Climate Action Plans and Long-Range Transportation Plans in the Pacific Northwest and Alaska

State of the Practice in Adaptation Planning

Lindsay Walker, Miguel A. Figliozzi, Ashley R. Haire, and John MacArthur

Research efforts in the past decade have produced a wealth of knowledge about the likely impacts of climate change on transportation infrastructure—effects witnessed to date as well as those anticipated in coming decades—the effects of which frequently conflict in both magnitude and scope. This research summarizes the findings of the surface transportation climate change literature and explores the efforts under way in the transportation planning realm with respect to adaptive preparations of transportation infrastructure for the effects of climate change. This research focuses on transportation facilities and operations in the Pacific Northwest region of the United States. This report builds on recent research on governmental climate change planning efforts to explore how agencies in Alaska, Idaho, Oregon, and Washington are preparing for climate change in their climate action plans, to investigate how the goals and recommendations of those plans are reflected in long-range transportation planning documents, and to identify key resources and strategies agencies may adopt to ensure that the anticipated impacts of climate change on transportation are addressed in transportation planning documents.

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 interruption of freight and passenger rail service. The economic consequences from storm-related effects on the transportation system, including freight disruption and infrastructure damage, were estimated in the tens of millions of dollars and Governor Chris Gregoire requested disaster relief from the federal government (*1*). However, this weather event was not an isolated case. The previous winter, a similar storm had created crippling conditions in the same areas. The costs of freight delays alone were estimated at around $75 million for the winter storm and flooding that closed I-5 and I-90 in the winter of 2007 and 2008 (*2*).

L. Walker, 1414 North Blandena Street, Portland, OR 97217. M. A. Figliozzi and A. R. Haire, Department of Civil and Environmental Engineering, Portland State University, P.O. Box 751 CEE, Portland, OR 97207. J. MacArthur, Oregon Transportation Research and Education Consortium, P.O. Box 751, Portland, OR 97207-0751. Corresponding author: M. A. Figliozzi, figliozzi@pdx.edu.

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It is difficult to determine whether specific weather events like the storms in Washington can be definitively attributed to climate change or if they are 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 a rising sea level, 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. These types of events have the potential to significantly damage the transportation system and impose costly delays on travelers; to date, relatively little has been done by government agencies to assess transportation system vulnerabilities and prepare for the unavoidable impacts of climate change.

Recent studies indicate that climate change planning efforts conducted by governments have overwhelmingly focused on mitigation strategies to reduce greenhouse gas (GHG) emissions, with few addressing adaptation approaches to climate change (*3*). Mitigation is 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 in the atmosphere will continue to warm the planet. Even in the highly unlikely circumstance that all GHG emissions were halted immediately, some climate change would still need to be addressed to moderate or avoid damage, including damage to transportation infrastructure and system delay (*3*). Thus, adaptation strategies are critically important in transportation planning to identify system vulnerabilities, to build resiliency, to reduce risk, and to capitalize on any opportunities presented by climate change.

This report includes a discussion of projected impacts of climate change on surface transportation infrastructure and operations. Furthermore, this report explores the climate change literature at multiple levels of government to identify the response of the transportation sector to climate change adaptation, with a focus on actions undertaken by agencies in the Pacific Northwest. The report examines how agencies in the Pacific Northwest are preparing for these impacts in their climate action plans (CAPs) and the level to which the goals and objectives of those plans have been incorporated into long-range transportation planning (LRTP) documents. Because CAPs 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 contacted to participate in a survey to identify recent and ongoing

climate change planning activities and adaptation planning resource needs. Key resources for agencies to address climate change adaptation for transportation in these plans are explored and strategies for integrating adaptation to climate change into future plans are presented.

MITIGATION AND ADAPTATION

Much of the existing climate change literature can be put into two categories: mitigation and adaptation. The Intergovernmental Panel on Climate Change defines mitigation as policies and strategies that reduce GHG emissions or enhance GHG absorption and storage (also known as GHG sinks). Adaptation to climate change is defined by the panel as "initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects" (*4*).

