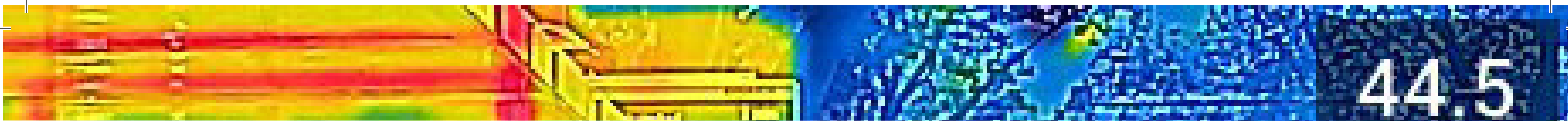
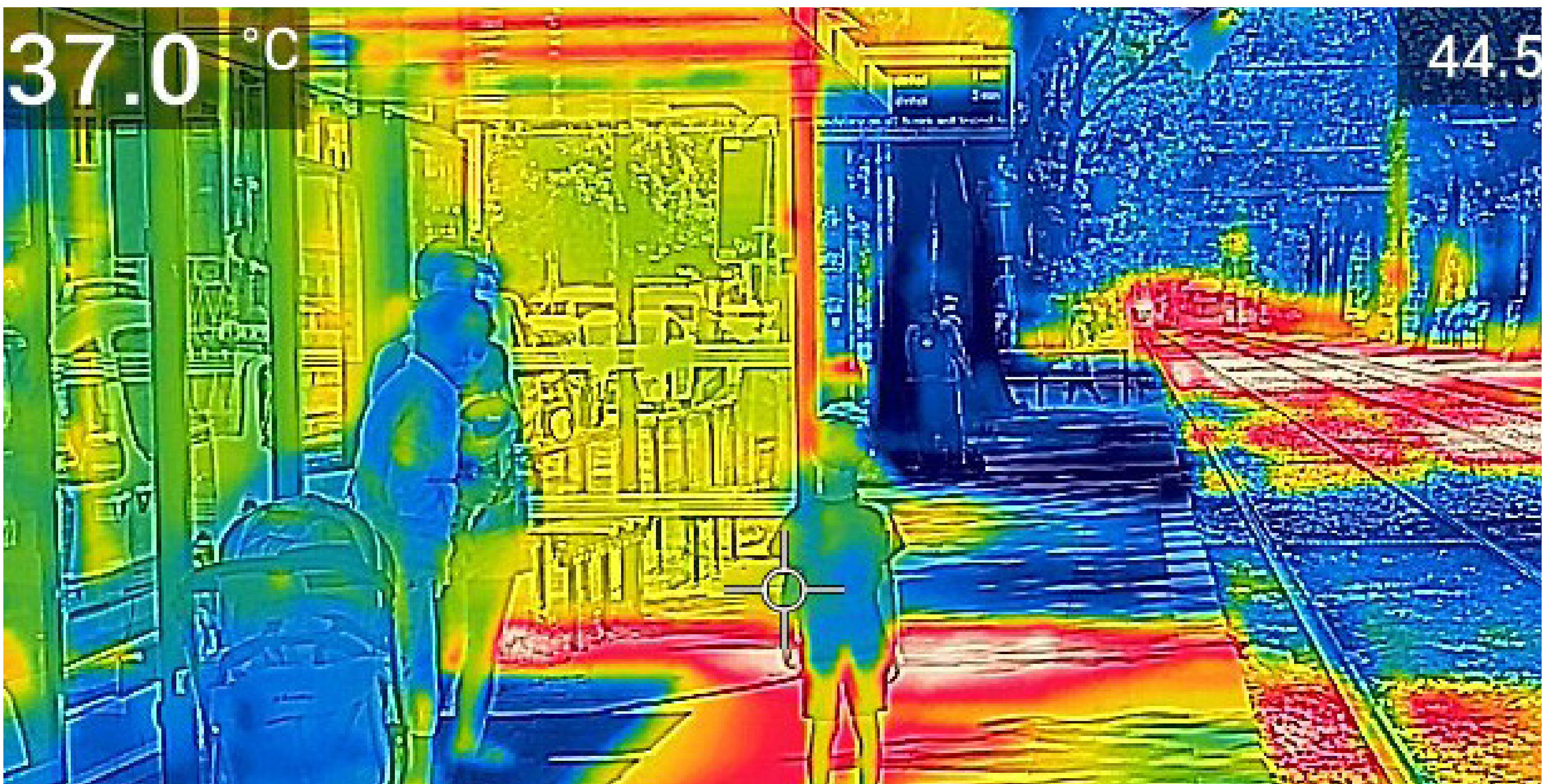


CDRI
Coalition for Disaster Resilient Infrastructure

Community of Practice for Extreme Heat Management in Public Transport Systems

Guidance Document



January 2025

Imprint

Community of Practice for Extreme Heat Management in Public Transport Systems, Guidance Document

Information about CDRI is available on the website:
www.cdri.world

Science Communication and Design: Building Health Lab (BHL)

Cover photo: Building Health Lab (BHL) www.buildinghealth.eu
The cover photos are part of a thermal study conducted in Berlin illustrating how temperatures surpass 40°C, impacting urban transport ridership, especially among vulnerable population groups.

Please print in recycled paper.

Acknowledgements

We thank all members of the Community of Practice for their collaboration in making the Guide on Extreme Heat Management in Public Transport Systems practical and relevant.

Kamal Achuthan, University College London
Abhishek Agarwal, Niti Aayog
Krati Agarwal, Building Health Lab
Rajnish Ahuja, AFD India
Amit Bhatt, International Council on Clean Transportation (ICCT)
Eugenie L. Birch, University of Pennsylvania
Indranil Bose, World Bank Group
Jaire Cajigal, Building Health Lab
Sarika Chakravarty, National Institute of Urban Affairs
Aswathy Dilip, Institute for Transportation and Development Policy (ITDP) India
Erick S. Guerra, University of Pennsylvania
Sivasubramaniam Jayaraman, Institute for Transportation and Development Policy (ITDP) India
RK Jenamani, IMD New Delhi
Jismi Joseph, Miyamoto International
Chris Kost, Institute for Transportation and Development Policy (ITDP) Nairobi
Mahesh Moroney, Maharashtra Metro Rail, Pune
Aarti Nain, United Nations Environment Programme
Tam Nguyen, Bechtel Corporation
Bhaskar Padigala, Foreign, Commonwealth, and Development Office (FCDO), UK
DR Pattanaik, India Meteorological Department
Safi Ahsan Rizvi, National Disaster Management Authority (NDMA), Government of India
Naushin Shaikh, Delhi Metro Rail Corporation
Anshu Sharma, SEEDS
Moumita Shaw, Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ)
Saurabh Shekatkar, T Consult and Associates
Gonggomtua Sitanggang, Institute for Transportation and Development Policy (ITDP)
Hemant R. Sonawane, Maharashtra Metro Rail-Pune
Geetam Tiwari, Indian Institute of Technology, Delhi

Our deepest gratitude goes to the individuals and organizations within CDRI's Community of Practice core team. Their leadership, expertise, case studies, and insights were instrumental in shaping this guide.

Kathy Baughman McLeod, Climate Resilience for All
Savina Carluccio, International Coalition for Sustainable Infrastructure (ICSI)
Tarun Garg, Rocky Mountain Institute (RMI) India Foundation
Sarga GS, Coalition for Disaster Resilient Infrastructure
Ashwani Kumar, Independent Professional- Urban Environment & Infrastructure Sustainability
Prerna Mehta, World Resources Institute (WRI) India
Talat Munshi, UNEP Copenhagen Climate Centre
Emma Pearlstone, Coalition for Disaster Resilient Infrastructure (CDRI)
Umamaheshwaran Rajasekar, Coalition for Disaster Resilient Infrastructure
Jagan Shah, Coalition for Disaster Resilient Infrastructure
Rhea Shah, Coalition for Disaster Resilient Infrastructure
Mrinal Shrivastava, Rocky Mountain Institute (RMI) India Foundation
Prerna Singh, Transitions Research
Vaishali Singh, Institute for Transportation and Development Policy (ITDP) India
Akhil Singhal, Rocky Mountain Institute (RMI) India Foundation
Shalini Sinha, CEPT University
Aparajita Suman, Coalition for Disaster Resilient Infrastructure
Prathna TC, World Resources Institute (WRI) India
Alvaro Valera Sosa, Building Health Lab (BHL)

Supporting Organizations

ICSI CLIMATE RESILIENCE for ALL Building Health Lab

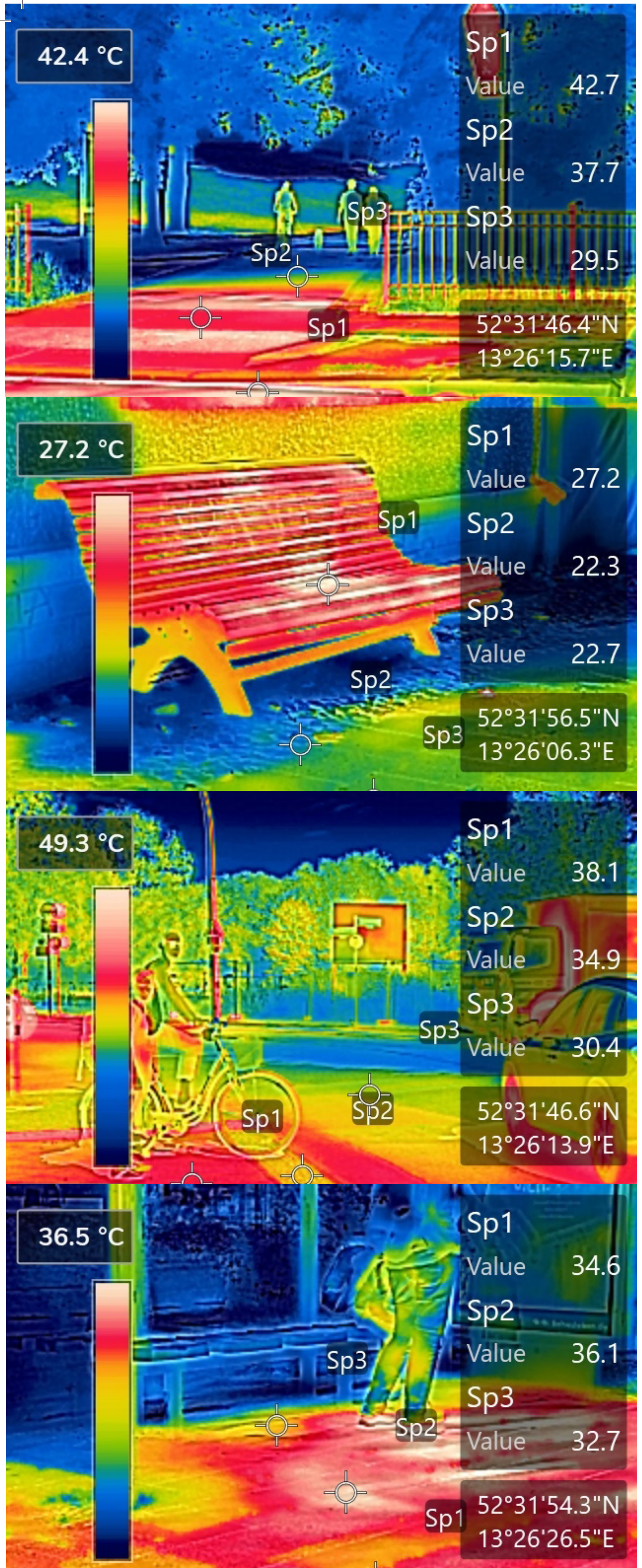


Table of Contents

Policymakers' Summary

This CDRI guidance document addresses the growing impact of extreme heat on public transport systems. It outlines challenges, key frameworks, practical recommendations, and real-world examples, providing a roadmap for developing heat-resilient infrastructure.
The guidance combines concise insights to support decision-making and promote sustainable, climate-adaptive public transport systems.

1 Context Setting

Health & Safety
Environment
Economy

- **Rising temperatures pose a threat** to infrastructure, health, environment, and economy.
- **Public transport is essential** for equitable economic growth and social inclusion.

2 Framework for Extreme Heat in Public Transport Systems

2.1 Research: Establishing Baselines

Knowledge mapping:
Identify gaps by engaging stakeholders and reviewing policies.
Institutional partnerships:
Partner with climate funds and research institutions.
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Analyze heat maps, energy use, and environmental data.
Use surveys and interviews to capture user vulnerabilities.

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Highlight heat stress areas with heat maps and metrics.
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Incorporate climate projections.
Performance-based design:
Assess thermal comfort, resilience, and co-benefits.

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Ensure accessible routes for vulnerable populations.

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Shorten waiting times to reduce crowding and heat exposure.

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improve warnings and updates on heat waves and service delivery.

Downloadable

Figure 1: Policymakers' Summary

Introduction

Public transport supports the economic growth of cities and plays a pivotal role in fostering social interaction, inclusion, and access to opportunities for millions of people daily. However, the intensifying impact of climate change—particularly the rising frequency and severity of extreme heat events—has exposed significant vulnerabilities within these urban transportation systems (Ji et al., 2022).

Extreme heat affects public transport infrastructure, operations, and ridership in myriad ways. Operational challenges such as buckling of rails, power surges, and track disruptions have been observed across global metro systems (Gössling et al., 2023). Additionally, extreme heat can trigger flash flooding, placing strain on infrastructure and exacerbating disruptions. The health and safety of passengers—especially vulnerable populations such as the elderly, children, women, and individuals with pre-existing medical conditions—are adversely affected by prolonged exposure to heat while waiting at stations or using multi-modal transport options (Rosenthal et al., 2022; Ramly et al., 2023). There is an urgent need to take stock of the effects of extreme heat on public transport systems, users, and operators.

