Discussion Document

Adapting Transportation Systems to Climate Change: a Multi-Modal Approach

April 3, 2013

Emilee Ritchie, Associate
Victoria Adams, Lead Associate

National Adaptation Forum
Climate Change and Infrastructure Panel

Table of Contents

How do we define systemic impacts of climate change on multi-modal transportation systems?

"Systemic impacts of climate change are those that affect the performance or scope of the transportation system. These impacts effect transportation operations, planning, and infrastructure design, and may influence national-scale estimates of transportation costs."

Categories of systemic impacts include:

1) **Changes in transportation systems induced by climate – induced changes in the economy or society**

2) **Changes in system capacity or reliability induced directly by climate effects**

3) **Changes in system capacity or reliability induced indirectly by damages to infrastructure**

SOURCE: U.S. Department of Transportation, *Systemic Impacts of climate change on transportation*, Workshop, October 11-12, 2012

Our systemic impact study consisted of two separate analyses looking at the *economic* and *business* impacts of climate change

Questions guiding the study:

1. ***How might climate change disrupt the multi-modal transportation system?***
2. ***What are the external and internal consequences of these disruptions on the system?***
3. ***Are there collaborative solutions to these multi-modal impacts?***
4. ***What are the challenges and opportunities to addressing these impacts collaboratively?***

1. Macroeconomic Analysis

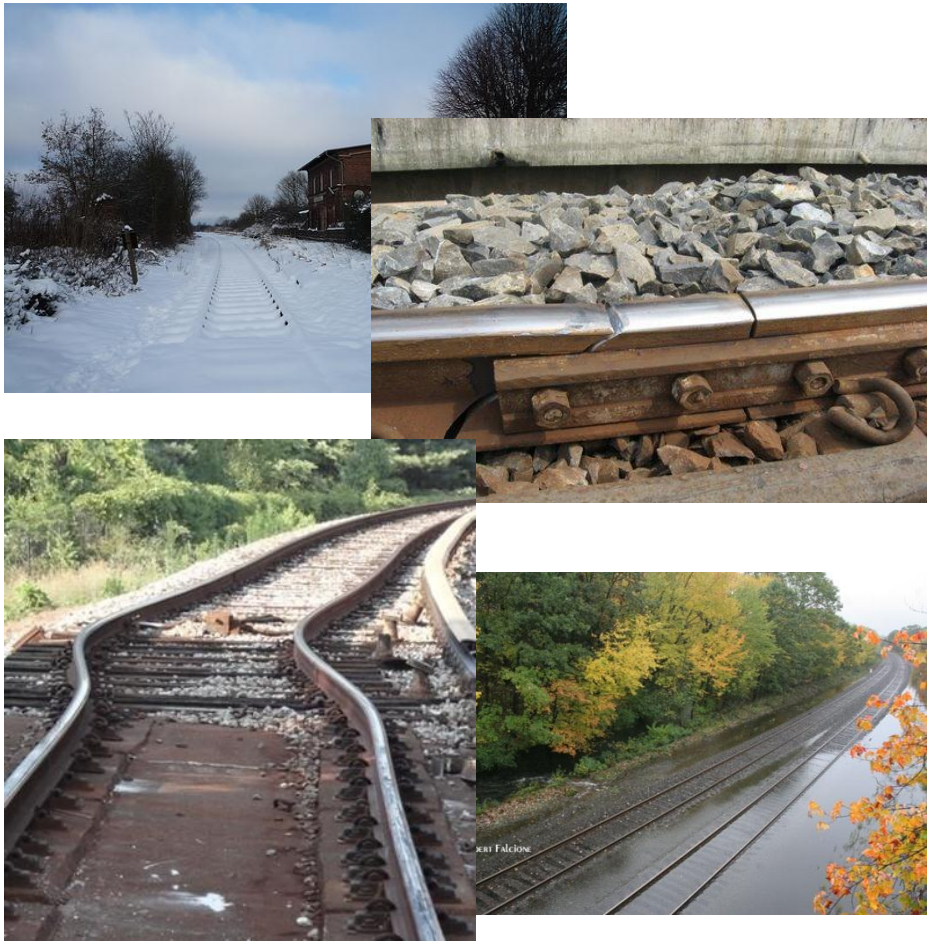
- **Objective**: Evaluate the macroeconomic consequences of transportation disruptions due to climate change and extreme weather.
  - Regional GDP
  - Regional Employment

2. Business Analysis

- **Objective:** Consider the business consequences of passenger rail and air transportation disruptions due to climate change and extreme weather.
  - Passenger and Revenue Flow
  - System as an industry

Climate change has the potential to impact railroad infrastructure and operations under a variety of extreme weather scenarios

