Climate Action Plans and Long-Range Transportation Plans in the Pacific Northwest: a review of the state of practice

Lindsay Walker
Portland State University
Phone: 707-362-1577
Email: lnwalker@pdx.edu

Miguel A. Figliozzi
Portland State University
Phone: 503-725-2836
Email: figliozzi@pdx.edu

Ashley R. Haire
Portland State University
Phone: 503-725-8928
Email: haire@pdx.edu

John MacArthur
Oregon Transportation Research and Education Consortium
Phone: 503-725-2866
Email: macarthur@pdx.edu

ABSTRACT

Research efforts of the last few years have produced a wealth of knowledge regarding the impacts of climate change on transportation infrastructure—impacts witnessed to date, as well as those anticipated in coming decades, the effects of which frequently conflict in both magnitude and scope. The research presented here explores the breadth of the climate change literature as it relates to surface transportation and synthesizes it to determine the greater consensus regarding the ways our transportation infrastructure may be affected by the changing global climate with a specific focus on transportation facilities and operations in the Pacific Northwest. This report builds upon recent research on governmental climate change planning efforts to explore (1) how agencies in the Pacific Northwest are preparing for climate change in their climate action plans (CAP), (2) how the goals and recommendations of CAPs are reflected in long-range transportation planning (LRTP) documents, and (3) to identify key resources and strategies for agencies to adopt to ensure that the anticipated impacts of climate change on transportation are addressed in planning documents.

INTRODUCTION

In early January 2009, a severe winter storm hit the Pacific Northwest. Heavy snow followed by abundant, warm rain led to extreme flooding and destructive landslides throughout the State of Washington, forcing emergency closures of multiple state and local highway routes, including Interstate 5 and Interstate 90, and the interruption of freight and passenger rail service. The economic cost of transportation impacts including freight disruptions and infrastructure damage was estimated in the tens of millions of dollars and Governor Gregoire eventually requested disaster relief from the federal government (Gregoire, 2009). However, this weather event was not an isolated case. During the previous winter, a similar storm created crippling conditions in the same areas. The costs of freight delays alone were estimated around 75 million dollars for the winter storm and flooding that closed I-5 and I-90 in the winter of 2007-08 (Washington State DOT, 2008).

At this time, is difficult to determine whether specific weather events like the storms in Washington can be definitively attributed to climate change or if they are instead severe storm occurrences within otherwise natural weather patterns. However, consensus in the scientific community indicates that major storms and other events including inundation of coastal roads from sea level rise, erosion of roadways and bridge supports from heavy precipitation, road and rail failures due to temperature extremes, and travel delays due to wildfires, are occurring more frequently and with greater intensity as a result of a warming climate. As seen in Washington, these types of events have the potential to cause significant damage to the transportation system and impose costly traveler delay, and yet to date, relatively little has been done by government agencies to comprehensively assess transportation vulnerabilities and prepare for the unavoidable impacts of climate change.

Recent studies indicate that climate change planning efforts conducted by governments thus far have overwhelmingly focused on mitigation strategies to reduce greenhouse gas (GHG) emissions, with few addressing climate change adaptation (Wheeler, 2008). Mitigation is indeed an important strategy to reduce the future impacts of climate change and possibly avoid the worst potential impacts. However, mitigation alone is not sufficient. Scientists agree that existing GHGs already present in the atmosphere will continue to warm the planet. Even in the highly unlikely circumstance that all GHG emissions were halted immediately we would still be committed to some climate changes that would need to be addressed in order to moderate or avoid damages, including damage to transportation infrastructure and system delay (Wheeler 2008). Thus, adaptation strategies are of critical importance in transportation planning to identify system vulnerabilities, build resiliency, reduce risk, and capitalize on any opportunities presented by climate change.

This report includes a discussion of the impacts climate change is projected to have on surface transportation infrastructure and operations. Furthermore, it explores the climate change literature at multiple levels of government to identify the transportation sector's response to climate change adaptation with a particular focus on actions

undertaken by agencies in the Pacific Northwest. It examines how agencies in the Pacific Northwest are preparing for these impacts in their Climate Action Plans (CAP) and the level to which the goals and objectives of CAPs have been incorporated into long-range transportation planning documents (LRTP). Since Climate Action Plans (CAP) and climate change adaptation planning efforts are relatively new planning concepts, recent climate change planning activities undertaken by agencies may not be revealed solely through review of publicly available planning documents. Thus, in addition to the literature review, representatives from transportation planning agencies were also contacted to participate in a survey to identify recent and/or ongoing climate change planning activities and adaptation planning resource needs. Key resources required by agencies in order to effectively address climate change adaptation for transportation in these plans are explored and strategies for better integrating climate change adaptation in future plans are presented.

MITIGATION AND ADAPTATION

Much of the existing climate change literature can be segmented into two categories: mitigation and adaptation. The Intergovernmental Panel on Climate Change (IPCC) defines mitigation as policies and strategies that reduce greenhouse gas emissions and/or enhance greenhouse gas absorption and storage (also known as GHG "sinks"). Climate change adaptation, on the other hand, is defined by the IPCC as "initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects" (Metz, et al., 2007).