CDRI has established a Community of Practice (CoP) focused on extreme heat resilience in public transport systems, leveraging the knowledge and experience of experts and practitioners from various countries. This cross-sector collaboration ensured that the solutions are inclusive, contextually relevant, and implementable.

The findings of the CoP can serve as guidance for cities facing extreme heat events, even in climatic regions where such high temperatures have been rarely recorded in history (White-Newsome et al., 2014). The CoP has emphasized that extreme heat affects all users, not just vulnerable populations; therefore, the measures taken to respond to extreme heat have wider social and economic ramifications.

The recommendations are addressed to CDRI's core constituency, the governments of member countries, which have the authority to instruct and equip their urban governments to take appropriate actions to safeguard public assets and lives. The recommendations highlight the opportunity to capture the co-benefits to public health, the economy, and the environment.

Extreme heat management is an urgent challenge for public transport systems worldwide. This document provides a roadmap for building climate and disaster resilience, and ensuring the safety, sustainability, and economic viability of urban public transport networks under the growing threat of extreme heat. By following these recommendations, governments can safeguard the mobility and well-being of their citizens while contributing to broader climate adaptation and sustainability goals.

Guidance

The recommendations in this document adopt a systems approach and can be applied across a range of cities with different climates, socio-economic conditions, and infrastructure maturity. Resilient and sustainable ways of cooling can contribute to other public goals such as improved human health, enhanced productivity, better stormwater management, improved air quality, reduced pressure on the city's electricity system, and lower GHG emissions (Khosla et al., 2020). Urban cooling, especially through passive methods, can also help countries achieve their Nationally Determined Contributions (NDCs) under the Paris Climate Accord.

Riders and operators of the public transport system are exposed to different levels of heat during different phases of their journey (Corcoran & Tao, 2017). This Guidance Document offers a framework for understanding their exposure to extreme heat during three key phases:

- ***Connecting:*** Exposure while accessing transit stops and hubs, often on foot or through other modes of transport. This phase is often referred to as the 'last mile'.
- ***Waiting:*** Exposure while waiting in transit stations and at bus stops.
- ***Riding:*** Exposure while inside public transit system rail cars and vehicles.

This Guidance Document describes the steps that cities and national governments must take to respond to extreme heat events in their public transport systems. These steps begin with understanding the effects in their own geographic, social, and economic context. City governments should supplement these with their own insights.

Call to Action

In addition to being a guide for governments, this document is also a call to action. It appeals to all international agencies, national and sub-national actors, cities, civil society organizations, and local communities to recognise the urgency and importance of responding to extreme heat impacts on public transit systems and align their work agendas to include this emergent climate change impact. The response to extreme heat must be multi-sectoral, coordinated, and enabled through appropriate technologies and mandates, while also being supported by proper financing (Keith et al., 2019). CDRI encourages its stakeholders and partners to join the Community of Practice and continue to work together to develop a common agenda.

Key Terms

This section defines important terms used throughout the guidelines to ensure a consistent understanding across stakeholders. These terms are crucial for interpreting the document and addressing the specific challenges of extreme heat in public transportation systems.

Disaster Resilient Infrastructure (DRI)
Infrastructure systems and networks, the components, and assets thereof, and the services they provide, that can resist and absorb disaster impacts, maintain adequate levels of service continuity during crises, and swiftly recover in such a manner that future risks are reduced or prevented, including extreme heat. Disaster Resilient Infrastructure (DRI) in public transportation focuses on ensuring that transit systems can continue functioning during and after extreme heat events, safeguarding health and safety while ensuring economic continuity.

Extreme Heat
Periods of excessively high temperatures, typically above the historical average for a specific region, which pose risks to human health, infrastructure, and the environment. In public transportation systems, extreme heat increases passenger vulnerability, equipment failures, and service disruptions.

Heat Index
A measure that combines air temperature and humidity to estimate how hot it feels to the human body. The heat index is a key indicator for assessing the risk of heat stress in public transportation, particularly in enclosed spaces like buses, trains, and stations.

Heat Island Effect
The urban heat island effect occurs when concrete, asphalt, and other surrounding grey infrastructure materials absorb and retain heat.

Heat Stress
The physiological burden caused by exposure to high temperatures, which can result in heat exhaustion, heatstroke, and other heat-related illnesses. In the context of public transportation, heat stress affects both transit users and operators.

Heat Shock
Heat shock occurs when the body is exposed to a sudden and extreme increase in temperature, causing rapid physiological stress. This can disrupt cellular processes and may result in symptoms like dizziness, confusion, rapid heartbeat, nausea, and muscle cramps. Prolonged or severe heat shock can lead to more critical conditions such as heat exhaustion or heat stroke, which require immediate medical attention.
In public transit and urban environments, heat shock can affect both transit users and operators, especially in unventilated, crowded, or unshaded areas where temperatures can quickly escalate.

Heat-related Illnesses
Heat-related illnesses are health conditions caused or exacerbated by prolonged exposure to high temperatures. They range from mild to severe and can escalate quickly if untreated. Common heat-related diseases include:

- Heat Cramps: Painful muscle spasms, often due to dehydration and salt depletion after intense sweating.
- Heat Exhaustion: Symptoms include heavy sweating, weakness, dizziness, nausea, headache, and fainting. It requires rest and cooling to prevent progression.
- Heat Stroke: A severe, life-threatening condition marked by a body temperature above 104°F (40°C), confusion, rapid heartbeat, and potential organ damage. Immediate medical attention is essential.
- Heat Syncope: Fainting or dizziness due to prolonged standing or sudden changes in position in high temperatures.
- Heat Rash: Skin irritation caused by excessive sweating, common in humid conditions.

Vulnerable population groups and those working or traveling in hot environments are particularly at risk of heat-related diseases. Preventive measures like hydration, shade, cooling systems, and protective clothing are essential in mitigating these health risks.

Public Transit (or Public Transportation)
Public transit refers to transportation systems that serve the general public, typically including buses, trains, subways, and trams. Public transit systems are vital urban infrastructure.

Resilience
The capacity of public transportation systems to absorb, adapt, and recover from extreme heat events. A resilient public transport system not only protects users and operators from heat-related risks, but also maintains service continuity.

Transit Stop/Transit Hub
A transit stop is a point where passengers board or exit a single transit service, like a bus. A transit hub connects multiple transit modes, often offering amenities like seating and shelter, which are critical during extreme heat events.

User/Rider/Passenger
Users engage with the transit system or transit infrastructure broadly. Riders are those actively travelling, while passengers are those currently on board.

Vulnerability
Refers to the degree to which people, systems, or environments are susceptible to harm from extreme heat.

- *Vulnerable populations* include people with existing health conditions, older adults, women, pregnant women, children, people with pre-existing health conditions, and low-income communities who rely heavily on public transport.
- *Vulnerable infrastructure* includes transit systems not designed to withstand high temperatures, impacting their reliability and safety.

1

Context Setting

Extreme heat impacts transport systems, infrastructure, health and the economy, posing climate-specific risks to cities in diverse global regions.

1.1 Criticality of Public Transport Systems

The global urban population has grown dramatically, with over half of the world's population now residing in cities (Adlakha & John, 2022; Clarke & Wolfson, 2020). Projections indicate that by 2050, approximately seven out of ten people will live in urban areas (Kohlhase, 2013; Clarke & Wolfson, 2020). Rapid urbanization creates an ever-increasing need for affordable mobility and puts considerable strain on public transport systems, especially in many CDRI countries where urban growth often outpaces urban infrastructure development.

Particularly in low-to-middle-income countries, public transport is an essential lifeline, supporting access to jobs, education, healthcare, and vital services. Transport hubs also often serve as centres of social and economic activity for local communities. Ensuring reliable public transport in these areas is critical to social inclusion and economic stability.

These systems vary significantly across CDRI countries, ranging from regional-scale systems such as the Tokyo Metro, New York City Subway, and Delhi Metro, to smaller systems like the São Paulo Bus System, Lagos BRT, Cape Town MyCiTi, and Medellín's Metrocable, which rely on buses, shuttle services, or limited rail-based options. Transport systems are multi-modal in character and serve large swathes of the population. Disruptions to the system can have cascading impacts on the urban and regional economy. In cities serving dispersed low-density habitations, disruptions can cripple the local economy.

Public transport systems also play a key role during disasters, providing evacuation routes and access to emergency services. This essential function emphasises the need for resilient design to maintain continuity during crises.

1.2 Extreme Heat Impacts on Urban Public Transport Systems

Extreme heat is becoming a more frequent and severe climate hazard, particularly in cities with dense populations. The intensifying heat island effect in combination with more frequent and prolonged heatwaves, is causing unprecedented stress and strain on public transport systems. Extreme heat critically impacts urban public transport systems, with infrastructure being the most visibly affected. However, three key dimensions require attention: infrastructure, public health, and economic activities.

1.2.1 Impacts on Infrastructure

Extreme heat degrades physical infrastructure and operational reliability of transport systems. High temperatures cause malfunctions and accelerate the wear of materials and mechanical and electronic parts, increasing the need for maintenance and repair, while raising operational costs. Climate change is projected to significantly impact transport infrastructure, particularly road and rail networks. For example, a 1.5°C increase in global temperatures is projected to raise annual operation and maintenance costs of EU and UK road and rail networks by €0.9 billion by the end of the century. (Mulholland & Feyen, 2021).
Lagos, Nigeria faces ongoing increases in road repair costs due to heat-related damage during dry seasons, further straining their limited infrastructure budgets. The spike in demand for air conditioning and ventilation inside public transport vehicles and stations during extreme heat can also lead to power grid overloads. For example, during a 2022 heatwave, Bengaluru's Namma Metro faced multiple power outages, disrupting services and overcrowding stations.

1.2.2 Impacts on Health and Safety

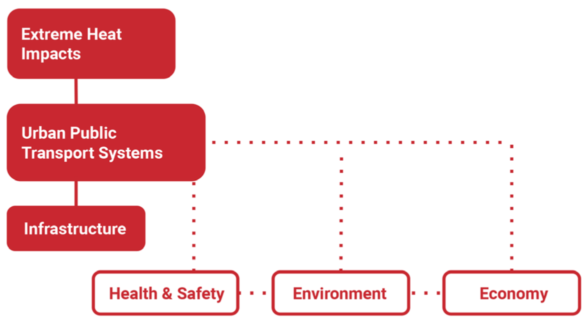


Diagram 1.1: Extreme Heat Impacts on Urban Public Transport Systems

Extreme heat in public transit primarily poses significant health risks to two groups: users and operators.
Many public transport users come from vulnerable groups that disproportionately face more cumulative heat exposure hours and are particularly susceptible to severe health impacts during extreme heat events. These groups include women, the elderly, children, individuals with preexisting health conditions, and lower income communities. Heat stress and the risk of heat-related illnesses are elevated for slower-paced groups as exposure to high temperatures increases while connecting to transport hubs or waiting for transport. Research indicates that individuals with pre-existing health conditions are particularly vulnerable to extreme heat. Neuropsychiatric disorders significantly increase the risk of heat stroke (Kim et al., 2014), while cardiovascular and respiratory diseases are associated with higher hospital admissions during high temperatures (Lin et al., 2009).

Women face additional risks, being nearly four times more likely to be heat intolerant than men (Kazman et al., 2015). Studies show that, on average, women have higher core and skin temperatures, heart rates, blood pressure, and sweating thresholds compared to men (Havenith and Kirch et al., 2005). Pregnant women are particularly vulnerable, with each 1°C rise in temperature linked to a 27–42% increase in the risk of miscarriage or stillbirth, as well as other life-threatening complications for the mother during labour and delivery. Women's heat stress is often compounded by their disproportionate share of informal sector employment and reduced overall access to cooling (Asian Development Bank, n.d.).

Transport operators are also at high risk, as their work may often require prolonged heat exposure, further exacerbated by equipment malfunctions or breakdowns. Heat stress impacts the performance of operators as the exhaustion and cognitive fatigue from extreme heat can impair focus, reaction time, and decision-making. These effects increase the likelihood of operational errors or accidents, compromising the safety of passengers, the infrastructure, and the operators themselves.

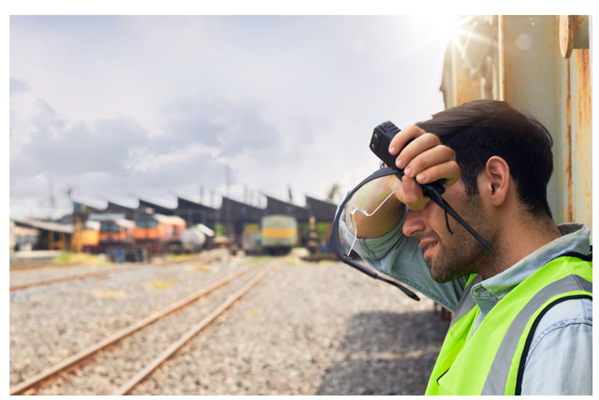


Image 1.1: Operator exhausted by heat; an overlooked issue

1.2.3 Impacts on the Environment

The high energy consumption required to mechanically cool public transport vehicles and stations to maintain service continuity during extreme heat conditions significantly increases the ecological footprint of cities. This creates a feedback loop, as higher energy demands often lead to increased greenhouse gas emissions, further exacerbating climate change and intensifying extreme heat events.

1.2.4 Impacts on the Economy

Extreme heat increases operational system costs due to cooling demands and infrastructure repairs, and healthcare costs related to heat stress incidents. Cities face significant economic losses when public transport systems experience heat-related service disruptions, impacting daily job commutes and resulting in ripple effects on larger economic activities and enterprises. Long-term or continuous disruptions may impact labor force participation and education access, inhibiting poverty reduction.

Demand for public transport often follows an inverted U-shaped curve in relation to temperature, as people may postpone trips or choose private vehicles on hot days, especially when transport facilities lack thermal comfort. Low ridership disrupts public transport revenue generation and the overall economic viability of the system.

