

NEW VOICES IN PUBLIC POLICY

Volume VIII

Spring 2014

Weathering The Storm: Developing a Climate Change Adaptation Policy for the Washington Metropolitan Area Transit Authority

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ISSN: 1947-2633

Executive Summary

This analysis compares options for the Washington Metropolitan Area Transit Authority (WMATA) to develop a climate change adaptation plan. The adaptation plan will help WMATA adequately prepare and respond to the impending consequences of climate change on the transit system's operations and strategic planning initiatives. As the occurrence of climate change has been firmly established, many transit systems, encouraged by the United States Department of Transportation, have begun to examine how climate change will impact transit and establish plans that equip systems to handle the consequences on their operations.

This paper examines climate change adaptation initiatives of other major transit systems to determine which adaptation measures, if any, could be effectively adopted by WMATA. This analysis presents several policy outcomes for WMATA, comparing their efficiency, equity, political feasibility, and robustness to evaluate which options are most likely to meet WMATA's requirements.¹

The report recommends that WMATA create a Climate Change Adaptation Task Force that commissions a qualitative and quantitative vulnerability assessment followed by a more extensive system-wide criticality review. Due to WMATA's unique governance structure comprised of four separate jurisdictions, WMATA must join these efforts with its current improvement and expansion ventures while building partnerships with environmental advocates and stakeholder groups to secure support within its financial and institutional constraints.

These recommendations cannot be successful without WMATA leadership's committed support. Without true commitment, WMATA's preparation for climate change will be fragmented, at best. At worst, WMATA will be unprepared to face the hazards of climate change and may waste precious resources achieving very little.

WMATA's Board of Directors must undertake a climate change adaptation plan now. Failure to prepare WMATA's transit system for the increasing consequences of climate change could have detrimental effects on the local, regional and national benefits that extend beyond traditional measures of mobility.

Introduction²

The Washington Metropolitan Area Transit Authority (WMATA) serves as the major rail and bus transportation system in the greater Washington, DC metropolitan area. WMATA's rail transit system, commonly referred to as the Metro, began operating in 1976 and has grown to include 86 passenger stations, 106.3 route miles and a fleet of over 1,100 rail cars.³ Additionally, WMATA's bus and paratransit service-Metro Access, has expanded operations to include over 1,500 square miles. Each day, approximately 1.2 million riders board the WMATA transit system.⁴

WMATA's policymaking process continues to evolve to address current needs. Though reduction of greenhouse gas emissions is critical in slowing climate change, this analysis focuses primarily on possible policies WMATA can implement to bolster the system's ability to withstand impacts of climate change.¹ This analysis acknowledges that WMATA is currently focused on several parallel demands such as improving safety and maintenance, customer service, meeting rider demand, and expansion. Therefore, the analysis seeks to provide a manageable pathway to achieve adequate climate change preparation within a highly constrained environment.

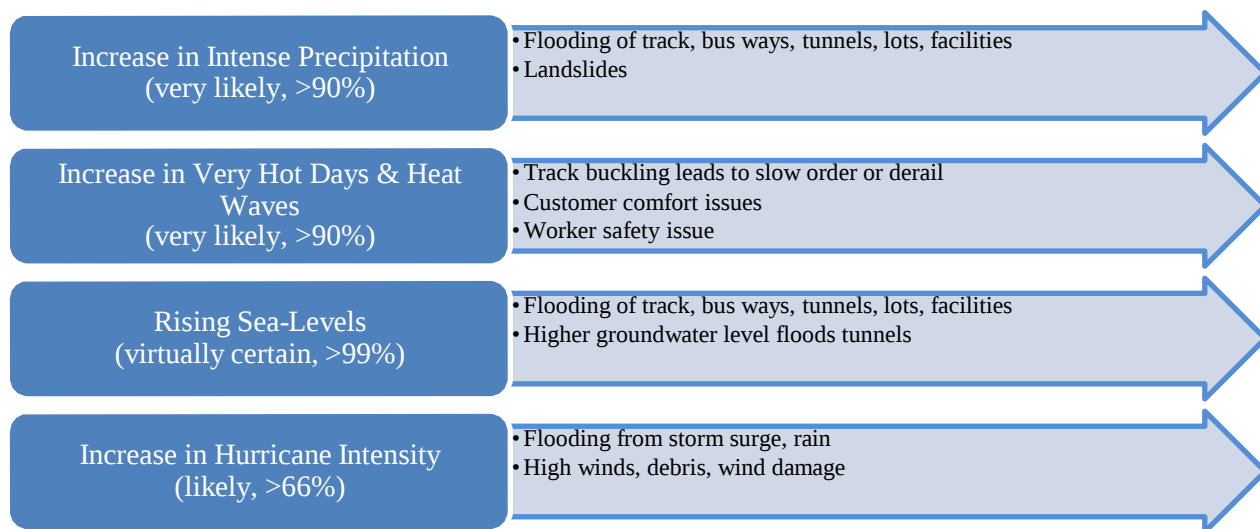
Why Should WMATA Care About Adapting to Climate Change?