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 the efficiency of travel, all of which reduce GHG emissions (*5*). TRB's *Special Report 299: Reducing Transportation Greenhouse Gas Emissions and Energy Consumption: A Research Agenda* describes climate change adaptation strategies as either reactive, addressing existing risks, or proactive, addressing anticipated future risks (*6*). 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), or managerial (e.g., a change in management of roadside vegetation to reduce the risk of wildfires and landslides) (*7*).

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 about 28% of GHG emissions nationally and an even greater percentage in the Pacific Northwest (*8*). Mitigation strategies that reduce the transportation sector's GHG contribution have the potential to lessen the magnitude of future impacts of climate change and the speed with which they occur. These approaches likely reduce the extent of adaptation required in the future and potentially buy time for communities to implement adaptation strategies and to avoid costly effects. Because of this relationship between mitigation and adaptation, mitigation has been referred to as the "number one preparedness strategy" (*9*).

However, although mitigation and adaptation strategies are complementary, it is recognized that the effects of climate change observed today are the result of past GHG emissions. Current reduction efforts are not sufficient and do not occur fast enough to avoid all future impacts. Furthermore, recent research indicates that some effects of climate change may occur sooner or more rapidly than was projected in climate models (*10*). There will be unavoidable impacts of climate change requiring adaptation, including changes in the way surface transportation is built and managed.

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. 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 effects can vary significantly depending on the 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 subnational level through state and city departments of transportation (DOTs) and metropolitan planning organizations (MPOs) (*11*).

National

Projected Climate Change

Over the course of this century, temperatures across the continental United States are projected to increase from 3°C to 7°C depending on location, 33% greater than the global average increase. Precipitation is expected to increase across the United States except in the Southwest, along with more intense heavy precipitation and hurricanes. Winter snowpack amounts are anticipated to decline and to melt earlier in the western United States and Great Lakes region (*10*).

Impacts on Transportation Infrastructure and Operations

In 2008, TRB released *Special Report 290: Potential Impacts of Climate Change on U.S. Transportation* (*12*). This report summarizes the impacts that 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: increased number of very hot days and heat waves, increased Arctic temperatures, rising sea levels, increased intense precipitation events, and increased hurricane intensity. Table 1 provides examples adapted from the TRB report of potential impacts from these changes on transportation systems.

Pacific Northwest: Idaho, Oregon, and Washington

Projected Climate Changes

In 2007, the Intergovernmental Panel on Climate Change released *Climate Change 2007: The Physical Science Basis*, which included comprehensive regional climate projections over the course of this century (*13*). 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 a 2°C to 3°C increase in average annual regional temperatures during this century. Temperatures are projected to increase 1.5°C to 2.5°C in summer months and 3.5°C to 7°C in winter months (*13*).

Average annual change in precipitation in the Pacific Northwest is projected to increase up to 10%. Precipitation is expected to decrease 5% to 15% in summer months and to increase 15% to 30% in winter months. An increase in extreme daily precipitation is forecasted (*14*).

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 instead of snow.

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 on marine transport	Damage to coastal transportation infrastructure and increased risk of failure

In addition to 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)" (*9*). Drier, warmer summers may also increase the risk of wildfires.

Potential Impacts on Transportation Infrastructure and Operations

Potential effects on transportation infrastructure and operations include increased flooding, travel delay associated with response to wildfires, damage to coastal infrastructure due to inundation and increased risk of storm surge related to a rise in sea level, and changes in surface water elevation that may affect river transportation (clearance and depth).

Alaska

Projected Climate Changes

Temperature and precipitation changes for the Alaska region were also obtained from the Intergovernmental Panel on Climate Change report following the same modeling assumptions and time frame as described for the Pacific Northwest.

Alaska is expected to experience greater temperature changes than the Pacific Northwest, with an average annual regional temperature increase of 3.5°C to 5°C. Temperatures are projected to increase 2°C to 2.5°C in summer months and 3.5°C to 10°C in winter months (*13*).

