



Example Adaptation Measures

INTRODUCTION

It's difficult to begin resilience planning from scratch. This document introduces different types of adaptation measures, and provide specific examples that transit agencies have already implemented. These examples are intended to inspire transit agencies and serve as ideas to build on of when beginning to plan for resilience.

This document includes:

1. A description of **six general types of transit adaptation measures**, and
2. **Specific examples of adaptation measures** that have been implemented by transit agencies, tagged by type of measure.

TYPES OF TRANSIT ADAPTATION MEASURES

When planning for resilience, it is often helpful to consider a *portfolio* of different types of measures rather than focusing on a single measure. For instance, people often first think about strengthening and protection measures to *avoid* damage or service disruptions, but sometimes it may be better to use operational adjustments *to mitigate the consequences of* damage or service disruptions. In fact, you can often achieve the same resilience results using a number of different types of measures, and sometimes using a combination of different measures allows for greater feasibility, cost-effectiveness, flexibility, and co-benefits. Thinking about adaptation across different types of measures can help ensure that an optimal portfolio is selected.

The following measure types are based on the [FTA's Flooded Bus Barns and Buckled Rails: Public Transportation & Climate Change Adaptation \(2011\)](#) document.

- **Plan and Prepare:** Develop climate risk management and/or emergency management plans and preparedness procedures.
- **Maintain and Manage:** Use maintenance and operations measures to enhance resilience. For instance, monitor and upgrade equipment more frequently, implement technologies that monitor climate stressors, etc.
- **Strengthen and Protect:** Fortify infrastructure to withstand future climate conditions. Strengthen existing infrastructure through retrofits, and strengthen planned infrastructure through designs which account for future conditions. Adaptation measures include designing structures with greater drainage capacity, using materials suited to higher temperatures, or building protective structures such as levees or vegetative buffers.
- **Enhance Redundancy:** Identify and develop alternatives to system components. One such measure is to increase bus service during rail interruptions.
- **Recover:** Develop post-event recovery and service restoration procedures.
- **Retreat:** Abandon facilities located in extremely vulnerable or indefensible areas, and relocate facilities to less vulnerable locations.

There are no hard rules of thumb regarding whether certain types of adaptation measures are better. The most appropriate measure—or suite of measures—will depend on situation-specific factors for the particular risk you are looking at. However, once you have identified a potential risk from climate change, it may be useful to first identify adaptation measures that fall within each type of measures, to make sure you're considering the full range of options. Then, you can evaluate those measures based on relative costs, feasibility, co-benefits, etc.

Example: Different Types of Measures to Reduce Impact from Intersection Flooding

Consider a situation where you expect more frequent flooding at an intersection within a critical bus route. You could address it a number of different ways:

First, you might want to **plan and prepare** for the flooding, so that whenever it floods, you can immediately execute a clear plan of action, your staff are trained in what to do, and you have appropriate communication materials and equipment available. This plan might include establishing alternate routes and having a plan for effectively communicating it to your customers.

You can ***maintain and manage*** your communication and monitoring systems, so that you are immediately aware of the flooded intersection when it occurs, and can get the message out efficiently.

You could ***strengthen and protect*** the area by improving the drainage features or building flood protection features, to reduce the incidence of flooding altogether.

To ***enhance redundancy***, you could consider whether there are nearby bus or rail lines, or other alternatives, that can provide similar service in the event of disruption, and ensure your customers know of these options.




If a stop is temporarily non-serviceable, you could plan to ***recover*** quickly by establishing a method to monitor the intersection so that you are quickly alerted to when it is passable again.

If the intersection floods too frequently and causes too many service interruptions or accommodations, you could choose to permanently reroute the bus route. In resiliency parlance, this action would be considered ***retreat***.

EXAMPLE ADAPTATION MEASURES PLANNED OR IMPLEMENTED BY TRANSIT AGENCIES

The following table describes adaptation measures being undertaken by transit agencies. The measure types are denoted by colored dots, each of which represents a different type of adaptation measure, as shown below.

- Plan & Prepare
- Maintain and Manage
- Strengthen & Protect
- Enhance Redundancy
- Recover
- Retreat

Transit Agency Adaptation Measures	Adaptation Measure Type	Source
		
Connecticut Department of Transportation <ul style="list-style-type: none"> ▪ Replacing a bridge that is critical to rail services in the Northeast Corridor and is vulnerable to storm surges 		2
Hillsborough Area Regional Transit Authority (HART)		1

Transit Agency Adaptation Measures

Adaptation Measure Type

Source

- Driving resiliency through sustainability and environmental management system processes
- Adopted infrastructure and practices to mitigate flooding; adopted operating procedures to manage temporary flooding; adopted an emergency operations plan to facilitate shut down and restoration in the event of a disaster

Honolulu Department of Transportation Services (DTS)