Climate change mitigation in the transportation sector includes a wide range of strategies including improvements in vehicle and fuel technologies, reductions in vehicle miles traveled, and improvements in vehicle and system operations to increase efficiency of travel, all of which reduce GHG emissions (Cambridge Systematics, 2009). The Transportation Research Board's (TRB) *Special Report 299: Adaptation Research Programs and Funding*, describes climate change adaptation strategies as either reactive, addressing existing risks, or proactive, addressing anticipated future risks (McNeil, 2009). Transportation adaptation strategies can be technological (e.g., enhanced monitoring or construction of infrastructure such as a sea wall), policy based (e.g., incorporating climate change projections into project planning processes), behavioral (e.g., restricting road access), and/or managerial (e.g., a change in management of roadside vegetation to reduce wildfire and/or landslide risk) (Parry et al, 2007).

Mitigation is clearly a critical aspect of transportation planning for climate change and has been the primary focus of government planning efforts to date. The transportation sector is estimated to account for approximately 28% of GHG emissions nationally and an even greater percentage in the Pacific Northwest (Transportation and Climate Change, 2008). Mitigation strategies that reduce the transportation sector's GHG contribution have the potential to lessen the magnitude of future climate change impacts and the speed with which they will occur. This reduces the level of adaptation required in the future and potentially "buys time" for communities to implement adaptation strategies and avoid costly impacts. In fact, due to this relationship between

mitigation and adaptation, mitigation has been referred to as the "number one preparedness strategy" (Climate Impacts Group, 2007).

However, while mitigation and adaptation strategies are complementary, it is recognized that climate change impacts observed today are the result of past GHG emissions. Current reduction efforts are neither sufficient nor are they occurring fast enough to avoid all future impacts. Furthermore, recent research indicates that some climate change impacts may occur sooner or more rapidly than initially projected in climate models (Pew Center for Global Climate Change, 2009). Simply put, there will be unavoidable impacts of climate change that will require adaptation, including changes in the way we build and manage surface transportation.

CLIMATE CHANGE PROJECTIONS AND IMPACTS ON SURFACE TRANSPORTATION

Climate change currently affects or will affect public life across a variety of sectors, including agriculture, public health, wildlife management, and water resources, to name a few. Transportation infrastructure and operations will be affected by climate change as well, with a direct impact on commerce. Climate change projections, including anticipated impacts on the transportation system, have been developed at the national level. However, these projections and their associated impacts can vary significantly depending on location. Climate change projections at the state or regional level (when available) are generally most useful for adaptation planning, as adaptive strategies will be implemented primarily at the sub-national level through state and city Departments of Transportation (DOTs) and Metropolitan Planning Organizations (MPOs) (Lindquist, 2007).

National

Projected Climate Changes. Temperatures across the continental U.S. are projected to increase from 3-7° Celsius depending on location, 33 percent greater than the global average increase. Precipitation is expected to increase overall across the U.S. except in the Southwest, along with more intense heavy precipitation and hurricanes. Winter snowpack amounts are anticipated to decline and melt earlier in the western U.S. and Great Lakes region (Pew Center for Global Climate Change, 2009).

Impacts on Transportation Infrastructure and Operations. In 2008, the TRB released *Special Report 290: Potential Impacts of Climate Change on U.S. Transportation*. This report summarizes the impacts climate change is having or is anticipated to have on U.S. transportation infrastructure and operations across a variety of modes. Five climate changes were identified that are expected to have the greatest impact on transportation: increases in very hot days and heat waves, increases in Arctic temperatures, rising sea levels, increases in intense precipitation events, and increases in hurricane intensity. Table 1 provides examples adapted from the TRB 290 report of potential impacts these changes are likely to have on transportation.

Table 1: Examples of climate change impacts on transportation operations and infrastructure

Climate Change	Impact on Operations	Impact on Infrastructure
Increases in very hot days and heat waves	- Limited rail operating speeds - Delays due to wildfire	- Railroad track deformities - Reduced pavement performance and life, increased maintenance
Increases in Arctic temperatures	- Shortened seasonal access to ice roads - Longer marine transport seasons and new routes	- Damage to roadway integrity due to thawing of permafrost
Rising sea levels	- Increased travel interruptions due to more frequent flooding	- Damage to coastal facilities due to erosion and inundation
Increases in intense precipitation events	- Increased travel delays and closures caused by flooding and severe storms	- Increased risk of landslide and roadway washouts - Bridge support scour
Increases in hurricane intensity	- More frequent emergency evacuations - Impacts to marine transport	- Damage to coastal transportation infrastructure and increased risk of failure

Pacific Northwest (Washington, Oregon, and Idaho)

Projected Climate Changes. In 2007, the IPCC released *Climate Change 2007: The Physical Science Basis*, which included comprehensive regional climate projections. The modeling effort responsible for these projections (MMD-A1B) assumes a "medium" or moderate emission scenario.

According to this report, the Pacific Northwest is expected to experience an approximate 2-3°C increase in average annual regional temperatures over the course of this century. Temperature changes during summer months are projected to increase approximately 1.5-2.5°C, and 3.5-7°C during winter months (Solman, et al, 2007).