Average annual precipitation in Alaska is projected to increase 10% to 15%. Precipitation is expected to increase in both summer and winter seasons: 10% to 20% in summer months and 15% to 30% in winter months.

Warmer temperatures in Alaska will contribute to thawing of permafrost, glacial melt, and loss of sea ice; they also may contribute to the frequency of forest fires (*9*). Retreat of glacial ice may cause land surface uplift in some locations (as observed in parts of southeast Alaska) while a rise in sea level results in coastal erosion, inundation, and increased risk of storm surge. Increased storm frequency and intensity are also projected.

Potential Impacts on Transportation Infrastructure and Operations

Potential effects on transportation infrastructure and operations include damage to roadway infrastructure due to permafrost thaw, travel delay associated with response to wildfires, damage to coastal infrastructure and erosion due to inundation and increased risk of storm surge related to a rise in sea level and coastal permafrost thaw, and reduced sea ice, which 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 nonprofit organizations to anticipate potential local effects. Although most agencies acknowledge the importance of planning for adaptation and the value of these types 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 focused on climate change. However, there is no broad federal policy addressing climate change and efforts to pass such legislation have made little progress at the time this research paper was written (*15*). In lieu of federal action on climate change, much of the mitigation and adaptation efforts have occurred at state, regional, and local levels.

At the national level, FHWA has made progress in research on climate change and in developing guidance 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" (*8*).

Nongovernmental organizations and research consortiums such as TRB and the International Council for Local Environmental Initiatives have also contributed a significant amount of research on adaptation to climate change, planning guidance, and technical assistance to communities across the nation.

State, Regional, and Local Responses

According to the Pew Center on Global Climate Change, 36 states now have a CAP completed or in progress (*16*). Most of these plans focus primarily (or exclusively) on mitigating climate change. Only 10 states have a plan for adapting to climate change that is completed or in progress. Table 2 presents an overview of transportation-related goals and objectives contained in CAPs and LRTPs in the Pacific Northwest and Alaska, with a focus on efforts to adapt to climate change.

TABLE 2 State, Regional, and Local Plans and Adaptation Efforts

	Climate Action Plan	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 (*17*). 2009 *Immediate Action Workgroup Recommendations to the Governor's Subcabinet on Climate Change.* Provides short-term immediate action adaptation recommendations (*18*).	2008 *Let's Get Moving 2030: Alaska Statewide Long-Range Transportation Policy Plan 2030.* Includes discussion of need to consider climate change and adaptation, but is not action-oriented (*19*).
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 (*20*). *Climate Change—2008 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 for areas at risk to flooding and inundation. Calls for comprehensive data collection (*21*).	2006 *Washington Transportation Plan 2007–2026.* Climate change discussion is limited to mitigation (*22*).
Oregon	2004 *Oregon Strategy for Greenhouse Gas Reduction.* Some discussion of need for adaptation. Calls for development of an adaptation plan (*23*). 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 (*24*).	2006 *Oregon Transportation Plan.* Some discussion about climate change primarily related to mitigation. Briefly mentions potential impact of sea-level rise on coastal facilities (*25*).
Idaho	Climate action plan is in progress. 2008–09 *Fiscal Year Greenhouse Gas Emission Reduction Action Plan.* Mitigation only, applies to state activities only (*26*).	2004 *Idaho Transportation Vision 2034.* No discussion of climate change (*27*).
Upper Willamette River Basin, Oregon	2009 *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 (*28*).	n/a
Local		
City of Portland, Oregon, Multnomah County	2009 *Portland and 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 (*29*).	2006 *Portland Transportation System Plan.* No discussion of climate change (*30*).
City of Olympia, Washington	2007 *Olympia's Response to The Challenge of Climate* . 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 (*31*). 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 (*32*).	2009 *Olympia Transportation Mobility Strategy*. Discussion of climate change in reference to mitigation only (*33*).
City of Seattle, Washington	2006 *Seattle Climate of Change.* Includes discussion of adaptation and projected impacts. Recommended actions are mitigation-focused (*34*).	2005 *The Transportation Strategic Plan Update.* No discussion of climate change (*35*).
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 (*36*).	2004 *King County Roads Strategic Plan.* Intended to bridge "high-level policy guidance and the day-to-day practices, procedures, and decision making" but does not mention climate change. Related comprehensive plan discusses mitigation and adaptation (*37*).
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 (*38*).
City of Homer, Alaska	2007 *City of 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 ports that consider climate change (*39*).	2005 *Homer Area Transportation Plan.* No discussion of climate change (*40*).