As the occurrence of climate change has been firmly established, it is only a matter of time before WMATA feels the effects of climate change more frequently and severely. The U.S.

¹

Initiative anticipates the consequences of four major aspects of climate change (see Figure 1).

Figure 1: Potential Impacts of Climate Change on Public Transit Systems



Source: U.S. Department of Transportation Federal Transit Administration 2011, 13.

It is uncertain how these predicted impacts will specifically affect the WMATA system but it is likely that WMATA's ability to provide service will be impeded by climate change. For example, warmer temperatures likely will result in "heat kinks," or the buckling of rails, and higher levels of precipitation will likely cause flooding in tunnels, stations, and bus stops. Climate change will also lead to rising sea levels, power blackouts, heavy snowfall, droughts, and wildfires and more frequent heat waves. These results of climate change will cause service delays and closures, jeopardize the safety of passengers and WMATA employees, and require more frequent maintenance and repair of WMATA train equipment (including rails, trains, and stations).⁵

Some could argue that WMATA was already impacted by climate change in 2012 when high temperatures, flooding, and hurricanes led to service disruptions. For example, during October 2012, Hurricane Sandy shut down the entire WMATA system for the day of Monday October 29th with services resuming throughout the day on Tuesday October 30th. In addition, during summer 2012, WMATA responded to high temperatures by operating trains at lower speeds which resulted in service delays. During September 2012, the Shaw-Howard University Metro station flooded and WMATA suspended rail service on segments of the Green and Yellow lines: “water was flowing between the rails in the [Shaw-Howard University] station, and two other stations on those lines, Columbia Heights and U Street, were also shut down. Trains were stopping at Georgia Avenue on one end of the affected zone and at Mount Vernon Square on the other.”⁶

WMATA’s ability to provide reliable, safe service will continue to be negatively impacted and lead to riders finding alternate transportation methods, resulting in lower levels of ridership on WMATA trains and buses and thus less revenue for WMATA. People with disabilities, older adults, and the low-income will be disproportionately impacted by service delays/closures and safety issues as they rely on public transportation more than other stakeholders.⁷

WMATA also plays a key role in generating profit for the greater Washington DC metro area. As noted by Nat Bottigheimer, “land value near Metrorail generates \$3.1 billion/ year in property tax revenues to [WMATA’s] funding partners.”⁸ In addition, as a result of service delays and closures, the production and profit of local businesses will be negatively impacted by

WMATA service issues because their employees will increasingly be unable to get to work, thus disrupting regional service and commerce. If WMATA does not develop policies to address the impact of climate change on the rail system, it is likely that the local economies serviced by WMATA will be negatively affected and the value of proximity to WMATA's rail system will decline, further reducing revenue for WMATA and its funding partners.

Thus, because it is extremely likely that WMATA's services and revenue will be impacted by climate change, it is necessary for WMATA to develop its own climate change adaptation plan. The following section further demonstrates WMATA's integral role in the greater metropolitan area connecting people and commerce.

Who is WMATA?

WMATA currently operates the second largest rail system and sixth largest bus system in the United States, but the aging system is in need of improvements to the safety and reliability of its services as it continues to meet the increasing demands of a growing region.⁹ An expansion of the system is already underway to extend service 23 miles into Northern Virginia from the current Orange line, adding 11 additional passenger stations. WMATA will face additional strains from growing utilization, tightening operating budgets and extreme weather due to climate change that will exacerbate structural challenges.