- Pursuing resilience through emergency preparedness, response, recovery, and risk mitigation
- Mapped critical infrastructure and assets in terms of vulnerability to hurricanes and storm surge; implemented procedures to ensure assets are protected during severe weather events; updated infrastructure design standards to require use of resilient materials in rehabilitation, reconstruction, and new construction

● ● ● ● ● ● 1

Houston Metro

- Developing clear communications about service cut-off times prior to storms, and communicate these to stakeholders
- Executing contracts so that during storms, the agency has access to catering and hotels for employees, access industrial equipment for clearing bus routes, and that Houston Public Works clears streets and that the police parks vehicles in garages to protect them from storms
- Setting up bank accounts and funds for emergency response expenses
- Developing partnerships so that buses help evacuate communities during emergencies
- Ensuring fuel availability by establishing priority fuel pickup at Shell during evacuations, ensuring that facilities are at 98% capacity before a known emergency event, tracking and replenishing fuel on an hourly basis following an emergency, leasing fuel storage at an offsite facility, receiving police escorts for fuel delivery as necessary

● ● ● ● ● ● 3

Transit Agency Adaptation Measures

Adaptation Measure Type

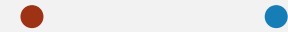
Source



- Maintaining satellite phones for emergency communications, in case phones and radios fail
- Using a regional emergency operations center to facilitate communications
- Identifying key personnel for emergency operations, and order of succession in case individuals are unavailable

Idaho Valley Regional Transit (VRT)

- Focus on event readiness and restoring service following an event
- Incorporating climate vulnerability and risk in service planning to make sure assets remain in a state of good repair as long as possible



1

Island Transit

- Siting new operations and maintenance facilities outside of 100-year floodplains
- For infrastructure that cannot be sited outside of 100-year floodplains, designing buildings to be raised high enough to avoid flood risk
- Collaborating with local jurisdiction public works departments to keep storm sewers clear in flood prone areas
- Identifying flood-prone route segments and preferred alternatives and procedures to implement during flood events
- Educating riders about reroutes
- Identifying procedures to reduce impacts of street flooding on vehicle maintenance (e.g., slow speeds, avoiding known flood areas), agency property (e.g., passenger amenities), and private property (e.g., reducing vehicle speed to avoid forcing water into private property)



3

Transit Agency Adaptation Measures

Adaptation Measure Type

Source



Kansas City Transit Authority (KCATA)

- Working on incorporating resilience into management plan for emergencies and to mitigate climate risks
- Focus on preparedness and service restoration
- Work w/ managers and front-line to identify assets, infrastructure, and services that are potentially vulnerable; work with a regional MPO to coordinate system planning across seven counties; use green infrastructure to mitigate flood risks



1

Los Angeles County Metropolitan Transportation Authority (LA Metro)

- Integrated resilience into Environmental Management System (EMS) to consider resilience in agency decisions related to maintenance, operations, and capital project development
- Developed a Resiliency Indicator Framework to track infrastructure and operational resiliency over time
- Developing a comprehensive resiliency policy and updating infrastructure and facility design criteria and construction specifications to include resilience in capital project construction, operations, and maintenance



1

Maryland Transit Administration (MTA)

- Focus on operations during extreme weather events
- Use operations & maintenance & emergency management procedures to protect infrastructure; developing an asset management system that incorporates climate and weather risk assessment; procedures that facilitate cessation and rapid recovery of services in response to winter weather threats



1

Massachusetts Bay Transportation Authority (MBTA)

- Focus on winter weather events



1, 2

Transit Agency Adaptation Measures

Adaptation Measure Type

Source



- Developed Winter Resiliency which will be implemented, including capital and operating investments, such as purchasing new snow removal equipment, infrastructure upgrades, operations during harsh weather to improve service reliability
- Raising a water retaining wall and installing watertight barriers to reduce flooding of MBTA's Green Line Fenway Portal

Metropolitan Atlanta Rapid Transit Authority (MARTA)

- Integrated resilience into O&M, asset management, safety management, risk management, capital improvement planning and prioritization, & sustainability initiatives
- Added weather-related identification codes to maintenance work orders
- Added a module to the Enterprise Asset Management System for capital projects that incorporates resilience and flags assets that are subject to climate risks
- Incorporated climate risk management measures into asset lifecycle management plans by monitoring assets and updating their asset record when changes in condition are identified
- Modified agency's capital improvement plan checklist to include resilience and sustainability components
- Focus on incremental improvements
- Identified additional potential measures to manage climate risks, including:
 - Revising design standards
 - Assessing how safety, service, and staffing operations will be impacted
 - Maintaining and monitoring facilities
 - Rehabilitating and replacing systems by discussing priorities, funding, and delivery methods



1

Transit Agency Adaptation Measures

Adaptation Measure Type

Source



Nashville Metropolitan Transit Authority (MTA)

- Focus on emergency preparedness and rapid recovery of services when disrupted by extreme weather or natural disasters; moved bus storage facilities and administrative offices out of flood prone areas



