoral Priorities	Action Tracks
Energy and Buildings	• Decarbonize electricity grid • Transition to clean fuels and resource efficiency • Promote low-carbon buildings • Encourage passive design strategies
Sustainble Mobility	• Enhance public transport ridership • Improve access to NMT transport and infrastructure • Transition to zero-emission vehicles • Shift to zero-emission freight
Sustainable Waste Management	• Reduce landfilled waste • Decentralize waste management • Expedite remediation and scientific management of landfills
Urban Greening and Biodiversity	• Increase vegetation cover and permeable surfaces • Reduce urban heat island effect • Promote equitable access to green spaces • Restore and enhance biodiversity
Air Quality	• Curb pollution concentration levels • Improve monitoring and availability of information • Decentralize planning and increase awareness to enable community health resilience
Urban Flooding and Water Resource Management	• Build flood resilient systems and infrastructure • Localize water conservation and efficiency • Reduce pollution and restore aquatic systems • Provide safe and affordable drinking water • Ensure clean, safe, and accessible toilets • Manage disaster risks and reduce impacts

Source: City of Mumbai, 2022.

Adaptation measures in non-transport sectors indirectly benefit transport resilience. Nature-based infrastructure, crucial to the MCAP's resilience strategy through mangrove conservation, can offer co-benefits for formal and popular transport systems. However, applications to transport services, particularly popular transport, could be more robustly incorporated. Likewise, how "prepar[ing] a heat action plan for the city" and "establish[ing] cooling centers and healthcare provisions within heat-stressed areas with high vulnerable populations" would benefit transport workers and users, though the popular transport needs, could be more explicitly mentioned.

The Plan acknowledges transport vulnerabilities, noting how flooding can reduce mass transit accessibility from 60.5% to 36.6% and how transport workers face increased extreme heat exposure. It also acknowledges popular transport (200,000 autorickshaws and 93,000 taxis operating in the city) and includes rickshaw unions as stakeholders in medium- and long-term priority actions. On the other hand, there are limited protection strategies when it comes to popular transport hubs, as the Plan places more emphasis on formal transport infrastructure such as metro corridors and bus depots. The main critique and limitation of the Mumbai Plan is its scope leaves out the "peripheral" areas that confront the largest climate vulnerabilities. The Plan is restricted to the Mumbai Corporation Area boundaries and does not include the larger urban extent of the Mumbai Metropolitan Region where many intermediate public transport modes operate.

IV. THE WAY FORWARD

Within the transportation sector, considerable attention is focused on reducing greenhouse gas emissions (mitigation) from what are considered "formal" modes, with growing attention to "informal" or popular transport systems as well (Behrens et al., 2021; Kustar et al., 2022). While mitigation is critical to stemming the climate problem at its source, climate impacts are already here and growing, making climate adaptation equally critical. We see growing work on adaptation–defined broadly and actively as making adjustments to address and protect from expected or actual climate impacts. Popular transport services operate in environments increasingly stressed by extreme weather, rising temperatures, and flooding, while at the same time connecting millions to urban amenities. Yet, they remain largely invisible in terms of climate adaptation planning and implementation. Thus, a key recommendation is to focus more on adaptation and popular transport.

Transport adaptation involves immediate resiliency in daily operations—such as shelters or cooling stations at stops (see Durban heat exposure study in Box 3), and early warnings for flood journeys. It also means long-term infrastructure investments, addressing interconnected threats from flooding, heat stress, and air pollution. While our focus on heat and flooding helps identify initial research gaps, more comprehensive studies should focus on how multiple city-specific hazards, including flooding, extreme heat, and air pollution among others, cascade and affect the popular transport system. This means another key recommendation **is to collect critical data, both standardized transport data** (DigitalTransport4Africa, n.d.; Klopp et al., 2023; Hatfield et al., 2025) **and layer on to that climate hazard and risk data to pinpoint key intervention areas**. For example, while mapping popular transport routes in Freetown, a World Bank team also looked at flood risk and where there was need for intervention and emergency planning (Global Facility for Disaster Reduction and Recovery, 2020).