NOTE: n/a = not available.

Compared with 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 have incorporated climate change adaptation strategies into these documents or have stand-alone adaptation plans. However, there is significant variation among these agencies in the scope and depth of discussion about adaptation planning, and there remains a tendency for agencies to focus on climate change mitigation, particularly when stating goals and objectives on which to take action.

There also appears to be a disconnect between CAPs and LRTPs for the corresponding jurisdiction. While CAPs may include recommendations for transportation adaptation, these recommendations are seldom incorporated into LRTPs. This oversight may be temporary because the reviewed transportation plans were generally adopted before the CAPs were developed and most CAPs have only recently been completed. This deficiency is likely to present issues with implementing recommendations for transportation adaptation as transportation planners rely on LRTPs for reference in planning and design guidance.

Although a lack of CAP integration in LRTPs does not necessarily indicate that climate change considerations will be overlooked in transportation planning efforts, the lack of CAP integration does limit planners' awareness of potentially valuable information and contributes to business as usual in transportation planning.

These findings are similar to results of research conducted separately by Wheeler (*3*) and Lindquist (*11*), who independently examined climate change planning activities by government agencies at various institutional levels in terms of 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 subnational level and tends to focus on mitigation (*3*). Lindquist's preliminary research findings revealed that, with the exception of four states (including Oregon and Washington), most 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 (*11*).

Although many CAPs include a high-level discussion of anticipated impacts of climate change and the need to adapt, few outline goals or actions with 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 could be subject to increased flooding, but the documents fail to specify the intensity of flooding, locations of potentially vulnerable infrastructure, and how vulnerable infrastructure will be identified. This tendency can be attributed to a general lack of localized data on the range of potential impacts of climate change, and CAPs 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, Oregon, metropolitan region require a substantial geomorphologic, hydrologic, and field data collection effort (*41*). In addition, the estimation of costs associated with the effects of climate change on flooding events is difficult because of the lack of complete and systematic record keeping and uncertainty related to estimation of incremental impacts of climate change on magnitudes, frequencies, and durations of flood events (*42*). In some cases, more specific data are available in other climate planning documents but can be difficult to identify and readily locate.

Of the CAPs reviewed for this report, the 2007 King County Climate Plan (*36*) 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 here, the LRTP was developed before 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 projections of the impact of climate change such as the extent to which a rise in sea level is anticipated to affect portions of Puget Sound and locations where climate-warming effects on snowpack will be most pronounced (*36*). It identifies critical infrastructure impacts including those to transportation systems through flood boundary delineation and other research efforts. To 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 as to act in an advisory role 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 impacts of climate change.

Because CAPs and planning efforts to adapt to climate change are relatively new planning concepts and there is often a lengthy internal process before draft plans are available, more recent 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 contacted to participate in a survey to identify recent and ongoing climate change planning activities and adaptation planning resource needs.

SURVEY OF TRANSPORTATION PLANNERS IN PACIFIC NORTHWEST

In fall 2009 and winter 2010, a brief online survey was conducted among transportation planners, engineers, and program managers in Alaska, Idaho, Oregon, and Washington to gain an understanding of which activities transportation agencies in the Pacific Northwest were undertaking in terms of planning for climate change. Survey participants at state, regional, and local levels were selected through a convenience sample, having been identified on agency websites as a climate change contact or by personal reference and through membership with a state chapter of the American Planning Association. In general, only responses from agencies that own and operate surface transportation facilities were analyzed.

