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Climate Adaptation and Resiliency Planning: Agency Roles and Workforce Development Needs

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A Research Report from the National Center for Sustainable Transportation

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National Center for Sustainable Transportation

The University of Vermont
Transportation Research Center

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NCST

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NCST

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EXECUTIVE SUMMARY

This report is one of two NCST Research Reports produced as part of a project to evaluate the state of practice and adequacy of technical tools for resiliency and adaptation planning. A companion report, *Network Requirements for Assessing Criticality for Climate Adaptation Planning*, focuses specifically on the technical challenges of conducting criticality assessment for climate adaptation and resiliency planning.

Because climate change is increasing the intensity and frequency of many extreme weather events, climate adaptation and resiliency planning are increasingly important tasks for transportation agencies at all levels of government. While specific climate threats and adaptation needs varies by location throughout the United States, all agencies face challenges in terms of resource availability (including staffing levels and staffing expertise) and the quality of the technical tools for adaptation planning. In 2015, the University of Vermont Transportation Research Center conducted a survey of planning organizations in the U.S. concerning climate adaptation planning intended to assess the adaptation planning capacity, workforce development needs, and current preparation levels of local and state agencies as well as the adequacy of currently available technical tools. The survey consisted of 14 multiple choice or open-ended questions and garnered 154 respondents, including representatives from planning organizations, state transportation agencies and others involved in transportation planning.

Given the significant infrastructure owned by local agencies, both local and regional agencies have an important role to play in adaptation planning. Particular attention must be paid to asset criticality rating that cannot be conducted in isolation by either the local or the state agency since it must account for the network redundancy and vulnerability of both state and local infrastructure. Additional policy discussions are needed regarding the roles of different agencies.

The study results point to preparation gaps for agencies at all levels. A preparation gap is any instance when an agency is aware of its exposure to a particular climate threat but is not yet preparing for that threat. The survey identified that only 20% to 80% (depending on the threat) of agencies at risk from a given threat are actively preparing for that threat. Presumably responses were biased towards more active and engaged agencies, so the preparation gap of all U.S. agencies is likely to be higher than the agencies that responded to this survey. State agency personnel generally indicated a smaller preparation gap for all threats and a higher percentage of state agencies were undertaking both procedural and infrastructure adaptations than local agencies.

Surprisingly few of the planners in the study indicated that their agencies were pursuing adaptation actions. As expected, more adaptation actions were procedural rather than infrastructure adaptations. However, 20% of local agencies indicated no procedural actions and 12% of all agencies indicated no infrastructure actions. This points to a need to track actions over time and ensure that identified barriers are reduced and that other significant barriers to action implementation are not present but unmeasured. Future surveys should also seek to understand which types of actions and preparation are reasonable within a given agency's mission.

Tools and resources, especially staff time, are clearly barriers to adaptation planning efforts. Both state and local agency respondents assessed many adaptation tools and resources as lacking. The number of staff was cited as the most limiting resource. The complexity of transportation networks makes the development of robust objective tools and the associated input data challenging. This part of advancing the planning effort may best be assigned at this time to academic institutions.

Respondents in this study affirmed that workforce development is an important part of advancing climate adaptation and resiliency planning. More work is needed in examining the workforce development needs of transportation agencies by factors such as region and type of organization. In addition, a higher level of specificity of the skills and qualifications is needed to inform development of new training, new hires, and educational curriculum that prepares the future workforce. Our recommendations include additional targeted funding, developing a continuum of workforce development offerings, developing professional communities of practice and using online technology as a platform for climate adaptation planning workforce development.

Introduction

Potential disruptions caused by extreme weather events are an increasing focus for many federal, state and local transportation agencies. Weather events are imposing significant costs on agencies throughout the United States (*1*). The number of disruptive events is projected to increase in both frequency and severity (*1*). In response, transportation and planning agencies are exploring climate adaptation measures. Adaptation and resiliency planning efforts are complicated by the fact that the extreme weather events, and the threats they pose to the transportation system, vary from region to region. Agencies at all levels, but especially local agencies, have limited financial and human resources to devote to climate adaptation. Given these constraints, and because the surface transportation system functions as an integrated unit across multiple jurisdictional boundaries, collaboration among national, state, local and regional transportation agencies is essential to maximize the effectiveness of adaptation efforts.

