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U.S. Department of Transportation
Federal Highway Administration

FTA Transit Climate Change Adaptation Assessment Pilot Project:

Chicago Transit Authority

In 2011, the Federal Transit Administration (FTA) selected seven pilot teams from across the country to conduct climate change adaptation assessments. The pilot projects were intended to advance the state of practice for adapting transit systems to the impacts of climate change. The selected projects assessed the vulnerability of transit agency assets and services to climate change hazards such as heat waves and flooding and developed initial adaptation strategies that fit with their transit agency's structure and operations. The pilot project effort is part of FTA's **climate adaptation initiative**, which also includes an **adaptation report**, workshops, and webinars.

Chicago Transit Authority

During recent extreme weather events, the Chicago Transit Authority (CTA) experienced impacts to infrastructure and service. The CTA pilot sought to quantify the consequences to capital, operations, and maintenance costs that have been observed in the past and assess the costs and benefits of proposed adaptation options. The City of Chicago had previously commissioned climate modeling research and climate impact and costs assessment efforts, which laid a foundation for this study. The CTA pilot developed quantitative and qualitative tools to integrate consideration of climate impacts into operations, infrastructure planning, and standard business practices that can be used as a template for further development by CTA and other transit agencies.

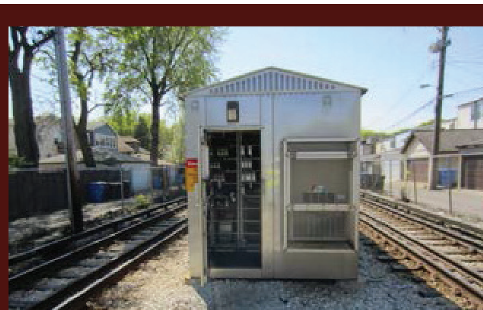
Scope

The first phase of the study evaluated the CTA bus and rail systems in seven primary areas of severe weather concerns: intense precipitation, prolonged heat, heavy snowfall, extreme cold, rapid temperature swings, storm-related impacts, and emergency-related impacts. An initial analysis and input from stakeholders helped identify priority assets, locations, and climate hazards for further analysis.

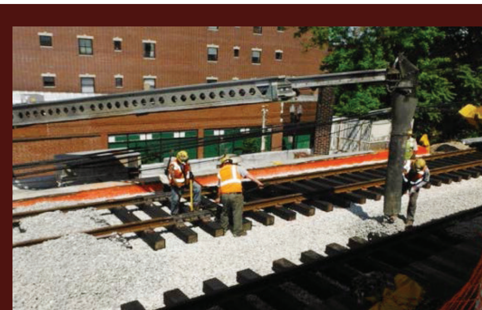
Objectives

- Survey historical and future system vulnerabilities to extreme weather events
- Develop and pilot a framework to assess costs and benefits of proposed adaptation strategies using a life-cycle cost assessment (LCCA) model
- Identify strategies to integrate climate adaptation into CTA's asset management and operating and budget planning processes

Overflow barrier around the O'Hare subway ventilation shaft to prevent flooding. Photo credit: CTA.



Signal house at Brown Line Rockwell Station that may be vulnerable to overheating during electricity outages. Photo credit: CTA.



Ballasted track structure construction. Photo credit: CTA.

Approach

Conduct interviews and collect data. The project team conducted group interviews with CTA subject matter experts across various departments and public-sector partners in order to identify general relationships between extreme weather events and CTA system disruptions. The departments identified data sources to help quantify severe weather impacts to CTA, such as data on service disruptions, financial costs of outlier storm events, ridership, bus and rail vehicle maintenance, and diesel consumption. CTA also worked with partners to collect external data including daily and hourly temperatures, rail power consumption and demand, urban heat island data, and flooding data.

Quantify extreme weather costs and impacts. The team analyzed the observed data in four principal areas:

- *Cost impacts*. Summarized the damage, maintenance and repair, and labor costs from three recent severe weather event types: severe flooding, heavy snowfall, and heavy wind.
- *Service disruptions*. Examined recent patterns in extreme weather-related service disruptions, including rail kinks and signal failures during prolonged heat.
- *Ridership impacts*. Produced a regression analysis to determine statistical relationships between extreme weather and daily system ridership.
- *System vulnerabilities*. Explored other factors that may yield direct and indirect vulnerabilities to the CTA system, including urban heat islands, right-of-way (ROW) flooding, and freeze-thaw cycles.

Prioritize areas of interest. The project team held another CTA stakeholder workshop to present the preliminary analysis and gather input on priority issues and selection criteria. The project team developed a risk matrix of frequency and severity of severe weather impacts to CTA infrastructure and operations, which captured the participants' rankings of issues for further analysis.