The online survey was composed of multiple-choice, short answer, and ranking questions. Questions elicited information such as whether the agencies' climate change planning activities were related to mitigation or adaptation, which activities they engaged in to assess potential impacts of climate change on their transportation facilities, and the relative importance of different resources to assess these impacts. Respondents were offered the opportunity to provide additional comments and to access hyperlinks to online reports and web pages as well as to upload files to researchers via File Transfer Protocol. Twenty-four completed surveys were received, representing

22 agencies. Likely due in part to reliance on personal references for sampling, all but one of the respondents were located in Washington and Oregon.

Nearly half of the respondents indicated that their agency was involved in planning activities focused on mitigating and adapting to climate change. 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 made progress in terms of planning for both climate change mitigation and adaptation, and several Oregon agencies recently began adaptation planning. Furthermore, the process of plan development and update requires significant time, and agency adaptation efforts may not be documented until the approval of the next plan update. Consistent with findings in a review of CAPs, nine agencies were involved solely in mitigation activities.

The most common activities taking place by surveyed agencies were climate change research and strategy meetings followed by location-specific efforts (e.g., considering potential impacts of climate change for a particular project site). Less common activities included scenario testing, both to identify facilities that may be affected under different climate change impact assumptions and to inform the location or design of planned transportation facilities. Nearly a third (seven) of respondents indicated they were not engaged in activities to identify potential impacts to their transportation system resulting from climate change.

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

Two-thirds of respondents reported that their transportation facilities had been affected by flooding and major storm events in the past decade. Half the respondents also reported erosion effects on facilities. Impacts from inundation, wildfire, heat waves, and drought were reported infrequently. As a result of these flooding and other inclement events, about half the respondents indicated that facilities were damaged, service was affected, or facilities were closed. Only six respondents specified that their agency collects cost data associated with these events, and four indicated that their agencies have a mechanism for recording the frequency with which facilities are affected; nearly a third of the respondents did not know. Nearly half the respondents indicated that their agencies have methods to identify facility vulnerabilities to these types of events. Estimation of costs associated with impacts of climate change on the prevalence of flooding events is difficult because of the lack of complete and systematic record keeping and the uncertainty related to estimation of incremental impacts of climate change on flood event magnitude, frequency, and duration.

In addition to the online survey, six phone interviews were conducted with respondents who indicated they could be contacted for a follow-up interview. These interviewees represented three agencies: a major city, a state DOT, and an MPO. The interviews were intended to follow up on specific responses from the survey about adaptation activities, methods of identifying vulnerabilities, and resource needs. The responses are summarized as follows:

- Respondents indicated that flooding was generally viewed as the most significant threat to their operations and infrastructure.
- Although the MPO was not directly responsible for operating or maintaining transportation infrastructure, it is heavily involved in activities to adapt to climate change, in particular activities that involve identifying the effects in coordination with local partners.
- Perceptions of awareness of climate change and impacts were mixed. Some respondents indicated very high awareness within their agency while others indicated the topic is largely "off the radar" for most staff.
- Two agencies indicated that they had begun mapping efforts utilizing geographic information systems to map areas of potential impact, specifically examining the rise in sea level. Both indicated that the uncertainty of effects and the availability of data (as well as level of detail in the data) were barriers to adaptation activities.
- Staff time was noted as a limitation because of budget shortfalls.
- In contrast to the online survey, respondents in the follow-up interviews generally appeared eager for guidance and methodology on how to incorporate adaptation strategies into their transportation plans.
- These respondents also underscored the importance of, and lack of access to, local climate data.