Compared to other large transit systems, WMATA is unique in that it is an interstate compact agency formed in 1967 by the U.S. Congress, Virginia, Maryland and the District of Columbia.¹⁰ The compact is designed to operate jointly between all four stakeholders to collectively achieve solutions beyond each individual state or district.¹¹ A 16-member WMATA

Board of Directors manages policy, funding, and operations. The Board delegates many of its functions to specific WMATA committees for issue areas such as safety, administration, finance, and customer relations.¹²

WMATA is also unique because it does not have a dedicated funding source. WMATA receives funding through an array of Federal, state and local sources which include annual contributions from each local jurisdiction WMATA serves (see Figure 2) and federal grants. As a result, it must compete annually for these funds in order to operate.¹³ Rider fares, parking fees and advertising revenue supplement the system's funds.¹⁴

Figure 2: Subsidy Amounts Paid by Four Jurisdictions

Jurisdiction	Amount Paid in Subsidy
Federal Government	\$391M (30 %)
District of Columbia	\$348M (26 %)
Maryland	\$360M (27 %)
Virginia	\$231M (17 %)
Total Fiscal Year 2011 Subsidy:	\$1.3 Billion

Stakeholders: Who Cares About WMATA?

WMATA's presence in the Washington area has helped shape of the current economic, residential, and land use trends. As a result, millions of people rely on the transit system or utilize it in some capacity creating broad categories of interested stakeholders that must be considered in any strategic planning developments or initiatives. WMATA's stakeholders can be broadly classified into three categories: user/consumer groups, commercial and non-commercial interest groups, and governments.

User/consumer groups are system riders who are the most directly affected by WMATA's policy change. Riders include residents and employees of the region as well as tourists. These riders are a latent group who are not formally organized as an interest group. However, this large number of people has the potential to become a potent interest group in setting WMATA's policy if encouraged by media or civil societies.¹⁵

Interest groups consist of commercial real estate developers and local business owners as well as non-commercial groups such as environmental lobbying groups, and the residents of the areas served by WMATA. The various priorities of these interest groups can significantly influence WMATA's operations and policies. Residents and developers would likely both welcome the increase of real estate properties proximate to metro stations while some local residents and environmental advocacy groups might oppose such developments. Developers might also attempt to undermine the rigorous environmental standards promoted by environmental advocacy groups or ignore local government plans to increase affordable housing options surrounding stations. Each group in this category is politically influential and can mobilize financial and political resources to influence WMATA's climate change adaptation policy for its own benefit.

Finally, the governments include the Federal, state and local government agencies that are responsible for planning and monitoring the region's public transportation options and also have authority to allocate public funding for WMATA's operations. The government agencies are the ultimate decision-makers that must balance the budgetary pressures incurred by WMATA and the welfare of the public served by it. Government policymakers are heavily

influenced by various interest groups; however, any serious failure to protect the public interest will draw criticism and could damage their reputation as political leaders.¹⁶

All recommendations put forth in this analysis carefully weigh the interests of each stakeholder group and the potential of climate change adaptation plans to affect them.

How Do Other Public Transit Systems Address Climate Change Adaptation?

Though many public transportation systems have not yet developed or made public their climate change adaptation plans, Los Angeles County Metropolitan Transit Authority (LAC MTA), New York Metropolitan Transit Authority (NY MTA), and Transit for London (TfL) have published climate change adaptation plans.

Published in October 2008, *MTA Adaptations to Climate Change: A Categorical Imperative* explores how the NY MTA, the largest public transit agency in the U.S., can and should adapt to climate change and includes projections of climate change impact.¹⁷ LAC MTA's June 2012 *Climate Action and Adaptation Plan* presents comprehensive mitigation strategies in addition to adaptation strategies as well as preliminary findings from high-level risk and vulnerability screenings and a criticality assessment.¹⁸ Unlike both the LAC MTA and NY MTA plans, TfL's May 2011 *Providing Transport Services Resilient to Extreme Weather and Climate Change* is similar to a status report: it summarizes how the agency has projected climate change impacts on the service region, risks and vulnerabilities to system assets and services, strategies for addressing the impact of climate change, and the integration of the system's adaptation plan into its Risk Management System.¹⁹

Examining each of these systems' climate change plans reveal that their plans include the following components:

- Projecting Climate Change Impacts on Service Region
- Conducting Vulnerability and Criticality Assessments
- Enhancing Business Operations to Respond to Climate Change
- Mitigation Strategies to Reduce Greenhouse Gas Emissions

The following section analyzes how the LAC MTA, NYC MTA, and TfL climate change adaptation plans address each of these components.