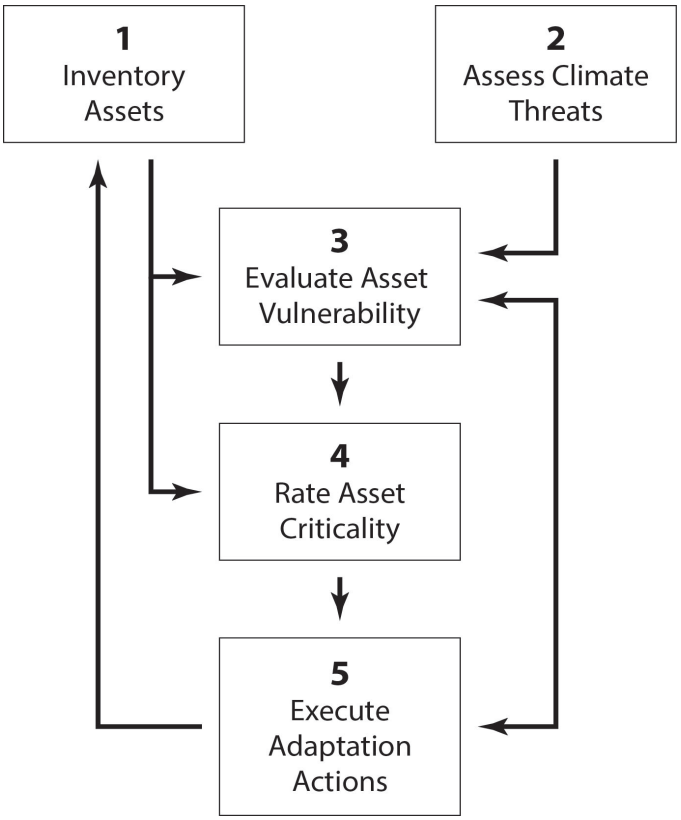

Figure 1. Five-step Framework for Climate Adaptation Planning for Transportation Systems

Considering the variety of events that impact the transportation system, transportation professionals must consider a host of different adaptation actions, ranging from changes in maintenance and communication procedures to changes in design and even the relocation or replacement of infrastructure. The importance and complexity of this work is spurring a rapid

expansion of new adaptation tools and numerous adaptation pilot projects. The different roles for different types of agencies in implementing these measures have yet to be clearly delineated. Moreover, while, workforce development in transportation is recognized as a critical issue for organizations on a national level and in all modes of transportation, relatively little is currently known about the more specific workforce development needs for climate adaptation.

In order to provide a structure for understanding the climate adaptation capacity and workforce development needs of state and local transportation agencies, recent NCST work has described a straightforward, five-step framework for climate adaptation planning developed in (*2*, *3*) and depicted in Figure 1. In this follow-on report we describe the execution and response to the Climate Adaptation Planning Survey (CAPS), an online survey of planners[1] and other professionals conducted in June 2015. Using the results of this survey, we compare the adaptation planning capacity, adequacy of technical tools and current preparation levels of local versus state agencies. Finally, we report on the workforce development needs faced by transportation planning agencies as they increasingly focus their work on adaptation to climate change. This work was previously presented at the Transportation Research Board Annual Meeting (*4*, *5*).

Framing Adaptation Planning in Transportation

Several groups have developed adaptation guidance and frameworks (*1*, *6*–*9*). The FHWA's Climate Change and Extreme Weather Vulnerability Assessment Framework (*7*) is among the most prominent of these and was used in five pilot adaptation projects in 2010-2011 (*10*–*14*). From 2013 – 2015, 19 additional pilots were undertake. Key lessons learned from the second round of pilots are summarize in (*15*). For broad policy and education purposes a simplified five-step transportation adaptation framework synthesized from common elements of existing resources is useful (Figure 1). Common language for and classification of steps in the resiliency planning processes assist in the delineation of responsibilities between state and local agencies, including agencies responsible for transit and non-highway modes.

The steps in this framework are:

1) inventorying and monitoring transportation assets;
2) assessing climate threats;
3) evaluating asset vulnerability;
4) rating asset importance or criticality; and
5) identifying and executing adaptation actions.

[1] Note, for brevity we use "planner" interchangeably with respondent in this report. We recognize planners are a specific set of licensed professionals and that our respondents include planners, engineers and others.

Inventorying and monitoring infrastructure (step 1) is the process of creating and maintaining a database of an agency's assets and their condition. It is necessary for assessing asset vulnerability and criticality. Inventory databases need the capacity to store information on infrastructure design and condition, location (latitude and longitude), relevant system data (e.g. traffic volumes) and environmental factors (e.g. elevation above coasts and rivers). Databases should be digitized and easy to integrate with other data sources.

Assessing climate threats (step 2) is the process of identifying the type and magnitude of climate threats that could impact the transportation system in a given region. Threat assessment should be conducted at spatial and temporal resolutions sufficient to enable the evaluation of infrastructure vulnerability and inform design considerations. Ideally it should include all pertinent variables needed for engineering purposes (e.g. peak stream flow, number of days above 95 degrees). This step can rarely be conducted by transportation agencies alone and the necessity of new partnerships has required new investment of resources by many agencies.