1.3 Extreme Heat in Different Climatic Regions

CDRI countries experience a wide range of climatic conditions, and each presents unique challenges for public transport systems. Member countries need to respond to the impacts of extreme heat on their public transport systems in regionally and climatically appropriate ways.

- Arid climates: Prolonged heatwaves and drought degrade infrastructure and spike cooling energy demand.
- Tropical climates: High humidity and extreme heat heighten heat stress for passengers and operators.
- Temperate climates: Increasingly frequent, intense heatwaves strain transport systems.
- Continental climates: Extreme seasonal temperature swings place stress on transport infrastructure.

While these climatic categories highlight region-specific challenges for CDRI countries, extreme heat impacts must also be understood globally. In South Asia, cities like those in India, Pakistan, and Bangladesh face prolonged heatwaves, often exceeding 45°C, and severe monsoon flooding. In Latin America, cities like São Paulo and Mexico City grapple with tropical climates, where high humidity intensifies heat stress, and temperate climates are increasingly affected by intense heatwaves and seasonal flooding. Similarly, in Sub-Saharan Africa, rapidly urbanizing cities such as Lagos, Nairobi, and Kinshasa face rising heatwaves and recurrent flooding.

These global examples underscore shared challenges: dense populations, inadequate infrastructure, strained power grids, and an urgent need for climate-resilient transport systems.

Image 1.2: Riders wait for a bus at an inadequately shaded stop

2

Framework for Extreme Heat in Public Transport Systems

Evidence is essential for developing strategies to address extreme heat challenges in public transport systems.

Coordinated Planning and Integrated Design

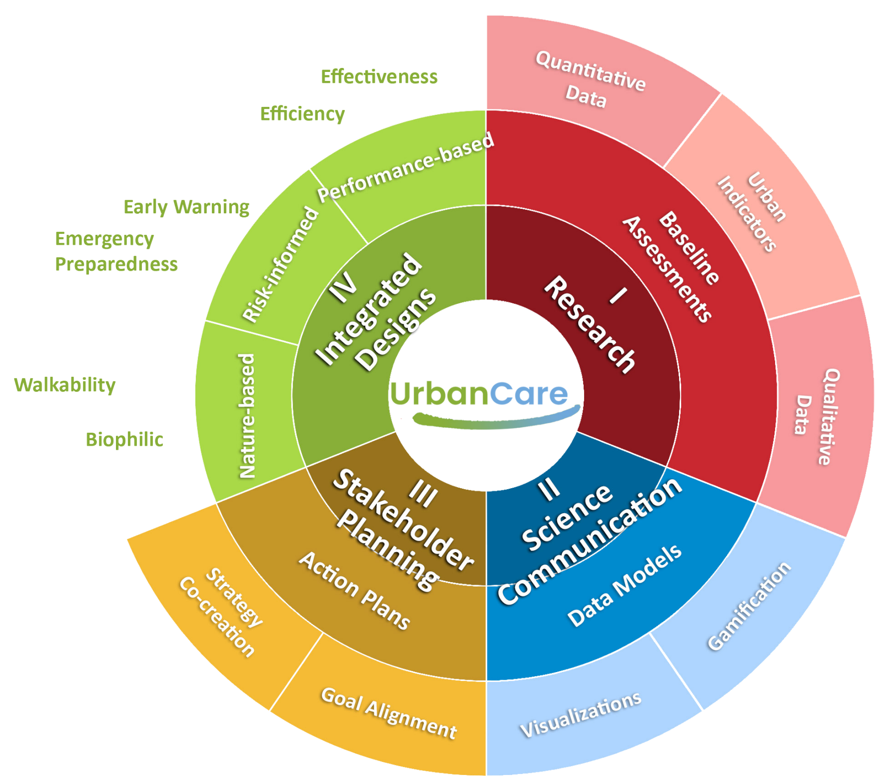


Figure 2.1: The UrbanCare framework, developed by Building Health Lab (A. Valera Sosa, 2021), organizes case studies to address urban health and climate challenges with support from the European Union.

Managing extreme heat in public transport systems requires structured methodologies to bridge gaps in data, planning, and execution while integrating public health, climate resilience, and economic objectives. By addressing fragmented management and fostering collaboration, a systems-based approach delivers scalable, investment-ready solutions tailored to local contexts. This chapter outlines actionable guidance for coordinated planning steps to achieve integrated designs that tackle the challenges of extreme heat in public transport.

2.1 Research: establishing baselines

Building resilience to extreme heat in public transport systems requires a structured approach that integrates comprehensive knowledge and strategic support. This involves two key steps: consolidating fragmented data to create a solid foundation for decision-making and leveraging partnerships and resources to implement effective, sustainable interventions. Together, these steps equip cities to address heat challenges with informed and actionable strategies.

2.1.1 Knowledge Mapping

Knowledge mapping is the first step in building resilience, aimed at addressing the fragmentation of critical urban data across institutions and stakeholders. By consolidating diverse inputs, identifying gaps, and synthesizing information, this process creates a comprehensive foundation for effective planning and decision-making. The following key actions support this process:

- **Stakeholder Engagement:** Engage planners, responders, utilities, operators, experts, and communities. Conduct public hearings and gather feedback.
- **Expert Consultations:** Consult transport, climate, and public health experts to validate recommendations and align with objectives.
- **Literature Review:** Review existing policies and guidelines on climate adaptation and disaster-resilient public transport.
- **Case Study Analysis:** Study cities with similar climates to identify best practices for managing heat impacts on transport systems.

2.1.2 Assessing Support from Resource Institutions

Achieving heat resilience in public transport systems requires leveraging strategic partnerships for financial, technical, and policy support. By engaging with diverse organizations, cities can access the resources necessary to design and implement effective interventions. The following institutions and mechanisms offer valuable avenues for collaboration:

- **Multilateral Development Banks (MDBs):** Collaborate with institutions like the World Bank, ADB, and AfDB for grants, loans, and expertise.
- **Climate Resilience Funds:** Tap into resources like the Green Climate Fund and Adaptation Fund for projects addressing climate vulnerabilities.
- **United Nations and Specialized Agencies:** Work with UNDP, UN-Habitat, and ILO for training, grants, and sustainable urban development practices.
- **Bilateral Assistance Programs:** Secure funding and guidance from countries with advanced heat resilience strategies.
- **Research Institutions and Universities:** Partner with academia for data-driven insights and innovative urban heat solutions.
- **Public-Private Partnerships (PPPs):** Collaborate with private-sector stakeholders for smart cooling, green infrastructure, and funding.

2.1.3 Defining Urban Indicators and Establishing Baselines

Building on the knowledge mapping process, the next step is to develop a conceptual framework that defines urban indicators to guide data collection and analysis. This framework clarifies current vulnerabilities and capacities, forming the foundation for comprehensive baselines that identify priorities, measure progress, and guide investments in heat resilience. Urban public transport systems across CDRI member countries face diverse challenges shaped by economic, climatic, and social contexts, requiring tailored approaches driven by defined indicators.

Defining Indicators

Indicators serve as the backbone of the conceptual framework. Quantitative indicators focus on metrics such as temperature thresholds and biotope quality (see Table 2.2), while qualitative indicators capture social dimensions, including user vulnerabilities and adaptive behaviors (see Table 2.3).

Establishing Baselines

With defined indicators, data is gathered to assess vulnerabilities and capacities, creating baselines that guide decision-making. Key baselines include:

- Health Baseline: Captures data on heat-related health risks for passengers and operators, identifying vulnerable groups including outdoor workers.
- Environmental Baseline: Maps urban heat islands around transport hubs and transit routes, analyzing factors like impervious surfaces, vegetation coverage, and ventilation in transit areas.
- Economic Baseline: Quantifies the economy of extreme heat, including infrastructure maintenance costs, ridership changes, and health-related expenses.

Baseline	Key Areas	Details
Health and Safety Baseline	Public Health Data	Collects heat-related illness statistics, including gender- and age-segregated data on conditions like heatstroke and respiratory issues.
	Vulnerable Groups	Focuses on high-risk populations such as older adults, children, women, and low-income communities..
	Heat Stress Risks	Assesses exposure during all journey phases (connecting, waiting, riding), especially in high-heat zones.
	Operators' Health	Examines risks to drivers and maintenance staff in poorly ventilated or enclosed environments.
Environmental Baseline	Urban Heat Islands	Measures how transit infrastructure contributes to heat retention, focusing on materials like asphalt and concrete.
	Green Infrastructure	Evaluates cooling contributions from shade trees, green roofs, and permeable surfaces.
	Energy Efficiency	Reviews energy use for cooling systems in vehicles, stations, and terminals to identify inefficiencies.
	Climate Resilience	Analyzes how well transport systems integrate sustainable design and withstand heatwaves.
Economic Baseline	Investment Resources	Assesses funding availability from government budgets, international adaptation funds, and partnerships.
	Economic Impacts of Heat	Evaluates disruptions such as increased maintenance costs, lost ridership revenue, and healthcare expenses.
	Cost of Inaction	Highlights long-term risks like infrastructure degradation and higher public health costs.
	Resilience ROI	Calculates savings and benefits from heat resilience measures like reduced energy consumption and fewer service disruptions.
	Equity Impacts	Examines how heat disproportionately affects low-income groups, limiting access to opportunities and deepening inequalities.

Table 2.1: Establishing Baselines for Heat-Resilient Transport Systems

Measuring, and Tracking Progress for Heat-Resilient Public Transport Systems

The next step applies the indicators through quantitative and qualitative research to provide a holistic understanding of conditions, vulnerabilities, and intervention priorities. These methods enable progress tracking, advance project co-benefits, and support evidence-based decisions, outcome forecasting, and sustainable investments.

Quantitative Research

This part fo the research establishes measurable baselines by analyzing current environmental conditions, infrastructure performance, and energy use. It identifies heat vulnerabilities and highlights intervention priorities through tools such as GIS mapping, thermal imaging, and energy audits.

Qualitative Research

Qualitative research captures the lived experiences of users and operators, focusing on behavioral patterns, vulnerabilities, and adaptive practices during extreme heat. It complements quantitative findings by providing insights through interviews, surveys, and focus groups, highlighting challenges across the journey phases—Connecting, Waiting, and Riding.

Progress and Co-benefits Tracking Criteria

Tracking mechanisms evaluate research outputs to guide planning and design, assessing vulnerabilities, heat risks, and system performance while emphasizing co-benefits in health, safety, the environment, and the economy. Collaborative partnerships and iterative feedback loops ensure tracking results align with planning priorities and investment goals.

Quantitative Indicators	
Challenges	**Details**
Temperature Thresholds	Measure critical levels impacting infrastructure and passenger comfort.
Biotope Quality	Assess ecological health near transit hubs.
Overcrowding Metrics	Evaluate passenger density during peak hours to address system strain.
Cooling Demands	Analyze energy consumption and emissions related to heat management.
Aging Infrastructure	Quantify frequency of breakdowns and unsafe conditions worsened by heat.
Environmental Impacts	Measure cooling demands and emissions due to outdated systems.

Table 2.2: Defining Quantitative Indicators

Qualitative Indicators	
Challenges	**Details**
Accessibility Barriers	Identify challenges in routes, connectivity, and inclusivity for vulnerable groups.
Reliability Issues	Capture user perceptions of delays, inconsistent service, and breakdowns.
Adaptation Behaviors	Understand how passengers cope with extreme heat and overcrowding.
Supply and Demand Imbalance	Gather qualitative insights on overcrowding caused by high urbanization.
Investment Gaps	Explore perceptions of insufficient funding for necessary upgrades.

Table 2.3: Defining Qualitative Indicators

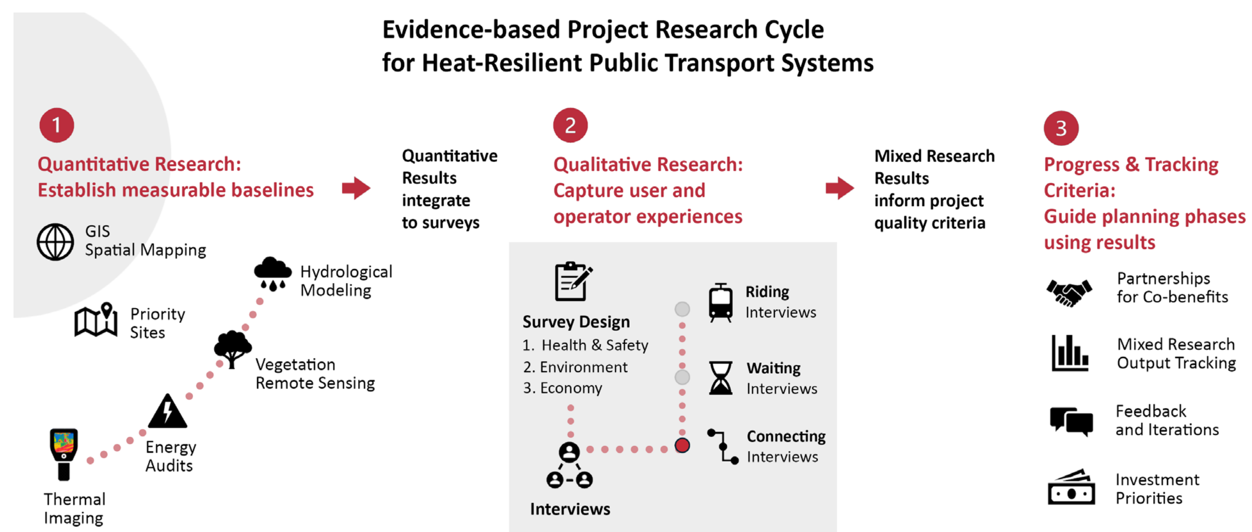


Figure 2.2: Evidence-Based Project Research Phase for Heat-Resilient Public Transport Systems

2.2 Science Communication: Data Models

Effective visualizations transform complex data into clear, actionable insights, empowering stakeholders to address challenges and develop targeted solutions.