Future studies may explore how mitigation and adaptation strategies intersect and might be co-implemented across the popular transport sector. This includes making sure mitigation strategies like low-emissions transportation systems can resist challenges ahead; electric buses or two-and-three-wheelers and their users, for instance, should be able to function and thrive during extreme heat and flooding. In effect, adaptation is essential—not optional—for climate resilient transport. Failing to strike this balance may lead to a vicious cycle: declining infrastructure intensifies shifts toward higher-emitting private vehicles (Jain & Singh, 2021), further accelerating climate impacts that continue to undermine and degrade low-carbon transport systems. Hence the recommendation is **to integrate mitigation and adaptation concerns while including popular transport in our research and policy** (Figure 6).

Bridging this gap begins with the explicit acknowledgment of popular transport in policy frameworks at all levels. Depending on the city and the mode, popular transport recognition may trigger pushbacks. Understanding the reasons behind this resistance, from contrasting interests to complex political-economic factors, is critical to be able to engage, sensitize and convince the authorities and policy makers. Climate resilience also means understanding, negotiating and building trust by addressing the popular transport sector's pressing needs, from road safety to economic livelihoods. When local concerns and dynamics are overlooked, maladaptation can happen, and even well-intentioned interventions can inadvertently compound existing vulnerabilities by reinforcing systemic issues and/or posing additional risks for already disadvantaged populations (Eriksen et al. 2021). This means **it is key to engage in meaningful partnerships with popular transport users, owners and workers in transport and climate planning**.

Overall, popular transport should not be viewed as merely a climate vulnerability to be managed but instead as a potentially untapped partner in building transport resilience and making smart investments in often rapidly growing cities and regions. From this lens, climate research, policy and action must involve collecting good context specific local data, transcend mitigation and adaptation silos and be part of meaningful community engagement and deliberately inclusive planning approaches. By respecting and listening to operators, drivers, owners, users, local policymakers and other key actors as critical knowledge-holders, we can co-produce successful ways to reduce emissions and build resilience together. When engaged properly like this, popular transport can be an integral part of a sustainable, resilient, multimodal transport strategy that delivers reduced emissions and climate protection and co-benefits for all.

Figure 6 | **Towards Solutions: Integration of Popular Mobility in Adaptation Planning, Financing, and Implementation**

Enable Inclusion	Enable meaningful participation of operators, users, and unions in climate resilience research and planning
Integrated Data & Planning	Gather data and integrate popular transport into city adaptation metrics, climate finance frameworks, and urban planning tools
Expand Resilience	Expand urban resilience mandates to explicitly include people-powered, self-organized systems and mesh mitigation with adaptation effort

Source: Compiled by the authors.

IMAGE SOURCES

Cover, Dibakar Roy; Page 7, Prince Beguin; Page 12, Vincent van Zeijst; Page 19, Dieuvain Musaghi; Page 28, Dibakar Roy.

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APPENDIX

Urban Characteristics and Climate Hazards of Living Lab Cities

CITY	CHARACTERISTICS	DESCRIPTION
Accra, Ghana	Population (2024)	▪ 2.7 million
	Location	▪ Capital city on southern coast of Ghana
	Geographic features	▪ Located between two lagoons (Korle to west, Kpeshie to east) ▪ Low-lying with highest elevation of 61m above sea level
	Transport modes	▪ Walking (51% of all trips; 2012 data), while only 20% roads has sidewalks. ▪ Metro Mass Transit Limited (MMT) bus service (less than 10% of road-based passengers) ▪ Limited commuter rail on two routes (Eastern Line) ▪ Minibus tro-tros (15-23 passenger capacity), quasi-regulated and accounting for largest road-based modal share (over 62%). ▪ Motorcycle taxis are banned.
	Climate hazards	▪ Flooding from extreme rainfall and poor drainage ▪ Urban heat islands ▪ Coastal erosion ▪ Sea level rise
Bangkok, Thailand	Population (2024)	▪ 11.2 million
	Location	▪ Capital city situated at the mouth of the Chao Phraya River delta, including areas adjacent to Gulf of Thailand
	Geographic features	▪ Low-lying river delta area with extensive canal network ▪ Tropical with monsoon influence ▪ Heavy rainfall during monsoon season
	Transport modes	▪ BTS (Skytrain), MRT (subway), Airport Rail Link, public bus system, accounting for significant portion of mobility needs
	Climate hazards	▪ Flood: urban floods (especially during monsoon), coastal floods, and river floods from Chao Phraya ▪ Tropical cyclones ▪ Extreme heat ▪ Rising sea levels worsening flood impacts
Bogotá, Colombia	Population (2024)	▪ 11.7 million
	Location	▪ Capital city located in the eastern Andes cordillera
	Geographic features	▪ Located on Andean high plateau (Altiplano) with elevation of 2,630m above sea level ▪ Boarded by Cerros Orientales (eastern hills), Sumapaz páramo, and Bogotá River ▪ Average annual rainfall of 800mm ▪ Bimodal climate regime (two distinct rainy seasons - March to May and September to November, alternating with dry periods)
	Transport modes	▪ SITP (Integrated Public Transport System) including: TransMilenio BRT (114.4 km trunk); zonal routes (1889.6 km), feeder routes (441 km) and TransMiCable (3.3 km)
	Climate hazards	▪ Flood-related hazards: river overflow; urban waterlogging (due to drainage limitations) and torrential flash floods ▪ Landslides ▪ Forest fires (especially in dry seasons) ▪ Urban heat islands

