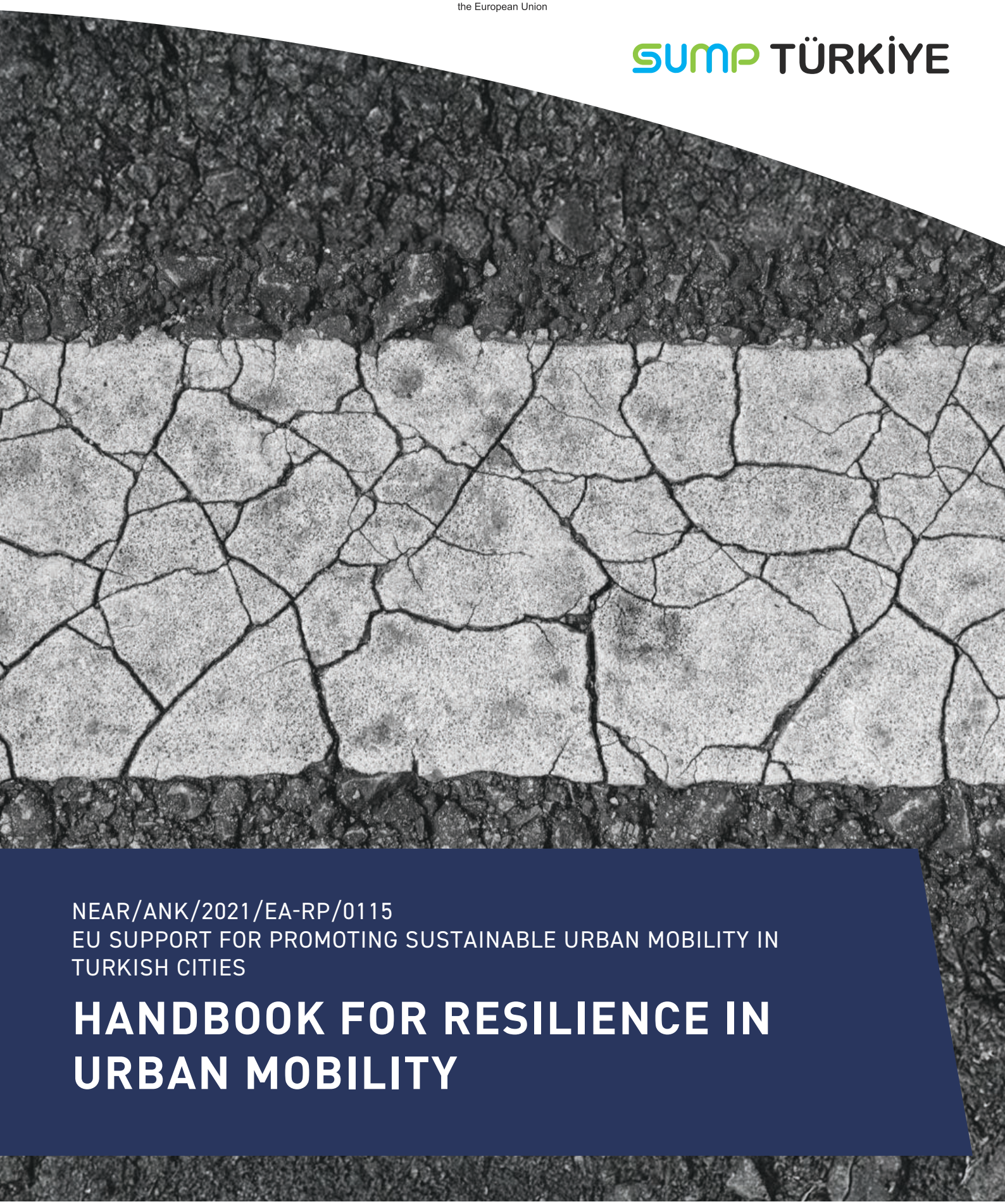
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SUMP TÜRKİYE



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EU SUPPORT FOR PROMOTING SUSTAINABLE URBAN MOBILITY IN TURKISH CITIES

HANDBOOK FOR RESILIENCE IN URBAN MOBILITY

REPUBLIC OF TÜRKİYE
MINISTRY OF TRANSPORT
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List of Acronyms

AFAD	Disaster and Emergency Management Presidency
AKOM	Disaster Coordination Centre
BAKOM	Balıkesir Disaster Coordination Centre
DSİ	General Directorate of State Hydraulic Works
EU	European Union
EWS	Early Warning System
FMEA	Failure Mode and Effects Analysis
GHG	Greenhouse Gas
GIS	Geographic Information System
GPS	Global Positioning System
IMM	Istanbul Metropolitan Municipality
IEMP	İstanbul Earthquake Master Plan
ITS	Intelligent Transportation Systems
KGM	General Directorate of Highways
KPIs	Key Performance Indicators
M&E	Monitoring and Evaluation
MaaS	Mobility-as-a-Service
MGM	General Directorate of Meteorology
MoEUCC	Ministry of Environment, Urbanisation and Climate Change
MoTI	Ministry of Transport and Infrastructure
NESAP	National Earthquake Strategy and Action Plan
NGOs	Non-Governmental Organisations
PDRRP	Provincial Disaster Risk Reduction Plans
SUMP	Sustainable Urban Mobility Plan
TCDD	Turkish State Railways
TDRP	Türkiye Disaster Response Plan
TDRRP	Türkiye Disaster Risk Reduction Plan
TMP	Transport Master Plan
UNDP	United Nations Development Programme

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Executive Summary

Urban mobility systems face disruptions from a wide range of causes, including natural disasters, infrastructure failures, economic shocks, and unforeseen crises. While resilience efforts often prioritize response and recovery, the critical "before" phase, proactive preparedness and long-term planning, is frequently overlooked. This handbook addresses that gap by focusing on strengthening urban mobility systems before disruptions occur, ensuring continuity rather than just reaction.

Rather than categorizing resilience strategies by specific disaster types, this handbook takes a broader approach, emphasizing preparedness for any kind of disruption, whether natural or man-made. By shifting the focus from emergency response to strategic planning, it equips cities with the tools to anticipate risks, integrate resilience into everyday mobility planning, and safeguard transport networks against future shocks.

The core objective is to provide a simplified perspective on the complex topic of resilience planning in mobility, making it actionable and applicable across different urban contexts. Instead of focusing on isolated disaster response measures, this handbook provides structured guidance on building mobility systems that remain functional, adaptable, and forward-looking, ensuring continuity amid disruptions while also preparing for future mobility demands.

The handbook is structured to guide readers from a broad conceptual understanding of resilience in mobility toward increasingly focused, practical applications, while following the logic and rationale of Sustainable Urban Mobility Plan (SUMP) phases applied to resilience planning:

Chapter 1: Adopts a wide-angle lens, defining resilience's role in urban mobility, laying out its core principles to build the first "definition" foundation, and examining Türkiye's resilience-planning landscape with a comprehensive overview of national practice.

Chapter 2: Begins to funnel that perspective: still addressing broad, multilevel actions (national, regional and local) to bridge the gaps and challenges identified in Chapter 1, but also providing strategic action items cities can take to prepare for hands-on, practical resilience planning at the local scale.

From **Chapter 3** onward, the focus becomes decidedly hands-on:

Chapter 3: Guides municipalities through assessing their current mobility systems ("status quo"), using data for risk mapping, leveraging stakeholder input for in-depth assessment, and showcases tool examples for each step.

Chapter 4: Builds on Chapter 3 by showing how to translate assessment results into long-term plans, using data projections to anticipate future conditions, and guiding readers through the steps needed to define clear, measurable resilience goals reflecting those projections. It also provides tool examples for each step.

Chapter 5: Shifts to implementation, detailing the five main mobility pillars (aligned with the Green and White Policy Papers of Türkiye), explaining how each pillar should address both sustainability and resilience, and helping cities ensure operational and service-continuity outcomes.

Chapter 6: Delves into monitoring and evaluation: it provides an overview of how to establish effective monitoring and evaluation systems, offers a list of possible indicators for resilience in mobility and shows cities how to initiate the M&E process to track progress and close the loop on resilience planning.

1. Understanding Resilience in Urban Mobility

1.1 The Role of Resilience in Sustainable Mobility Planning

Urban mobility systems form the backbone of cities, enabling economic activity, social interactions, and access to essential services. However, these systems are increasingly vulnerable to disruptions, including extreme weather events, natural disasters, economic shocks, pandemics, and infrastructure failures.

Disruptions to mobility systems can have far-reaching consequences, affecting economic productivity, emergency response capabilities, and social cohesion. Ensuring continuity in transport services is essential for maintaining urban functionality and protecting the well-being of residents. Resilience plays a crucial role in achieving this by enabling cities to withstand, absorb, and recover from various challenges.

Resilient mobility planning not only prepares cities for unexpected shocks but also strengthens their capacity to adapt to long-term changes, such as population growth, climate change, and technological advancements. By integrating resilience into mobility strategies, cities can safeguard transport networks, enhance service continuity, and create a transport system that is robust, adaptable, and future-ready. This approach is particularly critical for Türkiye, where urban mobility systems must contend with a wide spectrum of overlapping hazards (including earthquakes, floods, landslides, and climate-related extremes) by making resilience an operational imperative.

Key Principles of Resilience in Mobility Planning

Resilience in mobility planning is built on several foundational principles that help cities design and implement systems capable of withstanding and recovering from disruptions.

Sustainability: Long-Term Viability of Transport Systems

Sustainable resilience planning ensures that mobility solutions are not only resistant to disruptions but also environmentally and economically sustainable. Climate-resilient infrastructure, electrification of public transport, and investments in green mobility solutions contribute to both resilience and sustainability goals.

Proactive Governance and Coordination

Resilient mobility planning requires strong governance frameworks, institutional coordination, and proactive policy-making. Effective collaboration between local authorities, transport operators, emergency services, and community organizations ensures a rapid response to disruptions and strengthens long-term mobility resilience. Cities with established mobility crisis management plans and emergency response coordination teams can quickly deploy resources and restore transport services.

Flexibility: Adapting to Changing Conditions

A resilient mobility system must be adaptable to different types of disruptions, whether they are short-term shocks, such as extreme weather events, or long-term trends, such as evolving travel patterns due to demographic changes. Flexible transport networks offer multiple options for movement, ensuring that if one route or mode fails, the system can adapt and provide an alternative.

Redundancy: Ensuring Backup Options

Redundancy means designing transport systems with backup options, so a failure in one component does not lead to a total system breakdown. This principle ensures that mobility continuity is maintained even when parts of the system experience stress or failure. Multiple transit routes, alternative bridges or tunnels, and diversified public transport fleets, such as a mix of buses, trams, and metro systems, create redundancy, ensuring that disruptions do not paralyze mobility.

Inclusivity: Ensuring Access for All

A resilient mobility system must cater to all users, including vulnerable populations such as the elderly, people with disabilities, and low-income communities. Inclusive mobility ensures that disruptions do not disproportionately impact specific groups and that everyone has access to reliable transport options. Designing transport infrastructure that includes step-free access, audio-visual announcements, and real-time travel information makes the mobility system more resilient and accessible to all users.

Figure 1: Key Principles of Resilience in Mobility Planning

1.2 Resilience in Urban Mobility in Türkiye

Key Challenges for Resilience in Türkiye's Urban Mobility Systems

Türkiye, due to its geographic location and diverse climatic and geological conditions, faces a wide range of natural and human-induced disasters. These disasters significantly impact the country's urban mobility systems by disrupting transportation networks, accessibility, and emergency response capabilities.

Among these natural hazards, earthquakes are the most catastrophic. Türkiye's location on several active fault lines, including the North Anatolian Fault (NAF), East Anatolian Fault (EAF), and Aegean Fault Zone, renders it highly vulnerable to seismic activity. This vulnerability is exacerbated by the fact that, between 1900 and 2015, 72% of Türkiye's population lived in seismically active areas, with earthquakes accounting for two-thirds of total disaster-related losses.[1]

Historical records show that, during the 20th century alone, over 130 major earthquakes caused more than 80,000 fatalities and tens of thousands of injuries, alongside extensive infrastructure damage.[2] Several of these events stand out for their direct impact on urban mobility. For instance, the 1939 Erzincan Earthquake (Ms: 7.9) resulted in over 32,000 fatalities and left more than 100,000 buildings uninhabitable, which isolated the entire region and disrupted transportation systems for months. The 1999 Kocaeli Earthquake (Mw: 7.6) impacted northwest Anatolia, severely damaging roads, bridges, and railways, including major corridors like the D100 highway. This disrupted not only emergency response efforts but also regional and national logistics operations.

More recently, the 2023 Kahramanmaraş Earthquake event included two major tremors (Mw 7.7 and 7.6), which has impacted provinces including Hatay, Kahramanmaraş, Adıyaman, Gaziantep, Malatya, Osmaniye, Adana, Diyarbakır, Şanlıurfa, Kilis, and Elazığ, and caused widespread destruction to urban mobility systems[3]. According to the Strategy and Budget Office of Türkiye, the total economic cost of the 2023 earthquakes including property, infrastructure, public support spending, and macroeconomic losses was roughly 9% of Türkiye's 2023 GDP. Earlier assessments by the World Bank had estimated around 34.2 billion USD in direct physical damage alone[4]. In addition to these direct losses, the disaster disrupted essential infrastructure and economic activity across the affected regions. Key highways, such as the Adana-Gaziantep

[1] Türkiye Country Report 2019. Asian Disaster Reduction Centre.

[2] Keleş, Ş. (2002). Disaster statistics for Türkiye. *Journal of Earthquake Studies and Preparedness, 18*(3), 45–59.

[3] International Labour Organization. (2024, July 8). One year after: Living and working conditions in Adıyaman, Hatay, Kahramanmaraş and Malatya after the February 2023 earthquakes in Türkiye. International Labour Organization. Retrieved June 26, 2025, from https://www.ilo.org/publications/one-year-after-living-and-working-conditions-adiyaman-hatay-kahramanmaras

[4] World Bank. (2023, February 27). *Earthquake damage in Türkiye estimated to exceed $34 billion: World Bank disaster assessment report*. Retrieved June 26, 2025, from https://www.worldbank.org/en/news/press-release/2023/02/27/earthquake-damage-in-turkiye-estimated-to-exceed-34-billion-world-bank-disaster-assessment-report

corridor, were rendered impassable, while transport hubs like Hatay Airport were temporarily shut down, which delayed evacuations and supply chain operations.[5]

Flooding is another common hazard in Türkiye, particularly in coastal and low-lying urban areas. Intense rainfall, poor drainage systems, and rapid urbanization exacerbate flood risks, which leads to severe disruptions in mobility. In the Black Sea Region, repeated flooding events have washed away bridges and roads, isolating communities and interrupting vital transportation routes. Similar impacts have been observed in the Mediterranean Region, where exceptional rainfall events have damaged key mobility infrastructure and prompted large-scale evacuations. Major urban centres like Istanbul are not immune either, flash floods in recent years have inundated streets and disrupted transit operations especially in densely built districts. Though less frequent, tsunamis also present a coastal risk such as the one triggered by the 2020 Aegean Sea Earthquake, which inundated streets in Izmir by immobilizing vehicles and cutting off access to vital areas.[6]

Wildfires, increasingly frequent due to climate change, particularly affect Türkiye's Mediterranean and Aegean regions. In 2021 alone, over 200,000 hectares of land were burned, with extensive damage in Antalya and Muğla. These events led to road closures and large-scale evacuations, which strained mobility systems. The relocation of thousands of residents and tourists underscored the critical need for robust evacuation routes and contingency planning for transportation networks during emergencies.

Landslides are another common risk, particularly in the Black Sea Region, where steep terrains and heavy rainfall combine to create frequent disruptions. Landslides often block roads and railways by isolating rural areas and hindering economic activities. For example, recurrent landslides along the Samsun-Ordu corridor regularly disrupt trade and mobility in the region.

Extreme weather events, including snowstorms and heatwaves, have also become more frequent and intense in the recent years, further impacting cities. Snowstorms periodically paralyze major urban centres like Istanbul and Ankara by closing roads and disrupting public transport services. Rising temperatures during heatwaves affect rail infrastructure by causing track deformities and operational delays.

Pandemics also bring unique challenges to urban mobility. The COVID-19 pandemic, for instance, highlighted the vulnerabilities of transportation systems during global health crises. Nationwide lockdowns, curfews, remote working and social distancing measures led to a drastic reduction in public transport usage, with ridership in major cities like Istanbul and Ankara dropping by over 80% during peak restrictions[7]. This shift placed increased pressure on private vehicles and active mobility modes, such as cycling and walking. Supply chains faced delays as

[5] Strategy and Budget Office of the Presidency of Türkiye (2023). 2023 Kahramanmaraş and Hatay Earthquakes Report.

[6] AFAD (2020). Disaster Statistics 2020.

[7] Sahraei, M. A., Kuşkapan, E., & Çodur, M. Y. (2021). Impact of COVID-19 on public transportation usage and ambient air quality in Türkiye. *Promet – Traffic & Transportation*, 33(2), 179–191. https://hrcak.srce.hr/file/392684

logistics networks struggled to adapt to changing demands. The pandemic underscored the importance of resilient and adaptable mobility systems to ensure continuity during such crises.

Collectively, these challenges reveal that Türkiye's urban mobility systems face not only high exposure to diverse natural hazards (especially earthquakes and floods), but also significant structural and institutional vulnerabilities. The recurrence of seismic and climatic events exposes challenges in critical transport infrastructure particularly in major urban centres and geographically constrained regions. Simultaneously, increasing compound risks such as wildfires, landslides, and extreme weather are testing the adaptability of transport networks built without multi-hazard considerations. The COVID-19 pandemic further underlines the fragility of mobility systems in the face of unexpected shocks. These dynamics point to the urgent need for integrated, forward-looking resilience planning that strengthens physical infrastructure, anticipates cascading failures, and ensures that national strategies are effectively localized to address unique urban and regional vulnerabilities.

Institutions and Coordination for Resilience in Türkiye

To address these challenges, Türkiye has developed a disaster management framework that emphasizes centralized coordination, inter-agency collaboration, local implementation, and the strategic use of planning instruments and technological tools. The following are the key aspects of Türkiye's current efforts and instruments.

Centralized Coordination: At the national level, disaster management is led by the Disaster and Emergency Management Presidency (AFAD), established in 2009 under the Ministry of Interior. AFAD oversees pre-disaster preparedness, mitigation, response, and recovery efforts across the country through a network of provincial directorates. Its central role ensures alignment of resources and policies across regions. For example, during emergencies, AFAD coordinates with multiple ministries, such as the Ministry of Transport and Infrastructure (MoTI) and the Ministry of Environment, Urbanization, and Climate Change (MoEUCC), to mobilize expertise and resources effectively.

Inter-agency Collaboration: Disaster response in Türkiye benefits from a collaborative approach involving several government ministries, non-governmental organizations (NGOs), and international institutions. The Disaster and Emergency Board, for instance, evaluates disaster-related information at the highest level, which enables coordinated action among national bodies. Organizations such as the Turkish Red Crescent (Kızılay) and the Turkish Earthquake Foundation supplement government efforts by providing humanitarian and logistical support. This multi-stakeholder coordination ensures rapid mobilization of resources during crises but is often limited to response and recovery phases rather than proactive resilience-building.