2.2.1 Quantitative Data Visualizations

Visual data empowers stakeholders to explore and interpret complex datasets. By transforming technical findings into clear visual formats, these tools provide focus and accessibility for informed decision-making. Quantitative formats include:

- Heat Maps: Highlight critical thermal stress zones in transit networks, such as urban heat islands near bus stops and train stations, offering immediate insights for interventions.
- Comparative Charts: Display baseline projections, like cooling needs or thermal stress zones, for future comparisons.
- Performance Metrics Visuals: Visualize key indicators, including temperature extremes, stormwater-prone areas, and high-vulnerability locations.
- Interactive Gamification: Offer a dynamic web-based platform integrating all visualizations, enabling stakeholders to explore conditions, simulate scenarios, and gain insights interactively.

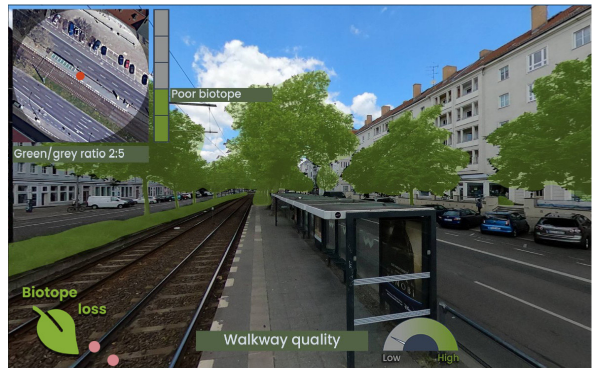


Image 2.2: A Data Viewer user clicks on the Biotope Loss icon to access an infographic evaluation

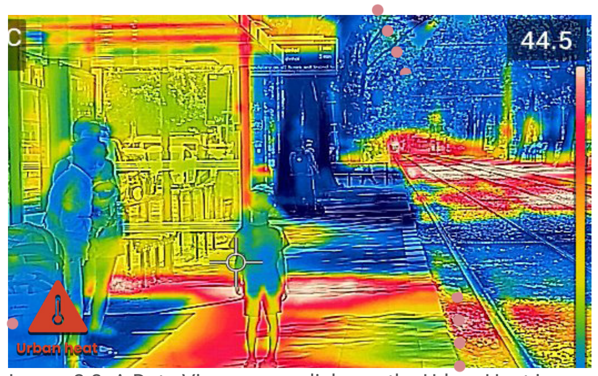


Image 2.3: A Data Viewer user clicks on the Urban Heat icon to access an infographic thermal survey

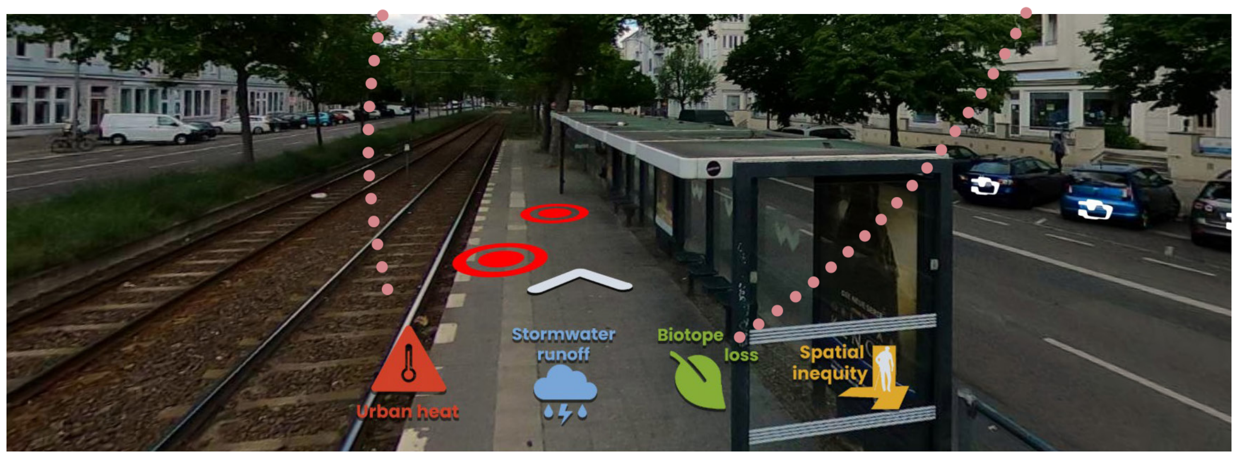


Image 2.1: The UrbanCare Data Viewer by Building Health Lab provides an immersive, gamified experience with embedded urban environmental data to support stakeholder decision-making workshops

2.2.2 Qualitative Data Visualizations

The qualitative research phase builds on insights gained during the preceding quantitative research phase. The data and findings help shape the design of surveys and focus discussions, ensuring that qualitative methods—such as interviews, focus groups, and surveys—gather relevant and practical insights from participants.

Storytelling techniques are then employed to translate qualitative findings into relatable narratives that highlight the lived experiences of users and operators during extreme heat conditions. These narratives evaluate rider journeys across the key phases of public transport interaction—Connecting, Waiting, and Riding—to uncover challenges and opportunities for targeted interventions.

- Connecting Phase: Focuses on the journey to transit hubs, identifying challenges such as unshaded pathways, heat-exposed crossings, and limited access to water. Operators' perspectives are equally important, highlighting efforts to manage foot traffic and ensure pedestrian safety during extreme heat.
- Waiting Phase: Captures user experiences at stops and stations, emphasizing discomfort, safety concerns, and the absence of cooling infrastructure like shaded seating or air-conditioned waiting areas. This phase also considers operators' challenges in managing crowds and ensuring safety in overheated environments.

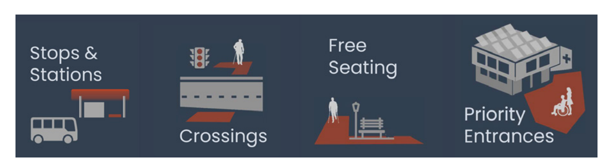


Image 2.4: Icons showing key scenes in the pedestrian journey, from stops to priority entrances for services


Image 2.6: UrbanCare Workshop in Gothenburg, Sweden, facility managers using planning boards to align goals

- Riding Phase: Chronicles interactions inside transit vehicles, where thermal stress from poor ventilation, malfunctioning cooling systems, or overcrowding significantly impacts user comfort. It also examines operators' efforts to maintain reliable services and minimize heat-related disruptions.

Urban Scenes in the Pedestrian Journey

The Connecting Phase is further illustrated through specific urban scenes that emphasize the pedestrian journey:

- Stops & Stations: Entry points where shaded structures and accessible pathways help mitigate heat stress.
- Crossings: Critical intersections requiring shaded, safe, and well-marked routes to ensure pedestrian comfort and safety.
- Free Seating: Rest areas along routes, equipped with shade and hydration points to support vulnerable users.
- Priority Entrances: Key destinations like hospitals or schools, where shaded, accessible pathways improve usability for all, particularly those with limited mobility.

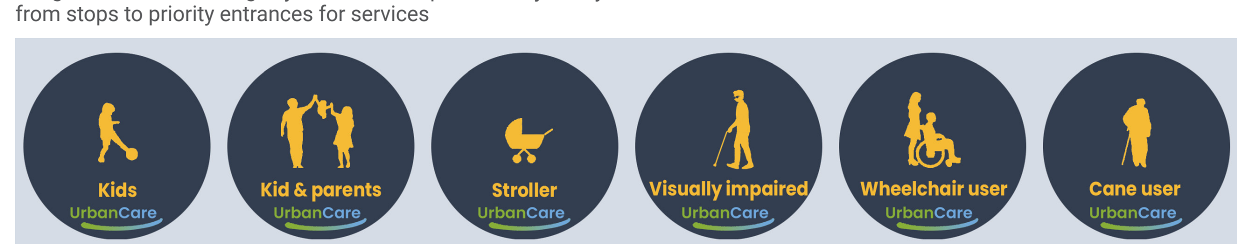


Image 2.5: Icons representing diverse user groups with specific mobility needs, highlighting inclusive and accessible transport solutions used in qualitative surveys of pedestrian scenes

2.3 Stakeholder Planning: Multiple Goal Alignment

This phase focuses on stakeholder collaboration to align multi-goal objectives and co-create strategies for managing extreme heat in public transport. Unlike earlier research-focused phases, Phase 3 emphasizes participatory planning to translate insights into actionable solutions. By structuring objectives and activities, it ensures dynamic, iterative decision-making, delivering context-specific solutions aligned with health, climate, and economic goals.

Image 2.7: UrbanCare Workshop in Curitiba, Brazil, employing a Data Viewer to support decision-making

Scenario Analysis: Evaluating Feasibility and Impact

Objective: Use data models from the science communication phase to explore and discuss potential interventions and their outcomes.

- Developing Scenarios: Present alternative strategies for addressing identified challenges, such as cooling strategies for transit hubs or enhancing shaded connectivity.
- Evaluating Scenarios: Analyze environmental, social, and economic impacts using data models and baselines from Phases 1 and 2 to guide decision-making.

Strategy Co-Creation: Aligning Goals

Objective: Facilitate collaboration among stakeholders to harmonize diverse priorities and co-create integrated strategies.

- Stakeholder Workshops: Conduct interactive sessions with transport operators, urban planners, public health experts, and policymakers to ensure solutions align with operational needs and local priorities.
- Community Feedback: Gather input from transit users and communities to validate that strategies address real-world challenges, such as comfort at bus stops or shaded pedestrian access.
- Consensus Building: Utilize visualization tools (developed in Phase 2) to align diverse perspectives and build actionable strategies.

Technical and Economic Resource Optimization: Feasibility Checks

Objective: Ensure strategies are technically viable and cost-effective in achieving measurable health, climate, and economic outcomes.

- Resource Evaluation: Assess the technical, financial, and operational feasibility of interventions, such as enhanced cooling systems or shaded infrastructure.
- Prioritization Tools: Use structured methods, such as cost-benefit analysis, to identify and optimize strategies that provide maximum impact with available resources.

Action Plans: Deliverables for Design

Objective: Develop a guiding document that consolidates agreed strategies and serves as the foundation for the design phase.

- Action Plan Development: Compile a roadmap detailing timelines, roles, responsibilities, and resource allocation for heat-mitigation projects in transport systems.
- Documentation: Ensure the action plan provides clear guidance for the transition into the Climate-Sensitive Design phase.

Image 2.8: UrbanCare Workshop in Gothenburg, Sweden, facility managers using planning boards to align goals

2.4 Integrated Design: Solutions and Performance Evaluations

The Design Phase is a critical step in transforming collaborative planning strategies into tangible, performance-driven solutions. It focuses on creating adaptable, user-centered designs that address the spatial and infrastructural needs of vulnerable populations while advancing health, environmental, and economic objectives.

- Nature-based Design Strategies that enhance walkability, reduce heat retention, and integrate green infrastructure into urban transit environments.
- Risk-informed Design Approaches to predict and mitigate extreme heat impacts through data-driven systems and emergency-ready features.
- Performance-based Design Principles that ensure thermal comfort, energy efficiency, and resilience in transport systems through innovative retrofits and long-term redesigns.

Building on these approaches, the Framework for Design Decision-Making translates principles into actionable, strategic, and sustainable plans, focusing on time frames, costs, outcomes, and user-centered iterations.

Time Frames in Design

- Short-Term: Temporary shading and cooling measures.
- Medium-Term: Retrofit hubs and expand shaded pathways.
- Long-Term: Redesign systems for resilience and sustainability.

Implementation Costs

- Short-Scale ($): Low-cost solutions like shading and vegetation.
- Medium-Scale ($$): Moderate upgrades, like greening hubs or retrofitting vehicles.
- Long-Scale ($$$): Large-scale system transformations.

Outcome-Oriented Design

- Immediate: Reduce heat stress and boost ridership.
- Delayed: Improve energy efficiency and resilience.

Facilitating User-Centered Iterations

- Pilot Projects: Test cooling systems and shaded pathways.
- Collaborative Refinement: Engage stakeholders for design improvements.

Category	Key Strategy	Details
Nature-based Design Strategies	Walkability	Design shaded, accessible pathways with wayfinding tools to connect transport hubs to key destinations, accommodating children, older adults, and persons with disabilities.
	Urban Surface Revitalization	Replace asphalt with permeable pavements and rain gardens near transit hubs to manage runoff and reduce heat retention.
	Shading	Install canopies, pergolas, or green roofs at platforms, bus stops, and pedestrian corridors.
	Greenification	Add vegetated buffers, tree-lined avenues, and vertical gardens around transit hubs to mitigate heat islands.
Risk-informed Design Solutions	Early Warming Systems	Use data-driven systems to predict and mitigate extreme heat risks in public transport networks.
	Emergency Preparedness	Integrate features like shaded assembly points and cooling zones in transport systems.
Performance-based Design Principles	Indoor Comfort	Implement cooling and shading interventions, solar shading devices, and biophilic elements in hubs and terminals.
	Vehicle Retrofitting	Equip vehicles with cooling systems, reflective materials, and heat-resistant seating to enhance passenger comfort.

Table 2.4: Integrated Design Solutions and Performance Evaluations

3

Actions for Implementation

Tackling heat-related transport challenges requires evidence-based baselines of existing issues and clear goals for health, safety, efficient infrastructure, and economic impact.

Addressing Challenges Across Connecting, Waiting, and Riding Phases

This section provides a roadmap for addressing heat-related challenges in public transport using evidence-based interventions. It focuses on three journey phases—Connecting, Waiting, and Riding—to identify baseline vulnerabilities, existing challenges, and strategies for improvements across health, green infrastructure, and economic impacts.

Through two end-user perspectives (commuters and vulnerable populations) and one operator perspective, the impact phases illustrate shared but distinct challenges such as unshaded pathways, overheated waiting areas, and operating vehicles in extreme heat.