Projecting Climate Change Impacts on Service Region

The NY MTA plan analyzes multiple projections of climate change impacts specific to the NY MTA service region, especially historical data on the average rate of the rising sea level over the last century, which was measured at The Battery tide gauge. The NY MTA plan advocates for the use of multiple climate change scenarios when developing adaptation, design, and recovery plans.

Similarly, the LAC MTA plan includes local historical data and projections specific to the LAC MTA service region. Projections include data from six models of temperature and precipitation developed by global climate change centers. In contrast to NY MTA and LAC MTA, which used multiple sources of local historical data and projections, TfL developed its adaptation strategies based on the 2009 United Kingdom's Climate Projections which include both regional and national projections.²⁰

Conducting Vulnerability and Criticality Assessments

The NYC MTA plan reviews the vulnerabilities²¹ of NY MTA assets by agency and suggests "temporary fixes" that the agency can employ while developing more comprehensive,

durable solutions.²² The plan recommends that the NY MTA conduct a quantitative vulnerability assessment, noting that “the absence of a *systematic and quantitative assessment* of MTA’s vulnerabilities to varying current and future climate conditions using proven engineering and risk management methods is a deficiency that needs to be rectified as soon as possible.”²³ In addition, the NY MTA plan recommends the creation of a climate database to store data on climate change impacts, such as temperature, precipitation, and sea-level rise, in the NY MTA service region.

The June 2012 LAC MTA plan presents findings from a high-level assessment of the transit system; for example, vulnerabilities in the LAC MTA bus system in general are presented but specific vulnerabilities of bus routes, facilities, and services are not. Similar to the NY MTA plan, the LAC MTA plan recommends that LAC MTA conduct a vulnerability assessment on how specific aspects of services and facilities will be impacted.

TfL’s plan assesses vulnerability to the system differently: using data from the United Kingdom’s 2009 Climate Projections, each business unit within TfL created graphs depicting the likelihood and impact of risks such as rain and flooding resulting in track and signal drainage. Unlike NY MTA and TfL, LAC MTA’s adaptation plan includes a criticality assessment. LAC MTA describes a criticality assessment as a process which determines the “services and assets...that are essential to transporting Metro’s customers.”²⁴ The criticality assessment ranks the criticality of services, assets, and facilities on an index from 1 to 7 with 7 being the maximum ranking based on daily weekday ridership, “connectivity to other lines,” expert opinions, and past and future plans for development with other systems.²⁵

Enhancing Business Operations to Respond to Climate Change

Each plan includes a range of strategies to integrate climate change adaptation plans into its public transit agency's operating structure and to better position the agency to respond to climate change. Both the NY MTA and LAC MTA plans encourage the agencies to position and advertise themselves as leaders in climate change adaptation in their regions. Additionally, NY MTA's plan recommends the following:

- Assemble an internal Adaptation Team by February 2009.
- Create a basic adaptation policy by no later than mid-2009.
- Complete a strategic climate change adaptation master plan by no later than 2015.
- Establish a task force to explore creative adaptation measures and opportunities.
- Create a "Pre-Disaster-Plan for Post-Disaster-Redevelopment."
- Assess the climate change risks to planned infrastructure development and improvement.
- Assess the system's insurance and balance self-insurance with insurance by other entities.²⁶

LAC MTA proposes different recommendations to enhance the agency's business operations to better address climate change:

- Create an outreach strategy and plan to communicate climate change adaptation goals and activities to staff and customers.
- Investigate financial and social costs climate change and adaptation strategies.
- Align the agency's climate change adaptation efforts with its organizational structure.
- Develop and implement performance measures to track the agency's climate change adaptation efforts.²⁷

TfL's climate change adaptation plan differs from the NY MTA and LAC MTA plans by including strategies to address short-term impacts of climate change. For example, the TfL report cites the London Underground's *Stay Cool* campaign as a strategy designed to alleviate the impact of high temperatures by encouraging riders to take bottles of water with them. In

addition, TfL has added risks to assets and services resulting from climate change to its Risk Management System.²⁸

Mitigation Strategies to Reduce Greenhouse Gas Emissions

Though the purpose of this paper is to explore climate change adaptation, not mitigation, strategies for WMATA, it is important to note that some public transit agencies include mitigation strategies in their climate change adaptation plans. Mitigation strategies are designed to reduce greenhouse gases and slow climate change. Half of LAC MTA's plan focuses on reducing greenhouse gas emissions. In contrast, NY MTA references strategies for mitigating greenhouse gas emissions briefly. TfL's plan does not include strategies for reducing greenhouse gas emissions.