Average annual change in precipitation in the Pacific Northwest is projected to increase by up to about 10 percent. During summer months, precipitation is expected to decrease approximately 5-15 percent, and increase during winter months approximately 15-30 percent. Overall, an increase in extreme daily precipitation is forecasted (Mote, P. and Salathé, E., 2009).

Other reports suggest that changes in extreme precipitation are uncertain, however, they also suggest that with warmer winter temperatures, precipitation is more likely to fall as rain rather than snow. In addition to a reduced winter snowpack, increased rain will result in "higher winter streamflows, earlier spring snowmelt, earlier peak spring streamflow, and lower summer streamflows in rivers that depend on snowmelt (i.e., most rivers in the Pacific Northwest)" (Climate Impacts Group, 2007). Drier, warmer summers may also increase wildfire risk.

Potential Impacts on Transportation Infrastructure and Operations.

- Increased flooding
- Travel delay associated with wildfire response
- Damage to coastal infrastructure due to inundation and increased storm surge risk related to sea-level rise
- Changes in surface water elevation may impact river transportation (clearance and depth)

Alaska

Projected Climate Changes. Temperature and precipitation changes for the Alaska region were also obtained from the IPCC report following the same modeling assumptions and timeframe as that described for the Pacific Northwest.

Alaska is expected to experience greater temperature changes compared to the Pacific Northwest, with an average annual regional temperature increase of approximately 3.5-5°C over the course of this century. Temperature changes during summer months are projected to increase approximately 2-2.5°C, and 3.5-10°C during winter months (Solman, et al, 2007).

Average annual precipitation in Alaska is projected to increase approximately 10-15 percent. Precipitation is expected to increase in both summer and winter seasons; approximately 10-20 percent during summer months and 15-30 percent during winter months.

Warmer temperatures in Alaska will contribute to thawing of permafrost, glacial melt, loss of sea ice, and may contribute to frequency of forest fires (Climate Impacts Group, 2007). Retreat of glacial ice may cause land surface uplift in some locations (as seen in parts of southeast Alaska) while sea level rise presents coastal erosion, inundation and storm surge risks. Increased storm frequency and intensity are also projected.

Potential Impacts on Transportation Infrastructure and Operations.

- Damage to roadway infrastructure due to permafrost thaw
- Travel delay associated with wildfire response
- Damage to coastal infrastructure and erosion due to inundation and increased storm surge risk related to sea level rise and coastal permafrost thaw
- Reduced sea ice may offer new maritime shipping routes

In some locations, such as Puget Sound in Washington, more localized climate change projections have been developed by agencies and non-profit organizations in order to anticipate potential local impacts. Although most agencies acknowledge the importance of planning for adaptation, and the value of this type of local data, it generally does not appear to be developed in most locations.

TRANSPORTATION SECTOR RESPONSE TO CLIMATE CHANGE ADAPTATION

National Response

The U.S. federal government contributes significantly to research and public-private partnerships on climate change, however there is currently no broad federal policy addressing climate change. One such policy, the "American Clean Energy and Security Act" (H.R. 2454: Waxman-Markey Bill), recently approved by the U.S. House of Representatives and currently being debated in the U.S. Senate, contains legislation addressing both mitigation and adaptation (Cruces, 2009). In lieu of federal action on climate change, much of the mitigation and adaptation efforts have instead occurred at the state, regional and local levels.

At the national level, the Federal Highway Administration has made progress in climate change research and guidance development to facilitate mitigation and adaptation efforts at lower levels of government. Activities include "meeting with experts to gather information and plan activities, educating division offices, developing a clearinghouse of climate change data for DOTs and others, and providing technical assistance" (Transportation and Climate Change, 2008).

Non-governmental organizations and research consortiums such as the Transportation Research Board and International Council for Local Environmental Initiatives (ICLEI) have also contributed a significant amount of climate change adaptation research, planning guidance and technical assistance to communities across the nation.

States, Regional and Local Responses

According to the Pew Center on Global Climate Change, 36 states now have a CAP completed or in progress (Pew Center for Global Climate Change, 2009). The majority of these plans focus primarily (or exclusively) on climate change mitigation. However, only ten states have a climate change adaptation plan completed or in progress. Table 2 provides an overview of transportation-related goals and objectives contained in CAPs and LRTPs in the Pacific Northwest and Alaska, with a focus on climate change adaptation efforts.