Scenarios	Infrastructure Impacts	Operational Impacts
Extreme Heat	• Sun kinks and track warping • Power failures	• Derailments • Signal Outages
Extreme Cold	• Brittle track • Track fracturing	• Derailments • Signal outages
Sea Level Rise/Storm Surge	• Track flooding • Soil and coastal erosion to track beds	• Track impassibility • Road impassibility for safety and maintenance vehicles
Increased Precipitation (rain/snow/ice)	• Track flooding • Snow impassibility • Catenary damage • Tunnel flooding	• Track impassibility • Need for train rerouting
Increased frequency of hurricanes	• Track flooding • Catenary damage • Locomotive stability in high cross-winds • Damage to bridges	• Scheduling disruptions • Route Cancellations



Climate change has the potential to impact aviation infrastructure and operations under a variety of extreme weather scenarios

Scenarios	Infrastructure Impacts	Operations Impacts
Extreme Heat	• Limits to airport construction due to health and safety concerns	• Aircraft performance limitations (e.g. take off field length) • Cargo weight restrictions
Extreme Cold	• Infrastructure/systems reliability	• De-icing • Operational disruptions
Sea Level Rise/Storm Surge	• Vulnerability to inundation	• Airport closures
Increased Precipitation (rain/snow/ice)	• Runway/taxiway system flooding • Need for additional de-icing of aircraft	• Grounding of aircraft causes delays and cancellations
Increased frequency of Hurricanes	• Airport infrastructure and Naiads damages	• Grounding of aircraft causes delays and cancellations • Aircraft damage

The Northeast Megaregion

- The Northeast Megaregion is one of the economic powerhouses of the nation:
  - Population 2010: 52,332,123
  - Percent of U.S. Population: 17%
  - Population 2025: 58.4 million
  - Population 2050: 70.8 million
  - Projected Growth (2010 - 2050): 35.2 percent (18.4 million)
  - Gross Domestic Product (2010): $2.92 trillion
  - Percent of U.S. GDP (2010): 20%

SOURCE: http://www.america2050.org/northeast.html

The Northeast macroeconomic analysis focused on the impact of increased storms on rail, road, air and maritime transportation

- The Northeast Megaregion connects the Northeast Corridor via road (I-95), rail and air for freight and passenger movement – all of these are highly vulnerable to disruption from storms
- Currently, approximately ten major storms hit the Northeast Megaregion each year
- Based on data from NOAA these storms vary in seriousness and impact on the transportation industry:

Intensity of Storm	Probability of Occurrence, 1958 to 2010	Number of Days Transportation was Impacted
Extreme	0.05	7
Crippling	0.24	5
Major	0.32	3
Significant	0.19	2
Notable	0.19	1

Scientific reports and case studies were reviewed to determine the percentage increase of storms in the region between 2015-2050

Based on NOAA and Union of Concerned Scientists modeling, the number of storms in all categories should increase by 9 %in the period 2015-2050 due to climate change:

Intensity of Storm	Probability of Occurrence, 1958 to 2010	
	1958 to 2010	2015-2050
Extreme	0.05	0.06
Crippling	0.24	0.27
Major	0.32	0.35
Significant	0.19	0.21
Notable	0.19	0.21

SOURCES:
NOAA, *Coastal impacts, adaptations, and vulnerabilities*, 2012
Union of Concerned Scientists, *The changing northeast climate*, 2006

Booz Allen used DIME (Dynamic Impact Macroeconomic) model to analyze economic and employment losses from storm impacts

- **What is DIME?**
  - DIME is Booz Allen's derivation of REMI (Regional Economics Model, Inc.)
  - Dynamic economic and gravity models explore the impacts of a shock to a system
- **What are the component of the model?**
  - **Input-Output:** inter-industry relationships and transactions between industries
  - **General Equilibrium**: stabilization of an economic system
  - **Econometric**: measure speed of economic response
  - **Economic Geography**: spatial dimension of economic system
- **Assumptions**
  - Study limited to storms, did not account for other climate change scenarios
  - All estimates developed by regional macroeconomic input/output models
  - Storm estimates based on current available data

SOURCE: http://www.remi.com/the-remi-model

The analysis used a baseline of 2005 economic and employment data to estimate regional impacts from storms between 2015-2050

Using DIME, we estimated the economic impacts on the region between 2015-2050 under both existing storm probabilities, and the 9% increase in probability.

	GDP		Employment	
Regions	Fixed 2005 $B	% Change	Jobs (thousands)	% Change
Baseline – Current Pattern of Storms without 9% increase				
Northeast Corridor	-16.2	-0.0033	-111.5	-0.0026
Climate Change Scenario – 9% Increase in Storms Compared to Baseline				
Northeast Corridor	-17.7	-0.0036	-121.5	-0.0028
Change Between Baseline and Climate Change Scenario				
Northeast Corridor	-1.5	-0.0003	-10.0	-0.0002

The impacts of increased storms on transportation may produce manageable effects on employment and GDP in the region

Based on our analysis, as a result of climate related increase in storm activity in the Northeast in the period 2015-2050, disruption in transportation is likely to produce the following impacts:

The loss of more than 121,000 jobs and a reduction in regional income of almost $18 billion

Compared to the normal storm activity currently seen, more than 10,000 additional jobs would be lost and income would be reduced by an additional $1.5 billion

The second analysis concerns the business impacts various climate scenarios will have on two modes - passenger rail and air

- What are the **emerging business costs to** these modes due to climate change?
  - Loss of passenger revenue
  - Infrastructure costs
  - Public perceptions of mode reliability over time

- What are the **long-term business considerations** due to climate change?