Options for WMATA's Climate Change Adaptation Plan

As demonstrated by these examples, WMATA has several options to consider for developing a climate change adaptation plan. These options, listed below, can be combined to form a variety of climate change adaptation initiatives. It is important to note that the LAC MTA, NY MTA, and TfL plans do not thoroughly discuss strategies to fund climate change adaptation initiatives, which is a major challenge for WMATA. The merit of these options is assessed based on the criteria on pages 15-17.

- Do nothing to adapt to climate change.
- Create a Climate Change Adaptation Task Force.
- Create a budget and identify funding for climate change adaptation activities.
- Conduct a vulnerability assessment of the WMATA system.
- Conduct a criticality assessment to identify which WMATA assets and services are essential to the system.

Criteria: What Values Should Be Used to Assess the Policy Outcomes?

The following criteria will analyze the proposed policy options WMATA could choose to adapt to climate change. The criteria used to measure these policy outcomes include the values of efficiency, equality, political feasibility and robustness.²⁹ These criteria will determine whether WMATA can operate with minimal disruption of service, prevent hazardous situations in affected areas, and whether WMATA's climate change adaptation strategies are financially sustainable given the budgetary pressures experienced recently. All four criteria have been determined to be of equal urgency for the purpose of evaluating outcomes from the climate change adaptation strategies pursued by WMATA.

Efficiency

In this analysis, WMATA's efficiency is achieved by extending public transportation service to all Washington, DC-area residents even during the abnormal weather conditions caused by climate change.³⁰ WMATA's chosen policy should increase the system's resilience against climate change impacts through technological solutions while ensuring any climate change adaptation efforts preserve WMATA as a reliable transit option.³¹

Equity

It is critical that WMATA maintains services for all Washington, DC residents, regardless of socioeconomic status. The mobility of the Washington metropolitan area is increasingly dependent on WMATA and residents in low-income neighborhoods, as well as senior citizens and individuals with disabilities, will be disproportionately affected by a failure to prepare the WMATA system for climate change. Public transportation is critical for transporting these

people to and from work, to buy groceries, and access medical care. Additionally, business owners rely on consumer access facilitated by the WMATA system to survive. Providing transportation services to the area's most vulnerable groups connects them to the broader community and must be considered when measuring the success of the policy outcomes.

Political Feasibility

WMATA's multi-jurisdictional board has unique political challenges when enacting new policies. The first is acquiring necessary funding to implement these policies. WMATA must appeal to each jurisdiction, as well as compete for grants to receive funding. Second, the jurisdictions which WMATA serves are controlled independently, which presents coordination and implementation challenges to climate change adaptation plans. The absence of both legislation and support from federal agencies exacerbates these challenges to developing climate adaptation strategies, and the local governance framework cannot adapt fast enough to adequately address impending climate change impacts. The chosen policy should ensure participation and cooperation among local authorities and be able to move swiftly through the political process.³²

Robustness

As the number and intensity of incidents caused by extreme weather increase in the future, the pressure on the WMATA system will rise, namely through maintenance costs. The robustness of WMATA's policy outcomes are measured on whether WMATA is to some degree more prepared to withstand the impacts of climate change without service disruption if the policy recommendations are implemented.

Figure 3 applies these criteria to the range of possible alternatives presented on below.

Figure 3: Assessing WMATA's Options

Policy Outcomes	Maximize Efficiency	Maximize Equity	Politically Feasible	Robustness
Option 1: Do nothing to adapt to climate change.	-1	-1	+1	-1
Option 2: Create a Climate Change Adaptation Task Force.	0	0	+1	+1
Option 2A: Create a budget and identify funding for climate change adaptation activities.	+1	+1	-1	+1
Option 2B: Conduct a vulnerability assessment.	+1	0	-1	+1
Option 2C: Conduct a criticality assessment.	+1	0	-1	+1

Scale:

+1= Yes.

0=Neutral or Not applicable.

-1=No.