Local and Sectoral Engagement: While national coordination is vital, local and regional authorities are instrumental in translating resilience strategies into practical actions. For example, the Istanbul Metropolitan Municipality (IMM), operates risk-management bodies like the Earthquake Risk Management and Urban Renewal Department, AKOM (Disaster Coordination Centre), and the Disaster Works Directorate to align local preparedness with

national strategies. Other metropolitan municipalities have also developed similar structures. The İzmir Metropolitan Municipality has established a dedicated Earthquake Risk Management Department responsible for risk assessment and scenario planning such as the İzmir Earthquake Master Plan.[8] In the Aegean region, Balıkesir's municipal disaster coordination centre (BAKOM) actively coordinates emergency services during events like the COVID-19 response[9]. Across the Marmara Region, numerous metropolitan municipalities participate in collective resilience efforts through the Marmara Municipalities Union, which supports local governments in urban resilience, climate adaptation, and disaster preparedness. These examples illustrate that resilience planning in Türkiye extends with different local governments nationwide establishing institutional capacity and tailored emergency frameworks to address metropolitan-specific vulnerabilities.

Specific institutions also contribute to mobility resilience through targeted efforts. The General Directorate of Highways (KGM) and Turkish State Railways (TCDD) manage transport infrastructure before and after disasters, which ensures critical routes remain operational. The General Directorate of Meteorology (MGM) and the General Directorate of State Hydraulic Works (DSI) develop predictive models and provide early warnings for extreme weather events, including floods and heatwaves. These inputs are crucial for ensuring timely responses and minimizing disruptions to transport networks.

International Partnerships and Financial Instruments: Recognizing the complexity and cost of resilience-building, Türkiye collaborates with international organizations to access funding and technical support for urban mobility resilience projects. World Bank projects have funded the retrofitting of vulnerable infrastructure such as highways and bridges to withstand seismic events. The European Bank for Reconstruction and Development (EBRD) supports modernization projects aimed at strengthening urban transit systems against disaster risks. UNDP partnerships facilitate resilience planning at the municipal level, particularly by helping cities integrate mobility systems into broader disaster risk management frameworks.

Risk and Vulnerability Assessment Tools for Urban Transport: Türkiye employs different tools to assess vulnerabilities and inform planning for resilient transportation infrastructure. Seismic risk assessments are conducted on critical transport assets including Istanbul's metro network and the Bosphorus bridges to identify structural weaknesses and prioritize retrofitting. Flood risk mapping, developed by MGM and DSI, informs urban design decisions and ensures that transportation corridors incorporate appropriate drainage and protective infrastructure, especially in flood-prone urban centres.

Technological Tools to Support Mobility Resilience: Technology plays an increasingly central role in Türkiye's urban mobility resilience strategy. Geographic Information Systems (GIS) are widely used by AFAD and local governments to map hazard zones, plan evacuation routes, and

[8] İzmir Büyükşehir Belediyesi, Yapı İnceleme ve İyileştirme Şube Müdürlüğü. (2021, October 6). İzmir Deprem Senaryosu ve Deprem Master Planı, İzmir Büyükşehir Belediyesi Açık Veri Portalı. Retrieved June 26, 2025, from https://acikveri.bizimzir.com/dataset/izmir-deprem-senaryosu-ve-deprem-master-plani

[9] United Nations. (n.d.). BAKOM — Balıkesir Disaster Coordination Centre. Partnerships for the Sustainable Development Goals platform. United Nations. Retrieved June 26, 2025, from https://sdgs.un.org/partnerships/bakom-balikesir-disaster-coordination-centre

ensure critical infrastructure remains accessible during emergencies. Early warning systems, developed collaboratively by MGM and AFAD, provide real-time alerts for extreme weather events and earthquakes, which allows for timely adjustments to transport operations. Smart mobility solutions are being piloted in cities like Istanbul, where real-time traffic management systems optimize flow and support coordinated emergency responses during disruptive events.

Planning Documents and Regulation for Resilience

Türkiye has developed a comprehensive framework of national planning documents to strengthen disaster resilience across sectors, including urban mobility. These documents, categorized into **national strategies, action plans, and regulatory frameworks**, establish the guidelines for disaster preparedness, risk reduction, and sustainable development. They aim to create resilient urban and transportation systems that can withstand and recover from crises such as earthquakes, floods, pandemics, and further disaster risks. The following overview reflects the main policy instruments as well as their relevance and application to mobility resilience:

National Strategies and Action Plans

These documents define the long-term vision and strategies for enhancing resilience across Türkiye's urban and transportation systems. These documents provide a broad policy framework, which focuses on sustainable development, multi-hazard resilience, and integration of advanced technologies such as ITS. They also emphasize intermodal transport connectivity and preparedness for extreme events, and climate adaptation. Crucially, these national strategies are translated into context-specific local actions through instruments such as the Provincial Disaster Risk Reduction Plans (PDRRPs), which are prepared by governorships in coordination with AFAD to identify and mitigate risks at the provincial level.

The key national-level strategies include:

- Twelfth Development Plan (2024–2028)
- Transport and Logistics Master Plan (2053)
- National Transportation Master Plan (2035)
- Türkiye Disaster Risk Reduction Plan (TDRRP) (2022–2030)
- Climate Change Adaptation Strategy and Action Plan (2024–2030)
- Climate Change Mitigation Strategy and Action Plan (2024–2030)
- National Climate Change Action Plan (2011–2023)
- National Earthquake Strategy and Action Plan (NESAP) (2012–2023)
- Türkiye Disaster Response Plan (TDRP) (2012–2023)

- Pandemic Influenza National Preparedness Plan (2019)
- National Intelligent Transportation Systems (ITS) Strategy Document and Action Plan (2020–2023)
- Türkiye Post-Disaster Recovery Plan (2025)
- Green Deal Action Plan of Türkiye (2021)

These documents support various dimensions of urban mobility resilience. For example, NESAP continues to guide the seismic strengthening of transport infrastructure and the improvement of evacuation routes, even as its initial period has concluded. Similarly, the TDRP outlines protocols for transport management during emergencies including evacuation coordination, debris clearance, and maintaining critical connectivity with agencies such as KGM and TCDD.

The newer Climate Change Adaptation and Mitigation Action Plans introduce a critical focus on long-term resilience by promoting low-carbon transport and ensuring infrastructure can withstand climate-related hazards such as floods and heatwaves.

Regulatory Frameworks (Rules, Laws, and Regulations)

The regulatory frameworks provide the legal basis for implementing resilience measures in urban planning and transportation systems. These laws focus on ensuring compliance in areas like zoning, urban development, and emergency response operations and establish clear responsibilities for various stakeholders. Key regulatory documents include:

- Law no: 7269 on Measures to be Taken and Assistance to be Provided due to Disasters Affecting Public Life
- Presidential Decree No:4 Regulating the Organization and Duties of the Disaster and Emergency Management Presidency
- Law No: 3194-Zoning Law
- Law No:5216-Metropolitan Municipality Law
- Law No: 5393-Municipality Law
- By-Law on the Coordination Centres of Metropolitan Municipalities
- Law No: 6306 on the Transformation of Areas Under Disaster Risk
- Planned Areas Zoning By-Law (2017)
- Disaster and Emergency Response Services By-Law (2022)

Law No. 6306 on the Transformation of Areas Under Disaster Risk (usually called Urban Transformation Law in public) indirectly supports mobility resilience by enabling redevelopment of vulnerable neighbourhoods and their surrounding transport infrastructure.

The Planned Areas Zoning By-Law mandates integration of flood mitigation in urban design while the Disaster and Emergency Response Services By-Law codifies operational roles in maintaining transit access during crises.

The review of these documents in both categories demonstrates varying degrees of coverage of urban mobility systems, which highlights strengths in disaster preparedness and resilience strategies while also reveals gaps and areas for improvement in addressing multi-hazard risks and implementation challenges (Table 1). Key strengths and resilience strategies include:

Seismic Resilience

Strategic and legal documents like the NESAP[10] and the Law on the Transformation of Areas Under Disaster Risk[11] focus on retrofitting critical transport infrastructure and enhancing evacuation routes. In high-risk zones like Istanbul, these efforts are guided by localized seismic assessments. Foundational studies like the İstanbul Earthquake Master Plan (IEMP) along with ongoing vulnerability analyses by IMM have led to systematic reinforcement programs for critical infrastructure such as metro systems, bridges, and highway viaducts[12].

Flood and Climate Adaptation

The National Climate Change Action Plan[13] and Green Deal Action Plan[14] prioritize climate-resilient urban development. Climate adaptation measures increasingly factor into urban mobility planning especially through updated zoning regulations and the deployment of flood risk maps.

[10] Disaster and Emergency Management Presidency (AFAD), Official Gazette 18.08.2011, No: 28029, Retrieved from: https://deprem.afad.gov.tr/assets/pdf/udsep_010915_kitapENG.pdf

[11] Law No. 6306 on the Transformation of Areas under Disaster Risk. (2012). Official Gazette, No. 28309, May 31, 2012. Retrieved from: https://www.resmigazete.gov.tr/eskiler/2012/05/20120531-1.htm

[12] Istanbul Metropolitan Municipality, Department of Earthquake Risk Management and Urban Improvement. (n.d.). Transportation Structures Projects. Retrieved from https://deprem.ibb.istanbul/calismalarimiz/ulasim-yapilari-projeleri/

[13] Ministry of Environment, Urbanisation and Climate Change (MoEUCC), Directorate of Climate Change. (2010). Retrieved from: https://webdosya.csb.gov.tr/db/iklim/editordosya/iklim_degisikligi_stratejisi_EN(2).pdf

[14] The Ministry of Trade. (2021). Retrieved from: https://webdosya.csb.gov.tr/db/dongusel/icerikler/turk-ye-yes-l-mutabakat-eylem-plan--20220615123955.pdf , Republic of Türkiye - Ministry of Trade

Emergency Preparedness

TDRP[15] outlines emergency logistics and evacuation protocols, supported by the Disaster and Emergency Response Services Regulation[16], which codifies emergency operations. It coordinates agencies in clearing and restoring key transportation corridors. Local coordination centres like Istanbul's AKOM integrate these national directives with localized transport response plans including emergency vehicle routing and public transit adjustments.

Sustainability and Innovation

Strategic plans like the Transport and Logistics Master Plan[17] and the National ITS Strategy Document and Action Plan[18] promote sustainable, resilient transport networks by integrating intelligent traffic systems, data-driven mobility management, and low-emission transport infrastructure into resilience planning.

Key Gaps and Areas of Intervention

While these approaches provide rapid and effective disaster response, there remains limited emphasis on strategic, long-term, and integrated resilience planning especially concerning urban mobility systems (Table 1). These gaps span from high-level strategy to on-the-ground implementation:

Strategic Vision vs. Operational Reality: A primary challenge lies in the gap between high-level, long-term national strategies and their operational execution. Visionary documents like the Twelfth Development Plan and the Transport and Logistics Master Plan (2053) set ambitious goals for resilient and sustainable infrastructure. However, they often lack the detailed, short-term actions and specific funding mechanisms needed for municipalities to implement them effectively. This leaves a gap between national vision and local capacity.

Predominance of Reactive and Single-Hazard Approaches: Despite the multi-hazard scope of the TDRRP, Türkiye's policy framework remains heavily oriented towards seismic risk and emergency response. Foundational documents like NESAP are earthquake-focused, while the TDRP and its accompanying regulation are designed for immediate, post-disaster action. This leaves gaps in proactive, long-term resilience planning for other growing threats, such as climate-induced floods and heatwaves, which are addressed more from a sustainability perspective in the Green Deal Action Plan rather than a hard infrastructure resilience one.

[15] Disaster and Emergency Management Presidency (AFAD). (2022). Retrieved from: https://www.afad.gov.tr/kurumlar/afad.gov.tr/e_Kutuphane/Planlar/TAMP.pdf
[16] Official Gazette, 24.02.2022 No: 31760, Retrieved from: https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=5211&MevzuatTur=21&MevzuatTertip=5
[17] Ministry of Transport and Infrastructure (MoTI). (2023). Retrieved from: https://www.uab.gov.tr/uploads/pages/bakanlik-yayinlari/20221025-2053-ulastirma-ve-lojistik-ana-plani-eng.pdf
[18] Ministry of Transport and Infrastructure (MoTI). (2019) Retrieved from: https://hgm.uab.gov.tr/uploads/pages/akilli-ulasim-sistemler-aus/ulusal-akilli-ulas-im-sistemleri-strateji-belgesi-ve-2020-2023-eylem-plani-eng.pdf

Inconsistent Local Implementation and Funding Barriers: A recurring gap identified across multiple documents is the challenge of local implementation. While laws like the Law on Transformation of Areas Under Disaster Risk (Law No. 6306) provide powerful tools for urban renewal, their application is often slowed by inconsistent enforcement, funding shortages, and public opposition. Similarly, national plans like the TDRRP call for local action, but municipalities often face significant barriers in accessing the financial resources and technical capacity needed to meet these mandates from retrofitting transport infrastructure to developing local data systems.

Lack of Measurable Indicators and Monitoring Systems: Many key strategic documents including the foundational NESAP, lack concrete, numerical KPIs. Without specific targets (such as the percentage of critical bridges to be retrofitted by a certain date or required emergency response times) it is difficult to track progress, ensure accountability, and adapt strategies based on performance. This makes it challenging to assess whether resilience is actually improving over time.

Data Fragmentation and Governance Barriers: Most of the plans emphasize the need for integrated, GIS-based, and open-data platforms for better decision-making. However, achieving this in practice remains a major challenge. Persistent barriers in inter-institutional data sharing, standardization, and governance obstruct the creation of the seamless information ecosystem envisioned in these strategies, which limits the effectiveness of both planning and response.

In this context, the fragmented nature of Türkiye's current policy framework poses a significant challenge. Addressing these gaps through stronger vertical coordination between national and local actors, clearer institutional mandates, the adoption of multi-hazard planning approaches, better integration of measurable indicators, and ensuring that local authorities are financially and technically equipped to adapt national strategies to their unique mobility contexts will be essential for building a cohesive and adaptive disaster resilience framework.

Table 1: Main Strategies, Coverages, and Gaps of Key Documents

Document	Main Resilience Strategies	Coverage of Mobility Systems	Identified Gaps
Twelfth Development Plan (2024–2028)	*Establishes "Disaster-Resilient Living Spaces" as one of its five core pillars.* • Mandates disaster-resilient design for all transport infrastructure, including city-specific emergency/evacuation routes (Article. 605, 886). • Prioritizes making all infrastructure and building stock resilient to disasters and climate change by 2053 (Article. 280). • Promotes inter-institutional data sharing via a disaster management IT infrastructure (Article. 831).	*Comprehensive and Strategic*: The plan's coverage is extensive, providing the high-level policy direction that influences all mobility systems and related sectors: • Urban & Intercity Networks: Addresses the resilience of both urban and intercity transport facilities and infrastructures, including specific attention to the Marmara Region (Article 838.1). • Emergency & Evacuation Infrastructure: Directly targets the designation and expansion of assembly areas and evacuation corridors (Articles 834.3, 886). • Multi-Hazard Focus: Includes resilience against earthquakes and climate impacts like sea-level rise in coastal cities, affecting the design of transport systems in these areas (Article 886).	• *High-Level Strategic Focus*: As a national development plan, its objectives are broad and require translation into specific, operational actions and regulations by ministries (e.g., MoTI, MoEUCC) and local governments. • *Implementation & Funding Ambiguity:* While it sets clear goals (KPIs), the plan does not detail the specific funding mechanisms or enforcement tools to ensure municipalities can meet these new resilience standards for their local transport networks. • *Data Sharing Challenges*: The goal of inter-institutional data sharing (Article 831) is ambitious and faces practical barriers related to technical compatibility, bureaucratic hurdles, and data governance, which are not resolved within the plan itself.
Transport and Logistics Master Plan (2053)	*Promotes a safe, efficient, and sustainable multi-modal transport system.* • Shift to Resilient Modes: Prioritizes shifting freight from road to rail and maritime to reduce network vulnerability and environmental impact. • Smart & Sustainable Mobility: Mandates the use of ITS, promotes green terminals, and aims to reduce emissions.	*Extensive & Multi-Modal:* Covers all national transport systems with a long-term vision: • Freight & Logistics: Strong focus on main logistics corridors, production centres, and logistics hubs. • Passenger Mobility: Includes analysis of national passenger	• *Long-Term Focus vs. Short-Term Action:* The 2053 horizon means many goals are aspirational; lacks detailed, short-term implementation plans for immediate resilience needs. • *Local Implementation Challenges:* Success depends on the capacity and willingness of municipalities and

Document	Main Resilience Strategies	Coverage of Mobility Systems	Identified Gaps
	• Data-Driven Planning: Relies on a revised Multi-Modal Transport Model and calls for an "Open Data" platform and a National Transportation Database to support data-driven decisions. • Infrastructure Integrity: Focuses on creating high-quality, integrated transport corridors and improving emergency response capabilities for safety and security.	mobility and aims to reduce journey times. • Urban & Intercity Integration: Aims for physical integration of major centres into the national network and promotes smart mobility in urban transport.	private sector actors to align with its long-term vision, which can be inconsistent. • *Digital Governance & Data Access:* The "Open Data" platform is a goal, but its operationalization faces significant hurdles related to data standards, institutional sharing agreements, and privacy concerns.
Türkiye Disaster Risk Reduction Plan (TDRRP)	*A comprehensive, multi-hazard plan to reduce existing disaster risks and prevent new ones.* • Integrates risk reduction into central/local government strategic plans (Action B.6.1.1). • Mandates making urban infrastructure earthquake-resistant and provides financial incentives for retrofitting (Actions C.4.1.2, D.6.3). • Promotes ITS to mitigate climate risks (Action i.1.1). • Focuses on developing EWS for hazards like floods.	*Broad & Multi-Hazard:* • Addresses 11 disaster types (earthquake, flood, climate change, etc.). • Covers the resilience of all transport structures. • Includes emergency evacuation systems and public transport reliability.	• *Implementation & Funding Barriers:* Success depends on budget allocation (Action C.1.1.3) and the capacity of local governments to implement the actions, which can be inconsistent. • *Data Integration Challenges:* While it calls for databases (e.g., National Flood Database), achieving seamless data sharing and decision support across institutions remains a major hurdle. • *General Goals over Sector-Specific Actions:* Provides broad strategic goals, detailed operational plans for the transport sector are often left to other documents.
National Climate Change Action Plan (2011–2023)	*A foundational plan focused on GHG emission control and initial adaptation measures for key sectors including transport.* • Promoted a modal shift to more efficient rail and sea transport.	*Partial & Sector-Focused:* • Primarily addressed urban public transport, non-motorized transport, and low-carbon logistics. • Covered inter-modal freight and passenger	• *Expired & Superseded:* Its period has ended, and it has been replaced by more detailed, separate Adaptation and Mitigation plans (2024-2030). • *Limited Transport-Specific KPIs:* Lacked