  Integration of climate change considerations into:

  - **Service Availability**: Extending existing services to accommodate displaced passengers from other mode, contracting services due to loss of passengers within mode
  - **Existing Operations and Infrastructure**: Operations and Maintenance (O&M) budgets, retrofitting existing infrastructure for greater resiliency
  - **New Operations and Infrastructure**: Airport Master Plans and Amtrak's State of Good Repair (SOGR) schedules (decision-making documents)
  - **Safety and Emergency Preparedness**: Airport Emergency Plans (AEPs), Amtrak's Emergency Management and Corporate Security Department

With the impacts of climate change, will there emerge a transportation mode within the system that is considered most reliable? Does one mode hold an advantage over the other?

Each scenario causing systemic impacts may lead to mode shifting between passenger rail and air

Scenario	Systemic Impact	Rail	Aviation
Extreme Heat	Passengers from rail expected to shift to aviation due to catenary failures and track warping	High Costs	Low Costs
Extreme Cold	Unlikely to cause major disruptions for either mode	Low Costs	Low Costs
Sea Level Rise/Storm Surge	Likely to cause major service disruptions and impacts to infrastructure for both modes	High Costs	High Costs
Increased Precipitation	Passengers from air expected to shift to rail due to grounded flights	Low Costs	High Costs
Increased frequency of hurricanes	Both modes expected to suffer passenger loss and infrastructure damage	High Costs	High Costs

The proposed study is a collaboration with Amtrak to determine any correlation between ridership and certain climate scenarios

Purpose of the Study: Determine how extreme weather events in the northeast region impact ridership along Amtrak's NEC passenger lines, and subsequent revenue generated from those lines.

Multimodal Transportation Indicators			
Title	Amtrak Ridership		
Subject	Passenger Usage		
Mode	Rail		
Source	http://safetydata.fra.dot.gov/OfficeofSafety/		
Date	October 26, 2012		
AMTRAK RIDERSHIP			
unit	passengers		
month	Number of Passengers		
Jan-11	2,126,429		
Feb-11	2,099,010		
Mar-11	2,610,567		
Apr-11	2,688,955		
May-11	2,691,371		
Jun-11	2,812,202		
Jul-11	2,890,763		
Aug-11	2,719,462		
Sep-11	2,521,110		
Oct-11	2,389,179		
Nov-11	2,631,290		
Dec-11	2,515,467		

***Would conduct a similar study using airline data to evaluate multi-modal impacts**

- **Data Needs**:

Data	Source
Number of cancellations due to weather conditions (NEC)	Amtrak
Daily ridership data	Amtrak
Daily weather reports in northeast region	NOAA

- **Questions:**
  - What happens to ridership given various extreme weather events? (decrease or increase)
  - What is the revenue lost or gained during those occurrences?
  - Based on this baseline, can future losses and gains be extrapolated given extreme weather predictions over the next 50 years?
  - When do these losses or gains in revenue necessitate the need for changes in operations and infrastructure?

Given that extreme events will impact multi-modal systems, how can we build resiliency and adapt to climate change as a system?

Challenges:

- **Funding of Transportation Studies**: funding for transportation studies are often silohed by mode, creating difficulty in coordinating across modes to explore multi-modal solutions
- **Multiple Stakeholders**: variety of stakeholders with competing interests adds complexity to multi-modal solutions (Amtrak, airlines, transit authorities, port authorities, state and local governments, etc.)
- **Mode Competition**: profit-making industry, air and rail passenger companies won't necessarily concede revenue opportunities to the other mode under a multi-modal solution
- **Climate Change Data**: difficult to assess multi-modal solutions in the absence of granular climate change data at the transportation planning level

Opportunities:

- **Climate Change Data:** united transportation industry demonstrates a strong need for the data at the planning level
- **Sustainable Communities**: encourage regional, smart growth that accounts for climate impacts of the multi-modal transportation system
- **Transfer Points**: development of transfer points between air and rail has a revenue generating advantage, and can accommodate weather induced passenger shifts when necessary

Questions?

Emilee Ritchie
Booz Allen Hamilton
Ritchie_Emilee@bah.com
202-346-9315

Victoria Adams
Booz Allen Hamilton
Adams_Victoria@bah.com
703-377-4942