Recommendation: Create a Climate Change Adaptation Task Force

This policy analysis recommends that WMATA's Board of Directors should approve the creation of a Climate Change Adaptation Task Force to report directly to the Policy, Program Development and Intergovernmental Relations Committee. The Task Force should be comprised of representatives appointed by the Board of Directors with related experience in preparedness and response efforts. It is crucial that WMATA's leadership, including the Board of Directors and senior management officials, realize the importance of a climate change adaptation process and support the Task Force. Without this necessary buy-in, the system will lack the strategic leadership required to implement recommendations proposed by the Task Force.

Once created, the Task Force should identify areas where climate change preparation efforts can be joined with current ventures, such as WMATA's ten-year \$11 billion Capital Improvements project. Coordination efforts will reduce climate change adaptation plan costs. Data and evidence must drive adaptation plan expenditures due to the current fiscal environment and WMATA's unique circumstances requiring four separate jurisdictions to approve funding. This will require skilled oversight by the Task Force to commission experienced engineers and environmental experts who can conduct the assessments and effectively convey the urgency with which adaptation must proceed.

Though a detailed vulnerability assessment of the entire WMATA system is ideal, the Task Force should commission experts to conduct a general vulnerability assessment because it is more financially and politically feasible due to limited funding. The Task Force may also consider a fractured approach to assessing WMATA's services and assets which first reviews the heaviest traveled areas of the system such as the transfer stations of L'Enfant Plaza, Gallery-Place Chinatown, Metro Center and Union Station as well as the most densely utilized bus routes. This approach would restrain initial costs by first reviewing system sites which have the greatest ability to spur inefficiency and widespread service disruptions. Conducting the vulnerability assessment in stages allows for a more manageable implementation process but it is essential that the assessment eventually reviews the entire system to ensure that all areas are equally examined and serviced.

The Task Force could fund the criticality assessment with WMATA's operating budget and include it with WMATA's current performance examinations that evaluate specific areas of

the system's vulnerability.³³ The criticality assessment is a natural fit for coordination with performance examinations and combining the two also makes the assessment more politically and financially manageable. Though a partial criticality review may initially be more feasible, it would be extremely misguided for a WMATA climate change adaptation plan to conclude having only focused on the most densely populated or affluent areas serviced by WMATA. An adequate long-term adaptation plan must ultimately examine climate change impacts system-wide to ensure WMATA continues to offer all Washington area residents safe, reliable and affordable transportation access.

Limitations

If WMATA attempts to brand its climate change adaptation plan, WMATA member jurisdictions may oppose it as a big-ticket initiative in the current fiscal environment. In addition, it would be counterproductive for the Task Force to first address climate change mitigation strategies for reducing greenhouse emissions, as these steps could suffer from "mission creep," diverting resources from the original objectives, or alter the outcome of the experts' assessments. If the Task Force is disciplined in their objectives and has support from WMATA leadership, the process should overcome these challenges.

Additionally, all implementation efforts must be evaluated using the criteria outlined earlier. The Task Force recommendations must ensure the system's efficiency, reliability and access to services, and minimize the financial burden on stakeholders, the plan may be benefiting climate change preparedness while damaging WMATA's ability to fulfill its mission.

Who Pays For It?

As WMATA's funding structure indicates, any WMATA initiative with a large initial investment will require political maneuvering to obtain approval of the necessary funding sources. As a result, WMATA's best approach to secure funding would be working under the auspices of existing federal and local initiatives for climate change adaptation plans and finding the best avenues to gain stakeholder support.

Building a positive image is essential for building public support for WMATA's new climate change policies.³⁴ Rebranding WMATA as at the forefront of the climate change adaptation effort would improve its reputation among environmentally-concerned citizens and organizations, which could become a new source of funding.³⁵ As a first step to transform its image, WMATA should urge the North Capital Region Transportation Planning Board to actively participate in the FTA's Climate Change Adaptation Initiative.³⁶ Also, WMATA should urge the federal and local governments to incorporate climate change issues to the transportation planning laws and to adopt climate adaptation standards in all future expansion projects even if this is viewed as rent seeking behavior.³⁷

Upon completing the vulnerability and criticality assessments, the Task Force should work with regional urban planning authorities to obtain a dedicated funding source for WMATA's climate change adaptation strategies, and with real estate developers to boost operating revenue through increased ridership derived from urbanization in the region such as the development of the Silver Line. Appreciating property values surrounding WMATA stations

may prompt more participation from the private sector in local development projects and accelerate the urbanization process in such areas.