Practical solutions are presented for each phase, with baselines to assess conditions and goal-setting strategies for actionable interventions. These goals aim to reduce heat risks, enhance safety and comfort, and drive economic benefits.

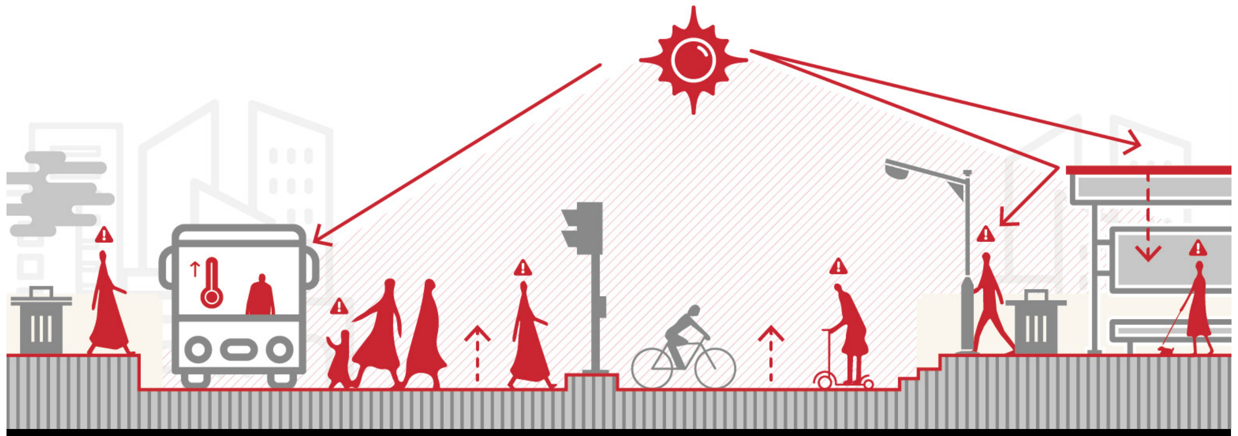
Illustrations contrast current vulnerabilities, like unshaded pathways and overcrowded vehicles, with future heat-resilient systems featuring shaded walkways, cooling infrastructure, and climate-adaptive designs, offering clear guidance for implementation. A hypothetical example demonstrates how a metropolitan city with 5 million users transformed its transport network into a safe, reliable, and heat-resilient system by adopting these strategies.

This approach equips stakeholders with tools to mitigate heat risks, enhance user and operator experiences, and foster urban resilience and climate adaptation.

Image 3.1: A tram stop at the entrance of a major urban hospital features narrow platforms, creating challenges for wheelchair users and caregivers to access the stop and wait safely

Connecting Phase Impacts

The connecting phase encompasses the initial and final segments of the journey, or "first" and "last mile," where users and operators often rely on walking, biking, or feeder services (such as shared mobility options) to reach transport stations and hubs. Exposure to solar radiation and outdoor heat is common in this phase and highlights the need for safe, reliable access to shaded or cooled pathways, and improved connections to transport stations and stops.



Connecting Phase: obstacles for slower groups on the way to a stop or station include unfit or missing pavers, steps, misplaced bins and poles, obstructing furniture and sealed surfaces that trap or emit hazardous heat

Figure 3.1: Connecting Phase Impact Illustration

Story 1: Ximena and her child walking to a high-density legacy system

On a scorching afternoon with temperatures above 45°C in the crowded city centre, Ximena picks up her 7-year-old son, Juan Carlos, from school. They walk 200 metres to the bus stop for a ride home, 6 km away in a peri-urban area. The path has no shade and frequent encroachments force them onto the roadway. Navigating close to cars emitting heat, Juan Carlos, due to his height, is especially exposed. Already tired from school, he pauses several times, so Ximena carries his heavy school bag. Finally, they reach the bus stop, exhausted and overheated, to wait.

Story 2: Seema and little Harshita connecting to a low-density, sparsely developed system

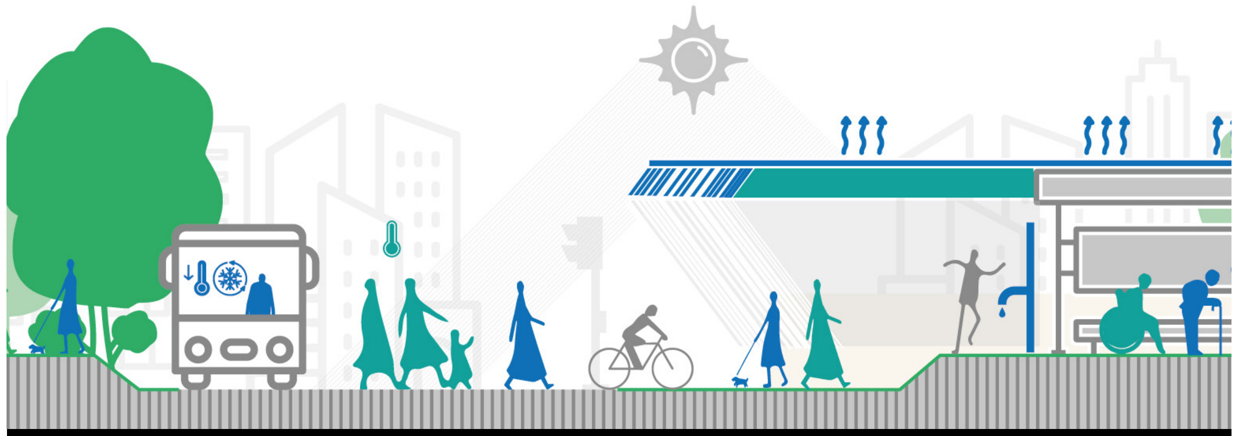
Seema picks up her 10-year-old daughter, Harshita, from school on a hot late summer afternoon. They take a battery-operated rickshaw to reach the nearest metro station, 1 km away. With temperatures exceeding 45°C and high humidity, the uninsulated metal rickshaw heats up quickly, and the open structure exposes them to hot winds and vehicle emissions along the way. Traffic is heavy, and the rickshaw makes frequent stops along the crowded road, further prolonging their heat exposure. After a taxing 15-minute journey, they reach the transport station, overheated and fatigued.

Story 3: Daniel commutes to work as a transport system operator

Daniel, a bus driver for the city's transport authority, has a midday shift on a day when temperatures have reached 42°C, with oppressive humidity. To reach the bus depot, he walks 1.5 km through a crowded market and across an 8-lane arterial highway. Without shade, Daniel contends with intense heat radiating from paved surfaces, worsened by humidity that leaves him drenched and breathless. Midway, he encounters a delay: a section of the road has buckled under the heat, forcing pedestrians onto congested walkways. By the time he arrives at the depot, Daniel feels fatigued, overheated, and struggling with his asthma, with little time to recover before his shift.

Connecting Phase Actions

The connecting phase focuses on enhancing the pathways and spaces users navigate to access public transport, ensuring these are safe, comfortable, and heat-resilient. The image illustrates key interventions such as shaded pathways, tree cover, cooling features, and accessible transit stops that prioritize vulnerable groups like children, the elderly, and people with disabilities. These improvements aim to reduce heat exposure, encourage active mobility, and create equitable, sustainable transport systems.



Connecting Phase: Some solutions involve integrating green corridors and shaded pathways to ensure routes are accessible, safe, and provide thermal comfort, as well as installing heat-mitigating materials and smart cooling

Figure 3.2: Connecting Phase Actions Illustration

Health and Safety Baseline

Users, particularly vulnerable populations like the elderly, children, women, pregnant women, and people with disabilities, often face high exposure to heat while navigating unshaded and exposed paths to transport hubs. Emergency response options are sparse along these routes, leaving high-risk individuals unsupported during extreme heat events.

Green Infrastructure Baseline

Most transport access pathways lack tree cover, green corridors, or shade structures, raising surface temperatures and amplifying the urban heat island effect. The absence of cooling features, such as hydration spots, exacerbates heat stress on users.

Economic Impact Baseline

Uncomfortable, hazardous access routes deter public transport use, reducing ridership revenue and decreasing foot traffic to local businesses.

Health and Safety Goal Setting

Establish accessible, shaded walkways with cooling stations along high-traffic routes, prioritizing those serving vulnerable populations. Integrate first-aid and hydration stations to reduce heat-related health risks by 30%.

Green Infrastructure Goal Setting

Develop tree-lined paths and green corridors to lower surface temperatures by 5–7°C, while enhancing the aesthetic and ecological value of routes. These green features absorb CO_2, mitigate flooding, cool urban areas, and improve user experience.

Economic Impact Goal Setting

Increase comfort through well-connected and continuous pedestrian networks to encourage transport use, resulting in a 15% rise in ridership. Enhanced foot traffic and transport utilization drive economic activity and elevate property values along transport pathways.

Waiting Phase Impacts

The waiting phase occurs at transport hubs, stops, and stations as users and operators await buses, trains, or other public transport vehicles. This often results in prolonged heat exposure, exacerbated by poorly ventilated or crowded spaces. The scenarios of this phase emphasise the need for transport hubs with enhanced cooling systems designed to mitigate exposure, improved scheduling and maintenance of systems to reduce delays, and the importance of shaded and ventilated depot areas to protect operators.

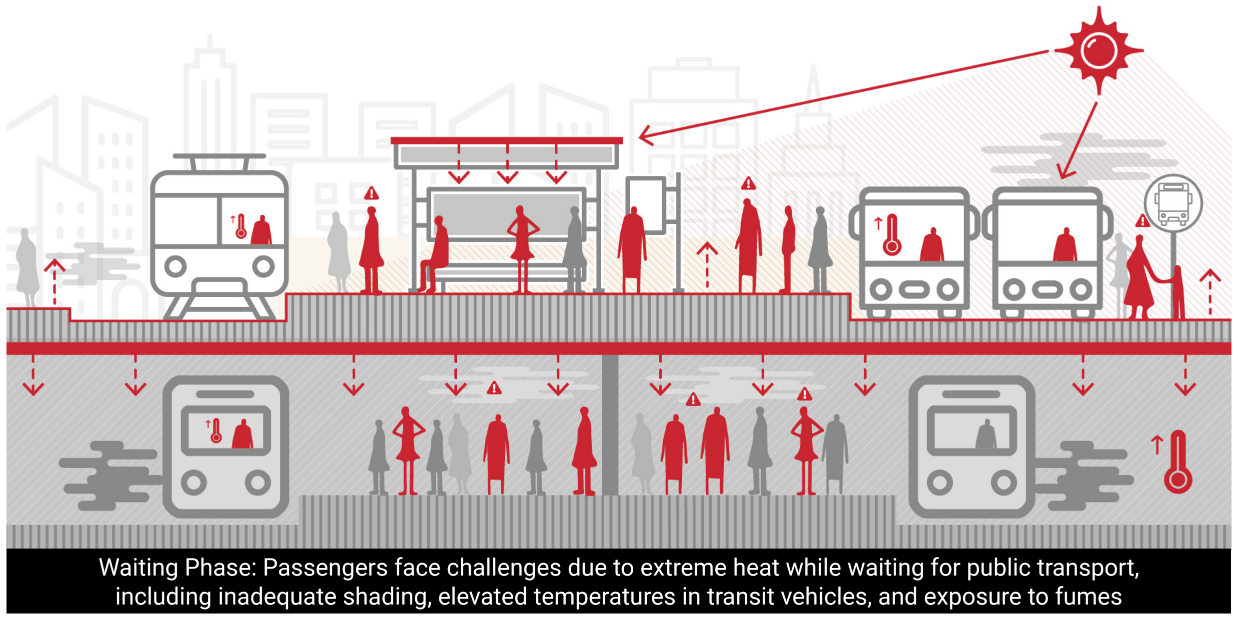


Figure 3.3: Waiting Phase Impact Illustration

Story 1: Ximena and her child waiting in a high-density, legacy system

Ximena and her son Juan Carlos wait at the bus stop for their ride home. Although the bus stop is shaded, the air surrounding them feels stiflingly hot. The waiting area is crowded, and to secure a better boarding position, Ximena and Juan Carlos stand closer to the road, adding exposure to heat radiating from nearby vehicles. Their preferred air-conditioned bus has a medium frequency and arrives every 15-20 minutes, but after 12 minutes of waiting, a non-AC bus arrives. Exhausted from the heat and knowing her son is hungry, Ximena decides to board the bus despite the lack of cooling. They both struggle to find space as they board alongside the large crowd.

Story 2: Seema and little Harshita waiting in a low-density, sparsely built system

Seema and her daughter Harshita reach the overground metro station to wait for their train. Typically, their Mass Rapid Transport System (MRTS) has a high frequency, with trains arriving every 5 minutes. However, on this day, frequent hot temperatures have led to a derailment, delaying the trains by over 30 minutes. Although the station has a shaded roof, its open sides leave them exposed to the hot wind that intensifies their fatigue. Seema and Harshita grow increasingly uncomfortable and anxious as the minutes pass until their train arrives.

Story 3: Daniel waits his turn at the bus depot

At the bus depot, Daniel prepares for his shift amidst sweltering temperatures. The depot, with its extensive vehicle movement and exposed surfaces, has become a heat island, amplifying both ambient and surface temperatures. Daniel feels the heat intensely as he approaches his bus, which has been parked in direct sunlight all morning. As he climbs into the driver's seat, he is met with stagnant, hot air, and the metal components are uncomfortably hot to the touch. His bus lacks air conditioning, so he relies on open windows for ventilation, exposing himself to emissions from surrounding buses. Daniel waits at the bay for his turn to drive out.

Waiting Phase Actions

Extreme heat poses significant challenges for the waiting phase in urban transport systems, where passengers often face prolonged exposure to high temperatures. Insufficient cooling and shading compromise passenger safety and comfort, while dependence on energy-intensive cooling systems raises operational costs and environmental impact. The targeted goals- such as sustainable cooling solutions and green infrastructure- aim to enhance resilience, lower costs and improve user experience, paving the way for safer, more sustainable transport systems.