1

New Jersey Transit Corporation (NJ TRANSIT)

- Focus on incorporating designs and materials that can resist and survive weather events
- Designing and constructing NJ TRANSITGRID, a micro-grid backup power generation and distribution system which relies on natural gas and solar power, and is capable of supplying highly-reliable power during storms or other times when centralized power grid or distribution networks are compromised
- Developing a Coast Storm Surge Emergency Warning System in partnership with NOAA and Stevens Institute of Technology
- Implemented detailed, mode-specific Comprehensive Emergency Management Plan
- Uses FTA's Hazard Mitigation Cost Effectiveness Tool to evaluate resilience as a part of capital planning process
- Adopted new service cessation and rapid recovery procedures



1

New Orleans Regional Transit Authority (NORTA)

- Incorporating resilience throughout investment and operational decisions
- Implemented procedures to relocate moveable assets to remote, safe locations when flooding is expected
- Key functions for system operation can be provided when necessary
- Mobile dispatch and communication unit that is central in the New Orleans' City-Assisted Evacuation Plan, designed to serve carless populations



1

Transit Agency Adaptation Measures	Adaptation Measure Type	Source
New York City Department of Transportation		
<ul style="list-style-type: none"> ▪ Acquiring resilient ferry vessels, upgrading ferry landings, and flood-proofing ferry terminals 		2
New York Metropolitan Transportation Authority		
<ul style="list-style-type: none"> ▪ Flood-proofing New York City Transit substations, street-level openings, and support facilities 		2
Port Authority of New York and New Jersey		
<ul style="list-style-type: none"> ▪ Flood-proofing above-ground facilities and equipment to protect underground assets, and building an automatic flood barrier at a maintenance facility 		2
San Francisco Bay Area Rapid Transit (BART)		
<ul style="list-style-type: none"> ▪ FTA pilot on BART asset vulnerability to natural hazards and SLR ▪ Pursuing measures for extreme weather resilience and earthquake safety ▪ Active participant in regional planning efforts to address SLR 		1
Southeastern Pennsylvania Transportation Authority (SEPTA)		
<ul style="list-style-type: none"> ▪ Focused on event readiness and restoration of service after weather related service disruptions ▪ Investing in infrastructure protection where feasible and cost-effective (e.g., flood proofing, bank stabilization, bridge scour protection) <ul style="list-style-type: none"> ○ Stabilizing commuter railroad embankments to reduce failure risk following severe rainfalls ▪ Incorporating resilience into maintenance and capital project construction 		1

Transit Agency Adaptation Measures

Adaptation Measure Type

Source



- Engaging front-line workers to collect data & information on system vulnerabilities and performance, and use asset management systems to flag preventative maintenance needs/requirements/issues

SFMTA/MUNI: San Francisco Municipal Railway

- Incorporating climate risk into planning and policy initiatives, including city's capital planning process
- Will follow approved Capital Planning Committee's policies for projects, which includes guidelines and a checklist which ensure that capital projects account for various climate change stressors, including SLR and floods, sensitivity to SLR, adaptive capacity, planning horizons, costs and other details. Initiated pilot aiming to build on this effort to integrate resilience and sustainability into SFMTA's capital planning process.



1

Transport for London (TfL)

- Developed infrastructure planning standards that require a 120-year design life that accounts for climate change and mitigation measures
- Focus on operational preparedness: collect and analyzes performance data as part of O&M activities & makes info publicly available



1

Utah Transit Authority (UTA)

- Focused on emergency management, safety, and asset management
- Use FEMA's Threat Hazard ID and Risk Assessment framework to ID system vulnerabilities
- Use a hazard mitigation approach to address risk
- Require that capital project infrastructure designs meet seismic standards



1

Transit Agency Adaptation Measures

Adaptation Measure Type

Source

- In asset management, follow “fix before failure” approach, requiring a proactive inspection program; trucks are inspected twice a week
- Inspection data collected w/ computer tablets that store inspection checklists and uploaded to a database. Use data to continually monitor asset condition and performance

Washington Metropolitan Area Transit Authority

- Installing drainage improvements such as raising vent covers above subway systems

2

To search these measures by measure type, please see the accompanying spreadsheet titled “7_Example Adaptation Measures.xls.”

SOURCES

1. TCRP. 2017. TCRP 70 Improving the Resilience of Transit Systems Threatened by Natural Disasters Case Studies. <https://www.nap.edu/catalog/24972/improving-the-resilience-of-transit-systems-threatened-by-natural-disasters-volume-3-literature-review-and-case-studies>
2. FTA. 2013. Federal Transit Administration (FTA) Emergency Relief Program: Sandy Disaster Aid Resilience Projects. <https://www.transit.dot.gov/funding/grant-programs/emergency-relief-program/hurricane-sandy-disaster-relief>
3. FTA. 2013. Federal Transit Administration (FTA) Gulf Coast Climate Change Adaptation Pilot Study. https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_Report_No._0072.pdf