Next Steps and Potential Opportunities

Should WMATA's Board of Directors seek to move forward with this analysis's recommendations, it should adopt performance measures to evaluate the success and timeliness of its implementation efforts. The Board of Directors should appoint members to the Climate Change Adaptation Task Force within six months of its creation, followed by implementation of vulnerability and criticality assessments shortly thereafter. The criticality assessment will also serve as a benchmark to evaluate whether the adaptation plan is advancing.

After reviewing the assessments, the WMATA Board of Directors should implement plans to address the systems' weakest, at-risk areas within a period of six months to a year. It is important that the completion of one phase leads immediately into the next. Long transitions between phases increase the likelihood that the project will be postponed indefinitely or discarded.

During this planning phase it may be advantageous to launch a public relations campaign to raise awareness of adaptation efforts and WMATA's work to advocate on behalf of environmental standards. This effort will serve to improve WMATA's reputation as a leader of climate change and environmental planning initiatives that can also induce key public support influential in securing additional funding sources. Similarly, WMATA can align its plans with related initiatives in the region.

Conclusion

The time to address the adaptability and long-term strategic planning of WMATA is now. With the system already under strain and expansion projects underway a climate change adaptation plan should be integrated into current sustainability planning. The WMATA transit system has drastically altered the economic, residential and land use patterns of the Washington DC area and plays a crucial role in the Capital region's economy. WMATA's leadership should take climate change adaptation seriously by developing a disaster response plan and preparing the system for increased risks. This effort should be launched with the creation of a Climate Change Adaptation Task Force to oversee the commissioning of vulnerability and criticality assessments. Failing to adequately prepare WMATA's transit system for the increasing consequences of climate change on its operations could have detrimental effects on the local, regional and national benefits that extend beyond traditional measures of mobility.

¹ The criteria of efficiency, equity, political feasibility and robustness were derived from Eugene Bardach, *A Practical Guide for Policy Analysis: The Eightfold Path to More Effective Problem Solving* (New York: Chatham House Publishers, Seven Bridges Press, 2000), 27-38.

² This paper was developed Fall 2012 and may not reflect the most current climate change adaptation plans for WMATA, the New York Metropolitan Transit Authority, Transport for London, and the Los Angeles County Metropolitan Transportation Authority.

³ U.S Government Accountability Office, 2011. *Public Transportation: Washington Metro Could Benefit from Clarified Board Roles and Responsibilities, Improved Strategic Planning*. Report to Congressional Requesters. Washington, DC, 4. <http://www.gao.gov/assets/330/320529.pdf>

⁴ Washington Metropolitan Area Transit Authority Office of Long Range Planning, AECOM, and Smart Growth America, 2011, *WMATA Making the Case for Transit: WMATA Regional Benefits of Transit*, Technical Report. Washington, D.C., 1.

<http://www.wmata.com/pdfs/planning/WMATA%20Making%20the%20Case%20for%20Transit%20Final%20Report%20Jan-2012.pdf>

⁵ U.S. Department of Transportation Federal Transit Administration, 2011, *Flooded Bus Barns and Bucked Rails: Public Transportation and Climate Change Adaptation*, 16-21. http://www.fta.dot.gov/documents/FTA_0001_-_Flooded_Bus_Barns_and_Bucked_Rails.pdf.

⁶ Martin Weil, 2012, "Rain Floods Streets and Metro Just North of Downtown D.C.," *The Washington Post*, September 3, sec. Local, 1.

⁷ U.S Department of Transportation Federal Transportation Administration, *Flooded Bus Barns*, 1.

⁸ Nat Bottigheimer, "WMATA Planning for Climate Change Adaptation in an Operating Environment." March 21, Arlington, Virginia, 5.

⁹ GAO, *Public Transportation*, 1.

¹⁰ *Ibid*, 1.

¹¹ *Ibid*, 41.

¹² *Ibid*, 6.

¹³ William D. Middleton, 2001, "Washington's Magnificent Metro," *Railway Age* 202 (9) (September), 67.

¹⁴ GAO, *Public Transportation*, 4.

¹⁵ The group theory concepts discussed in this paragraph are taken from Mancur Olson's *The Logic of Collective Action: Public Goods and the Theory of Groups*. (Cambridge: Harvard University Press, 1971).