Document	Main Resilience Strategies	Coverage of Mobility Systems	Identified Gaps
	• Encouraged sustainable urban mobility (public transit, cycling, walking). • Advocated for alternative fuels, clean vehicle tech, and ITS. • Included strategic objectives for flood risk management and EWS	transport from an emissions perspective. • Included adaptation measures like flood mapping, relevant to transport infrastructure.	specific, measurable resilience targets for the transport sector, KPIs were general (e.g., "decrease in emissions"). • *Weak Link to Disaster Resilience:* While it mentioned flood risks, the connection between climate adaptation and the physical resilience of transport infrastructure was not strongly developed.
National Earthquake Strategy and Action Plan (NESAP) (2012–2023)	*A foundational, single-hazard strategy focused on creating a seismically resilient society and infrastructure.* • Mandates seismic safety assessments and retrofitting for critical transport structures (bridges, viaducts) (Strategy B.1.6). • Calls for new regulations for the earthquake-resistant design, maintenance, and inspection of transport systems. • Aims to improve transportation systems for emergency response and develop effective recovery protocols.	*Strong & Focused:* • Primarily targets the physical resilience of road and rail networks, bridges, and tunnels. • Covers emergency access and evacuation logistics from a seismic perspective. • Addresses the resilience of critical logistics hubs.	• *Single-Hazard Focus:* Primarily addresses earthquake risk, with limited integration of other hazards like floods or climate change impacts. • *Lack of Numerical KPIs:* The plan sets goals but lacks specific, measurable targets (e.g., % of infrastructure to be retrofitted by a certain date), making progress difficult to track. • *Uneven Local Uptake:* Implementation of retrofitting and new design standards has been inconsistent across different municipalities and regions.
Türkiye Disaster Response Plan (TDRP)	*An operational framework defining roles and actions for effective disaster response and coordination.* • Establishes a modular structure with 25 national "disaster groups" (e.g., transport, logistics) for coordinated action.	*Focused & Operational:* • Concentrates on emergency roads, airports, seaports, and key intercity corridors needed for response. • Covers the immediate operational tasks: traffic management,	• *Response-Focused, Not Proactive:* Exclusively deals with actions during and after a disaster, not with long-term risk reduction or resilience-building. • *Limited Integration with Local Transport Plans:* Focuses on

Document	Main Resilience Strategies	Coverage of Mobility Systems	Identified Gaps
	• Prioritizes rapid transport access to disaster areas by identifying alternative routes and managing traffic flow. • Mandates the quick repair of damaged transport infrastructure (roads, railways, airports, seaports) and debris clearance. • Defines national and provincial support systems (e.g., designated provinces to support Istanbul).	debris removal, and infrastructure repair. • Defines the command structure for the "Disaster Transportation Infrastructure Group," led by MoTI.	national-level coordination and major corridors, with less detail on how it integrates with municipal-level urban mobility and transport plans. • *Unclear Post-Disaster Recovery Strategies:* While it covers immediate repairs, it lacks a detailed framework for long-term, resilient reconstruction ("build back better") which falls outside its response scope.
Green Deal Action Plan of Türkiye (2021)	*Aims to align Türkiye with the European Green Deal, focusing on sustainable development and carbon reduction.* • Promotes low-emission transport through electric vehicles (e-vehicles) and charging infrastructure development. • Encourages a modal shift to rail and green shipping, including improving EU-Türkiye railway connections. • Supports sustainable urban mobility, including e-vehicles in public transport and promoting micro-mobility (bicycles, e-scooters). • Includes a "Green Port" certification program to reduce maritime sector emissions.	*Partial & Sustainability-Focused:* • Concentrates on sustainable urban mobility, rail and maritime freight, and the electrification of transport. • Addresses the environmental impact of transport, particularly emissions from road and sea. • Linked to EU pre-accession funding for urban mobility projects.	• *Less Emphasis on Disaster Scenarios:* Primarily focused on long-term environmental sustainability and climate mitigation, not the acute resilience of transport systems during disasters like earthquakes or floods. • *General Policy Framing:* The actions are often framed as high-level strategic goals (e.g., "strategy development") rather than immediate, operational plans for infrastructure resilience. • *Dependency on Green Finance:* Implementation relies heavily on securing "green finance" and international funding, which can be a limiting factor.
Law on the Transformation of Areas Under	*Enables risk-based urban regeneration by facilitating the*	*Indirect & Urban-Focused:*	• *Inconsistent Enforcement & Implementation:* The application of the law

Document	Main Resilience Strategies	Coverage of Mobility Systems	Identified Gaps
Disaster Risk (2012)	*demolition and reconstruction of vulnerable buildings and areas.* • Authorizes the identification of "hazard areas" and "risky buildings" for transformation. • Provides legal mechanisms for evacuation, demolition, and land reallocation. • Offers financial support (loans, grants) to property owners to incentivize renewal. • Aims to create safer, more resilient living environments built to modern standards.	• Does not directly regulate transport systems. • Enables transport resilience by allowing for the complete renewal of vulnerable urban neighbourhoods, which can include redesigning street networks and improving access. • Affects the surrounding infrastructure of transformation zones.	varies significantly between municipalities, leading to uneven progress. • *Public Opposition & Social Issues:* Projects often face resistance from residents due to displacement, property rights disputes, and gentrification concerns, causing major delays. • *Unclear Timelines & Complexity:* Large-scale urban transformation projects are inherently complex and slow, with implementation timelines often unclear or prolonged.
Disaster and Emergency Response Services Regulation (2022)	*Codifies the specific operational roles and responsibilities of institutions for disaster response.* • Mandates that MoTI coordinates transport services, ensures fast/safe access to disaster areas, and manages debris removal on key routes. • Requires municipalities to maintain updated, GIS-formatted inventories of buildings and roads and share them with AFAD. • Assigns municipalities the duty to establish and clearly mark assembly areas and prepare temporary shelters with adequate infrastructure.	*Targeted & Operational:* • Focuses on the practical execution of emergency mobility: route clearance, evacuation logistics, and resource transport. • Leverages data systems (GIS) for urban response planning. • Defines the coordination chain from national ministries (MoTI) down to local authorities (municipalities).	• *Focuses More on the Emergency Phase:* Primarily deals with immediate response and life-saving operations, with less emphasis on long-term transport resilience or proactive risk reduction. • *Implementation Consistency:* The effectiveness depends on the capacity and compliance of each municipality to fulfil its duties (e.g., keeping GIS data updated), which can vary. • *Potential for Coordination Gaps*: While it defines roles, seamless coordination between different ministries and local actors during a large-scale, chaotic event remains a significant practical challenge.

The above-identified gaps and areas of intervention clearly span across multiple levels of governance, highlighting the need for a coordinated multilevel approach to effectively enhance resilience in urban mobility. While fully addressing these challenges requires systemic alignment and action at all levels, this handbook focuses on what can be done within its scope: supporting cities in navigating these challenges from a local perspective. As explored in the following chapters, we approach some of the identified issues through a multilevel lens, while also providing practical guidance for municipalities to take proactive steps, regardless of whether higher-level frameworks are fully in place.

2. Laying the Foundation for Resilient Mobility Planning

2.1 Institutionalising Resilience in Mobility Planning

To effectively integrate resilience into urban mobility planning, it is crucial to institutionalise resilience as a core principle. This involves embedding resilience considerations into all aspects of planning, policymaking, and implementation processes. By doing so, cities can ensure that their mobility systems are better prepared to withstand and recover from disruptions.

Bridging the Gaps: From Fragmentation to Coherence

Current resilience actions are often isolated in separate documents or limited to emergency response. Hence, action must start with governance. Cities are encouraged to move beyond reactive measures by adopting the following strategies:

- **Establish Unified Leadership Structures:** Establish a shared responsibility model between transport planners, emergency agencies, urban developers, and climate authorities. This means joint leadership structures and formal cooperation protocols. This inter-agency taskforce will be responsible for aligning policies, overseeing implementation, and ensuring accountability at both local and national levels.

- **Create Clear Pathways for Collaboration:** Develop standard operating procedures for cross-sector integration, including data-sharing, joint risk assessments, and resilience scoring of planned infrastructure.

- **Embed Resilience into Decision-Making Processes:** Local authorities should require that every mobility project includes resilience criteria from the planning stage through to implementation and monitoring. This involves integrating risk assessments, scenario planning, and stress testing as core components of all planning and infrastructure projects.

Rethinking the Role of Resilience in Mobility Plans

Current Transport Master Plans (TMPs) and other mobility plans, such as Sustainable Urban Mobility Plans (SUMPs) provide an important basis for urban mobility planning, but often treat

resilience as an isolated element, limited to emergency evacuation routes or reactive measures after disasters. To make mobility plans truly resilient:

- **Audit and Enhance Existing Plans:** Conduct systematic evaluations to identify where resilience measures are currently included and where they are lacking. This audit should assess the adequacy of risk management sections, emergency planning provisions, and continuity strategies within existing plans.

- **Embed resilience throughout the entire planning process,** from vision-setting to monitoring. This includes risk-informed scenario development, stress-testing of networks, and infrastructure prioritization based on vulnerability.

- **Adapt the planning language.** Instead of treating resilience as a theme, it should become a design principle, shaping the logic of investments, route planning, and service delivery.

- **Localize national frameworks.** Translate broad national documents into practical checklists or decision tools that municipalities can use when shaping their TMPs and SUMPs.

This is not (only) about creating more plans, it is about making the existing ones work together under a shared resilience ambition.

Shifting Policy Foundations to Support Resilience

To translate the integrated resilience framework into actionable outcomes, urban planning policies must be recalibrated. The following policy adaptations are recommended:

- **Revising Regulatory and Zoning Frameworks:** Amend local zoning laws and land use regulations to incentivize risk-aware, transit-oriented developments. Update building codes and design standards to require multi-hazard resilience features in new projects.

- **Establishing Dedicated Funding and Incentive Mechanisms:** Create resilience funding streams, such as dedicated municipal resilience bonds or public–private partnership programs, to finance retrofitting, infrastructure upgrades, and digital innovation. Provide performance-based incentives for cities that achieve specified resilience targets.

- **Mandating Integrated Risk Assessments for All Projects:** Require that all mobility-related developments, whether new or retrofit projects, include comprehensive risk and vulnerability analyses based on standardized criteria. This should be enforced through planning approvals and regulatory review processes.

2.2 Building a Culture of Resilience

Creating truly resilient urban mobility systems requires more than enhanced institutional set-ups and technical upgrades, it demands a cultural shift in how cities plan, govern, and engage. This culture of resilience must be cultivated across institutions and communities alike, embedding preparedness, adaptability, and inclusivity into daily decision-making.

Capacity Building: Empowering Local Authorities for Resilient Urban Mobility

Building the capacity of local authorities is another critical component of fostering a culture of resilience. Local authorities play a pivotal role in the planning, implementation, and management of urban mobility systems. Therefore, it is essential to equip them with the knowledge, skills, and tools necessary to effectively integrate resilience into their work.

- **Institutionalizing Training and Skill Development Programs:** Develop comprehensive capacity-building initiatives that equip municipal staff with the knowledge and tools to anticipate, plan for, and respond to disruptions. Training programs should cover core areas such as resilience assessment, scenario planning, continuity of operations, and cross-sector coordination. These efforts must be institutionalized within municipal structures and linked to broader urban development goals.

- **Facilitating Knowledge Exchange and Peer Learning Platforms:** Create opportunities for cities to engage in cross-municipal learning through exchange visits, thematic workshops, and participation in resilience-focused networks. Encourage documentation and dissemination of lessons learned and successful pilot initiatives.

- **Embedding Resilience Competencies in Local Governance Structures:** Develop clear mandates within municipal departments for resilience planning, supported by dedicated staff positions and interdepartmental coordination mechanisms. Ensure that resilience responsibilities are integrated into performance evaluations and institutional workflows.

- **Leveraging Technical Assistance and Advisory Services:** Mobilize support from national institutions, universities, and international partners to provide technical advisory services tailored to local challenges. This includes access to planning toolkits, scenario modelling instruments, and implementation guidelines.

Fostering Inclusive Resilience through Engagement

Engaging communities and stakeholders in the planning process is essential for building a culture of resilience. Inclusive resilience planning ensures that the needs and perspectives of all segments of the population are considered, leading to more equitable and effective solutions.

- **Institutionalizing Community Participation in Resilience Planning:** Design and implement structured engagement frameworks that guarantee the inclusion of diverse community voices in resilience planning processes. Utilize participatory planning workshops, public forums, and digital platforms to ensure communities can meaningfully contribute to decision-making. Emphasize the inclusion of vulnerable groups to address equity gaps in risk exposure and adaptive capacity.

- **Broadening Stakeholder Coalitions for Systemic Resilience:** Engage civil society organizations, academic institutions, and private sector actors as co-creators of resilience strategies. Establish multi-stakeholder advisory committees to guide mobility resilience planning, bringing technical, social, and economic expertise to the table.

- **Enhancing Risk Awareness and Communication:** Implement targeted communication campaigns to raise awareness of urban risks and resilience strategies. Provide communities with accessible information on hazard exposure, evacuation routes, and emergency preparedness. Use mapping tools, visual simulations, and multilingual materials to ensure clarity and inclusivity.

Checklist for Laying the Foundation for Resilient Mobility Planning

The following checklist provides key actions to support planners, policymakers, and practitioners in embedding resilience into their urban mobility strategies.

Box 1: Checklist for Laying the Foundation of Resilience in Mobility Planning

1. Resilient Mobility Planning in Regulation

- Resilient planning as a coherent approach within urban development.
  - **Align policies and ensuring multilevel** accountability by enforcing joint leadership structures and cooperation
  - **Standardisation** of cross-sector integration.
  - **Resilience as required criteria** in decision making.

- Rethinking the importance of resilient mobility plans
  - **Identify** gaps in resilience, focusing on risk management, emergency provisions, and continuity strategies.
  - **Embed resilience** across the entire planning cycle using risk-informed scenarios, stress tests, and vulnerability-based prioritization.
  - **Reframe resilience** as a core design principle.
  - **Turning national frameworks** into practical tools for municipalities to apply in their TMPs and SUMPs.

- Shifting policy foundations
  - **Revising regulation and frameworks** to require multi-hazard resilience features in upcoming projects
  - Offer funding tied to **performance-based incentives for** cities that meet resilience targets.
  - Make resilience criteria a **mandatory requirement** for planning approval

2. Resilience as part of decision-making culture

- Empowering local authorities with knowledge, skill and tools.
  - **Create training programs** on the fundamentals of resilient planning.
  - Facilitate cross-municipal **knowledge exchange** opportunities.
  - Incorporate resilience into **institutional processes and performance reviews**.
  - **Provide technical advisory services** tailored to local challenges.

- Engaging communities and stakeholders in the planning process.
  - **Institutionalize inclusive community participation** in resilience planning.
  - **Involve engagement from broader stakeholders** and establish multi-stakeholder advisory committees.
  - **Strengthen risk communication** with targeted campaigns, accessible information, and inclusive tools.

3. Assessing the Status Quo: Mapping Risks and Vulnerabilities in the Mobility System

3.1 Assessing Existing Mobility Systems for Risks and Weaknesses

Mobility systems, encompassing physical infrastructure, public transit services, logistics networks, accessibility and social aspects, are inherently vulnerable to disruptions. These vulnerabilities stem from both external hazards, such as natural disasters, and internal inefficiencies, such as aging infrastructure and systemic bottlenecks. These vulnerabilities can manifest in the form of physical damage, service disruptions, or reduced access to essential services during crises. In Türkiye, where earthquakes, floods, and wildfires are frequent, the impact on mobility infrastructure can be both severe and enduring. Bridges may collapse, transit corridors may become submerged, and key routes may be rendered impassable. However, disruptions of transit services can also occur due to inadequate maintenance or system failures within the mobility system, hindering accessibility.

Analysing Critical Components of the Transport Infrastructure

An essential first step in assessing these vulnerabilities is to analyse critical components of the transport infrastructure. These include roads, bridges, tunnels, railways, and transport hubs that function as lifelines during emergencies. Particular attention must be paid to identifying single points of failure, such as heavily trafficked routes or structurally unsound infrastructure, which could cause cascading disruptions across the network.

- Earthquake-prone cities like Istanbul require comprehensive structural assessments of bridges, tunnels, and metro lines. Retrofitting vulnerable infrastructure can significantly mitigate potential disasters.

- Coastal cities like Izmir face heightened risks from flooding, which can paralyze key transit hubs, and waterlog roads and transit services, underscoring the importance of effective drainage systems.

- Issues such as aging fleets, insufficient maintenance, and uncoordinated responses during crises worsen vulnerabilities. Public bus systems, for example, often struggle with vehicle downtime during emergencies, limiting service coverage when it is most needed.

To effectively address the **vulnerabilities in transport systems**, a systematic and thorough assessment approach is essential. Local authorities need to conduct comprehensive audits of both physical assets and operational processes of the transport system of their cities. These audits should account for interdependencies with other sectors, such as energy and water systems, which directly influence transport reliability. Some of the common audit methods used in risk assessment and mitigation are listed in the table below. These can be tailored to focus on the transport infrastructure.

Table 2: Methods and Tools for Analysing Critical Components of the Transport Infrastructure

Method	Definition	Use Case	Output
(Threat) Hazard Identification and Risk Assessment (T-HIRA)[19] [20] [21]	A qualitative and quantitative approach to identify and evaluate both external and internal hazards, such as natural disasters, operational inefficiencies, or cyber threats. It estimates the likelihood and impact of these risks across the entire transport system.	Ideal for strategic, system-wide planning to understand overall risks and inform broader resilience strategies.	A detailed report or presentation that identifies potential hazards, assesses their likelihood and impact, and prioritizes risks. It includes visual tools like risk matrices and GIS-based maps, along with actionable recommendations for mitigation, emergency response, and long-term resilience planning.