Table 2: State, Regional and Local Plans and Adaptation

	Climate Action Plan(s)	Long-Range Transportation Plan
STATE		
Alaska	- *2009 Alaska's Climate Change Strategy: Addressing Impacts in Alaska (Draft).* Comprehensive adaptation plan, including climate change impacts and recommended actions for public infrastructure including transportation. - *2009 Immediate Action Workgroup Recommendations to the Governor's Subcabinet on Climate Change.* Provides short-term immediate action adaptation recommendations.	- *2008 Alaska Statewide Long-Range Transportation Policy Plan 2030.* Includes discussion of need to consider climate change and adaptation, but is not action-oriented.
Washington	- *2008 Growing Washington's Economy in a Carbon-Constrained World: A Comprehensive Plan to Address the Challenges and Opportunities of Climate Change.* Mitigation-focused, but calls for inclusion of adaptation in Environmental Impact Statements and State Environmental Policy Act documents. - *2008 Climate Change Interim Report: Leading the Way on Climate Change: The Challenge of Our Time.* Combines Transportation with other infrastructure (e.g., stormwater). Provides some impact projections as areas at risk to flooding/inundation. Calls for comprehensive data collection.	- *2006 Washington Transportation Plan 2007-2026.* Climate change discussion is limited to mitigation.
Oregon	- *2004 Oregon Strategy for Greenhouse Gas Reduction.* Some discussion of need for adaptation. Calls for development of an adaptation plan. - *2008 Final Report to the Governor: A Framework for Addressing Rapid Climate Change.* Places greater emphasis on adaptation strategies across disciplines including transportation. Provides recommendations to improve planning processes. Transportation actions relate to mitigation only.	- *2006 Oregon Transportation Plan.* Some discussion about climate change primarily related to mitigation. Briefly mentions potential impact of sea level rise on coastal facilities.

	Climate Action Plan(s)	Long-Range Transportation Plan
Idaho	- Climate action plan is in progress. - *2008-09 Fiscal Year Greenhouse Gas Emission Reduction Action Plan.* Mitigation only, applies to State activities only.	- *2004 Idaho Transportation Vision 2034.* No discussion of climate change.
Upper Willamette River Basin, Oregon	2*009 Preparing for Climate Change in the Upper Willamette River Basin of Western Oregon.* Discusses climate change impacts on transportation and acknowledges need for adaptation, but recommendations are mitigation-focused.	n/a
LOCAL		
City of Portland, Oregon/Multnomah County	- *2009 Portland/Multnomah County Climate Action Plan.* Primarily mitigation with a brief discussion of adaptation. Calls for "integrating climate change adaptation…into major planning efforts," but lacks specificity. Interestingly, the original draft of this document did not include adaptation, but was later incorporated based on public comment.	- *2006 Portland Transportation System Plan.* No discussion of climate change.
City of Olympia, Washington	- *2007 Olympia's Response to The Challenge of Climate Change Background Report and Preliminary Recommendations.* Discusses existing and future adaptation efforts, mostly in relation to sea level rise, though not well tied to transportation. Calls for vulnerability assessments with participation from Public Works. - *1991 City of Olympia's Response to the Challenge of Global Climate Change*. One of the first city climate plans. Discusses climate change impacts and responses including planned location of infrastructure.	- *2009 Olympia Transportation Mobility Strategy.* Discussion of climate change in reference to mitigation only.
City of Seattle, Washington	- *2006 Seattle Climate Action Plan.* Includes discussion of adaptation and projected impacts. Recommended actions are mitigation-focused.	- *2005 Seattle Transportation Strategic Plan.* No discussion of climate change.

	Climate Action Plan(s)	Long-Range Transportation Plan
King County, Washington	- *2007 King County Climate Plan.* One of the most comprehensive plans reviewed. Not only discusses climate change impacts but also outlines specific goals and actions for both mitigation and adaptation across sectors including transportation.	- *2004 County Roads Strategic Plan.* Intended to bridge "high-level policy guidance [in the Comprehensive Plan] and the day-to-day practices, procedures, and decision-making" but includes no mention of climate change. Related Comprehensive Plan does discuss both mitigation and adaptation.
City of Boise, Idaho	- No climate change planning document. - Climate Advisory Committee has been established but is mitigation-focused.	- *2006 Boise Communities in Motion: Regional Long-Range Transportation Plan 2030.* No mention of climate change.
City of Homer, Alaska	- *2007 Homer Climate Action Plan.* Primarily mitigation-focused. Includes brief discussion of adaptation measures. Calls for consideration of climate change in all long-range planning including transportation. Calls for proactive measures to protect or relocate at-risk infrastructure to avoid sea level rise impacts and management plans for the port that consider climate change.	- *2005 City of Homer Transportation Plan.* No discussion of climate change.

When compared to similar agencies across the United States, agencies in the Pacific Northwest and Alaska are exceptional in that nearly all have existing CAPs or plans in progress, and several either have incorporated climate change adaptation strategies into these documents or have stand-alone adaption plans. However, there is significant variation among these agencies in the scope and depth of adaptation planning discussion, and there remains a tendency for agencies to focus predominantly on climate change mitigation, particularly when stating goals and objectives on which to take action.

There also appears to be disconnect between CAPs and the LRTPs for the corresponding jurisdiction. While the CAP may include recommendations for transportation adaptation, these recommendations are seldom incorporated into the LRTP. This oversight may be temporary due to the fact that the reviewed transportation plans were generally adopted prior to development of the CAPs and that the majority of climate action plans have only recently been completed. Nonetheless, this deficiency is likely to present issues with implementation of transportation adaptation recommendations since

transportation planners rely on LRTPs for reference in planning and design decision-making. Although a lack of CAP integration in LRTPs does not necessarily indicate that climate change considerations will be overlooked in transportation planning efforts, it does limit planners' awareness of potentially valuable information and contributes to transportation planning "business as usual."