¹⁶ As Deborah Stone explains, "public interest" can have different meanings but here we refer to it as "things that are good for a community as a community." Deborah Stone, *Policy Paradox: The Art of Political Decision Making*. Rev. ed. (New York: Norton, 2002), 21.

¹⁷ Klaus Jacob, Cynthia Rosenzweig, Radley Horton, David Major, and Vivien Gornitz, 2008, "MTA Adaptations to Climate Change: A Categorical Imperative."

http://www.mta.info/sustainability/pdf/Jacob_et%20al_MTA_Adaptation_Final_0309.pdf

¹⁸ Los Angeles County Metropolitan Transportation Authority, 2012, "Climate Change and Adaptation Plan".

http://www.metro.net/projects_studies/sustainability/images/Climate_Action_Plan.pdf

¹⁹ Transport for London, 2011, *Providing Transport Services Resilient to Extreme Weather and Climate Change*.

<http://archive.defra.gov.uk/environment/climate/documents/adapt-reports/06road-rail/transport-london.pdf>

²⁰ Transport for London, *Providing Transport Services*, 4.

²¹ The term "vulnerability assessment" is used in climate change adaptation literature and refers to processes which identify components of systems likely to be negatively impacted by the affects of climate change.

²² Jacob et al., *MTA Adaptations to Climate Change*, 20.

²³ Jacob et al., *MTA Adaptations to Climate Change*, 18.

²⁴ Los Angeles County Metropolitan Transportation Authority, "Climate Change and Adaptation Plan," 38.

²⁵ *Ibid*, 38.

²⁶ These recommendations are paraphrased/excerpted from Klaus Jacob et al. 2008. "MTA Adaptations to Climate Change: A Categorical Imperative."

http://www.mta.info/sustainability/pdf/Jacob_et%20al_MTA_Adaptation_Final_0309.pdf, 9, 37-44.

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- ²⁷ These recommendations are paraphrased/excerpted from Los Angeles County Metropolitan Transportation Authority. 2012. "Climate Change and Adaptation Plan."
http://www.metro.net/projects_studies/sustainability/images/Climate_Action_Plan.pdf, 61-62.
- ²⁸ Transport for London, *Providing Transport Services*, 19.
- ²⁹ Eugene Bardach, *A Practical Guide for Policy Analysis: The Eightfold Path to More Effective Problem Solving* (New York: Chatham House Publishers, Seven Bridges Press, 2000), 25-37.
- ³⁰ Ibid, 27.
- ³¹ Nikolai Bobylev, 2009, "Urban Underground Infrastructure and Climate Change: Opportunities and Threats," presented at the Fifth Urban Research Symposium 2009, June 29, Marseille, France.
- ³² Nicholas Perrin and Arun Agrawal, 2008, "The Role of Local Institutions in Adaptation to Climate Change." in Washington, DC: The World Bank, 10; Peter Plumeau and Stephen Lawe, 2009, "Meeting the Challenge of Institutional Fragmentation in Addressing Climate Change in Transportation Planning and Investment." *Transportation Research Record: Journal of the Transportation Research Board* 2139 (-1) (December 1): 85-86; Miranda A. Schreurs, "From the Bottom Up." *The Journal of Environment and Development* 17 (4), 351.
- ³³ WMATA, *Technical Report*, 47.
- ³⁴ A full discussion of the relationship between public opinion and the policy development can be found in Giandomenico Majone's *Evidence, Argument, & Persuasion in the Policy Process*. (New Haven: Yale University Press, 1989), 145-149.
- ³⁵ Though WMATA is viewed as one of the best public transit systems in the U.S., many local riders are very critical of WMATA and view it as too costly and incompetent. Middleton, "Washington's Magnificent Metro," 69.
- ³⁶ Although pilot projects for the FTA's Climate Change Adaptation Initiative have already been selected, WMATA could seek out opportunities to collaborate with the pilot projects. "FTA - Site Map - Announcement of Project Selections: Transit Climate Change Adaptation Assessment Pilots." http://www.fta.dot.gov/sitemap_14228.html.
- ³⁷ Alexander Veitch. 2012. "Adapting Rail Infrastructure to a Changing Climate- Public Private Collaboration" presented at the Policy Forum on Adaptation to Climate Change in OECD Countries, May 11, Paris.
<http://www.oecd.org/env/climatechange/50427617.pdf>