Example

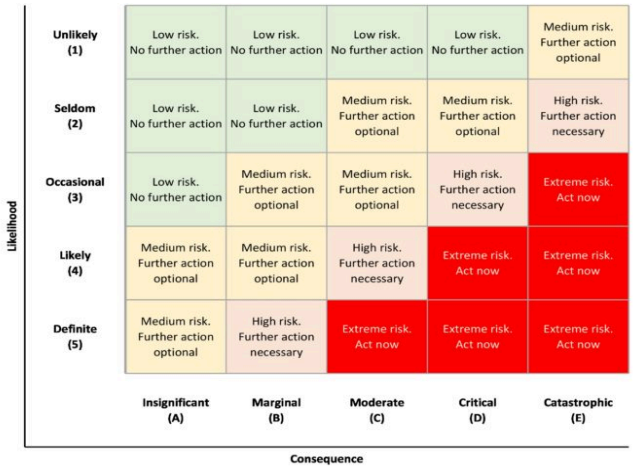


Figure 2: Risk Assessment Matrix Example. (Source: templatelab.com)

[19] Building Resilient Infrastructure for Natural Disasters and Climate Change

[20] Multi-hazard risk assessment narrative

[21] 2019 National Threat and Hazard Identification and Risk Assessment (THIRA) – FEMA (link)

<table>
<tr><th>Method</th><th>Definition</th><th>Use Case</th><th>Output</th></tr>
<tr><td>Failure Mode and Effects Analysis (FMEA)[22]</td><td>A systematic method for identifying potential failure modes in a transport system, assessing their effects, and prioritizing mitigation actions based on risk severity, occurrence, and detectability.</td><td>Used in evaluating failure modes in specific transport infrastructure components (e.g., bridges, roads, transit systems), operational processes (e.g., ticketing, traffic management), or vehicles to enhance safety, reliability, and efficiency.</td><td>A table listing potential failure modes, their effects on the system (e.g., delays, accidents), root causes, and a Risk Priority Number, followed by recommended actions to reduce risk and improve resilience.</td></tr>
<tr><td colspan="4">Example

<table>
<tr><th>Risk event</th><th>Severity</th><th>Occurrence</th><th>Detection</th><th>RPN</th></tr>
<tr><td>Poor site management and Quality Control (QC) by the contractor.</td><td>~5</td><td>~4</td><td>~4</td><td>4.1</td></tr>
<tr><td>Poor communication and coordination of the owner with designer and/or contractor.</td><td>~4</td><td>~3</td><td>~5</td><td>3.97</td></tr>
<tr><td>Lack of contractor staff on the project.</td><td>~3</td><td>~4</td><td>~3</td><td>3.3</td></tr>
<tr><td>Delay in approving project documentation.</td><td>~3</td><td>~3</td><td>~4</td><td>3</td></tr>
<tr><td>Ineffective delay penalties provisions in contract.</td><td>~2</td><td>~4</td><td>~3</td><td>3</td></tr>
<tr><td>Time consuming decision-making process of the owner.</td><td>~3</td><td>~3</td><td>~2</td><td>3</td></tr>
</table>

Figure 3: Example of FMEA of Railway Infrastructure Projects in Serbia (Source[2])</td></tr>
</table>

[22] (PDF) Risk Analysis Model with Interval Type-2 Fuzzy FMEA – Case Study of Railway Infrastructure Projects in the Republic of Serbia

Method	Definition	Use Case	Output
Risk Analysis Mapping[23]	A spatial analysis technique, often using GIS, that evaluates the intersection of risks (e.g., floods, earthquakes) with transport infrastructure. It visualizes vulnerabilities through maps to highlight risk-prone areas and affected assets.	Most effective for urban and regional planning, enabling geographically informed mitigation strategies.	A map or series of maps showing risk areas, severity levels, and vulnerabilities in the transport network, alongside risk categories (e.g., natural hazards, operational disruptions). It also includes prioritized risk areas for mitigation.

Example

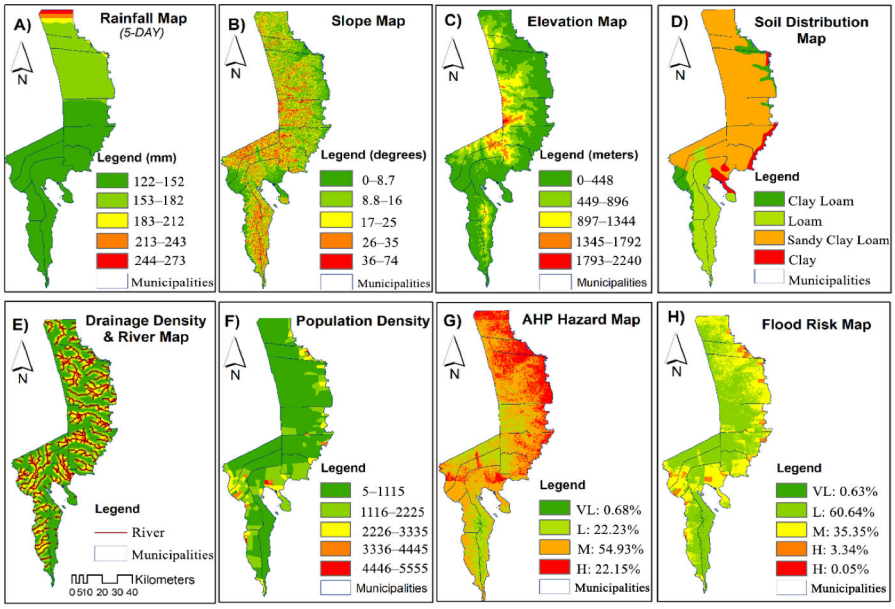


Figure 4: Flood Hazard Map Philippines (Source: Cabrera, Soo Lee, 2019)

[23] Risk Analysis using ArcGIS

Critical Services and Emergency Preparedness

Access to critical services, such as hospitals, fire stations, emergency shelters, or even airports and ports, depends heavily on resilient transport networks. Disruptions to these routes, as presented above, during emergencies can have life-threatening consequences, delaying medical treatments, rescue operations, and evacuation efforts. For effective disaster response, it is crucial to ensure that transport routes to these services remain operational and accessible even in the face of major disruptions. This requires cross-sector planning, robust communication and coordination.

- Transport Networks for Emergency Access: Reliable transport networks are vital for ensuring that emergency services can reach hospitals and shelters without delays. Secondary roads, dedicated emergency vehicle lanes, and alternative routes should be planned to guarantee that service disruptions on primary roads do not hinder access to critical facilities.

- Accessibility of Critical Service Locations: Hospitals and shelters must be strategically located near key transport corridors to ensure swift access during emergencies. Additionally, integrating public transport hubs with these services can offer multiple means of transportation for residents in urgent need.

To ensure **access to critical services,** cities must conduct thorough assessments of the transport routes that lead to essential services. Identifying potential vulnerabilities, such as flood-prone areas or traffic bottlenecks, can inform improvements to infrastructure and routing strategies. Examples of methods to be used include:

Table 3: Methods and Tools for Analysing the Access to Critical Services and Emergency Preparedness

Method	Definition	Use Case	Output
Transport Network Vulnerability Assessment[24]	Analyses transport routes to determine their capacity to manage emergencies and the effects of disruptions in major routes on the broader network. It uses tools like GIS and traffic simulation to model and evaluate risk scenarios.	Ideal for assessing network-wide impacts of disruptions and identifying which routes are critical for maintaining access to essential services during crises.	A report or map highlighting vulnerable components of the network, potential impacts of failures, and prioritized recommendations for strengthening or adapting the system to reduce risk.

Example

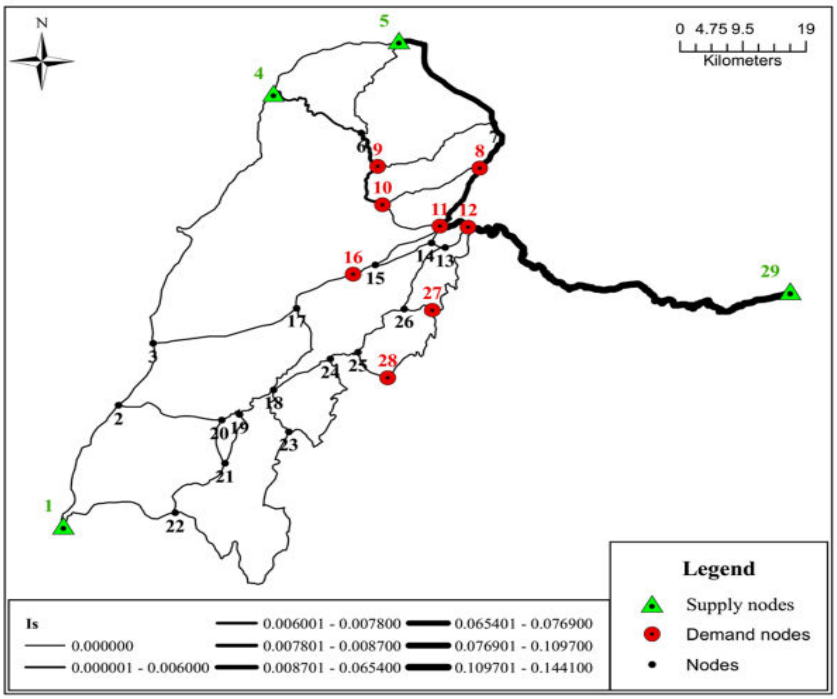


Figure 5: Transport Network Vulnerability Assessment (Source: Cantillo et al., 2018)

[24] Taylor, M.A.P., D'Este, G.M. (2007). Transport Network Vulnerability: a Method for Diagnosis of Critical Locations in Transport Infrastructure Systems (link)

Method	Definition	Use Case	Output
Service Area Accessibility Analysis[25]	Uses GIS and accessibility metrics to evaluate how different areas are served by critical services (e.g., healthcare, emergency response) during disruptions. It measures the ability of communities to access services based on transport network performance.	Useful for understanding how mobility disruptions affect service access for specific communities.	Maps or reports showing service coverage areas, accessibility gaps, and recommendations to enhance connectivity, such as adding transit routes or improving infrastructure.

Example

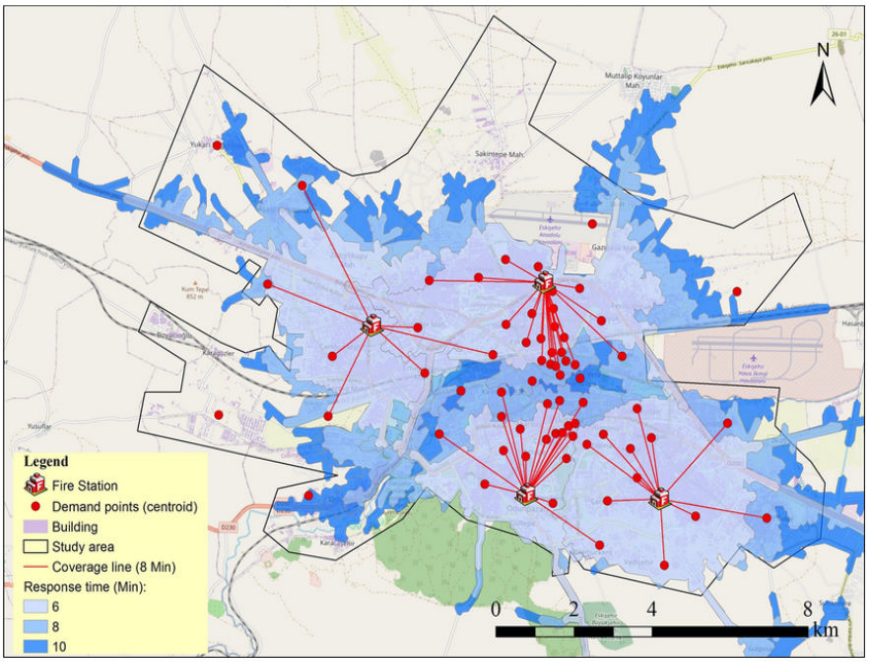


Figure 6: Service areas of existing fire stations in Eskişehir (Source: Deliry, Uygucgil, 2023)

[25] Accessibility assessment of urban public services using GIS-based network analysis: a case study in Eskişehir, Türkiye

Considering Social Vulnerabilities and Equity

Equally important to the assessment of the resilience of the transport infrastructure and mobility services is the recognition of the populations affected by mobility disruptions. Not all urban residents are affected equally. Marginalized groups, such as the elderly, individuals with disabilities, and low-income households, are disproportionately reliant on public transport systems and are often the least resilient in the face of disruptions. These groups may face reduced access to essential services, intensifying social inequalities. For example, residents on the outskirts of cities frequently face challenges such as insufficient transport infrastructure, fewer transit options, and longer commute times. In emergencies, these areas risk isolation due to limited road networks or blocked primary routes. Emergency response efforts are often delayed in these regions, compounding the difficulties faced by residents. Developing stronger connections between peripheral and central areas can mitigate these risks. Also, narrow sidewalks, inaccessible metro stations, and the absence of audible or visual aids in public transport systems could worsen accessibility for specific groups as during emergencies, such barriers can prevent these groups from safely evacuating or accessing critical services.

An understanding of these disparities is vital for crafting inclusive resilience strategies that prioritize equitable outcomes. Assessing social vulnerabilities, authorities must evaluate how transport disruptions affect different demographic groups, identifying areas of greatest need. Data from these assessments should inform policies aimed at addressing systemic inequalities, ensuring resilience measures are inclusive and responsive. Some of the most common methods to assess social vulnerabilities are listed below:

Table 4: Methods and Tools for Assessing Social Vulnerabilities and Equity

Method	Definition	Use Case	Output
Social Vulnerability Index (SVI)[26] [27]	A quantitative tool that measures the social and demographic factors that make certain populations more vulnerable to harm from disasters, climate change, or other disruptions. It includes factors such as income, age, health, housing, and mobility.	Best for prioritizing resilience strategies that focus on protecting the most vulnerable communities.	A ranked index or map showing areas of high, medium, and low social vulnerability, highlighting factors like poverty, access to transportation, and healthcare proximity, with recommendations for targeted interventions.
Example			

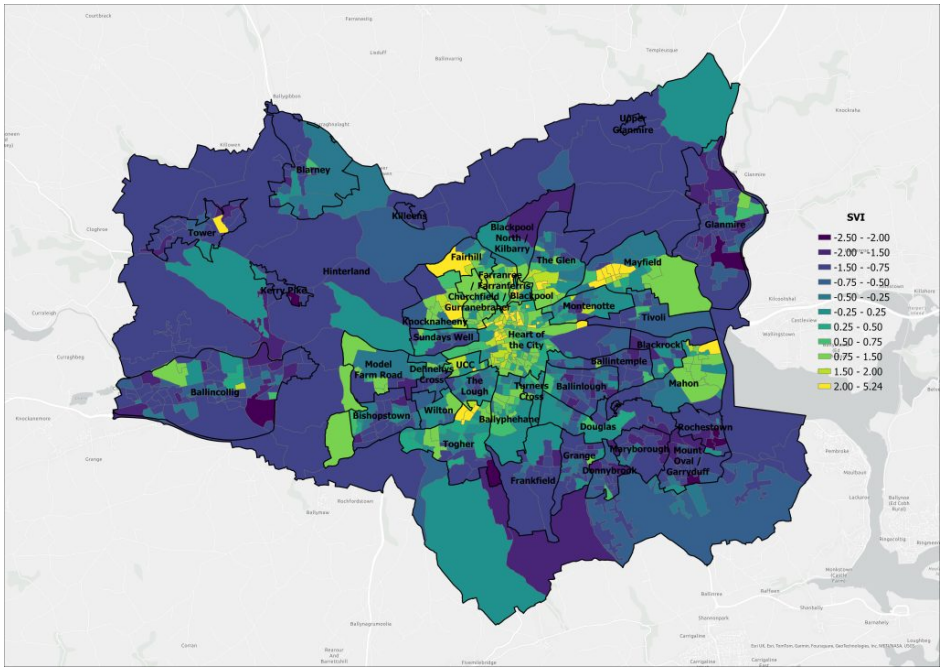


Figure 7: Example of the SVI Tool (Source: reachout-cities.eu)

[26] Social Vulnerability Index (SVI) EU

[27] Social Vulnerability Index | Place and Health - Geospatial Research, Analysis, and Services Program (GRASP) | ATSDR

Method	Definition	Use Case	Output
Equity and Access Mapping[28] [29]	A GIS-based method to analyse the accessibility of mobility services across various population groups, emphasizing underserved or marginalized communities. It identifies areas where disruptions or poor access disproportionately affect certain groups.	Ideal for addressing spatial inequalities and improving access to mobility for marginalized populations.	A map or report illustrating access disparities, equity gaps, and prioritized recommendations for improving access to underserved populations.

Example

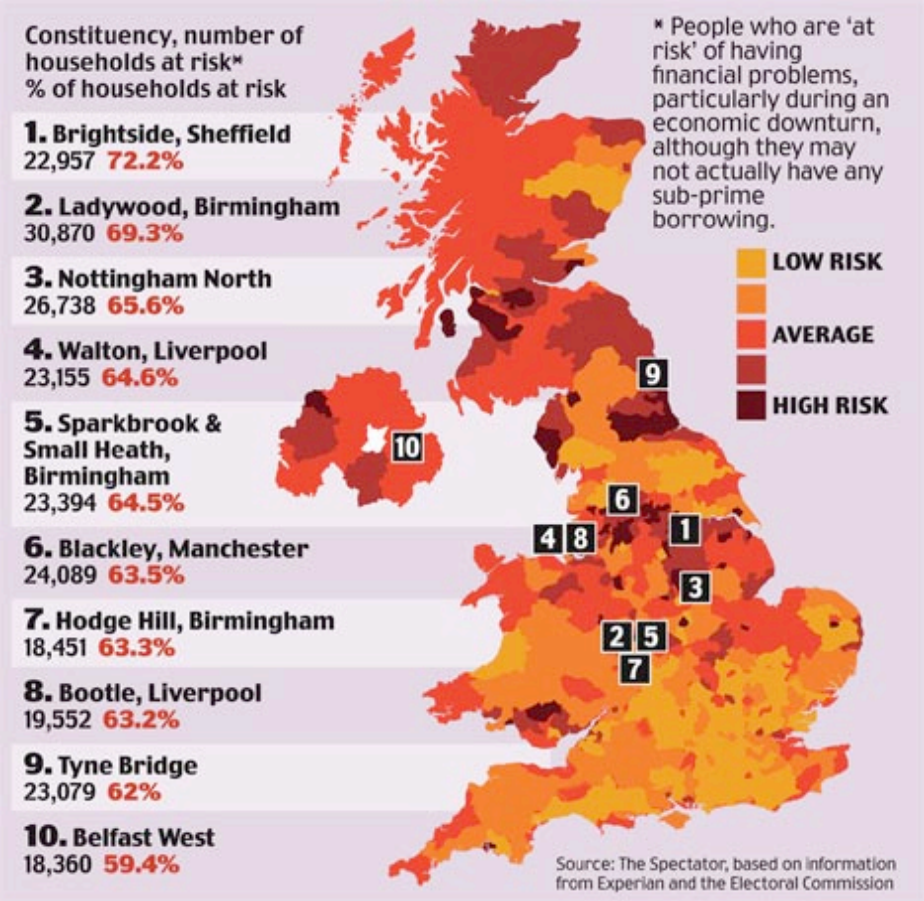


Figure 8: Equity Map of Britain on Sub-Prime (Source: The Spectator)

[28] Equity Mapping and the Geography of Opportunity | NNIP

[29] Equity Mapping and the Geography of Opportunity | HUD USER

Method	Definition	Use Case	Output
Social Impact Assessments (SIA)[30] [31]	A qualitative and quantitative approach to evaluate the social consequences of transport disruptions on specific groups, considering demographic factors, community needs, and service access. It assesses how mobility issues may worsen social inequalities.	Useful for understanding the broader societal implications of transport disruptions and targeting interventions.	A report identifying affected groups, the nature and extent of impacts, and recommendations for minimizing disruptions
Example N/A			

[30] Re-designing Social Impact Assessment to enhance community resilience for Disaster Risk Reduction, Climate Action and Sustainable Development - Imperiale - 2024 - Sustainable Development - Wiley Online Library

[31] From project-based to community-based social impact assessment: New social impact assessment pathways to build community resilience and enhance disaster risk reduction and climate action - Angelo Jonas Imperiale, Frank Vanclay, 2024

Assessing the Resilience of Communication Systems and Network Management

Effective communication is critical during any crisis, particularly when managing disruptions in urban mobility systems. A resilient communication network ensures that information flows efficiently between stakeholders, including local, regional and national authorities, emergency responders, and the public. Similar to the transport infrastructure, communication systems are vulnerable to a range of threats, from natural disasters to cyberattacks, which can disrupt their effectiveness. Cities must therefore assess whether their current communication infrastructure is robust enough to withstand these disruptions or whether interventions are necessary to enhance its resilience. A comprehensive assessment of communication networks involves the identification of potential weak points in both the infrastructure of the network and the software that supports it.