These findings are overall similar to results of research conducted separately by Wheeler and Lindquist, researchers who have examined climate change planning activities by government agencies at various institutional levels in terms of both climate change mitigation and adaptation. Both researchers performed content analysis of planning documents and conducted phone interviews with agency representatives to assess climate change planning activities nationwide. Wheeler focused on general climate change planning efforts of state and city governments, while Lindquist focused on transportation planning efforts of state DOTs and MPOs. Wheeler's research confirms that most climate change planning activity occurs at the sub-national level and tends to focus on mitigation (Wheeler, 2008). Lindquist's preliminary research findings revealed that with the exception of four states (including Oregon and Washington), most of the DOT and MPO general planning documents, mission statements and strategic plans available at the time of analysis failed to address climate change in any regard (Lindquist, 2007).

Although many climate action plans include a high-level discussion of anticipated climate change impacts and the need to adapt, few outline goals or actions in enough specificity to be useful to transportation planners. These omissions may provide another reason why CAP goals have generally failed to be incorporated into LRTPs and may hinder future attempts to incorporate CAP goals during LRTP updates. For example, a CAP may state that infrastructure may be subject to increased flooding, but fails to specify the intensity of flooding, locations of potentially vulnerable infrastructure or how vulnerable infrastructure will be indentified. This tendency can be attributed to a general lack of localized data on the range of potential climate change impacts and plans frequently defer this type of data collection to later research efforts. For instance, detailed research efforts looking at the impact of climate change on local transportation infrastructure in the Portland metropolitan region require a substantial geomorphologic, hydrological, and field data collection effort (Chang, et al.). In addition, the estimation of costs associated with climate change impacts on flooding events is difficult due to the lack of complete and systematic records and the uncertainty related to the estimation of the incremental impacts of climate change on flood event magnitudes, frequencies, and durations (Figliozzi, 2010). In some cases, more specific data is available in other climate planning documents, but can at times be difficult to identify and readily locate.

Of the CAPs reviewed for this report, the 2007 King County Climate Plan provides perhaps the best example of plan recommendations that can be integrated into an LRTP, although this has not yet occurred (like many plans reviewed in this document, the LRTP was developed prior to the CAP). However, the 2007 CAP is not intended to be a stand-alone document and specifically calls for review of the LRTP and other

relevant planning documents to ensure that recommendations and actions of the CAP are incorporated.

The King County plan also provides specific, locally relevant climate change impact projections such as the extent sea-level rise anticipated to affect portions of Puget Sound and locations where climate-warming impacts on snowpack will be most pronounced. It identifies critical infrastructure impacts including those to transportation through flood boundary delineation and other research efforts. In order to better understand current and potential climate impacts, the CAP relies on an expert technical advisory team to continue local climate change research and monitoring, as well act as an advisor to departments and decision makers. The CAP recognizes the importance of outreach and coordination within and across agencies at all levels of government and details education efforts aimed at staff, decision makers and the public about climate change impacts.

Since CAPs and climate change adaptation planning efforts are relatively new planning concepts and there is often a lengthy internal process before draft plans are available, more recent climate change planning activities undertaken by agencies may not be revealed solely through review of publicly available planning documents. Thus, in addition to the literature review, representatives from transportation planning agencies were also contacted to participate in a survey to identify recent and/or ongoing climate change planning activities and adaptation planning resource needs.

A SURVEY OF TRANSPORTATION PLANNERS IN THE PACIFIC NORTHWEST

In fall 2009, a brief online survey was conducted among transportation planners, engineers and program managers in Alaska, Washington, Oregon and Idaho in order to gain an understanding of what activities transportation agencies in the Pacific Northwest were undertaking in terms of planning for climate change. Survey participants at the state, regional and local levels were selected through a convenience sample, either having been identified on agency websites as a climate change contact or by personal reference.

The online survey was composed of nine multiple-choice, short answer and ranking questions. Questions elicited information such as whether the agencies' climate change planning activities were related to mitigation and/or adaptation, which activities they have or are currently engaged in to assess potential impacts of climate change on their transportation facilities and the relative importance of different resources to effectively assess these impacts. In addition, respondents were offered the opportunity to provide additional comments, hyperlinks to online reports and webpages, as well as to upload files to researchers via File Transfer Protocol. In all, nine responses were received for a response rate of approximately 33 percent (n=27). Likely due in part to reliance on personal reference for sampling, all but one of the respondents were located in Washington and Oregon.

Nearly all respondents indicated that their agency was involved in both mitigation and adaptation climate change planning activities. This result was initially surprising considering that the existing climate change literature from the Pacific Northwest and Alaska reviewed for this report tends to favor climate change mitigation. Washington agencies have in general made progress in terms of planning for both climate change mitigation and adaptation, and several Oregon agencies recently began adaptation planning. Furthermore, as mentioned previously, the process of plan development and update requires a significant amount of time and agency adaptation efforts may not be documented until the approval of the next plan update.