Assess implementation strategies. The functional issues for further analysis were right-of-way flooding, rail heat kinks, and signal house overheating. For each of the three issues, the team identified specific locations of the assets (see Figure 1) to serve as case studies for analysis of the costs and benefits of implementation strategies.

Assess costs of no adaptation action. The project team first established a "no-build" baseline of the performance of each case study asset under extreme weather without any capital improvements. The scenario considers the climate impacts to the infrastructure and service, and resulting service costs and maintenance and repair costs based on input from CTA. To estimate reduced revenue for CTA, the analysis assumes a bus shuttle when a line is shut down due to flooding or rail kink during an average weekday.

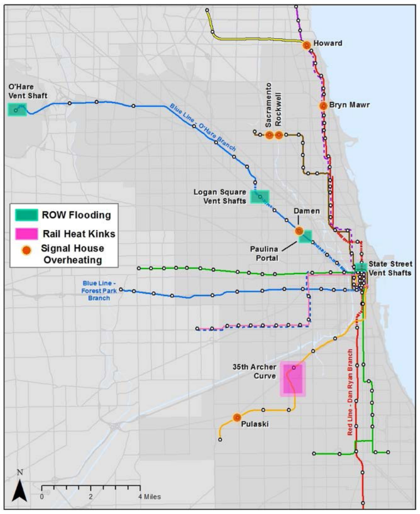


Figure 1: Geographic locations of prioritized areas of investigation.

Assess costs of adaptation infrastructure investment. Next, the team developed estimated capital costs for the "build" scenarios, which includes the one-time capital improvement costs and ongoing maintenance costs of each of the proposed improvements (see Table 1).

Priority Issue	Build Scenarios
Right-of-way (ROW) flooding	Install barrier devices around ventilation shafts to prevent water infiltration.
	Install drainage structures to capture and detain stormwater at subway portal entrances, to be released to municipal drainage systems over time.
Rail heat kinks	Upgrade existing ballasted track structure with improved materials and installation methods.
	Replace existing track structure by fixing running rail to a structural concrete base (direct fixation).
Signal house overheating	Install a backup A/C unit in each signal house to maintain temperature in case of failure of the primary A/C unit.
	Install dual A/C system and connect to a backup power source.

Table 1: Proposed adaptation infrastructure investments.

Implement life-cycle cost analysis model. The project team developed an LCCA methodology to identify if the proposed adaptation options provide positive financial benefits over the lifetime of the asset by comparing the no-build and build scenarios. The framework draws from similar methodologies used by the U.S. Department of Transportation (USDOT) and other Federal agencies to evaluate the costs and benefits of performing projects.

Using the no-build and build cost assumptions, the Excel-based model calculated the expected cost in 2050 net present value for no action and for each adaptation strategy (see Figure 2). The costs of no capital investments were projected against three multipliers of the number of future occurrences of the severe weather-related issue. Then, the team adjusted the no-build and build inputs to the model to identify thresholds at which the proposed improvements would provide a positive return on investment.

Assess adaptation opportunities in standard business practices. The pilot assessed potential interactions between climate impacts and CTA's enterprise asset management system to identify strategies to integrate adaptation. Additionally, the team developed a framework model for forecasting CTA operational and budgetary impacts from extreme weather to allow the agency to anticipate future labor, materials, and budgeting needs. The model was piloted to correlate temperature with bus heating, ventilating, and air conditioning (HVAC) defects and diesel fuel consumption.

Key Results & Findings

Observed extreme weather costs and impacts. The most significant climate impacts on CTA infrastructure, transit operations, and service were from extreme heat and precipitation. Between 2008 and 2012, extreme heat resulted in nearly 40 heat kink events. More than 50 percent of heat kink events occurred on two rail branches (Red and Orange), suggesting broader vulnerabilities of this infrastructure including age of track, operation in highway medians, and location within urban heat islands. Recent extreme precipitation and flooding resulted in significant capital, operating, and maintenance cost impacts, and secondary costs due to replacement service, reduced reliability, and lost ridership revenue.

Model Run - Template			
Results	Frequency Increase	Events / Year	2050 NPV
Baseline	1.0	2	$ 8,631,090
Frequency 1	1.5	3	$ 10,350,480
Frequency 2	2.0	4	$ 12,069,870
Frequency 3	3.0	6	$ 15,508,649
Model No-Build Cost Assumptions			
No-Build Service Costs	Weekday Cost / Day	Days	Cost / Incident*
CTA Service Costs			
Slow Zones	$ 2,500	120	$ 300,000
Bus Bridges	$ 250,000	0.25	$ 62,500
CTA Revenue Costs	$ 10,000	0.25	$ 2,500
Passenger Value of Time	$ 10,000	0.25	$ 2,500
Total			$ 367,500
No-Build Maintenance Costs	Cost / Year		
Work Involved	$ 20,000		
No-Build Repair Costs	Cost / Incident		
Work Involved	$ 15,000		
Model Capital Cost Assumptions			
One-Time Capital Improvement Costs			
Work involved	$ 500,000		
On-Going Capital Improvement Costs			
Work involved	$ 50,000		
Model Assumptions			
Discount Rate	3.5%		
Baseline Year	2013		

Figure 2: Illustrative LCCA model template. The model captures cost assumptions for the no-build option and capital costs of the build option. In this example, the build option shows a positive net present value, where the benefits outweigh costs, under current conditions and scenarios of increases in frequency.