- **Risk Assessments for Cybersecurity**: With the growing reliance on digital platforms, cybersecurity becomes a priority. Conducting regular cybersecurity risk assessments allows cities to identify vulnerabilities and address potential threats proactively. These assessments should cover all communication platforms, including emergency alert systems, transport management systems, and public service communication channels. For example, hacking into traffic management systems could create chaos by altering signals or rerouting emergency vehicles.

- **Communication Network Vulnerability Assessment**: A detailed assessment that evaluates the infrastructure's ability to handle emergencies, accounting for network load, redundancy, and cybersecurity defences. This is especially important for critical communication channels used by emergency services, healthcare facilities, and transport networks.

- **Real-Time Communication System Assessment**: To ensure timely dissemination of critical information during emergencies, it is essential to evaluate the effectiveness of real-time communication systems. This includes assessing the capacity of transport authorities to provide updates on road closures, alternative routes, and transport availability, ensuring they reach all community members, particularly vulnerable populations.

- **Network Interdependence Evaluation**: Communication networks must also be integrated with other vital systems, such as energy grids and transport networks. For example, when transit routes are disrupted, real-time updates need to be provided to the public, requiring secure and uninterrupted communication between the transport network and citizens. Evaluating this interdependence is key to improving overall network resilience.

3.2 Use and Visualisation of Data for Risk Mapping and Analysis

Decision-makers from urban planners to policymakers need robust analysis to anticipate vulnerabilities, optimize resource allocation, strengthen mobility networks against potential disruptions and make quick decisions during times of crisis. In this respect, effective resilience planning hinges on data and analysis. Local authorities, being most familiar with their city's unique context, play a critical role in gathering and analysing these data, whereas also regional and national authorities might use these data and analyses. Therefore, data collection approaches need to be comprehensive across physical, environmental, and social dimensions, as well as accessible, comparable and processable for other institutions.

Data Categories

The following six data categories can track and analyse the readiness, response, and recovery of mobility services during disasters. In the table below, the specific indicators of those data categories are presented. Data can be gathered from real-time monitoring systems, historical records, and manual observations.

1. **Infrastructure Maintenance & Monitoring**

The resilience of urban mobility systems heavily depends on the robustness and reliability of their infrastructure. Well-maintained and adequately designed transportation infrastructure, such as roads, bridges, transit stations, and railways, ensures that the system can withstand and recover from disruptions. Monitoring infrastructure conditions, along with the ability to identify overutilisation or underutilisation, allows planners to make informed decisions about maintenance and capacity expansion.

2. **Network & System Resilience**

Network and system resilience refers to the ability of a transportation network to maintain its functionality during and after disasters or disruptions. A reliable and efficient system is one that can handle disruptions and return to normal operations quickly. Monitoring service reliability, including delays, cancellations, and breakdowns, is essential for identifying weaknesses in the system that could be intensified during a crisis.

3. **Service Capacity & Demand**

Service capacity and demand are key to understanding how well transportation systems can handle varying passenger loads under both normal and emergency conditions. By monitoring both factors, cities can optimize resources, anticipate vulnerabilities, and implement strategies to maintain service continuity, ensuring that critical mobility needs are met during both regular and crisis situations.

4. Environmental and Climate Resilience

Urban mobility systems must be designed to cope with environmental and climate-related challenges, making environmental resilience a cornerstone of urban mobility. As cities increasingly face extreme weather events, such as flooding, storms, and heatwaves, transportation systems need to be adaptive to these conditions. Monitoring environmental data, such as air quality, temperature changes and flood risks, allows for better urban planning and the development of transport systems that can mitigate these impacts.

5. Post-Disaster Data

Post-disaster data is essential for building a resilient urban mobility system capable of responding to and recovering from disruptions. Tracking the frequency and severity of previous incidents, such as accidents, natural disasters, or public health emergencies, allows cities to anticipate potential future risks and prepare the transport system accordingly. Assessing exposure to various risks enables better preparedness and response planning, enhancing the overall resilience of the system.

6. Social and Economic Factors

Urban mobility resilience relies on the ability to provide equitable access to transportation services while minimizing disruptions' social and economic consequences. Vulnerable populations are disproportionately affected by disruptions in transport services. Therefore, assessing equity of access ensures that these groups have reliable alternatives in times of crisis. Additionally, understanding the economic impacts of transport disruptions, such as lost productivity or increased costs, helps in quantifying the broader costs of mobility failures.

Table 5: Data Types to be Collected for Resilience Mobility Planning

Category	Data Name	Description	Metric
Infrastructure Maintenance & Monitoring	Infrastructure Condition	Data on the condition of key transport infrastructure and any scheduled maintenance plans or inspections.	Infrastructure condition reports, maintenance schedules, and any backlog of repairs needed. Average downtime, repair cycle time
	Resource Availability	Availability of resources (parts, teams) for emergency maintenance.	Resource readiness index (parts availability, repair staff capacity)
Network & System Resilience	Critical Network Vulnerability	Data on critical transport corridors and their vulnerability to various disaster types (e.g., flood, earthquake).	A list of corridors, their vulnerability score, and types of risks.
	Network Redundancy	Data on alternate routes and network options available during disruptions.	Route IDs, alternative route availability, and travel time differences between primary and alternative routes. Number of redundant connections, alternative transport options, service availability during disruptions
	Service Reliability	Frequency of delays, cancellations, and breakdowns in services.	Percentage of on-time arrivals, service interruptions rate
	Service Continuity (during disruptions)	Data on which routes and services are operational, and the extent of disruptions during the disaster.	Binary (0/1) data indicating route status (operational or disrupted).
Service Capacity & Demand	Utilization Rate	Frequency of use of critical transport systems (e.g., public transit, roads).	Passenger numbers, traffic volumes, vehicle occupancy rates
	Surge Capacity	Data on the number of extra vehicles and resources available during emergencies.	Number of buses/trains on standby, number of emergency staff available.
	Demand & Capacity Balancing	Data on actual passenger load, capacity limits, and the balance of supply and demand for each route.	Real-time passenger counts, vehicle capacity, and load factor (passengers/vehicle capacity).
	Peak Demand Readiness	Data on historical peak demand and transport capacity during peak hours.	Hourly ridership data for each transport mode (e.g., bus, metro), vs. available capacity during peak times.
	Overcrowding & Safety Measures	Data on passenger overcrowding, and safety measures implemented to manage it.	Number of overcrowded vehicles, implementation of crowd control measures (e.g., barriers, staff).
Environmental and Climate Resilience	Weather Patterns and Extreme Events	Frequency and severity of climate-related disruptions (e.g., storms, floods).	Number of extreme events, event severity index
	Urban Microclimates	Monitoring of air quality, temperature, and pollution levels in urban areas.	AQI (Air Quality Index), temperature ranges, pollution concentration

Category	Data Name	Description	Metric
	Flood Risk and Sea Level Rise	Risk assessment based on flood history and projections of sea level rise.	Flood risk index, sea level rise projection (cm/year)
Post-Disaster Data	Incident Frequency and Severity	Number and severity of accidents, service interruptions, or health crises.	Number of incidents, severity score (based on impact)
	Response Time to Disruptions	Time taken to restore service following a disruption or incident.	Average response time (hours or days)
	Risk Exposure Assessment	Frequency of natural or human-made risks affecting transportation systems.	Risk exposure index (based on historical and projected risk events)
	Impact of Service Interruptions	Data on the financial, social, and operational impacts of service disruptions caused by the disaster.	Estimated cost of downtime, number of passengers affected, missed economic opportunities due to disruption.
Social and Economic Factors	Vulnerable Population Mapping	Identifying groups with limited mobility access (e.g., elderly, low-income).	Percentage of vulnerable population within transport reach
	Economic Impact Indicators	Assessment of the financial impact of transport disruptions.	Economic loss due to disruptions (e.g., productivity loss, transport costs)
	Equity of Access	Evaluation of service distribution to ensure fairness across demographics.	Access ratio (transport availability vs. population density)

Risk Visualization

Risk visualisation supports urban planners, policymakers, and mobility managers to assess potential threats to transportation systems, including natural disasters, accidents, or operational inefficiencies. It provides a clear, accessible way of depicting complex data, enabling stakeholders to better understand potential risks and their impacts. Visualisation also aids in identifying patterns and trends that might otherwise be overlooked.

Several data-driven tools are essential for effective risk visualization, including Geographic Information Systems (GIS), real-time monitoring systems, and other visualisation methods. These tools can aggregate and process large amounts of data from diverse sources, to generate (real-time) visualisations of risk factors.

The following table shows important examples of such methods and tools.

Table 6: Methods and Tools for Risk Visualization

Method	Definition	Use Case
GIS-Based Mapping	A spatial analysis tool that maps and visualizes risk data by layering various geographical features (e.g., flood zones, congestion areas). GIS tools integrate multiple datasets to identify areas at risk.	Ideal for visualizing spatial risks and identifying vulnerable locations for targeted intervention.

Example

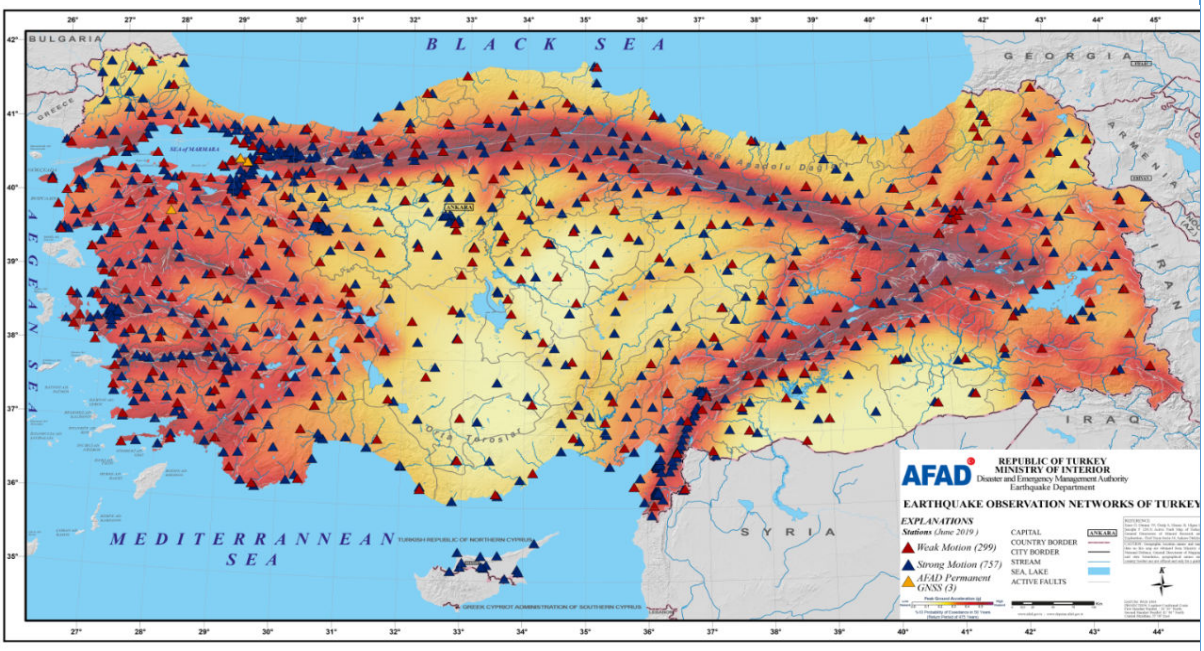


Figure 9: Earthquake Hazard Map of Türkiye and Türkiye National Seismic Network (Source: AFAD, 2019)

Method	Definition	Use Case
Temporal Heatmaps	A visual tool that represents data variations over time using colour intensity or gradients. They are commonly used to illustrate patterns, trends, and anomalies in time-series data, making it easier to identify when specific events or conditions are more frequent or intense. It can be applied to spatial data but is not limited to GIS.	Effective for identifying time-dependent trends or understanding how risks evolve.

Example

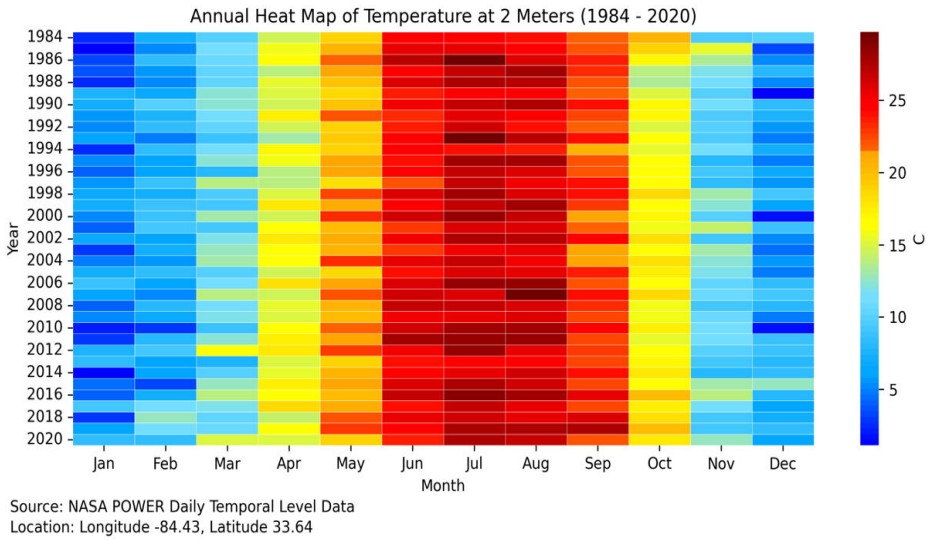


Figure 10: Temporal Heatmap Example (Source: NASA)

Method	Definition	Use Case
Flow Diagrams and Network Visualizations	Visualizes the flow of goods, services, or information through a network, helping identify disruptions or bottlenecks. This is usually more abstract and can be represented through flow charts or network diagrams.	Best for illustrating the dynamic relationships between components in a system, such as traffic flows or service disruptions.

Example

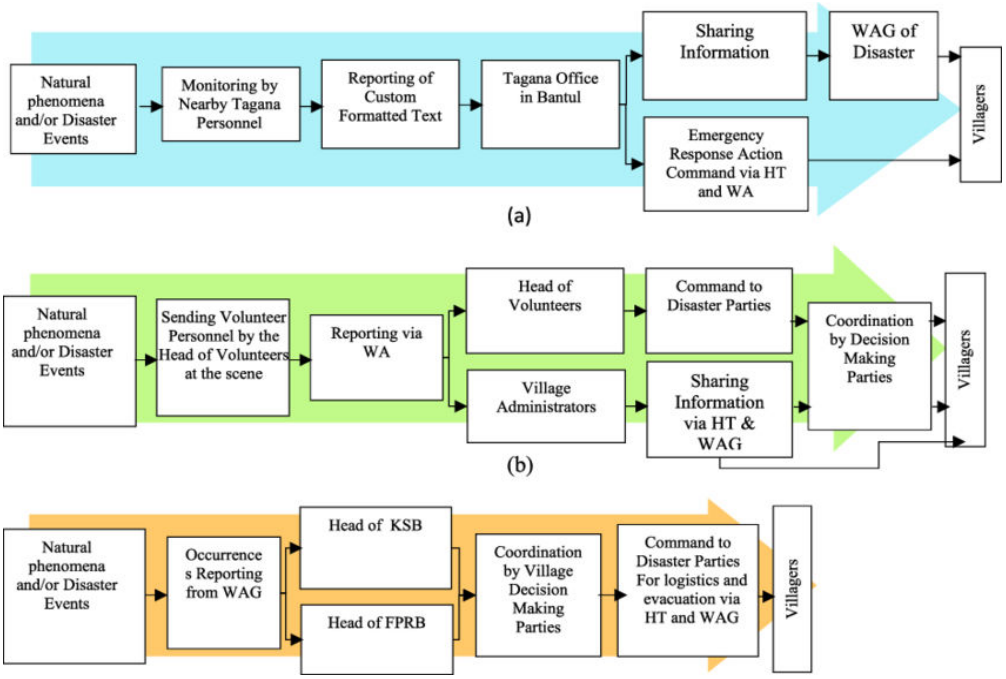


Figure 11: Flow of Disaster Information in Research Locations (Source: Ruslanjari et al., 2023)

3.3 Leveraging Stakeholder Input for User-Perspective

Building resilient urban mobility systems requires more than technical expertise and data-driven models. It demands also input from the people who use these systems daily, particularly those most affected by disruptions. Engaging stakeholders ensures that resilience strategies are inclusive, equitable, and grounded in lived experiences.

Gathering input from diverse stakeholders, ranging from policymakers to marginalised communities, strengthens resilience planning in several ways:

- While technical audits highlight structural risks, stakeholders, including citizens, can offer insights into less obvious challenges, such as poorly lit transit stops or unsafe pedestrian crossings. For example, residents in informal settlements often identify flood-prone pathways or neglected roadways that city-wide assessments might overlook.

- Inclusive planning builds trust and ensures that citizens feel a sense of responsibility for implemented solutions. When citizens are part of the decision-making process, they are more likely to support and sustain resilience measures.

- Engaging vulnerable groups ensures that resilience strategies address systemic inequalities. For instance, elderly residents may highlight the need for accessible transport routes during emergencies, while low-income commuters might advocate for maintaining affordable transit options.

To streamline the process, avoid redundancy, and maximise the impact of stakeholder contributions, the focus should be on **leveraging input already gathered through other planning processes**, such as Sustainable Urban Mobility Plans (SUMP) or other mobility or urban development plans, rather than starting from scratch.

Cities can draw from existing stakeholder engagement activities, communication streams, and user feedback mechanisms already in place. These may include consultations conducted during other planning efforts, feedback received via city hotlines, or insights from previous surveys or community reports. By synthesising this information, cities can identify patterns, gaps, and areas needing further investigation.

If the initial review reveals critical gaps or issues requiring deeper exploration, targeted stakeholder engagement activities can be implemented to complement the existing data. These may include:

- **Community Workshops and Focus Groups:** Facilitating workshops with diverse community members to gather qualitative insights into specific risks and service gaps.

- **Surveys and Digital Platforms:** Using surveys distributed through apps, SMS, or community centres, and digital platforms for real-time feedback on issues like damaged infrastructure or service delays.

Checklist for Assessing the Status Quo

The following checklist outlines the essential steps for a comprehensive status quo assessment process for Turkish Cities.

Box 2: Checklist for Assessing the Status Quo of Existing Mobility Systems

Identify vulnerabilities of mobility systems towards external hazards and internal inefficiencies**.**

- **External Hazards**: Assess vulnerability to natural disasters (e.g., earthquakes, floods, wildfires).
- **Internal Inefficiencies**: Review aging infrastructure, system failures, and service disruptions.

Address critical infrastructure by running audits and risk assessments

- **Audit Critical Assets**: Review roads, bridges, tunnels, railways, and transport hubs as they are lifelines during critical events.
- **Single Points of Failure**: Identify heavily trafficked routes and structurally unsound infrastructure.

Ensure reliable emergency access to critical services

- **Access Routes**: Review secondary roads, emergency lanes, and alternative routes to define prioritized area for improvement.
- **Accessibility of Critical Services**: Assess proximity of hospitals, shelters, and emergency services to the transit nodes.