The most common activities taking place by surveyed agencies include climate change research and strategy meetings, followed by location-specific efforts (e.g., considering potential impacts of climate change for a particular project location). Less common activities included scenario testing, both to identify facilities that may be impacted under different climate change impact assumptions and to inform the location or design of planned transportation facilities.

The availability of projected climate change impacts at the local level was rated as most important by respondents in terms of resources required by agencies to effectively assess the impacts of climate change on agency facilities, followed by staff expertise and financial resources. Overall, respondents rated methodology guidance resources as less important than other resources.

Nearly all respondents reported that their transportation facilities had been impacted by flooding and major storm events in the last decade. Many respondents also reported erosion as an impact. As a result of these events, the majority of respondents indicated that facilities were damaged, service was impacted or facilities were closed. Slightly less than half of the respondents indicated that their agency collects cost data associated with these events, but very few indicated that their agencies have a mechanism for recording the frequency with which facilities are impacted. Most respondents indicated that their agencies have methods to identify facility vulnerabilities to these types of events. As previously indicated, the estimation of costs associated with climate change impacts on flooding events is difficult due to the lack of complete and systematic records and the uncertainty related to the estimation of the incremental impacts of climate change on flood event magnitudes, frequencies, and durations.

KEY RESOURCES AND STRATEGIES TO PLAN FOR CLIMATE CHANGE ADAPATION IN LONG RANGE TRANSPORTATION PLANNING

Agencies in the Pacific Northwest and Alaska have been recognized as early adopters of climate change planning, in terms of both climate change mitigation and adaptation. However, literature review and survey results conducted for this study reveal a continued need to better integrate CAPs and LRTPs, as well as the need for key resources in order for agencies to effectively plan for adaptation of transportation infrastructure and operations.

There are several documents that highlight the key resources and strategies recommended for adoption in order to plan for climate change adaptation including ICLEI's *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments*, the Transportation Research Board's *Special Report 290: Potential Impacts of Climate Change on U.S. Transportation* and the Federal Highway Administration's *Summary Report: Peer Workshop on Adaptation to Climate Change Impacts*. In the following section, recommendations based on the results of this study are briefly summarized along with complementary key recommendations provided in these documents.

Develop Locally Relevant Climate Change Projections and Collect Data on Impacts Already Observed.

Both in the survey conducted for this report and in multiple guidance documents the availability of local climate change impact projections (often ranging depending on scenario) were noted as one of the most important resources necessary for effective climate change adaptation planning. Geographically specific climate projections and impacts are key for transportation and other agencies to identify system vulnerabilities and develop appropriate proactive and/or reactive planning scenarios. Examples include local estimates for sea-level rise and changes in intensity and frequency of storm events. It is highly recommended that agencies at different levels of government and across different sectors work to develop common impact scenarios to better facilitate information sharing and coordinated planning efforts. In addition to preparing for anticipated future impacts of climate change, agencies need also to collect data on climate change impacts already observed as well as monitor changes that occur over time.

Inventory System Vulnerabilities and Identify Critical Infrastructure.

Local data on existing and projected climate change impacts are necessary in order to assess transportation vulnerabilities and to mitigate or avoid the impacts of climate change. In the survey conducted for this report many agencies indicated that they already have existing methods to identify existing transportation system vulnerabilities to flooding and major storm events. An inventory of system vulnerabilities and critical infrastructure assists planners in prioritizing adaptation improvements and provides assurance that funding resources are directed appropriately. It is commonly recommended that agencies adopt a "risk-management" approach wherein the consequences of potential delay on, damage to or loss of a transportation facility and the probability of the its occurrence are considered when developing adaptation strategies.

These efforts can be completed as part of the CAP or, if too complex and specific for a CAP that addresses multiple sectors, completed as a follow-up effort by the relevant agency. However, funding should be secured to ensure follow through and coordination is required to ensure consistency among specific plans. Strategies developed from scenario testing should then be integrated in LRTPs as well as capital improvement and other plans.

Cooperate Across Disciplines and Agencies.

Although CAP development is likely to include some representation from transportation agencies or departments, environmental or other departments have often been responsible for coordination and development of CAPs. Significant cooperation between agencies is needed to share information and ensure that goals and actions are consistent across plans. At a minimum, representatives developing the CAP should be involved in development and update of the LRTP and vice-versa. In some circumstances, incorporation of a new plan element such as climate change planning and adaptation may require changes in department procedures and potentially in legislation describing required components of the CAP and/or LRTP.

Development of clearinghouses for climate change data projections and planning documents are frequently recommended to ensure that multiple agencies and disciplines have access to common data and to avoid the costs associated with parallel data collection and analysis efforts.

Outreach and Education.

The results of our survey indicate that most agencies in the Pacific Northwest are aware of the need for climate change adaptation planning in transportation. All respondents have been impacted in recent years by many of the weather events expected to increase in frequency and severity due to climate change, and most already have or are beginning to consider climate change adaptation in their transportation planning efforts. However, furthering awareness of the likely climate change impacts at the local level in the near and more distant future elevates the importance of adaptation planning among the public and decision makers. This increased awareness of the risks posed by climate change may contribute to allocation of funding to conduct necessary data collection and comprehensive planning efforts. Outreach and education within and across government agencies and development of staff expertise on projected climate change impacts and adaptation strategies are also necessary to ensure successful implementation of planning actions.