CITY	CHARACTERISTICS	DESCRIPTION
Cape Town, South Africa	Population (2024)	▪ 5 million
	Location	▪ Coastal city at Southwestern tip of Africa, Western Cape province
	Geographic features	▪ 307 km coastline ▪ Mediterranean climate characterized by cold, wet winters and warm, dry summers ▪ Home to Cape Floristic Region (global biodiversity hotspot)
	Transport modes	▪ Rail system (historically backbone, currently in crisis) ▪ MyCiTi BRT (limited coverage) ▪ Minibus taxis (fleet of about 8000 vehicles) operating on licensed routes under unscheduled cash-base system ▪ Equity issue: poorest 25% spend about 43% of household income on transport; spatial legacy of apartheid affecting access
	Climate hazards	▪ Severe drought (2015-2018) ▪ Flooding: mainly affecting low-lying areas with water tables (not necessarily from extreme rainfalls) ▪ Coastal erosion ▪ Fire (due to location within Cape Floristic Region) ▪ Urban heat island effect
Mumbai, India	Population (2024)	▪ 21 million
	Location	▪ Southwestern India, coastal estuary city at the Arabian Sea
	Geographic features	▪ 146 km coastline with creeks and bays ▪ Four rivers: Mithi, Dahisar, Poisar and Oshiwara ▪ Mangrove swamps (east coast), sandy/rocky beaches (west coast) ▪ Tropical climate with monsoon season
	Transport modes	▪ Suburban railway: 7 million passengers/day ▪ BEST bus network: 4128 buses, 507 routes, 5.5 million passengers/day ▪ Metro: One operational line (11.4km) ▪ Monorail: 19.5km, 17 stations ▪ About 200,000 auto-rickshaws ▪ 75000 commercial cabs (including 18000 black-and-yellow taxis)
	Climate hazards	▪ Urban flooding (monsoon season) ▪ Heat stress (particularly post-monsoon with high humidity) ▪ Storm surge and coastal flooding ▪ Landslides during heavy rainfall

Source: Compiled by the authors from Climate Action Plans.

The Partnership for Research on Informal and Shared Mobility (PRISM) is a global consortium that focuses on better understanding informal transport and shared mobility (ISM) with a focus on Asia, Africa, and Latin America. Centered on the "3 Es"- equity, ecosystems and engagement-PRISM relies on the methodology of urban living labs, located in eight cities (Accra, Bangkok, Beijing, Bogotá, Cape Town, Kumasi, Mumbai, and San José) to co-create knowledge and solutions for inter-related challenges with ISM like access, affordability, safety, emissions reduction, inclusion, integration, labor conditions and public health. As part of the PRISM work, World Resource Institute and the Center for Sustainable Urban Development at Columbia's Climate School are collaborating on policy briefings that highlight key research and policy gaps emerging from the living lab work.

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This briefing contains preliminary research, analysis, findings, and recommendations. It is circulated to stimulate timely discussion and critical feedback and to influence ongoing debate on emerging issues. This work may eventually be published in another form and its content may be revised.

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