Social Vulnerabilities and Equity

- **Impact on Marginalized Groups**: Identify vulnerable groups (e.g., elderly, disabled, low-income) and their reliance on transport.
- **Peripheral Areas**: Review transport access in peripheral areas and isolation risks.
- **Affordability & Accessibility**: Evaluate public transport affordability and infrastructure accessibility.

Communication Systems and Network Management

- **Cybersecurity Risks**: Identify communication platform vulnerabilities.
- **Network Resilience**: Assess capacity, redundancy, and readiness of communication networks.
- **Real-Time Communication**: Review the ability to share updates on disruptions.

- **Network Interdependence**: Evaluate interdependencies with transport and energy systems.

Data for Risk Mapping

- **Infrastructure Data**: Review maintenance, usage, and service reliability data.
- **Service Data**: Assess capacity and demand fluctuations.
- **Environmental Data**: Collect data on environmental risks (e.g., flooding, temperature).
- **Post-Disaster Data**: Track past incidents and impacts.
- **Social and Economic Data**: Evaluate the consequences of disruptions on vulnerable groups.

Engaging Stakeholders

- **Existing Input**: Review feedback from stakeholders (e.g., from Sustainable Urban Mobility Plans)
- **Targeted Engagement**: Collect additional input if gaps are identified.

This streamlined checklist focuses on assessing current vulnerabilities and conditions within the transport system.

4. Planning for the Long-Term: Setting Strategic Goals for Resilient Mobility Planning

4.1 Using Data and Projections to Anticipate Future Mobility Disruptions

In preparing for long-term resilience, proactive planning based on data and projections is key. Mobility systems must evolve to anticipate disruptions rather than merely reacting to them. By using data and projections, cities can prepare for these disruptions, optimize infrastructure investments, and ensure systems remain resilient in the face of uncertainties.

Forecasting Disruptions through Scenario Planning, Simulation and Modelling

Scenario planning tools, dynamic simulation and modelling are essential for understanding and mitigating the potential impacts of disruptions on mobility systems. These methods enable cities to anticipate challenges, optimize resources, and design resilient transportation networks capable of withstanding a wide range of future conditions.

Scenario planning is a critical approach that enables cities to anticipate a range of potential futures and develop strategies that are adaptable to various uncertainties. This approach is particularly valuable in resilience planning for urban mobility, as it provides a structured way to analyse the impact of unpredictable events and trends. By exploring different scenarios, cities can build flexibility into their mobility strategies, ensuring they are prepared for both expected and unexpected changes at a strategic level. Key functions of scenario planning in resilience planning include:

- **Recognizing and Prioritizing Major Disruptions:** Scenario planning helps cities identify the most pressing risks to their mobility systems, such as natural disasters, technological failures, and infrastructure breakdowns. By understanding the likelihood and potential impact of these disruptions, cities can prioritize investments and interventions to mitigate risks effectively.

- **Assessing External Challenges and Opportunities:** External factors such as climate change, regulatory changes, population growth, and emerging technologies significantly shape the future of urban mobility. Scenario planning allows cities to assess these influences and their potential impacts, helping to uncover opportunities for

innovation while addressing risks**.** By analysing these scenarios, cities can identify gaps in their plans and develop strategies that are resilient under multiple conditions.

- **Testing Proposed Intervention and Guiding Investment Decisions**: Through scenario-based modelling, cities can test the effectiveness of proposed resilience interventions before committing resources. This way they ensure that these measures are both cost-effective and efficient and deliver high value under varying conditions. It can also evaluate the feasibility and potential impact of specific interventions before implementation. This ensures that proposed measures deliver desired outcomes without unintended consequences.

- **Fostering Strategic Thinking and Collaboration**: The scenario planning process encourages cross-sectoral collaboration and stakeholder engagement, fostering a shared understanding of potential risks and opportunities. Bringing together urban planners, policymakers, transport operators, and community representatives allows for a more holistic approach to resilience planning.

Box 3: Types of Scenario Planning

There are three types of scenario planning[32]

- **Predictive Scenario Planning**: This type focuses on forecasting trends that are relatively certain, such as demographic growth or gradual economic changes. Predictive planning is useful for anticipating increases in transport demand and identifying future congestion hotspots or infrastructure stress points.

- **Normative Scenario Planning**: This approach explores a range of possible futures, each based on different assumptions and policy decisions. In the context of mobility resilience, normative scenario planning allows cities to evaluate how different land use, environmental policies, or economic strategies might affect transport systems.

- **Exploratory Scenario Planning**: Exploratory scenarios are used to examine the resilience of current conditions to more unpredictable disruptions, such as major technological shifts, global economic downturns, or extreme climate events. This type of planning helps cities prepare for the unexpected, testing the robustness of infrastructure and transport networks against potential challenges.

Dynamic simulation and modelling tools play a crucial role in understanding the potential impacts of disruptions on mobility systems. By leveraging historical data and advanced algorithms, cities can create models that replicate various scenarios, such as natural disasters or population growth. These models allow planners to assess the effects of these disruptions

[32] Roadmap to Risk Management for Transportation Planning, FHWA, 2018

on mobility, from increased congestion to potential system failures. Their main applications in resilience planning are the following:

- **Pinpointing Vulnerabilities**: Simulation tools can pinpoint critical vulnerabilities in transport networks. For instance, simulations of earthquake scenarios can reveal weak points, such as bridges or tunnels, which may fail under stress. This insight allows authorities to prioritize investments in reinforcing these critical elements.

- **Planning for Growth**: Models that account for population growth and changes in travel demand can help cities predict where infrastructure might be strained. These simulations allow authorities to plan for future capacity needs, such as expanding public transportation or road networks.

- **Enhancing Emergency Response**: Disaster-specific simulations provide valuable insights for refining emergency response strategies. For instance, simulating evacuation scenarios can help authorities evaluate whether existing evacuation routes are adequate to handle the expected traffic volumes. If current routes are insufficient, alternative routes or additional measures can be identified.

Box 4: Predictive Models for Resilience Planning

Predictive models (predictive analytics) use historical data and machine learning algorithms to forecast potential disruptions before they occur. By analysing trends and patterns, predictive models can identify emerging risks and help cities take preventive actions to avoid or mitigate the impact of disruptions.

- **Traffic Flow Prediction**: Predictive models can forecast traffic congestion based on historical patterns, upcoming events, and real-time traffic data. This allows adjusting traffic management strategies to minimise congestion and improve overall traffic flow.

- **Infrastructure Failure Prediction**: Predictive maintenance systems use historical data and sensor information to anticipate potential infrastructure failures, such as road surface degradation or equipment malfunctions. By predicting when infrastructure elements are likely to fail, authorities can schedule repairs proactively, reducing the risk of unexpected disruptions.

Leveraging Smart Technology Systems for Resilience

While scenario planning, simulation and modelling provide critical foresight into potential future disruptions, smart technology systems enhance resilience by providing real-time insights and predictive capabilities. Leveraging these technologies allows cities to respond more effectively to immediate risks and optimise their mobility systems to prevent future disruptions. Key applications of smart technology systems to optimise resilience planning are:

Real-time monitoring systems, powered by sensors and IoT (Internet of Things) devices, provide authorities with up-to-date information on traffic patterns, weather conditions, and infrastructure performance. These systems offer valuable data that can help cities anticipate and mitigate disruptions as they occur.

- **Traffic and Infrastructure Monitoring**: Real-time traffic monitoring helps authorities identify bottlenecks, accidents, or infrastructure failures as they happen, enabling rapid response to prevent further congestion or system breakdowns. Monitoring key infrastructure elements, such as bridges, tunnels, and rail networks, helps identify when maintenance is needed or when a failure is imminent, allowing for timely interventions.

- **Weather and Environmental Monitoring**: Smart weather systems can provide early warnings for adverse conditions (e.g., heavy rain, floods, or extreme temperatures) that could affect mobility systems. This data allows cities to prepare for weather-related disruptions by rerouting traffic or activating contingency plans for emergency transport services.

Digital twins can provide cities with a dynamic model of their entire mobility ecosystem, from road networks to public transport systems, which can be used for predictive analysis and scenario testing. They integrate real-time data from sensors, IoT devices, and other sources to simulate and monitor performance.

1. **Real-Time Simulation and Monitoring**: By integrating real-time data into a digital twin, cities can continuously monitor transport systems, simulate potential disruptions, and respond proactively. For instance, authorities can use digital twins to visualise how weather events, accidents, or infrastructure failures will affect traffic flow and travel times, enabling them to take preventive measures before disruptions occur.

2. **Predicting Future Conditions**: Digital twins, combined with predictive analytics, allow cities to forecast future conditions, such as traffic congestion or infrastructure degradation, and implement timely interventions. This can include anticipating high-demand periods, such as rush hours or special events, and optimising traffic management strategies in advance.

3. **Optimizing Decision-Making**: Digital twins enhance decision-making by providing an interactive, data-driven model of the transport system. Authorities can test various resilience strategies, such as rerouting traffic or prioritising certain infrastructure repairs, before implementing them in the real world, ensuring that resources are used efficiently and effectively.

Anticipating and preparing for future mobility disruptions requires a multi-faceted approach. Simulation, modelling, and scenario planning allow cities to explore a range of potential futures and assess the resilience of their mobility systems. Meanwhile, leveraging smart technology systems, such as real-time monitoring and digital twins, empowers cities to make informed, proactive decisions, enhancing resilience in the face of immediate challenges. The insights gathered through these approaches and tools directly inform the setting of resilience goals, ensuring they address the most pressing vulnerabilities and align with a city's broader vision.

4.2 Defining Clear and Measurable Resilience Goals

Defining resilience goals is fundamental to transforming urban mobility systems into adaptive, sustainable networks capable of withstanding and recovering from disruptions. While vision-setting lays the groundwork, measurable goals provide the concrete framework for progress. These goals, informed by insights from the status quo assessments, scenario planning, simulations, and data-driven projections, ensure that resilience efforts are aligned with current challenges and future predictions. As cities prepare for uncertainties a clear set of actionable goals is essential for guiding decision-making and long-term planning.

From Vision to Strategy: Achieving the Preferred Future

A **well-defined** vision is essential for setting resilience goals, providing a strategic direction that aligns with the aspirations of a city while addressing its vulnerabilities. It serves as a unifying framework that not only guides decision-making but also inspires stakeholders to collaboratively work toward a resilient urban mobility system. This vision encapsulates the ambition for a transport network that is sustainable, adaptive, and capable of withstanding disruptions.

The vision for urban mobility resilience is shaped by a deep understanding of current challenges, as well as future uncertainties. For instance, cities experiencing recurrent flooding may aspire to create a transport network that prioritizes flood-resistant infrastructure and diverse transport modes. Similarly, regions facing rapid urbanization may envision a system capable of scaling efficiently to accommodate increased demand without sacrificing sustainability or accessibility. A compelling vision for resilient mobility must reflect the values, needs, and aspirations of the community it serves. Stakeholder engagement is crucial in this process, as it ensures the vision is inclusive and representative of diverse perspectives.

Scenario planning and simulations are instrumental in refining this vision by offering insights into possible future scenarios. These tools enable cities to anticipate potential challenges and opportunities, fostering a proactive rather than reactive approach to planning.

Once the vision is in place, it becomes the guiding principle for setting **specific resilience goals**. These goals should be actionable, measurable, and aligned with the overall vision, to effectively guide the resilience-building process. The status quo assessments and the projections provide a framework for setting these goals by identifying the vulnerabilities and opportunities that will shape the future mobility landscape.

- **Resilience goals must be aligned with the most critical vulnerabilities** identified in the assessments and projection exercises. Prioritising vulnerabilities ensures that resources are allocated effectively to areas that will have the most significant impact on system resilience.

- Urban mobility systems need to be flexible to cope with unpredictable changes, from shifts in technology to unforeseen environmental events. **Resilience goals should reflect this adaptability**. Scenario planning offers insights into these uncertainties, helping cities design goals that are responsive to new developments. To support long-term adaptability, cities should integrate resilience planning into the broader urban planning framework, as discussed below. This also involves incorporating regular reviews, stakeholder input, and an agile decision-making process into resilience strategies.

- The true value of **resilience goals lies not just in immediate achievements but in the ability to adapt and thrive in the long term**. As cities grow and evolve, so must the resilience strategies that support them. This requires setting goals that are not only achievable in the short term but also able to evolve as circumstances change.

Turning a vision of resilient urban mobility into reality requires translating resilience goals into **targeted strategies**. These strategies should be practical, actionable, and capable of addressing identified vulnerabilities while also positioning the city for future opportunities. Core principles of strategy development in mobility resilience planning are:

- **Data-Driven Insights:** Comprehensive data on urban mobility trends, infrastructure vulnerabilities, and emerging risks should guide the development of strategies.

- **Scenario Testing and Adaptability:** Strategies should be tested against multiple scenarios using tools like digital twins or predictive analytics. This ensures their robustness under various conditions and helps refine them to maximize effectiveness and minimize risk.

- **Integrated Approaches:** Resilience strategies should align with other urban objectives, such as reducing carbon emissions, promoting equity, and enhancing accessibility. For example, encouraging active transport modes not only builds resilience but also supports sustainability goals.

- **Flexibility and Scalability:** Strategies should be flexible enough to adapt to unforeseen changes and scalable to accommodate urban growth or shifts in technology.

- **Positioning for Future Opportunities:** Resilience strategies should not only address risks but also capitalize on opportunities like green infrastructure, new mobility technologies, and shifts toward sustainable practices.

Adapting Resilience Goals to Sustainability and Urban Planning Frameworks

Incorporating resilience into urban mobility systems requires more than just isolated planning for future disruptions. It involves aligning resilience goals with broader sustainability objectives and existing urban planning frameworks to create a unified, comprehensive approach. By integrating resilience with sustainability, climate adaptation, and urban development strategies, cities can ensure that their mobility systems are equipped to address both present and future challenges while capitalising on emerging opportunities.

Integrating Resilience with Sustainable Mobility Practices

One of the central principles of resilient urban mobility is its seamless integration with sustainable mobility practices. Sustainable urban mobility systems are designed to prioritize environmental sustainability, equity, and economic efficiency while maintaining flexibility in the face of unforeseen challenges. By integrating resilience with sustainable mobility practices, cities can create transport systems that not only address current needs but also anticipate and adapt to future uncertainties. This involves adapting existing mobility practices to be more robust through the adoption of sustainable technologies, reducing single-mode dependency, and offering diverse, environmentally friendly transport options.

For instance, the promotion of active mobility modes plays a dual role in both reducing carbon emissions and strengthening resilience. By reducing reliance on private cars, these modes not only decrease environmental impacts but also diversify transport options, ensuring mobility even when one mode of transport is disrupted. Similarly, the adoption of electric buses or other low-emission vehicles in public transportation systems reduces the carbon footprint and enhances the flexibility of public transit networks, which are crucial during disruptions like fuel shortages or air pollution events.

Moreover, enhancing public transport accessibility and coverage improves resilience by ensuring that individuals have multiple travel options. By diversifying transportation modes (electric buses, shared mobility, bike-sharing, etc.), cities can reduce their reliance on a single system or infrastructure, which may be vulnerable to failures due to natural disasters, system overloads, or technological disruptions.

Embedding Resilience Goals into Broader Planning Frameworks

Resilience in urban mobility should not be treated in isolation but rather as part of an interconnected planning process. This synchronization ensures that resilience efforts complement existing strategies and align with the long-term goals of cities. Some of the most critical planning frameworks for this integration include climate action plans, sustainable urban mobility plans (SUMPs), and urban development plans.

By embedding resilience into **Sustainable Urban Mobility Plans (SUMPs),** cities can take a holistic approach to urban mobility that strengthens not only environmental sustainability but also the adaptability of mobility systems. This strategic integration ensures that resilience is not an afterthought but a core component of mobility planning. Sustainability initiatives, such as

promoting active transport and low-emission vehicles, can be leveraged to also build resilience. The participatory nature of SUMPs also provides a valuable platform for resilience planning. Engaging a diverse range of stakeholders ensures that resilience strategies are rooted in the real needs and experiences of the community. By aligning resilience goals with the strategic objectives of SUMPs, cities can ensure that their mobility systems are both sustainable and capable of withstanding future disruptions.

Climate change poses significant risks to urban mobility, requiring resilience goals that address both current and future climate impacts. Cities can integrate resilience within **climate action plans** by focusing on adaptive strategies designed to cope with more frequent and intense weather events, such as flooding or heatwaves. This dual approach of reducing greenhouse gas emissions while building the capacity of transport systems to withstand climate disruptions ensures that resilience is a core component of climate strategies.

Effective urban mobility is closely tied to land-use planning and urban development. Integrating resilience into **urban development plans** ensures that mobility systems are prepared for future population growth and urban expansion. By prioritising transport infrastructure in emerging neighbourhoods and aligning mobility solutions with urban growth patterns, cities can anticipate and mitigate risks like congestion, inadequate infrastructure, and system overloads. This integrated approach supports resilient transport networks capable of adapting to both current demands and future urban dynamics.

Continuous Adaptation

The adaptation of resilience goals to existing plans requires ongoing collaboration and continuous monitoring. Regular reviews of resilience strategies ensure that they remain effective as urban dynamics and climate conditions evolve. By integrating real-time monitoring systems, such as digital twins, predictive analytics, and IoT sensors, cities can assess the performance of resilience strategies and adjust them as needed. These tools help identify emerging risks, such as congestion hotspots, infrastructure degradation, or weather-related disruptions, enabling cities to proactively address issues before they escalate.

Furthermore, the involvement of diverse stakeholders, including government agencies, transportation experts, urban planners, and community groups, ensures that resilience goals are responsive to local needs and values. Through collaborative planning and continuous feedback loops, cities can refine their resilience strategies and ensure that transport systems are not only resilient to current challenges but also adaptable to future uncertainties.

Checklist for Setting Strategic Goals

The following checklist outlines the essential steps for a comprehensive goal-setting process for Turkish Cities.

Box 5: Checklist for Setting Strategic Goals

Anticipating Mobility Disruptions

- Forecasting disruptions
  - **Implement scenario planning:** identify and prioritize major risks, assess external challenges like climate change and emerging technologies, and test resilience interventions to ensure their effectiveness. Integrate stakeholder collaboration to ensure long-term mobility resilience.
  - **Run simulations and use modelling tools:** assess the impact of disruptions on mobility by replicating scenarios like natural disasters or population growth.

- Leveraging Smart Technology Systems
  - **Real-time monitoring systems:** using sensors and IoT devices to identify current traffic, weather, and infrastructure conditions to respond quickly to disruptions.
  - **Digital twins:** continuously monitor real-time, data-driven model of the entire mobility ecosystem. Use these tools to simulate future conditions to prepare preventive measures and strategies.

Use clear and measurable resilience goals as guiding principles

- Defining specific vision
  - Use the vision as the guiding principle to formulate **resilience goals that are actionable, measurable, and aligned with the overall vision**.
  - Ensure these goals **address key vulnerabilities and are integrated into broader urban strategies** to support long-term adaptability and flexibility.
  - **Define** flexible and scalable **strategies** that are responsive to future changes, guided by data-driven insights on mobility trends and risks.
  - Address potential challenges but also **future opportunities that support sustainability goals.**

- Aligning Goals to Sustainability Objectives and Urban Planning framework
  - **Integrate resilience strategies into sustainable mobility practices** to not only meet current needs but also anticipate future challenges, thereby creating a more robust mobility plan.
  - **Synchronize resilience strategies** with Sustainable Urban Mobility Plans (SUMP), climate action plans, and urban development plans to ensure long-term implementation.
  - **Continuously monitor the performance of resilience strategies and ensuring on-going collaborations** with diverse stakeholders to forecast possible adjustments.