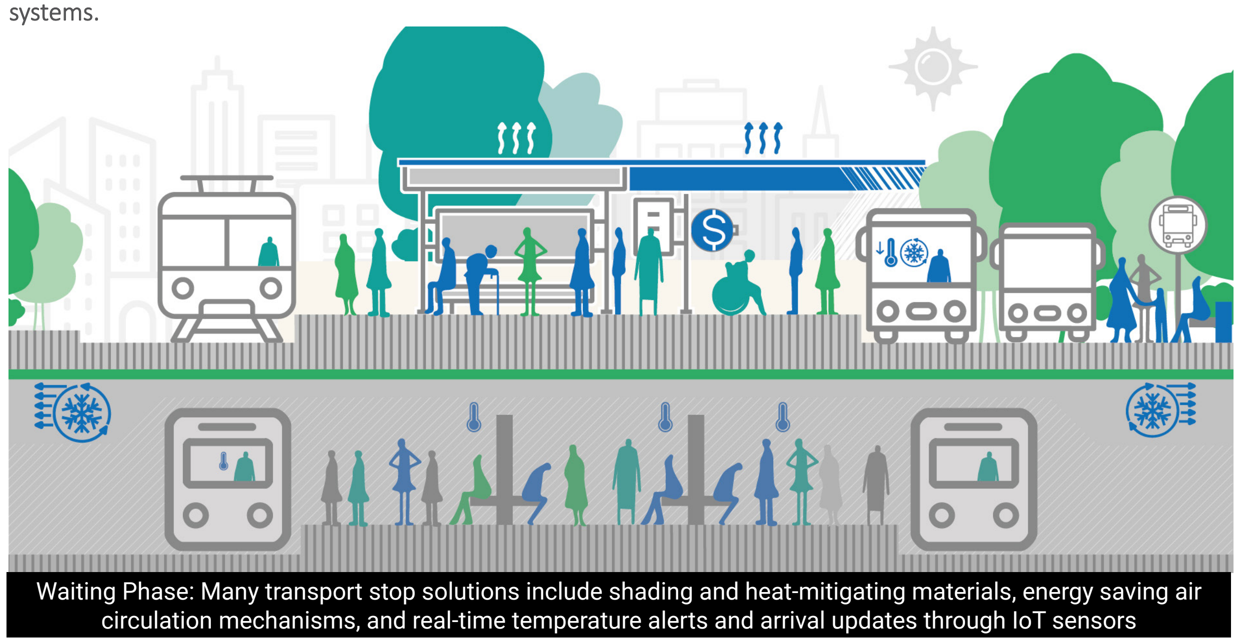


Figure 3.4: Waiting Phase Actions Illustration

Health and Safety Baseline

Many transport hubs and stops lack adequate shading and cooling, exposing waiting passengers, especially those with mobility challenges, to potentially hazardous heat conditions. High humidity exacerbates the discomfort, making it harder for passengers to cool down and increasing the risk of heat-related illnesses.

Green Infrastructure Baseline

Transport stations often rely on energy-intensive cooling systems instead of sustainable options, such as green roofs, permeable pavements, or passive cooling designs. This increases operational costs and contributes to elevated ambient temperatures.

Economic Impact Baseline

Insufficient cooling in waiting areas reduces user satisfaction and discourages ridership during extreme heat. The increased demand for temporary cooling solutions drives up operational and maintenance costs.

Health and Safety Goal Setting

Integrate energy-efficient cooling systems, shaded waiting areas, and real-time heat alerts displayed on digital screens to reduce heat-related incidents by 40%, ensuring safe and comfortable conditions for waiting passengers.

Green Infrastructure Goal Setting

Retrofit transport hubs with green roofs, green walls, and permeable pavements to reduce indoor temperatures and minimize energy demands. Passive cooling designs, such as misting fans and radiant cooling panels, lower surface heat and improve air quality around stations.

Economic Impact Goal Setting

Enhance thermal comfort to boost ridership by 10%, and green infrastructure improvements to cut energy costs by 10%, contributing to long-term operational savings.

Riding Phase Impacts

The riding phase encompasses the time users and operators spend on transport vehicles en route to their destination. In hot weather, poorly ventilated or overcrowded vehicles can become heat traps, significantly impacting rider comfort and safety, especially for vulnerable users. This phase highlights the importance of adequate cooling systems and ventilation to regulate temperatures inside and around transport vehicles for users and operators, and avoidance of overcrowding on transport vehicles, particularly during heatwaves.

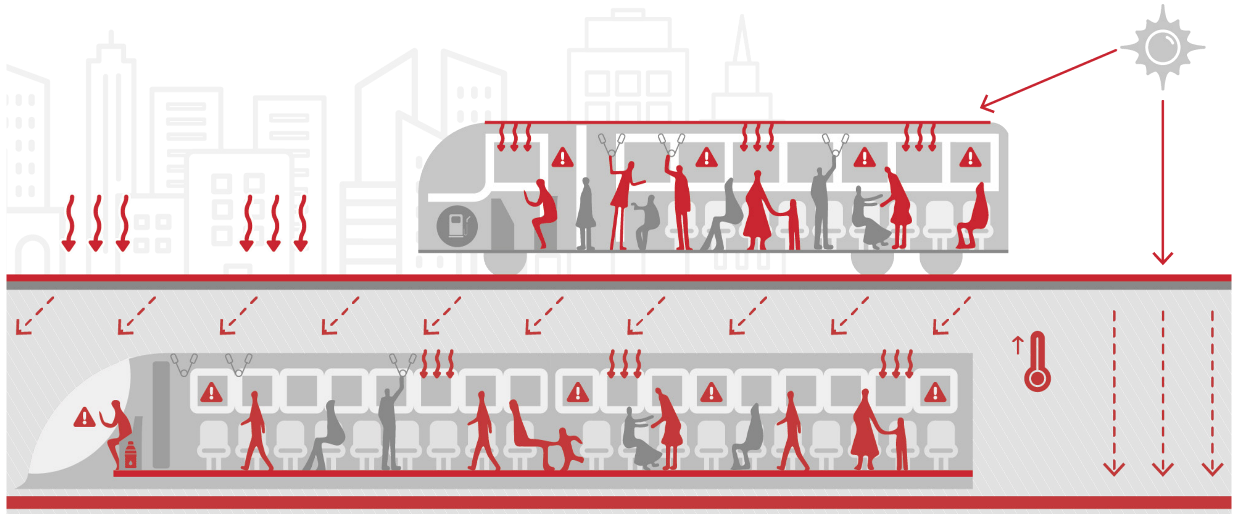

Riding Phase: Passengers experience challenges during their journey due to extreme heat, including inadequate ventilation and elevated temperatures inside transit vehicles, which pose potential health risks

Figure 3.5: Riding Phase Impact Illustration

Story 1: Ximena and her child traveling in a legacy transit system with frequent stops and options

Ximena and Juan Carlos board the crowded bus with limited seats available. Noticing the young child, a passenger offers Ximena his seat. Ximena, with Juan Carlos on her lap, appreciates the seat but remains uncomfortable in the cramped environment. The bus is hot and stuffy with minimal ventilation and many standing passengers crowding the aisle, blocking air circulation. The 30-minute journey becomes increasingly difficult for both mother and child. Upon reaching their final stop, Ximena and Juan Carlos walk the remaining 50 metres home, overheated and exhausted.

Story 2: Seema and little Harshita riding in a low-density, sparsely built system

Seema and Harshita board the overground metro train and manage to find seats amid the crowd. The metro is typically more comfortable than other transport options, but the sudden influx of commuters from the hot outdoors creates a suffocating environment. Seema worries, remembering how Harshita suffered heat shock on a previous ride after transitioning too quickly from the intense outdoor heat to the cooler metro. As the train completes the 20-minute ride, Seema becomes concerned once more, anticipating the gust of hot wind they'll face upon deboarding. Their ride concludes, but they must travel 1.5 km by electric rickshaw to finally reach home.

Story 3: Daniel works at his shift as a bus operator

Daniel drives out of the depot to start his route, facing intense heat through his open window as the vehicle accelerates. He keeps a bottle of water on the dashboard, but the heat from the windscreen has warmed it, making hydration challenging. Navigating the congested roads of the megacity under extreme heat conditions is stressful, and Daniel finds it difficult to keep his composure. The continuous exposure to hot temperatures, combined with long hours and challenging traffic conditions, leaves him fatigued and irritable as he ends his shift.

Riding Phase Actions

The Riding phase presents critical heat related challenges in transport vehicles, where insufficient cooling and ventilation compromise user and operator comfort and operator safety. Outdated energy systems and inefficient cooling systems raise operational costs. Key goals focus on upgrading to efficient cooling technologies, sustainable energy sources, and climate-adaptive design to support passenger well-being, lower fuel expenses, and build a resilient, financially sound transport system.

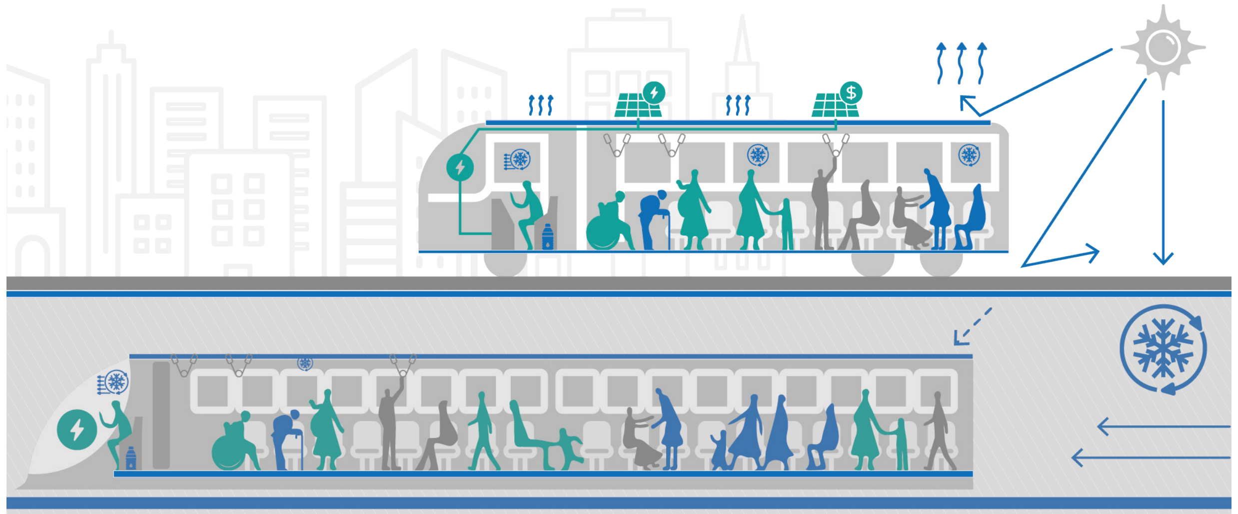

Riding Phase: Best practices for vehicles include enhancing priority seating, implementing smart ventilation for more effective air conditioning, and using heat-reflective materials to ensure thermal comfort and prevent burns

Figure 3.6: Riding Phase Actions Illustration

Health and Safety Baseline

Transport vehicles often lack adequate cooling and ventilation, resulting in uncomfortable, high interior temperatures and posing health risks for passengers and operators. Heat stress is common among drivers, who often receive minimal training on mitigating heat-related health risks.

Health and Safety Goal Setting

Upgrade the transport fleet with efficient air conditioning, heat-reflective coatings, and insulation to maintain interior temperatures at or below 25°C. Provide training for operators on heat stress management, reducing incidents and improving overall comfort.

Green Infrastructure Baseline

Most transport vehicles lack climate-adaptive features, such as insulation or heat-reflective coatings, and rely heavily on traditional fuels. Without efficient cooling systems, excessive heat buildup impacts passenger experience and operator well-being.

Green Infrastructure Goal Setting

Transition to electric or hybrid vehicles with energy-efficient cooling, such as solar-powered systems, to reduce environmental impact, cut greenhouse emissions, and support a sustainable transport system.

Economic Impact Baseline

Elevated fuel consumption and frequent maintenance for cooling machinery escalate operational costs. Reduced comfort discourages ridership in extreme heat, leading to revenue losses and strained transport budgets.

Economic Impact Goal Setting

Decreased fuel and energy demand lower cooling-related expenses by 25%, reduce maintenance requirements, and extend vehicle life. Enhanced comfort boosts ridership, reinforcing the resilience of the financially stable public transport network.

4

Guidance for Adapting Public Transport Systems to Extreme Heat

Coordinated actions and recommendations to protect urban public transport systems effectively align public health, climate resilience, and economic goals.

Strategic Approach

Extreme heat is an escalating concern that demands coordinated action across government agencies, sectors, and society to create safe, sustainable, and resilient public transport systems. This section provides strategic recommendations for government-led initiatives to mitigate heat-related risks, ensure continuity of service during extreme heat events, and support broader national priorities.

These recommendations are designed to address immediate heat-related challenges while establishing a framework for long-term, localized actions. They emphasize key co-benefits across critical agendas:

- Public Health: Reducing heat exposure minimizes illnesses among transport users and operators.
- Climate Adaptation: Green infrastructure and energy-efficient designs lower urban heat and support sustainability goals.
- Economic Resilience: Maintaining transport continuity during extreme heat sustains services, economic activity, and long-term growth.

Each recommendation provides a structured framework for action, ensuring relevance and practicality:

- Action: Defines a targeted strategy to address heat-related risks.
- Indicators: Provides metrics across four phases—Research (Input), Planning (Outcome), Design Performance (Output), and Evaluation (Impact)—to guide implementation and measure progress.
- Classification of Action: Outlines time frame, cost, and expected outcomes to prioritize and allocate resources effectively.
- Primary Goal: States the core objective of the recommendation to ensure focused interventions.
- Alignment with Other Goals: Highlights how the recommendation supports public health, sustainability, and economic resilience.
- Avenues of Action: Identifies pathways for collaboration among policymakers, researchers, community groups, and designers to create localized and equitable solutions.
- Recommendation in Practice: Features real-world examples of successful implementation.