DISCONNECTS BETWEEN CAPs AND LRTPs

Some disconnects between CAPs and LRTPs may be partly explained by the timing of each report. However, there are often institutional and analytical barriers as well. Some disconnects between CAPs and LRTPs may be related to intra-agency miscommunication or to lack of communication and common ground between CAP and LRTP teams. Changes in agency leadership or prevailing economic conditions may entail a shift in priorities away from research and planning on climate change. If the new leadership at an agency does not view climate change as a priority, then the staff are unlikely to work on these issues. However, a long-term, multidisciplinary problem such as climate change demands continuous attention to keep current with research and to coordinate between and within agencies. Additionally, as agency budgets decrease, as they have during the current economic downturn, existing staff must take on increased workloads that may not allow them the resources (in time and funding) to concentrate on long-term problems like climate change, which lack the immediacy of other agency concerns.

Other barriers may stem from the challenging nature of research on climate change. It often requires expertise that may not be readily available to staff and the uncertainty surrounding the ever-changing climate data and research may create situations in which staff do not know where to begin. Although research is being conducted at agencies and academic institutions to develop approaches to overcome some of these barriers, as with all novel ideas there will be a lag between the development of these approaches and their widespread implementation.

KEY RESOURCES AND STRATEGIES TO PLAN FOR ADAPTATION TO CLIMATE CHANGE IN LRTP

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

Several documents highlight the key resources and strategies recommended to plan for adapting to climate change: *Preparing for Climate Change: A Guidebook for Local, Regional, and State*

Governments (*9*); *Special Report 290: Potential Impacts of Climate Change on U.S. Transportation* (*12*); and *Summary Report: Peer Workshop on Adaptation to Climate Change Impacts* (*43*). The following section summarizes recommendations based on the results of this study along with complementary key recommendations provided in these documents.

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

In the survey conducted for this report and in multiple guidance documents, the availability of localized projections for climate change (often varying depending on the scenario) were noted as one of the most important resources necessary in effective adaptation planning for climate change. Geographically specific climate projections and impacts are key needs for transportation and other agencies to identify system vulnerabilities and develop appropriate proactive and reactive planning scenarios. Examples include local estimates for a rise in sea level and changes in the 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 scenarios to facilitate information sharing and coordinated planning efforts. In addition to preparing for anticipated future impacts of climate change, agencies need to collect data on the effects of climate change already observed as well as to monitor changes that occur over time.

Inventory System Vulnerabilities and Identifying Critical Infrastructure

Local data on existing and projected impacts of climate change are necessary 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 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 in which the consequences of potential delay on, damage to, or loss of a transportation facility and the probability of such an 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. Funding should be secured to ensure follow through, and coordination is required to guarantee consistency among specific plans. Strategies developed from scenario testing should then be integrated in LRTPs as well as capital improvement and other plans.

Cooperation Across Disciplines and Agencies

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

Development of clearinghouses for data projections and planning documents for climate change are often 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 this survey indicate that most agencies in the Pacific Northwest are aware of the need for adaptation planning for climate change in transportation. All respondents have been affected in recent years by weather events, which are expected to increase in frequency and severity because of climate change, and most already have or are beginning to consider climate change in their transportation planning efforts. However, furthering awareness of likely effects of climate change at the local level elevates the importance of adaptation planning among the public and decision makers. 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 the projected effects of climate change and adaptation strategies are also necessary to guarantee successful implementation of planning actions.

CONCLUSIONS

Transportation infrastructure and operations across the United States 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 GHGs, but few address strategies for adapting to climate change 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 agencies tend to focus on climate change mitigation, particularly when outlining recommended actions to respond to climate change.

Reviews of CAPs and LRTPs from state, regional, and local agencies in the Pacific Northwest and Alaska reveal a frequent disconnect between CAP and LRTP efforts. Although transportation officials are often consulted in the development of CAPs, the recommendations in these plans often have not been well incorporated into the LRTPs, presenting a potential for conflicts in implementing transportation-related action plans.

To address adaptation to climate change for transportation in future plans, key resources, such as locally relevant data on current and projected effects of climate change, must be developed along with inventories of critical infrastructure and transportation system vulnerabilities. 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

integrate recommendations for adapting to climate change into transportation plans.

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