5. Strengthening Infrastructure and Ensuring Operational Continuity

5.1 Enhancing infrastructural resilience through tackling the five Mobility Pillars

Sustainable mobility systems are inherently more resilient. By reducing environmental impact, promoting modal diversity, and creating flexible, people-centred transport networks, they provide a robust foundation for withstanding and adapting to shocks. A city built on sustainable mobility is not only cleaner and more efficient but also better equipped to handle disruptions, whether due to climate events, energy crises, infrastructure failures, or social and economic upheaval. Diverse transport options reduce dependency on any single mode or system, while human-scaled networks are easier to maintain, adapt, and recover. This section explores how each of the five key pillars, Active Mobility, Public Transport, Urban Logistics, Shared Mobility, and Space & Access, contributes to building mobility systems that are both sustainable and resilient, ensuring that cities remain accessible, connected, and functional in the face of uncertainty.

Box 6: Green and Grey Measures for Resilient Mobility

Resilience planning in urban mobility requires a balanced mix of "green" and "grey" measures, each contributing in different but complementary ways to the system's ability to withstand, adapt to, and recover from disruptions.

Green measures are nature-based solutions that enhance resilience by using natural processes and ecosystems. They are often multifunctional, low-carbon, and cost-effective over the long term.

Examples:

- Green corridors and urban forests to reduce heat stress and improve air quality
- Permeable pavements and rain gardens to manage stormwater
- Shaded walking and cycling paths to enhance thermal comfort
- Wetlands restoration near infrastructure to buffer flood risks

Grey measures are engineered, infrastructural solutions designed to physically protect mobility systems and ensure service continuity under extreme conditions.

Examples:

- Elevated roads, tunnels, and bridges to prevent flood damage
- Reinforced transport hubs and depots for climate and seismic resilience
- Emergency power supply for electric transport systems
- Smart traffic management systems for real-time response and rerouting

Combining green and grey approaches supports robust, adaptive, and sustainable mobility systems. Hybrid solutions can provide layered protection while enhancing urban liveability and environmental quality.

Active Mobility: Leveraging People-Centred Mobility for Resilience and Sustainability

Active mobility, encompassing walking and cycling, is more than a low-impact transport option. Walking and cycling produce zero emissions, consume minimal energy and material resources, and promote public health by reducing pollution and encouraging physical activity. Cities that prioritize walking and cycling reduce dependency on private vehicles, thus lowering both operational carbon and long-term infrastructure demand.

From Sustainability to Resilience

But the resilience value lies deeper: active mobility is **decentralized**, not reliant on centralised networks or fuel supplies, **low-tech**, no need for electricity, digital systems, or complex machinery, and **adaptive**, routes and flows can shift instantly in response to disruptions. In emergencies, from fuel crises to earthquakes, walking and cycling often remain the only operational options, particularly in dense or informal areas.

This resilience is reinforced in multiple ways. Walking and cycling create **redundancy** in the transport system, offering a dependable alternative when public transport is down or road traffic is blocked. Further, it supports **psychological and social resilience** by allowing people to access services, maintain social ties, and move freely, particularly in cities where other options might not be viable for vulnerable populations. And they provide **economic flexibility**, remaining affordable and accessible when other options become costly or unreliable, particularly during periods of hardship or recovery.

Designing for Resilient Active Mobility

To realize the full potential of active mobility as a resilience strategy, infrastructure must move beyond isolated cycle lanes or beautified sidewalks. It requires:

- **Integrated Network Planning**: Connect origin-destination corridors through continuous, safe, and legible active mobility infrastructure. This includes intersection redesign, underpasses, greenways, and bridges that prioritize non-motorised users.
- **Protection and Safety**: Physically separated bike lanes, wide and shaded sidewalks, traffic calming zones, and low-speed neighbourhoods reduce vulnerability and increase confidence in use.
- **Year-Round Accessibility**: Infrastructure must be climate-resilient, resistant to heat, waterlogging, ice, and wind, through appropriate surfacing, drainage, and maintenance regimes.
- **Equity in Access**: Investments must reach underserved communities, not just central districts, with attention to gender, age, and ability. Public space around schools, hospitals, and markets must be walkable and cyclable.
- **Policy and Incentive Frameworks**: Integrate walking and cycling into transport and climate strategies; offer bike purchase subsidies, repair vouchers, and training programs; and regulate car dominance through zoning and taxation

Box 7: Case Study "Plan Vélo" and Tactical Interventions during COVID-19

Paris, France – "Plan Vélo" and Tactical Interventions during COVID-19

In recent years, Paris has aggressively expanded its cycling infrastructure under the "Plan Vélo" strategy, aiming to become a 100% cyclable city. During the COVID-19 lockdown, the city deployed over 50 km of emergency bike lanes ("coronapistes"). These lanes were designed to be bi-directional and physically separated from motor vehicle traffic, enhancing safety and comfort for cyclists. Recognizing the success and popularity of these temporary measures, Paris made many of the coronapistes permanent and integrated them into the broader "Paris 100% Cyclable" plan. This initiative aims to create a fully interconnected cycling network across the city, with over 180 km of new secure routes planned by 2026. [33] These interventions demonstrated the strategic value of cycling in maintaining mobility under pressure, particularly when public transport capacity was limited due to distancing regulations. The city supported these measures with bike subsidies, cycle repair grants, and communication campaigns. By enabling safe, accessible, and affordable mobility, Paris highlighted how active transport infrastructure can double as an emergency response tool and a climate action measure.

[33] Cycling Through Covid-19 Paris

Public Transport: The Backbone of Sustainable Mobility and a Pillar of Systemic Resilience

Public transport systems, buses, rail, trams, metros, and emerging modes like BRT and cable cars, are central to sustainable urban mobility. When efficiently planned, equitably distributed, and environmentally optimized, they reduce emissions, congestion, and car dependency.

Sustainable public transport reduces per capita emissions by shifting mobility away from private vehicles. It also supports compact urban development, reduces land consumption, and improves accessibility for those without private means of travel. The electrification of fleets and investment in renewable-powered networks amplify environmental benefits.

Social sustainability is equally significant: affordable and inclusive transport allows marginalized communities to access education, employment, and healthcare. It fosters spatial equity and social integration, which are core principles of just and sustainable urban growth.

Resilience through Networked Systems and Modal Redundancy

Public transport contributes to urban resilience by providing a **high-capacity**, **collective**, and **modular** alternative to private mobility. A diversified public transport network with multimodal connections allows cities to maintain mobility even when one part of the system is disrupted.

Key resilience mechanisms for public transport include **distributed capacity**, where networks with multiple modes and routes can effectively redistribute demand during crises, such as shifting passengers from rail to bus. **Real-time data integration** enhances the system's ability to respond to emergencies or overloads through digital monitoring and dynamic routing. **Resilient infrastructure design** also plays a crucial role, with features such as elevated or waterproofed stations, tunnel protection, and heat-resistant tracks helping to safeguard physical assets against climate impacts. Additionally, **well-prepared crisis protocols** enable operating companies to maintain service continuity or prioritize essential travel by implementing emergency playbooks that include rerouting plans and the deployment of substitute fleets.

Designing for Resilient Public Transport

To realize the full potential of public transport as a resilience strategy, infrastructure must go beyond isolated lines or punctual service improvements. It requires:

- **Urban Compactness**: Reducing urban sprawl, limiting the exposure of infrastructure to natural hazards.

- **Institutional Readiness**: Effective coordination between operators, municipalities, and national transport authorities is critical for fast, unified responses.

- **Intermodal Hubs**: Co-located cycling facilities, shared mobility, and logistics drop-off points increase system flexibility.

- **Electrification & Energy Redundancy**: Transitioning to electric or hybrid fleets with backup power supplies helps manage both carbon emissions and energy crises. Electrified transit networks contribute to net-zero targets without sacrificing operational stability.

- **Continuity of Essential Services**: Ensuring mobility for health workers, emergency responders, and low-income commuters in times of crisis.

- **Maintenance Resilience**: Predictive and condition-based maintenance minimizes sudden breakdowns and prolongs asset life during stress events.

- **Adaptive Timetabling**: Demand-responsive scheduling and load balancing during heatwaves, floods, or pandemics maintain reliability under stress.

- **Inclusive Fare Policies**: Protecting access for low-income groups ensures resilience for the most vulnerable populations.

Box 8: Case Study: Robust Public Transport as a Social Resilience Tool

Seoul, Korea – Robust Public Transport as a Social Resilience Tool

Seoul, South Korea, stands out as a prime example of a robust and socially resilient public transport system. The city has made substantial strides in reducing emissions by integrating **electric vehicles (EVs) and hydrogen fuel-cell buses** into its transit fleet. These eco-friendly vehicles are part of a larger smart mobility initiative that leverages smart card data and AI to implement an **adaptive scheduling system**, enhancing service efficiency while lowering carbon emissions[34].

To further boost reliability and foster public trust, Seoul has introduced **real-time tracking apps** that offer commuters up-to-the-minute updates, improving communication between the transport system and its users. Moreover, some neighbourhoods have embraced **demand-responsive transit services**, allowing routes to adjust dynamically based on live passenger requests. This approach addresses challenges such as underserved areas in regional cities, where aging populations, population decline, reduced bus routes, and longer service intervals have led to greater transportation gaps[35].

[34] Real-Time Urban Data Service For 113 Major Sites In Seoul

[35] Demand Responsive Transit (DRT)

Shared Mobility: Flexible, Resource-Efficient, and Built for Disruption Recovery

Shared mobility, including car-sharing, bike-sharing, e-scooter systems, and ride-hailing platforms, represents a major shift away from individual car ownership. It reimagines urban transport as a service, not a possession, and offers the flexibility, modularity, and digital integration that modern cities increasingly depend on.

While it is often discussed in the context of innovation or convenience, shared mobility also holds significant potential for sustainability and resilience. At its core, shared mobility fosters a more resource-efficient urban environment. When properly regulated and integrated into the broader transport system, it can significantly **reduce private car ownership and use**, freeing up valuable urban space and cutting emissions. Shared fleets also tend to **adopt electric vehicles** more quickly than private ones, accelerating progress toward climate goals. Through Mobility-as-a-Service (MaaS) platforms, shared mobility is increasingly linked with public transport, cycling, and walking, creating a **seamless multimodal experience** that encourages users to shift away from car dependency. As parking demand declines, cities can **reclaim space** for green infrastructure, bike lanes, and public amenities, contributing to more liveable and resilient urban environments.

Resilience Through Flexibility and Digital Infrastructure

What makes shared mobility uniquely valuable to urban resilience is its **flexibility** and **responsiveness**. Unlike fixed infrastructure, shared fleets and platforms can be rapidly scaled, reprogrammed, or redeployed to meet shifting demands during a crisis. Shared bikes and scooters, for example, can be **dynamically repositioned using real-time data** to fill gaps caused by infrastructure outages or service disruptions. In times when buses or trains are overcrowded or unavailable, such as during system failures or emergencies, shared mobility offers a critical backup. **Digital platforms** enhance this responsiveness, enabling cities to communicate directly with users, issue alerts, and redirect movement in real time. The **data generated** by these services reveals usage patterns that help identify vulnerabilities, guide infrastructure investments, and support targeted recovery efforts. Shared vehicles can also be **mobilized for emergency logistics or medical transport**, adding to their versatility. It also promotes **behavioural flexibility**, encouraging adaptive, multimodal travel habits that reduce reliance on fixed assets and enhance overall urban resilience.

Designing for Resilient Shared Mobility

For shared mobility to contribute effectively to resilience, cities must move beyond a passive regulatory role and into **strategic partnership** with platform providers. This includes:

- **Data-Sharing Agreements**: Cities must have access to anonymized trip and usage data for planning and emergency response.
- **Licensing and Equity Requirements**: Operators should serve peripheral or disadvantaged areas, not just city centres, and maintain inclusive pricing models.

- **Platform Interoperability**: Promote open standards that allow integration with public transport ticketing and real-time info systems.

- **Contingency Protocols**: Embed shared mobility into citywide resilience and continuity plans (e.g., prioritizing vehicles for essential workers).

Box 9: Case Study: Shared Mobility for a Flexible and Responsive Mobility System

Amsterdam, Netherlands – Shared Mobility for a Flexible and Responsive Mobility System

Amsterdam, long celebrated for its active mobility culture, is now expanding its focus to build a more flexible and connected urban transport ecosystem through shared mobility solutions. In addition to its iconic bike-sharing system (**OV-fiets**), the city now offers a growing range of shared **electric mopeds (like Felyx)** and **car-sharing services (such as MyWheels and Greenwheels).** These options provide residents and visitors with convenient, on-demand alternatives to private car ownership, supporting both sustainability and space-efficiency in the dense urban environment.[36]

Crucially, Amsterdam integrates these shared mobility options with its **public transport network** through **digital platforms and apps** that allow users to plan and pay for multimodal journeys in real time. Digital tracking systems, GPS-based geo-fencing, and trip data monitoring help regulate parking, prevent clutter, and ensure vehicles are used responsibly. This integration enhances user experience and optimizes city-wide mobility, making Amsterdam a leading example of how shared mobility improves sustainability and resilience of a city.[37]

Urban Logistics: Decarbonising Deliveries and Safeguarding Urban Supply Chains

Urban logistics, the movement of goods and services within cities, is a critical, yet often under-addressed, pillar of sustainable mobility. It powers everything from e-commerce and construction to grocery delivery and waste collection. As cities become denser and more digitally connected, the complexity and intensity of last-mile logistics grow. This sector directly affects economic vitality, environmental performance, and crisis response.

By embracing sustainability principles, urban logistics can not only reduce its ecological footprint but also improve its resilience, ensuring essential goods continue flowing during shocks and stress events.

[36] Amsterdam Traffic and Transport- Shared Mobility

[37] Amsterdam-Shared Mobility

The traditional logistics model, heavily reliant on diesel-powered trucks and fragmented delivery networks, has long been a major contributor to air pollution, greenhouse gas emissions, congestion, and noise in urban areas. Sustainable urban logistics aims to reverse these impacts through a combination of innovative strategies. Fleet decarbonization is at the forefront, with growing adoption of electric delivery vans, cargo bikes, and the implementation of low-emission zones. Consolidation strategies, such as urban consolidation centres (UCCs), help streamline deliveries, reduce vehicle-kilometres, and minimize traffic. Smart routing and scheduling further optimize logistics operations by shortening travel distances and avoiding congested routes. In addition, shifting deliveries to off-peak or nighttime hours helps ease pressure on daytime traffic while improving overall energy efficiency.

Sustainable Urban Logistics and Resilience

Sustainable urban logistics contributes to resilience by creating more **adaptable, decentralized, and low-impact systems** for moving goods within cities. By shifting from large, centralized depots to localized micro-hubs, and by integrating low-emission vehicles such as electric vans and cargo bikes, cities reduce their dependence on vulnerable infrastructure and create redundancies that can maintain essential supply chains during crises. Digital tools, like real-time tracking, smart routing, and demand forecasting, enable logistics providers to **respond swiftly to disruptions**, **reroute deliveries, and prioritize critical goods**. Furthermore, sustainable logistics reduces emissions and congestion, improving air quality and public health, which strengthens communities' capacity to endure and recover from shocks. Altogether, these practices not only ensure continuity of services but also build long-term systemic robustness and environmental adaptability into urban supply chains.

Designing for Resilient Urban Logistics

Resilience in logistics means maintaining or rapidly restoring the movement of essential goods, especially food, medicine, and emergency supplies.

Key resilience considerations include:

- **Distributed Warehousing**: Micro-hubs in neighbourhoods create localized supply nodes, reducing reliance on single centralized depots.

- **Mode Diversification**: Combining electric vans, cargo bikes, and even waterborne freight (where available) ensures delivery continuity during road blockages.

- **Critical Goods Prioritization**: Algorithms and protocols to prioritize delivery of medical or food supplies during crises.

- **Digital Visibility**: Real-time tracking systems to detect and respond to delays, supply shocks, or infrastructure breakdowns.

- **Regulatory Flexibility**: Temporary exemptions (e.g. allowing different delivery hours) to support adaptive operations in emergencies.

- **Freight Zoning and Loading Policies**: Designated loading zones, dynamic curb side management, and low-emission freight zones can improve flow and reduce disruption.

- **Public-Private Coordination**: Involve logistics providers in emergency planning, infrastructure design, and scenario testing.

- **Urban Freight Data Sharing**: Encourage voluntary or regulated sharing of data between platforms, cities, and operators to improve demand forecasting and route optimization.

- **Reduced Road Vulnerability**: Smaller, distributed fleets and local hubs reduce pressure on congested or damaged transport corridors.

Box 10: Case Study: Resilient Urban Logistic System

Sweden – Resilient Urban Logistic System

Sweden is emerging as a leader in smart, sustainable urban logistics by combining **cargo bikes, decentralized warehousing**, and **advanced digital technologies**. Cities like Stockholm, Gothenburg, and Malmö are adopting innovative models where goods are delivered from central terminals to **localized urban micro-hubs**, often situated in repurposed spaces such as parking garages. From there, **electric cargo bikes** complete the final leg of delivery, significantly reducing emissions and easing urban congestion.[38]

What truly sets Sweden apart is its use of **digitalization to optimize these systems**. Real-time GPS tracking, IoT integration, and smart routing software help logistics providers dynamically adjust delivery routes based on traffic, demand, and environmental factors. Platforms such as **SMOOvit** in Gothenburg enable **multi-provider collaboration**, using shared data to consolidate deliveries, manage micro-hub operations, and ensure efficient last-mile distribution. These efforts are also integrated into broader **smart city platforms**, helping city planners regulate urban freight zones and curb access more effectively.[39]

[38] Velove Sweden-Flexible and Efficient Last Mile Delivery
[39] Systems for Sustainable Urban Goods Transports

Space and Access (Urban spaces and Traffic Management): Designing Resilient Cities through Spatial Justice and Adaptive Mobility Management

Space is the most limited and contested resource in cities. How we allocate and manage urban space, whether for movement, rest, commerce, or nature, shapes both the sustainability of mobility and the resilience of urban systems. Traffic management and access policies are the tools that control who move, how, and where, directly influencing emissions, equity, and the ability of a city to cope with stress.

This pillar addresses the physical and regulatory dimensions of mobility: streets, sidewalks, intersections, green corridors, parking spaces, pedestrian zones, and the rules that govern them. It is the foundational layer upon which active mobility, public transport, logistics, and shared mobility operate.

Prioritizing space for sustainable modes, such as walking, cycling, and public transport, not only advances low-carbon mobility but also creates more liveable, inclusive cities. When urban space is reassigned away from cars, the sustainability benefits are immediate and far-reaching. Fewer vehicles on the road lead to lower emissions, reduced traffic congestion, and improved air quality. Infrastructure that favours sustainable modes, like wider sidewalks, protected bike lanes, and bus-priority corridors, encourages a shift in how people move, making these options more attractive, accessible, and safe. Spatial reallocation also supports climate adaptation: replacing heat-retaining asphalt with trees, green infrastructure, and permeable surfaces helps mitigate urban heat island effects. At the same time, access policies that prioritize underserved communities and people with disabilities ensure that urban mobility is equitable. Tools such as congestion charges, low-emission zones, and restricted vehicle access further align spatial management with environmental goals, while also generating revenue that can be reinvested into sustainable transport systems.