Recommendations

- Establish a Long-Term Vision with Dedicated Funding for Heat-Resilient Urban Planning
- Mandate Heat Impact Screenings for Transport Projects with a Focus on Vulnerable Populations
- Integrate Heat-Resilient Materials in Transport Infrastructure Construction and Renovation
- Transition Public Transport Fleets to Clean Energy with Efficient Cooling Systems
- Incentivize or Mandate Shading and Cooling at Transport Stops
- Enable Data-Driven Decision Making and Predictive Maintenance for Transport Systems
- Improve Transport Frequency to Reduce Wait Times and Crowding
- Enhance the Communication and Timing of Heat Warnings and Service Updates

Figure 4.1: Policy Recommendation Overview

Establish a Long-Term Vision with Dedicated Funding for Heat-Resilient Urban Planning

Action

Develop and fund strategies for heat-resilient urban planning, including Transport Oriented Development (TOD) to minimize distances to transport hubs and cluster essential services around hubs. Ensure shaded and ventilated pathways along high-traffic routes for vehicles, pedestrians, and cyclists.

Indicators

Indicators support the development of heat-resilient strategies like Transport-Oriented Development (TOD) and shaded pathways, assessing baseline conditions, setting goals, and tracking progress to reduce heat exposure and enhance connectivity.

- Research Indicators (Input): Assess current distances to transport hubs, shading coverage, and proximity of essential services.
- Planning Indicators (Outcome): Set targets for reducing travel distances and increasing shaded and ventilated pathways along key routes.
- Design Performance Indicators (Output): Track the percentage of pathways upgraded with shade and ventilation features.
- Evaluation Indicators (Impact): Measure reductions in heat exposure during travel and improved accessibility for diverse populations.

Classification of Action

Medium to long-term implementation, low-to-moderate cost, with immediate and delayed outcomes.

Primary Goal

Reduce heat exposure for users and operators in first- and last-mile transport connections, supporting safe and accessible urban mobility.

Alignment with Other Goals

- Health and Safety: Reduces pedestrian and cyclist heat stress and promotes physical health through active transport.
- Environment: Lowers urban heat and reduces private vehicle reliance. Use of nature-based shading infrastructure enhances biodiversity, absorbs carbon, and reduces flooding and harmful runoff.
- Economy: Increases foot traffic, boosting local business revenues and property values.

Avenues of Action

- **Government Agency Staff & Policymakers:** Set targets for Transport Oriented Development (TOD) and shading infrastructure and align land use with transport strategies.
- **Researchers & Developers:** Test cost-effective, resilient shading and ventilation materials suited to local climate and urban environment.
- **Financiers:** Finance shading in TOD projects, offering incentives.
- **Community Groups:** Advocate for shaded and ventilated pathways.
- **Designers & Planners:** Collaborate with environmental engineers and landscape architects to design accessible, shaded, and well-ventilated transport pathways.
- **Operators & Managers:** Monitor shading infrastructure for damage and maintenance needs.

Recommendation In Practice: Medellin, Colombia

Image 4.1: Green corridors with shaded, tree-lined pathways can help reduce urban heat by up to 10°C

In Medellin, Colombia, a network of "green corridors" has been established throughout the city to combat heatwaves. These routes are lined with native trees, palms, bamboo, and plants along sidewalks, parks, and busy traffic routes, offering shaded pathways and gathering spots for residents. City officials estimate that after three years of implementation, the urban heat island effect in Medellín has been reduced by at least 2°C.

Mandate Heat Impact Screenings for Transport Projects with a Focus on Vulnerable Populations

Action

Require climate resilience assessments in transport project planning, with a focus on design adaptations that reduce extreme heat impacts for vulnerable users.

Indicators

Heat impact screenings ensure transport projects address vulnerable groups' needs. Indicators guide planning and design, targeting at-risk populations and promoting safer, more equitable systems.

- Research Indicators (Input): Evaluate demographic data and heat exposure levels for at-risk groups, such as older adults or children.
- Planning Indicators (Outcome): Define goals for reducing heat risks and increasing protective features in transport systems.
- Design Performance Indicators (Output): Monitor the number of transport projects incorporating heat screenings and adaptive measures.
- Evaluation Indicators (Impact): Assess reductions in heat-related incidents and enhanced safety for vulnerable populations.

Classification of Action

Medium to long-term implementation, moderate cost, with delayed outcomes.

Primary Goal

All new and upgraded transport infrastructure proactively addresses heat risks for the system and user populations, especially those of vulnerable users.

Alignment with Other Goals

- Health and Safety: Reduces heat exposure and enhances comfort for vulnerable users.
- Environment: Supports sustainable urban planning and nature-based infrastructure solutions.
- Economy: Decreases heat-related service disruptions and repair costs, and raises property values through resilient transport infrastructure.

Avenues of Action

- **Government Staff & Policymakers:** Establish mandates for heat-resilient design and screenings targeted at addressing the needs of vulnerable populations in all urban planning and transport projects.
- **Researchers & Developers:** Develop predictive tools and heat vulnerability mapping for identifying high-risk areas in transport. Disaggregate data to identify and address specific challenges of vulnerable group transit users.
- **Financiers:** Fund adaptive infrastructure and incentivize green urban development.
- **Community Groups:** Advocate for heat-resilient infrastructure to benefit vulnerable residents and facilitate community engagement.
- **Designers & Planners:** Incorporate heat resilience in design phases and engage with marginalized communities to incorporate their specific challenges and concerns into strategies.

Recommendation In Practice: London, UK

Image 4.2: White-painted train rails can remain 5-10°C cooler, helping to reduce heat expansion and the risk of buckling

In London, UK, Network Rail has painted train rails white at critical points to absorb less heat, thereby reducing expansion and avoiding buckling. The painted rails are found to be 5 to 10 degrees Celsius cooler compared to non-painted rails.

Integrate Heat-Resilient Materials in Transport Infrastructure Construction and Renovation

Action
Incorporate heat-resistant and reflective materials in transport infrastructure (e.g., rails, roads, stops, station roofs) to reduce heat absorption.

Indicators
Indicators track the use of heat-resilient materials, measuring their effectiveness in reducing heat absorption, enhancing durability, and lowering surface temperatures over time.

- Research Indicators (Input): Assess surface temperatures and the thermal performance of materials used in infrastructure.
- Planning Indicators (Outcome): Set goals for increasing the use of reflective and heat-resistant materials in transport projects.
- Design Performance Indicators (Output): Track the area of infrastructure constructed or retrofitted with heat-resilient materials.
- Evaluation Indicators (Impact): Measure reduced surface temperatures and enhanced durability of transport infrastructure.

Classification of Action
Short-to-medium term implementation, low-to-medium cost, with immediate and delayed outcomes.

Primary Goal
Mitigate heat-induced wear on infrastructure to extend lifespan and reduce maintenance demands, as well as reduce ambient heat exposure for users and operators.

Alignment with Other Goals
- Health and Safety: Lowers temperatures at stops and stations and reduces accidents and delays, improving comfort and safety.
- Environment: Lowers urban heat and prolongs infrastructure lifespan to reduce carbon demand from replacements like steel or concrete.
- Economy: Reduces repair and maintenance costs, improving infrastructure longevity.

Avenues of Action
- **Government Agency Staff & Policymakers:** Mandate use of reflective and heat-resistant materials; allocate budgets for upgrades, especially in high-heat zones.
- **Researchers & Developers:** Evaluate and refine materials to maximize durability and cost-effectiveness under local climate conditions.
- **Financiers:** Provide funding incentives for heat-resistant designs and retrofits, potentially through public-private partnerships.
- **Community Groups:** Advocate for safer, cooler infrastructure.
- **Designers & Planners:** Coordinate with engineers and material scientists to design infrastructure maximizing heat reflectivity and integrate into design plans.
- **Operators & Managers:** Monitor material performance and conduct routine inspections for sustained effectiveness.

Recommendation In Practice: Tokyo, Japan

Image 4.3: Tokyo subsidises cool pavements in priority areas to reduce urban heat

In Japan, the Tokyo Metropolitan Government has installed or provided a subsidy for cool pavements as part of road construction and maintenance in priority areas. Pavements are either coated with materials that reflect sunlight and reducing heat absorption, or are made water retentive, utilizing evaporative cooling to lower temperatures by 8-10* C.

Transition Public Transit Fleets to Clean Energy with Efficient Cooling Systems

Action
Upgrade public transport vehicles to clean energy sources (e.g., hybrid, electric) and install energy-efficient air conditioning and ventilation systems for riders, operators, and the system's electrical components.

Indicators
Indicators analyze fleet composition, set transition goals, and measure improvements in passenger comfort and environmental benefits from adopting clean energy and efficient cooling systems.

- Research Indicators (Input): Analyze the current energy sources of transit fleets and the efficiency of onboard cooling systems.
- Planning Indicators (Outcome): Define targets for transitioning to clean-energy fleets and upgrading cooling technologies.
- Design Performance Indicators (Output): Monitor vehicles converted to clean energy and equipped with efficient cooling systems.
- Evaluation Indicators (Impact): Assess reductions in emissions and improved passenger comfort during extreme heat conditions.

Classification of Action
Medium to long-term implementation, high cost with immediate and delayed outcomes.

Primary Goal
Ensure continued service of sustainable, comfortable public transport during extreme heat events.

Alignment with Other Goals
- Health and Safety: Reduces heat stress and harmful emissions and pollutants leading to respiratory issues.
- Environment: Lowers carbon footprint, reduces demand for cooling infrastructure, and decreases noise pollution.
- Economy: Saves costs from lower fuel use to offset high initial costs and reduces stigma around public transport, boosting ridership.

Avenues of Action
- **Government Staff & Policymakers:** Set policies and create tax incentives and subsidies for transitioning to energy-efficient vehicles and develop emission reduction targets for public transport.
- **Researchers & Developers:** Study cost-effective clean energy solutions and advanced cooling techniques for passengers and specific elements of the physical network that can overheat.
- **Financiers:** Offer funding and incentives for clean fleet transitions.
- **Community Groups:** Advocate for high-quality, eco-friendly public transport options.
- **Designers & Planners:** Plan for clean energy infrastructure, like charging stations.
- **Operators & Managers:** Emphasize maintenance of air conditioning systems and train staff on operation.

Recommendation In Practice: Shenzhen, China

Image 4.4: Shenzhen's electric bus fleet uses smart cooling to improve efficiency and comfort

Shenzhen, China, set a global precedent by converting its 16,000+ bus fleet to electric, integrating energy-efficient cooling systems that adjust to passenger occupancy and weather. This approach reduces emissions, extends battery life, and enhances comfort, showcasing a model for sustainable, climate-adaptive public transport.

Incentivise or Mandate Shading and Cooling at Transport Stops and Stations

Action

Develop and upgrade transport stops and stations with shading structures and cooling features, such as ventilation and misting fans, with an emphasis on nature-based infrastructure and passive cooling measures. Develop and upgrade stops and stations with seating for riders and operators.

Indicators

Shading and cooling upgrades improve comfort and usability. Indicators assess current conditions, guide interventions, and measure their impact on reducing heat stress for riders and operators.

- Research Indicators (Input): Assess shading and cooling coverage at transit stops and the associated heat exposure risks.
- Planning Indicators (Outcome): Define goals for increasing shaded areas and incorporating cooling features at stops.
- Design Performance Indicators (Output): Track the number of stops upgraded with shading and cooling infrastructure.
- Evaluation Indicators (Impact): Measure reduced heat stress and increased usability of transit stops.

Classification of Action

Short-to-medium term implementation, moderate cost, with immediate outcomes.

Primary Goal

Ensure stops and stations are comfortable and safe, especially for vulnerable users, reducing the risk of heat-related incidents.

Alignment with Other Goals

- Health and Safety: Provides comfort and reduces physical strain and heat stress, particularly for vulnerable populations.
- Environment: Shading can be combined with nature-based solutions, enhancing biodiversity and improving rainwater absorption. Develop and upgrade transport stops and stations with shading structures and cooling features, such as ventilation and misting fans, with an emphasis on nature-based infrastructure and passive cooling measures. Develop and upgrade stops and stations with seating for riders and operators.
- Economy: Increases ridership and foot traffic, boosting fare revenue and local business activity.

Avenues of Action

- **Government Agency Staff & Policymakers:** Mandate shading or cooling infrastructure in transport designs, especially in heat-prone areas.
- **Researchers & Developers:** Develop cost-effective cooling and shading solutions, with a focus on passive cooling techniques to minimize energy consumption.
- **Financiers:** Fund construction and maintenance of shaded infrastructure, especially in vulnerable areas.
- **Community Groups:** Ensure community needs are addressed in the design and placement of infrastructure.
- **Designers & Planners:** Design transport stops with integrated shading and seating.
- **Operators & Managers:** Install and maintain cooling and shading infrastructure, using real-time data and feedback to assess effectiveness.

Recommendation In Practice: Curitiba, Brazil

Image 4.5: Curitiba's tube-shaped bus shelters offer shade, weather protection, and accessible entry for all travelers

The tube-shaped bus shelters installed in Curitiba, Brazil, are shaded, protected on all sides, and raised up to be level with bus entry. The innovative design effectively shelters travellers from the hot winds, sun, and poor weather and creates a relatively level entry to and from the bus to accommodate those with mobility challenges.

Enable Data-Driven Decision Making and Predictive Maintenance for Transport Systems

Action

Leverage real-time data and predictive analytics to optimize operational adjustments, adjust transport worker shift schedules during heatwaves, regulate ventilation, and schedule retrofitting and preventive maintenance.