Return on investment of adaptation options. While many LCCA model runs did not present a positive return on investment at the baseline event frequency, the model demonstrated a positive return on investment for all adaptation options at higher event frequencies (see Table 2).

	No-Build Scenario		Build 1 Scenario			Build 2 Scenario		
	Capital Costs (cost per event)	Ongoing Costs (annual cost)		2050 NPV (by frequency)	Break Even (from 2013)		2050 NPV (by frequency)	Break Even (from 2013)
ROW Flooding	$332,000	-	Base	-$59,000	2089 (76 years)	Base	-$337,000	n/a
			High	+$494,000	2021 (8 years)	High	+$216,000	2034 (21 yrs)
			Install storage system to capture & detain storm-water at portal entrance			Install storage system with double base construction costs		
Rail Heat Kinks	$462,000	$137,000	Base	+$7,700,000		Base	+$7,700,000	2030 (17 yrs)
			High	+$29,700,000		High	+$29,700,000	2019 (6 yrs)
			Replace with tighter tie spacing, granite ballast & new anchoring system			Replace the entire structure with concrete direct fixation track		
Signal House Overheating	$12,000	-	Base	+$228,000	2015 (2 years)	Base	+$176,000	2020 (7 yrs)
			High	+$742,000	2013 (immediate)	High	+$690,000	2015 (2 yrs)
			Install single backup A/C unit to provide redundancy for primary unit failure ($30,000 capital cost)			Install dual A/C units & connect to traction power in case of grid failure ($84,000 capital cost)		

Table 2: Summary of LCCA model runs and payback periods.

The analysis suggests that certain investments made today are projected to offset the future cost impacts from climate change, given appropriate assumptions for inputs such as event frequency, no-build costs, and capital costs for each specific scenario.

Opportunities in standard business practices. The team proposed two strategies to integrate adaptation into CTA's asset management system:

- Develop qualitative risk assessment tables for major asset groups driven by severe weather impacts; and
- Incorporate exposure, sensitivity, and adaptive capacity fields in the database to indicate climate vulnerability of a given asset.

The piloted framework model for forecasting operational and budgetary impacts found that bus HVAC defects and bus diesel fuel consumption showed significant correlations with high temperatures, with more than 75 percent of failures occurring with temperatures above 80°F and greater fuel consumption at temperatures above 70°F.

Lessons Learned

Leverage existing studies. The project utilized data from existing local studies, particularly the downscaled climate modeling and analysis of city-wide climate impact and economic costs developed to support the Chicago Climate Action Plan (CCAP). The city had also conducted a study to collect data on urban heat islands, which this pilot used to understand broader vulnerabilities.

Carefully identify model assumptions. The outputs of the LCCA model runs demonstrated sensitivity to various input assumptions. All inputs must be adjusted for each unique CTA situation. For example, changes in location of a potential project would affect CTA service costs. Furthermore, prioritization of infrastructure improvements should not be performed exclusively from an LCCA analysis, and additional factors must be considered in the context of other key decision variables.

It is also necessary to revise the event frequency inputs as climate models are refined. For each extreme weather-related priority issue, the project team had estimated the frequency at which it would occur by examining climate indicators from the CCAP data, such as number of precipitation events of greater than 2 inches in 24 hours, occurrences of three consecutive 90°F+ days, and number of cooling degree days. However, there was either a large range in the projected number of future incidents, or a discrepancy between baseline projections and recent observed data.

Next Steps

Continue refinement of the tools. Refine the LCCA methodology with improved forecasting of short- and long-term severe weather event frequencies and other input assumptions. Additionally, extend the operational and budgetary model to include secondary impacts, such as station-specific climate-related ridership shifts.

Apply analyses in broader context. Incorporate the risk and adaptation findings to help prioritize projects. Identify strategies to extend the adaptation project-specific findings to system-wide impacts, using appropriate methodologies and order-of-magnitude cost estimates.

For More Information

Resources:

An Integrated Approach to Climate Adaptation at the Chicago Transit Authority

Contacts:
CTA

Kimberly Gayle
FTA Office of Policy Review and Development
kimberly.gayle@dot.gov, 202-366-1429