CONCLUSION

Transportation infrastructure and operations across the nation are at risk from the current and projected impacts of climate change. CAPs developed by agencies across the nation have focused primarily on mitigation strategies to reduce greenhouse gases, but few address climate change adaptation strategies to avoid or mitigate the projected consequences of a changing climate. In the Pacific Northwest and Alaska, most agencies have or are developing adaptation strategies in their CAPs, however, the scope and depth of adaptation planning among agencies is highly varied and there remains a tendency for agencies to focus predominantly on climate change mitigation, particularly when outlining recommended actions to respond to climate change.

Furthermore, reviews of climate action plans and long-range transportation plans from state, regional, and local agencies in the Pacific Northwest and Alaska reveal frequent disconnect between climate action planning and long-range transportation planning efforts. Although transportation officials are often consulted in the development of the CAPs, the recommendations in these plans have often not been well incorporated into the LRTPs, presenting future conflicts with implementation of transportation-related climate action plan goals and actions.

To better address climate change adaptation for transportation in future plans, key resources, such as locally relevant data on current and projected climate change impacts must be developed along with inventories of critical infrastructure and transportation system vulnerabilities. Additionally, planning strategies, including improved agency coordination to ensure that goals and actions are consistent across plans and education and outreach programs should be adopted to better integrate climate change adaptation recommendations into transportation plans.

REFERENCES

Adaptation Advisory Group to the Alaska Climate Change Sub-Cabinet, Alaska's Climate Change Strategy: Addressing Impacts in Alaska (Alaska Department of Environmental Conservation, 2009), http://www.climatechange.alaska.gov/aag/docs/AAG_dftrpt_pt1_1sep09.pdf

Alaska Department of Transportation and Public Facilities, "Let's Get Moving 2030: Alaska Statewide Long-Range Transportation Policy Plan," February 2008, http://dot.alaska.gov/stwdplng/areaplans/lrtpp/documents/SWLRTPPfinal022908.pdf.

"Boise Communities in Motion: Regional Long-Range Transportation Plan 2030," Regional Long-Range Transportation Plan 2030, August 21, 2006, http://www.communitiesinmotion.org/plandocuments.html.

"City of Homer Climate Action Plan," December 2007, http://www.ci.homer.ak.us/CLPL.pdf.

Cambridge Systematics, Inc., "Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions" (Urban Land Institute, July 2009).

Chang H., Lafrenz M., Figliozzi M., Platman D., and Pederson, C, "Climate Change and Urban Flooding: Potential Impacts on Transportation Systems." Forthcoming Annals of the Association of American Geographers.

Christine, Gregoire, "Governor Gregoire's Flood Disaster Declaration Request to President Obama.," January 21, 2009, http://www.piersystem.com/posted/1105/Governor_s_Flood_Disaster_Declaration_Request_.250185.pdf.

City of Homer, "2005 Homer Area Transportation Plan," June 2005, http://www.ci.homer.ak.us/transport.pdf.

City of Olympia Public Works, "City of Olympia's Response to the Challenge of Global Climate Change," December 1991, http://www.olympiawa.gov/en/community/sustainability/~/media/Files/PublicWo

rks/technicalservices/1991UpdatedCityofOlympiasResponsetotheChallengeofGlobalClimateChange.ashx.
City of Portland Bureau of Planning & Sustainability and Multnomah County, "City of Portland and Multnomah County Climate Action Plan 2009," October 2009, http://www.portlandonline.com/bps/index.cfm?c=49989&a=268612.
City of Portland Bureau of Transportation, "2006 Portland Transportation System Plan," Transportation System Plan, May 4, 2007, http://www.portlandonline.com/transportation/index.cfm?c=39112.
Climate Impacts Group, Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments, 2007, 142-143.
Climate Impacts Group, Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments, 2007, http://www.icleiusa.org/action-center/planning/adaptation-guidebook/.
Co-Beneficial Planning for Communities and Ecosystems, "Preparing for Climate Change in the Upper Willamette Basin of Western Oregon," March 2009, http://climlead.uoregon.edu/sites/climlead.uoregon.edu/files/reports/willamette_report3.11FINAL.pdf.
Cruces, Terri, Adaptation Planning – What U.S. States and Localities are Doing. Pew Center for Global Climate Change (Arlington, VA: Pew Center for Global Climate Change, 2009), http://www.pewclimate.org/docUploads/state-adapation-planning-august-2009.pdf.
ECONorthwest, "Olympia Transportation Mobility Strategy," Transportation Mobility Strategy, August 4, 2009, http://www.ci.olympia.wa.us/en/city-services/transportation-services/plans-studies-and-data/Plans%20and%20Studies%20-%20Mobility%20Strategy.aspx.
Eric Lindquist, "Climate Change and Adaptive Strategies in Sub-national Transportation Planning Agencies in the United States," in (presented at the 2007 Amsterdam Conference on the Human Dimensions of Global Environmental Change "Earth System Governance: Theories and Strategies for Sustainability", Vrije Universiteit, Amsterdam, 2007), http://www.2007amsterdamconference.org/Downloads/AC2007_Lindquist.pdf.
Figliozzi, et al., "Quantifying and Analyzing the Costs of Climate Change on Local Transportation Infrastructure: A case study from Portland, Oregon," (Proceedings of the 89th Transportation Research Board Annual Meeting CDROM - Washington DC. USA, 2010).
Governor's Advisory Group on Global Warming, Oregon Strategy for Greenhouse Gas Reductions, December 2004, http://www.oregon.gov/ENERGY/GBLWRM/docs/GWReport-FInal.pdf.
Governor's Climate Change Integration Group, Final Report to the Governor: A Framework for Addressing Rapid Climate Change, January 2008, http://www.oregon.gov/ENERGY/GBLWRM/docs/CCIGReport08Web.pdf.
Idaho's Transportation Partners, "Idaho Transportation Vision 2034," 2004, http://itd.idaho.gov/planning/futuretravel/Vision.pdf.
Immediate Action Workgroup, "Recommendations to the Governor's Subcabinet on Climate Change," March 2009, http://www.climatechange.alaska.gov/docs/iaw_finalrpt_12mar09.pdf.