Resilience through Flexible Design and Controlled Flow

Reallocating urban space for sustainable mobility not only drives environmental and social progress but also reinforces the city's **capacity to withstand and adapt to crises**. Healthier environments, with cleaner air, quieter streets, and opportunities for active travel, lead to stronger, more resilient populations that are better equipped to cope with both acute shocks and long-term stresses. Streets designed for people rather than cars **enhance safety and reduce the burden on emergency services**, while also supporting daily physical activity that boosts public health. Walkable, mixed-use neighbourhoods **reduce reliance on centralized transport systems**, allowing residents to access essential services even when wider infrastructure fails, be it due to extreme weather, fuel shortages, or network disruptions. Moreover, accessible and inclusive public spaces foster social cohesion by **encouraging civic life, interaction, and mutual support**, all of which are essential components of collective resilience.

In crisis situations, regulatory tools such as congestion charges, low-emission zones, and restricted vehicle access areas can be adjusted or scaled to **manage demand, redirect traffic, or protect vulnerable areas**. By discouraging car dependency and lowering traffic volumes, these measures help **prevent gridlock during emergencies**, ensuring that critical services and emergency vehicles can move efficiently.

Designing for Resilient Urban Space and Access

Resilience in this context means designing and managing urban space so that the city can **respond quickly, recover effectively, and adapt structurally** to changing conditions: climatic, social, or technological.

Key resilience strategies include:

- **Zoning and Urban Planning Alignment**: Ensuring transport planning is integrated with land use to minimize long trips and reduce sprawl.

- **Performance-Based Regulation**: Shifting from static rules to outcome-oriented frameworks that can evolve with context.

- **Dynamic Traffic Management Systems**: Real-time monitoring, adaptive traffic signals, and AI-based flow optimization can redirect traffic during emergencies or infrastructure failures.

- **Access Control in Emergencies**: The ability to limit access to certain areas or prioritize movement for emergency services is vital during disasters or public health crises.

- **Tactical Urbanism and Modular Streetscapes**: Quickly deployable and reconfigurable public space infrastructure (e.g., pop-up bike lanes, parklets) enables rapid adaptation during crises.

- **Multifunctional Streetscapes**: Streets designed for multiple functions (markets, mobility, recreation) increase a city's capacity to repurpose public space as needs evolve.

Box 11: Case Study: Allocating Urban Space

Moscow, Russia – Allocating Urban Space

Moscow is actively working to transform its urban space into a greener and healthier environment in alignment with its commitment to the C40 Green and Healthy Streets Declaration. This initiative aims to **reduce emissions, enhance public spaces, and promote sustainable mobility**.[40]

Moscow's transport planning is also **coordinated with broader urban development policies**. For instance, the city's General Plan and various sectoral programs work together to ensure cohesive development across housing, infrastructure, and transport sectors[41]. This integrated approach facilitates the creation of multifunctional neighbourhoods and the development of green spaces, aligning with the city's sustainability goals.

5.2 Building Operational Resilience in Mobility Services

Ensuring continuity and reliability in urban mobility systems is critical in the face of disruptions, be they natural, infrastructural, or digital. Operational resilience means that transport services remain functional, responsive, and inclusive during both anticipated and unforeseen events. This resilience is achieved by combining robust contingency planning, strengthened data ecosystems, and flexible service models that adapt to shifting needs.

Planning for Continuity: Emergency Preparedness in Mobility Services

Resilience begins with proactive preparation. Comprehensive emergency and contingency planning is essential to ensure transport systems can absorb shocks and continue serving the public, particularly vulnerable groups.

- **Continuity of Services**: Emergency response plans must define how essential mobility services are maintained or restored. This may include re-routing vehicles, activating backup fleets, or encouraging modal shifts to walking, cycling, or shared transport options when public transport is disrupted.

- **Stakeholder Forums and Advisory Committees**: Bringing together transport operators, NGOs, disability advocates, and resident associations enables inclusive risk analysis and collaborative planning. These forums ensure diverse needs are considered in response strategies, enhancing equity and public trust.

[40] Moscow Green And Healthy Streets Declaration

[41] Spatial Planning Urban Development in Russia, Moscow Metropolitan Area

- **Public Communication**: Transparent, timely communication is vital during crises. Multichannel alerts, real-time updates, and user-friendly information platforms help reduce confusion and encourage safe travel decisions.

- **Integrated Command and Control Systems**: Real-time coordination between transport operators, emergency services, and local authorities enables swift deployment of mitigation measures. Integrated digital platforms that combine weather, traffic, and operational data enhance situational awareness and responsiveness.

Strengthening Data Systems for Disaster Resilience

Data not only helps identify risks but also informs both immediate interventions and long-term policy adjustments. For example, integrating predictive climate data into zoning regulations can prevent construction in high-risk areas. By leveraging data, cities can better anticipate threats, design adaptive policies, and ensure coordinated responses.

- **Build a Robust Disaster Data Infrastructure**: Establishing a centralized national data repository, managed by authorities such as the Disaster and Emergency Management Presidency (AFAD), is essential for safeguarding critical datasets. This ensures continuity in case of local disruptions, particularly when city-based data sources are compromised during disasters. Such repositories allow for the preservation of vital transport and infrastructure data, enabling a quick response when needed.

- **Develop a National Disaster Information Network**: A National Disaster Information Network that provides real-time, accurate disaster-related information to all relevant stakeholders can significantly enhance response times and decision-making. This network ensures that critical data, including transportation and mobility system status, is easily accessible to emergency responders, city authorities, and the public, improving the coordination of responses during crises.

- **Foster Collaboration and Data Sharing**: Implementing platforms and protocols to facilitate seamless disaster-related data exchange among national and local authorities, central organizations, and other relevant institutions ensures that all parties can act on the most current information. Combining datasets from various sources—such as transportation, urban planning, environmental, and emergency management agencies—enables cities to prioritize risks effectively and adopt a more holistic approach to resilience.

- **Strengthen Local Data Maintenance Responsibilities**: Assigning local authorities the responsibility of maintaining up-to-date inventories of roads, infrastructure, and housing stock is vital. This data should be regularly submitted to the central repository, enhancing disaster preparedness and response. Local data maintenance allows for more accurate risk assessments and helps cities better understand the areas most in need of intervention during a disaster.

- **Data Visualization Dashboards:** Interactive, real-time dashboards that integrate and visualize data from multiple sources, such as sensors, weather stations, and transport systems. These dashboards provide a dynamic way to track and respond to emerging risks.

Offer Adaptive Mobility Services: On-Demand and Multimodal Solutions

Beyond contingency planning, resilience is also built into the everyday design of mobility systems. Services that are flexible, user-centric, and technologically enabled can better respond to unexpected conditions and changing mobility patterns.

- **On-Demand Mobility**: Services such as Demand Responsive Transport (DRT), ride-hailing, or micro transit allow for dynamic route planning and flexible deployment of vehicles based on real-time demand. These models are particularly valuable during service interruptions or in areas underserved by fixed-route public transport.

- **Multimodal Integration**: Enabling users to switch easily between transport modes—such as walking, cycling, shared micromobility, and public transport—builds redundancy into the mobility system. If one mode is disrupted, others can serve as viable alternatives.

- **Digital Platforms and Mobility-as-a-Service (MaaS)**: Resilient systems are underpinned by digital tools that provide users with real-time information, journey planning, and access to multiple services through a single interface. These platforms empower users to make informed decisions and adapt their travel behaviour in response to disruptions.

- **Community-Based Mobility Options**: Localized solutions, including community shuttles or bike-share schemes operated by neighbourhood groups, can complement formal systems and provide essential backup when large-scale services are temporarily unavailable.

Checklist for strengthening Infrastructure and ensuring operational continuity

To effectively implement the strategies explained in this chapter, the following checklist outlines key steps which will be a guideline to tackle the five mobility pillars and to build operational resilience in mobility systems.

Box 12: Checklist for Strengthening Infrastructure and Ensuring Operational Continuity

Upgrading the Five Mobility Pillars

Integrate resilience strategies in active mobility

- **Connect corridors** with continuous, safe, and legible active mobility infrastructure.
- **Build safe and comfortable bike lanes and sidewalks**.
- **Design infrastructure for year-round use** by ensuring it is heat-, flood-, ice-, and wind-resistant.
- **Prioritize equity of access** by directing investments to underserved areas.
- **Implement supportive policies**: Integrate active mobility into broader transport and climate strategies that offers incentives.

Providing public transport systems with multimodal networks, real-time data integration, climate-resilient infrastructure, and emergency protocols by:

- **Striving to create high-density urban areas** to improve public transport's punctuality.
- **Coordinating effectively with** institutional parties and policy makers.
- **Co-locating intermodal hubs** to ensure flexible mobility system.
- **Transitioning to electric or hybrid vehicles** with backup power supplies to achieve net-zero targets without sacrificing operational stability.
- **Ensuring mobility for essential commuters** in times of crisis.
- **Assuring resilient** maintenance to minimize sudden breakdowns and prolongs asset life during stress events.
- **Creating adaptive timetable** to ensure reliable mobility system under stress condition
- **Maintaining affordable fares** for an inclusive public transport system

Designing flexible and digitalized shared mobility

- **Create a suitable digital platform** to reposition, redeploy and repurpose shared mobility
- **Form strategic partnerships with shared mobility providers** by enforcing data-sharing agreements, inclusive licensing, platform interoperability, and integrate resilience plans with citywide policy.

Shifting to adaptable, decentralized, and low-impact urban logistic systems

- Distribute Warehousing in neighbourhoods.
- Diversify vehicle modes.
- Prioritize delivery of critical goods.
- Ensuring real-time tracking systems.
- Temporarily allowing flexible delivery regulations.
- Ensure loading and freight zoning is incorporating low-emission goals, practicality, and adaptability.
- Involve logistic providers in resilience planning process
- Promote urban freight data interoperability
- Reduce pressure on primary routes

Reallocating urban space for resilient mobility space that is quickly responsive, effectively recoverable, and structurally adaptive.

- Integrating transport planning in urban development plan
- Shifting to result-driven regulation system
- Redirecting traffic using dynamic traffic management system
- Providing cities with access to control traffic during emergency situations
- Using tactical urbanism and modular streetscapes as planning tools
- Designing multifunctional streetscape

Ensuring Operational Resilience and Continuity in Urban Mobility Systems during Disruptions

- Prepare for emergency conditions
  - **Maintain service continuity** through emergency mobility plans
  - **Establish stakeholder forums** with transport operators, NGOs, and community groups for inclusive risk analysis and collaborative planning.
  - **Ensure clear public communication** with timely, transparent updates and easy-to-access information across multiple channels.
  - **Implement integrated command systems** for real-time coordination between operators and the authorities

- Strengthen data systems
  - Build a **centralized disaster data infrastructure** managed by authorities to safeguard critical datasets for continuity during disruptions.
  - Develop a **National Disaster Information Network** to provide real-time and accurate data.
  - Foster collaboration and **data sharing through platforms** and protocols that enable seamless exchange of disaster-related data among national, local, and other relevant authorities.
  - **Assign responsibilities to local authorities** for maintaining up-to-date infrastructure inventories.
  - **Implement real-time data visualization dashboards** to integrate and display data from various sources, helping dynamic risk tracking and response.

- Offer flexible, user-centric, and technologically enabled mobility services
  - **Implement on-demand mobility services** for dynamic routing and flexible vehicle deployment during interruptions or in underserved areas.
  - **Enable multimodal integration** to allow seamless transitions between transport modes, ensuring availability of alternative modes.
  - **Utilize digital platforms and MaaS** to provide real-time information, journey planning, and access to multiple services through a single interface, empowering users to adapt during disruptions.
  - **Support community-based mobility options** to provide backup when large-scale services are unavailable.

6. Learning and Adapting: Monitoring and Evaluating Resilience Efforts

Building resilience in urban mobility systems requires more than designing robust infrastructures or planning for disruptions, it demands a continuous process of reflection, learning, and improvement. In this context, **evaluation** plays a central role in helping stakeholders understand what works, what does not, and why.

While **monitoring**, the ongoing collection of data, is often an essential input to evaluation, this chapter emphasizes **evaluation** as a strategic process to assess both the outcomes and implementation of resilience initiatives. Evaluation contributes to adaptive management by guiding evidence-based decisions, identifying weaknesses, and capturing lessons learned from real-world disruptions.

Understanding Evaluation in Resilience Planning

Evaluation is the systematic and periodic assessment of interventions, aimed at determining whether the intended goals were achieved and how interventions have affected communities, systems, and the environment. In the resilience context, evaluation is not only about results, it is about understanding systems under stress and how well they adapt, respond, and recover.

Two key types of evaluation are particularly relevant:

- **Impact Evaluation**
  This assesses the **long-term effects** and systemic changes brought about by a project or policy. It addresses questions such as: Did the intervention improve the resilience of the mobility system? What were the indirect benefits or unintended consequences?

- **Process Evaluation**
  This focuses on **how** an intervention was implemented. In resilience planning, where uncertainty, coordination, and adaptation are central, process evaluation helps identify operational challenges, stakeholder roles, and alignment with plans. It is essential for capturing the learning journey, especially in complex urban settings.

Both forms are complementary: **impact evaluation tells us what changed**, while **process evaluation tells us how and why** those changes occurred or failed to.

Evaluation as a Tool for Adaptive Resilience

The value of evaluation in resilience planning lies in its contribution to **adaptive learning**. By analysing responses to past disruptions and implementation experiences, cities can update their mobility strategies and institutional practices to remain effective in the face of evolving risk.

Evaluation helps to:

- Identify system vulnerabilities and gaps in response.
- Measure institutional and infrastructural recovery patterns.
- Improve coordination among stakeholders.
- Enhance future preparedness and planning quality.

This approach supports a **cycle of continuous improvement**, where each disruption becomes an opportunity to learn, adjust, and build stronger systems.

Evaluation Methods and Tools

Effective resilience evaluation relies on a mix of qualitative and quantitative methods that align with the complexity of urban mobility systems. These methods help generate a nuanced understanding of both process and impact. Common approaches include:

- **Program and Process Reviews**
  Evaluate whether activities, budgets, and timelines align with resilience goals.
- **Stakeholder Workshops and Reflection Sessions**
  Gather experiential insights on implementation processes, institutional coordination, and on-ground realities.
- **Audits and Peer Reviews**
  Provide independent assessments of effectiveness, compliance, and value for money.
- **Surveys and Interviews**
  Capture the perspectives of affected communities and stakeholders on service quality, response effectiveness, and accessibility.
- **Scenario-Based Evaluations**
  Simulate potential future shocks to test the robustness of current systems and plans.
- **GIS and Spatial Analysis**
  Analyse risk exposure, infrastructure distribution, and equity dimensions across geographic space.

The Role of Monitoring in Support of Evaluation

While this chapter centres on evaluation, it is important to acknowledge the supporting role of **monitoring**. Monitoring involves the regular collection of data against defined indicators and benchmarks. It provides the empirical foundation for evaluation, enabling trend analysis, early detection of issues, and progress tracking.

In resilience planning, monitoring helps to:

- Track performance during and after disruptions.
- Support real-time decision-making.
- Feed into evaluations with timely, consistent data.

However, monitoring alone is insufficient. Without interpretation, analysis, and contextual understanding, data cannot drive strategic adaptation.

Table 7: List of Possible Indicators for Monitoring Resilience Efforts in Mobility

Category	Data Name	Description	Indicator(s)	Metric / Measurement Approach	Frequency	Aimed Target Examples
Infrastructure Maintenance & Monitoring	Infrastructure Condition	Condition of key transport infrastructure and status of maintenance activities.	• % infrastructure rated poor or critical	Inspection reports, % backlog of repairs, average repair time	Monthly or Quarterly	Minimize downtime; timely identification of risks
	Resource Availability	Availability of resources for maintenance and emergency interventions.	• % of critical resources available	Inventory levels, staffing availability, tool/equipment status	Monthly or Quarterly	Ensure high emergency readiness
Network & System Resilience	Critical Network Vulnerability	Vulnerability of key transport corridors to disasters (flood, quake, etc.).	• % of network segments with high risk • Corridor risk classification	GIS-based risk mapping, vulnerability score per corridor	Annually	Identify and prioritize critical segments for protection
	Service Reliability	Reliability and stability of transport services.	• % on-time arrivals • Service interruption rate	Real-time operations data, delay logs, cancellations	Monthly or Quarterly	Improve service consistency and reduce breakdowns

Category	Data Name	Description	Indicator(s)	Metric / Measurement Approach	Frequency	Aimed Target Examples
Service Capacity & Demand	Utilization Rate	Usage rate of various transport systems.	• Average vehicle occupancy • Passenger km per mode	Passenger counts, sensor data, farebox or smartcard data	Monthly or Quarterly	Balance demand and capacity; avoid overcrowding
Environmental & Climate Resilience	Weather & Extreme Events	Climate-related impacts on the transport system.	• Number of weather-related disruptions • Duration of disruptions	Climate event logs, disruption reports, emergency activation data	Annually	Anticipate and prepare for climate risks
Post-Disaster Data	Response Time to Disruptions	Time taken to restore normal transport service after a disruption.	• Average response time • % of disruptions resolved within target time	Incident tracking data, service restoration logs	Monthly or Quarterly	Reduce time to recovery and enhance system robustness
Social & Economic Factors	Vulnerable Population Mapping	Equity of service coverage for vulnerable groups.	• % of vulnerable groups with access within X mins • Accessibility index	GIS accessibility models, demographic overlays	Annually	Ensure fair and inclusive access
	Economic Impact Indicators	Economic costs from transport system failures or delays.	• Estimated economic loss per disruption • Total cost of transport downtime	Economic modelling, business impact surveys, cost estimations	Annually	Mitigate socio-economic losses from transport failures

Checklist for ensuring the adaptation of resilience planning

These checklists serve as a guide to successfully implementing resilience planning through continuous monitoring and evaluation.

Box 13: Checklist for ensuring the adaptation of resilience planning.

Evaluating and Monitoring for a continuous adaptation and improvement

Evaluating resilience efforts through both outcome and process perspectives by:

- **Impact Evaluation** to look at the **long-term effects** of an intervention, including improvements in system resilience and any indirect or unintended outcomes.
- **Process Evaluation** to examine **how** the intervention was conducted, focusing on challenges, stakeholder roles, and alignment with plans.

Supporting a continuous improvement by learning from past disruptions, refine the strategies, and strengthen institutional practices through continuous assessment of system vulnerabilities, recovery patterns, stakeholder coordination, and preparedness.
Using combination of qualitative and quantitative evaluation methods:

- Review programs and processes for alignment with resilience goals.
- Conduct stakeholder workshops to gather insights on implementation and coordination.
- Perform audits and peer reviews to assess effectiveness and accountability.
- Use surveys and interviews to capture stakeholder and community perspectives.
- Run scenario-based evaluations to test system robustness under future shocks.
- Apply GIS and spatial analysis to examine risk, infrastructure, and equity.

Providing empirical foundation for evaluation through monitoring, accompanied by further interpretation, analysis, and contextual understanding to achieve strategic adaptation.

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