Indicators

Real-time data and predictive analytics optimize maintenance and operations during heat events. Indicators track adjustments and measure their impact on reliability and safety.

- Research Indicators (Input): Assess the availability of data systems for monitoring heat impacts and transport performance.
- Planning Indicators (Outcome): Define objectives for optimizing transport operations and maintenance during heat events.
- Design Performance Indicators (Output): Monitor predictive maintenance actions and operational adjustments implemented.
- Evaluation Indicators (Impact): Measure improved service reliability and reduced heat-related disruptions.

Classification of Action

Medium-to-long term implementation, moderate-to-high cost, with both immediate and delayed outcomes.

Primary Goal

Increase the safety and efficiency of transport operations during extreme heat events.

Alignment with Other Goals

- Health and Safety: Reduces infrastructure failure risks and improves station ventilation.
- Environment: Optimizes transport operations to reduce energy consumption and carbon demand from infrastructure replacements.
- Economy: Preserves ridership revenue, minimizes repair costs, and improves system reliability.

Avenues of Action

- **Government Staff & Policymakers:** Mandate or incentivize data-driven systems for transport operations.
- **Researchers & Developers:** Create predictive maintenance systems to monitor infrastructure and forecast failures.
- **Financiers:** Support installation of predictive maintenance technologies.
- **Community Groups:** Advocate for data-driven transport management.
- **Designers & Planners:** Install temperature sensors and monitoring systems along transport networks, especially around exposed sections of railway track and underground infrastructure with poor ventilation, and combine sensors with Internet of Things technologies.
- **Operators & Managers:** Adjust operations using real-time data to prevent overcrowding, infrastructure stress, and derailment.

Recommendation In Practice: Barcelona, Spain

Image 4.6: Barcelona's metro uses smart ventilation to optimize energy and lower temperatures by 2°C, enhancing comfort

In Barcelona, Spain, Transports Metropolitans de Barcelona (TMB) has launched a smart ventilation pilot in the metro network. A dynamic algorithm predicts conditions and adjusts fan operations using real-time data on temperature, humidity, air quality, and electricity consumption. The system optimizes energy use and has improved thermal comfort, lowering station temperatures by 2 degrees over the past two years.

Improve Transport Frequency to Reduce Wait Times and Crowding

Action
Increase the number of transport vehicles and use data-driven models to optimise fleet usage based on demand and weather patterns.

Indicators
Improved frequency reduces heat exposure and overcrowding. Indicators evaluate current performance, set operational goals, and track progress for better passenger experiences.

- Research Indicators (Input): Evaluate current wait times, passenger densities, and fleet deployment strategies.
- Planning Indicators (Outcome): Set targets for reducing average wait times and alleviating crowding.
- Design Performance Indicators (Output): Monitor the number of additional vehicles deployed and routes adjusted.
- Evaluation Indicators (Impact): Measure reduced waiting times and enhanced passenger satisfaction in diverse urban contexts.

Classification of Action
Medium to long-term implementation, high cost with immediate and delayed outcomes.

Primary Goal
Minimise wait times and reduce crowding at stops and on transport.

Alignment with Other Goals
- Health and Safety: Reduces heat-related health issues by minimising exposure times and crowding.
- Environment: Encourages public transport use, reducing emissions and urban heat from private vehicles.
- Economy: Boosts ridership, fare revenue, and long-term financial sustainability.

Avenues of Action
- **Government Agency Staff & Policymakers:** Support policies for fleet expansion and service frequency mandates.
- **Researchers & Developers:** Develop dynamic scheduling systems based on demand and weather.
- **Financiers:** Provide financing for fleet expansion and operational costs of increased service frequency.
- **Community Groups:** Advocate for reduced crowding and wait times and provide feedback on community needs for route planning and scheduling.
- **Designers & Planners:** Work with data scientists to incorporate real-time analytics into transport scheduling.
- **Operators & Managers:** Monitor occupancy and adjust frequencies based on real-time demand.

Recommendation In Practice: Helsinki, Finland

Image 4.7: Helsinki's Regional Transport adapts transit fleets to demand and weather

In Helsinki, Finland, the Regional Transport Authority (HSL) increases transport vehicles during peak hours and uses data-driven models to adjust fleet deployment. By analysing demand, weather, and traffic data, HSL improves service reliability, especially in winter, reducing wait times and overcrowding for a smoother commute.

Improve the Communication and Timing of Heat Warnings and Service Updates

Action
Issue detailed, actionable alerts across messaging platforms to help users manage extreme heat risks. Use AI-driven predictive analytics to proactively send warnings based on temperature forecasts, transport conditions, and projected demand patterns, with alerts timed well before peak commute hours.

Indicators
Effective alerts reduce heat risks during extreme weather. Indicators assess the reach and timing of warnings to ensure users are prepared and informed.

- Research Indicators (Input): Assess the coverage and effectiveness of current alert systems.
- Planning Indicators (Outcome): Define goals for issuing timely, actionable heat warnings and updates.
- Design Performance Indicators (Output): Monitor the number of alerts issued and the percentage of users reached.
- Evaluation Indicators (Impact): Evaluate improved user preparedness and reduced heat-related risks during extreme heat events.

Classification of Action
Short-to-medium-term implementation, low-cost, with immediate outcomes.

Primary Goal
Improve rider safety with timely heat warnings and updates to support protective actions and manage crowding and transport flow during extreme heat.

Alignment with Other Goals
- Health and Safety: Reduces unnecessary heat exposure by encouraging protective measures, especially for vulnerable groups, and prevents crowding during extreme heat.
- Environment: Decreases energy demand by reducing crowding, which lowers reliance on cooling systems in transport hubs and vehicles.
- Economy: Proper travel planning can prevent lost work hours by ensuring timely arrivals and minimizing delays.

Avenues of Action
- **Government Agency Staff & Policymakers:** Create policies mandating early heat warnings in transport systems and ensure accessibility for passengers with limited digital access. Prioritise funding for maintenance and continual updates to the alert systems.
- **Researchers & Developers:** Develop and test AI-driven systems for issuing personalized heat alerts.
- **Financiers:** Fund the development and integration of alert systems within transport infrastructure.
- **Community Groups:** Partner with transport and emergency agencies to ensure messaging is accessible and understandable.
- **Designers & Planners:** Design user-friendly alert systems compatible with various platforms (e.g., apps, SMS) and integrate alerts with public displays at transport hubs.

Recommendation In Practice: Singapore

Image 4.8: IoT sensors in Singapore's MRT stations monitor crowd density and provide real-time train arrival updates

Internet of Things (IoT) sensors installed in Singapore's Mass Rapid Transport (MRT) stations monitor passenger flow and analyze crowd density to provide real-time updates for commuters on train arrival times.

5

Annexure of Resources

Managing extreme heat in public transport is an emerging field, supported by valuable guides and resources from ongoing research and best practices.

Although managing extreme heat in public transport systems is still an emerging topic, a number of useful knowledge products and guides have been developed by organizations and cities on extreme heat management and public transport adaptation. We encourage stakeholders to explore these resources, learning from ongoing research and best practices, with the curated list below serving as a starting point.

Infrastructure

1. *Sustainable Cooling - The Hot Reality: Living in a +50°C World*
   Informative COP28 briefing note making a persuasive case for cooling as critical infrastructure.
   https://www.sustainablecooling.org/wp-content/uploads/2023/11/Hot-Reality-Living-in-a-50C-World.pdf
2. *Energy Sector Management Assistance Program (ESMAP) - Primer for Cool Cities: Reducing Excessive Urban Heat – With a Focus on Passive Measures*
   ESMAP, a global knowledge and technical assistance program administered by the World Bank, offers practical, actionable guidance and examples for implementers, policy makers, and planners tasked with mitigating urban heat impacts.
   http://documents.worldbank.org/curated/en/605601595393390081/Primer-for-Cool-Cities-Reducing-Excessive-Urban-Heat-With-a-Focus-on-Passive-Measures
3. *C40 - How-to-Manual: Steps to Develop a Heat Action Plan*
   This implementation guide, supplied by C40, a global network of city mayors, explains how cities can adapt to extreme heat to protect their citizens and economies.
   https://www.c40knowledgehub.org/s/article/How-to-adapt-your-city-to-extreme-heat?language=en_US
4. *UNEP - Beating the Heat: A sustainable cooling handbook for cities*
   A comprehensive guide to developing an urban cooling action plan with a whole system approach launched launched at COP26 by the Cool Coalition, UNEP, RMI, Global Covenant of Mayors for Climate & Energy (GCoM), Mission Innovation, and Clean Cooling Collaborative.
   https://www.unep.org/resources/report/beating-heat-sustainable-cooling-handbook-cities
5. *Examples of heat mitigation plans or climate action plans with heat considerations include:*
   - Tamil Nadu, India's Beating The Heat: Heat Mitigation Strategy
   - New York City's Cool Neighborhoods NYC
   - Los Angeles' Green New Deal (2019) and Resilient Los Angeles (2018) (Goal 6: Prepare and protect those most vulnerable to increasing extreme heat)
   - Barcelona's Climate Plan 2018 – 2030 (Line of Action 3: Preventing excessive heat)
   - Melbourne's Climate Change Adaptation Strategy Refresh 2017
   - Paris' Climate Action Plan
   - Sydney's Adapting for Climate Change long-term strategy (2017) and subsequent five-year Turn Down The Heat Strategy and Action Plan (2018)

Health and Safety

Managing the health and safety impacts of extreme heat on both public transport users and operators is a major concern. These resources provide essential guidance on public health responses to heat, protecting vulnerable populations, and ensuring safe working conditions in transport systems.

1. ***WHO - Heatwaves: Protecting Health in Europe***
   This guide outlines health strategies to reduce the risks of heat exposure, including public health messaging and specific actions for vulnerable populations and essential services like transportation. It's a vital resource for understanding heat's impact on public health and how to mitigate it.
   https://www.who.int/publications/i/item/public-health-advice-on-preventing-health-effects-of-heat
2. ***CDC - Extreme Heat***
   This page from the Centers for Disease Control and Prevention (CDC) provides comprehensive information on identifying and treating heat-related illnesses, particularly focusing on at-risk populations, including transit operators and users.
   https://www.cdc.gov/extreme-heat/about/index.html
3. ***ILO - Working on a Warmer Planet: The Impact of Heat Stress on Labor Productivity and Decent Work***
   This report discusses the health risks faced by workers, including those in public transport, during extreme heat, with guidelines on how to protect them.
4. ***The Global Heat Health Information Network***
   Run by the World Health Organization and the World Meteorological Organization, this is a voluntary forum of scientists, practitioners, and policy makers focused on promoting evidence-driven interventions and capacity building to protect populations from the avoidable health risks of extreme heat.
   https://ghhin.org/

Green (Climate Resilient Infrastructure)

Building climate-resilient infrastructure is essential for mitigating the impacts of extreme heat on public transport systems. These resources provide critical information on integrating green infrastructure, urban cooling strategies, and sustainable design practices.

1. ***UNEP - Green Infrastructure Guide for Urban Resilience***
   This guide emphasizes the role of green infrastructure in urban areas, focusing on heat mitigation through natural systems. It provides practical examples of integrating climate-resilient solutions into transit systems.
2. ***C40 Cities - Cool Cities: The Benefits of Urban Cooling***
   This report highlights various urban cooling strategies such as tree canopies and cool pavements, essential for mitigating the urban heat island effect around public transport hubs.
   https://www.c40.org/networks/cool-cities-network/
3. ***International Journal of Environmental Research and Public Health - Heat-Moderating Effects of Bus Stop Shelters and Tree Shade on Public Transport Ridership***
   This study examines how bus stop shelters and surrounding tree canopies moderate the effect of warm season temperatures and their equitable distribution.
   https://www.mdpi.com/1660-4601/18/2/463

Economic Impacts

Understanding the economic implications of extreme heat on transport systems is crucial for justifying investment in resilience measures. These resources provide tools and case studies to help governments and transport operators assess costs, savings, and returns on investment for heat resilience actions.

1. ***World Bank - Climate-Resilient Transport: A Policy Guide***
   This guide offers practical advice for policymakers on building climate resilience in transportation systems, including cost-effective strategies for heat resilience in public transport.
   https://transport-links.com/hvt-publications/climate-resilient-transport-a-policy-guide
2. ***OECD - The Economic Consequences of Climate Change***
   This report focuses on the long-term economic impacts of climate change, offering insights into the costs and savings of investing in heat-resilient transport infrastructure.
   https://www.oecd.org/en/publications/the-economic-consequences-of-climate-change_9789264235410-en.html
3. ***National Institute of Building Sciences - Natural Hazard Mitigation Saves: 2019 Report***
   This report outlines the economic benefits of investing in resilient infrastructure, with specific sections on public transport systems.
   https://www.nibs.org/projects/natural-hazard-mitigation-saves-2019-report

Each of these resources offers critical insights into managing extreme heat in public transport systems, helping governments, policymakers, and urban planners address challenges and achieve co-benefits. By leveraging these materials, decision-makers can deepen their understanding of heat resilience strategies and build robust, future-ready public transport systems.

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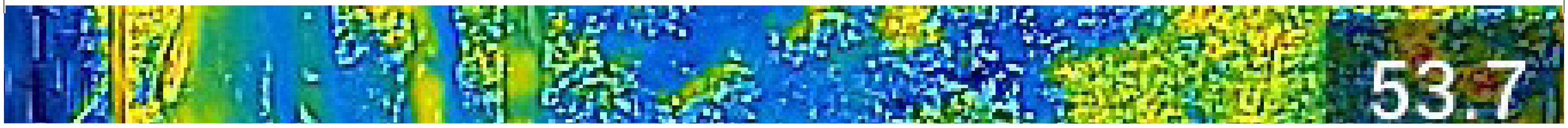

CDRI
Coalition for Disaster Resilient Infrastructure

ICSI

CLIMATE RESILIENCE for ALL

Building Health Lab