King County Department of Transportation Roads Services Division, "King County Roads Strategic Plan," March 2004, http://your.kingcounty.gov/kcdot/roads/wcms/planning/strategicplan/RoadsStrategicPlan.pdf.

King County, "King County 2007 Climate Plan," February 2007, http://your.kingcounty.gov/exec/news/2007/pdf/ClimatePlan.pdf.

Metz et al., Climate Change 2007: Mitigation of Climate Change (Cambridge, United Kingdom and New York, NY, USA: IPCC - Intergovernmental Panel on Climate Change, 2007), http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg3_report_mitigation_of_climate_change.htm.

Mote P. and Salathé E., Future climate in the Pacific Northwest, Chapter 1 in The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate (Seattle, Washington: University of Washington Climate Impacts Group, 2009), http://cses.washington.edu/db/pdf/wacciaexecsummary638.pdf.

Olympia Public Works Department, "Olympia's Response to The Challenge of Climate Change," September 2007, http://www.olympiawa.gov/documents/PublicWorks/Climate_Change/Climate_%20Change_1.pdf.

Oregon Department of Transportation, "Oregon Transportation Plan," September 20, 2006.

Otter, C.L., "State of Idaho Executive Order Establishing a State Policy Regarding the Role of State Government in Reducing Greenhouse Gases," http://gov.idaho.gov/mediacenter/execorders/eo07/eo_2007_05.html.

Parry et al., Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge, United Kingdom: IPCC - Intergovernmental Panel on Climate Change, 2007), http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-spm.pdf

Pew Center on Global Climate Change, "Climate Change 101: Preparing for a Warmer World", 2009, http://www.pewclimate.org/docUploads/Climate101-Complete-Jan09.pdf.

Pew Center on Global Climate Change, "U.S. Climate Policy Maps," 2009, http://www.pewclimate.org/what_s_being_done/in_the_states/state_action_maps.cfm.

Solman, et al., Regional Climate Projections. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge, United Kingdom and New York, NY: Cambridge University Press, 2007.), http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter11.pdf.

Stephen Wheeler, "State and Municipal Climate Change Plans: The First Generation," Journal of the American Planning Association 74, no. 4 (2008): 481-496.

Sue McNeil, Special Report 299: Reducing Transportation Greenhouse Gas Emissions and Energy Consumption: A Research Agenda: Adaptation Research Programs

and Funding (University of Delaware: Transportation Research Board, October 2009), 14, http://onlinepubs.trb.org/onlinepubs/sr/SR299Adaptation.pdf.
Transportation and Climate Change: Time to Think, Plan, Mitigate, and Adapt, Webinar, Center for Transportation and the Environment National Broadcast Series, 2008, http://cte.ncsu.edu/CTE/TechTransfer/Teleconferences/archive.asp.
Transportation Research Board, Transportation Research Board Special Report 290: Potential Impacts of Climate Change on U.S. Transportation, 2008, http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf.
U.S. Department of Transportation Federal Highways Administration, "Summary Report: Peer Workshop on Adaptation to Climate Change Impacts - Statewide Transportation Planning - Planning - FHWA," December 2008, http://www.fhwa.dot.gov/planning/statewide/pwsacci.htm.
Washington State Department of Ecology, "Climate Change - 2008 Climate Change Interim Report," 2008 Climate Change Interim Report: Leading the Way on Climate Change: The Challenge of Our Time, March 24, 2008, http://www.ecy.wa.gov/climatechange/interimreport.htm.
Washington State Department of Transportation Freight Systems Division, Storm-related closures of I-5 and I-90: Freight Transportation Economic Impact Assessment Report, Final Research Report WA-RD 708.1, September 2008.
Washington State Transportation Commission and Washington State Department of Transportation, Washington Transportation Plan 2007-2026, November 14, 2006, http://www.wsdot.wa.gov/NR/rdonlyres/083D185B-7B1F-49F5-B865-C0A21D0DCE32/0/FinalWTP111406.pdf.