Evaluating asset vulnerability (step 3) is the process of determining the susceptibility of agency infrastructure to degradation or damage by the climate threats identified in step 2. It is a function both of climate threats and asset condition. The technical methods to conduct this step are not unlike the engineering design typically used for building and retrofitting infrastructure so data availability on the threats and specific infrastructure is the greatest obstacle to completing this step. The U.S. DOT has produced multiple resources to support evaluations of asset vulnerability, including the Vulnerability Assessment Scoring Tool (VAST) (*16*).

Rating asset criticality (step 4) is the process of assessing the importance of specific assets to overall system functioning, community connection and access to important destinations. Given limited adaptation resources, criticality ratings are an important project prioritization tool. In our prior interviews, many DOTs reported difficulty with the criticality assessment phase and several also reported that the prioritization process could become politicized (*2*). Numerous factors contribute to an asset's criticality during routine and emergency system operation including traffic volumes, provision of connectivity between important origins and destinations, protective capacity and non-systematic factors such as replacement cost, historical/cultural value and political considerations. There is not yet a consensus on which factors to consider; methods to incorporate multiple factors and modes are not fully developed. It is not clear how accurate either the subjective (expert) or objective (mode-based) methods are in assessing criticality.

Figure 2 provides a simple illustration of the complexity of determining the relative criticality of even a small number of infrastructure links in a network — three bridges in this example. In the top scenario, all three bridges are identical in design and condition and face similar threats. Consequently, they are equally vulnerable. Assuming a uniform distribution of land use and travel demand on both sides of the river, the bridge on the right may be considered most

critical as the other bridges provide redundancy for one another. However, when one considers the lower scenario of Figure 2, the vulnerability of bridges varies, making the determination of criticality more challenging. If land use and traffic demand are not uniform, or if one bridge leads to an importance destination such as a hospital, the determination becomes yet more complicated. Criticality is a complex interaction between network redundancy and vulnerability as suggested by Figure 3.

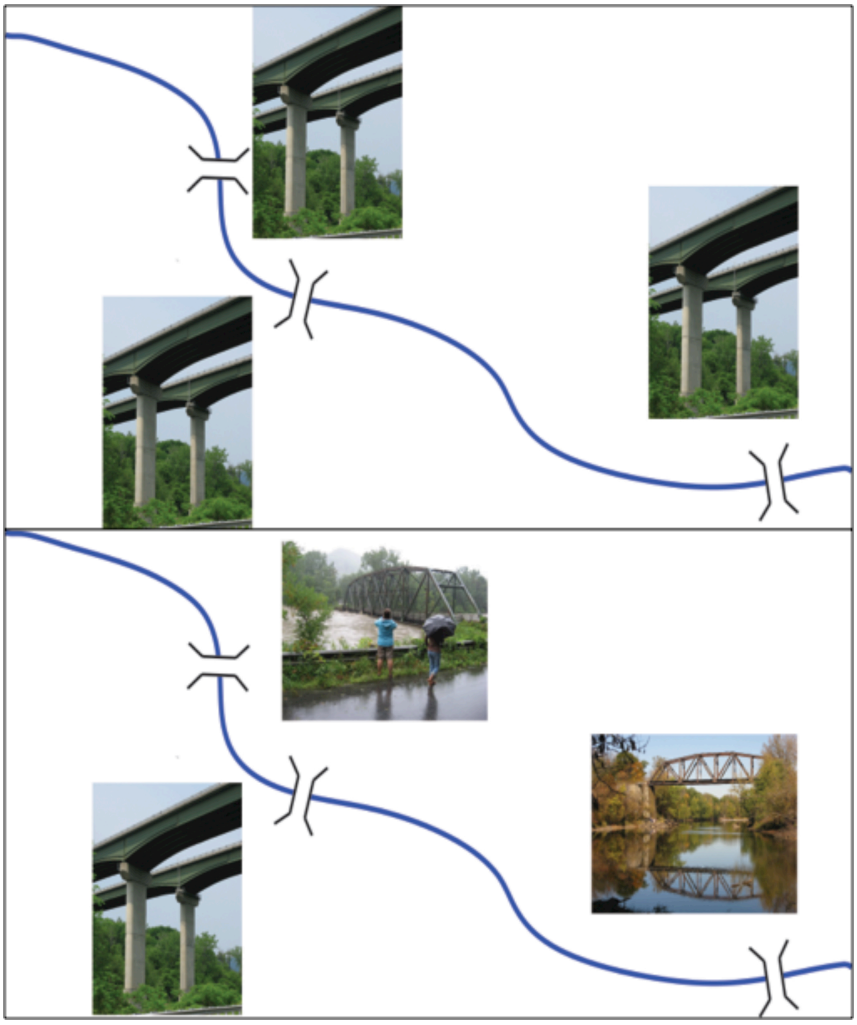

Figure 2. Two Hypothetical Networks – Criticality, Redundancy and Vulnerability

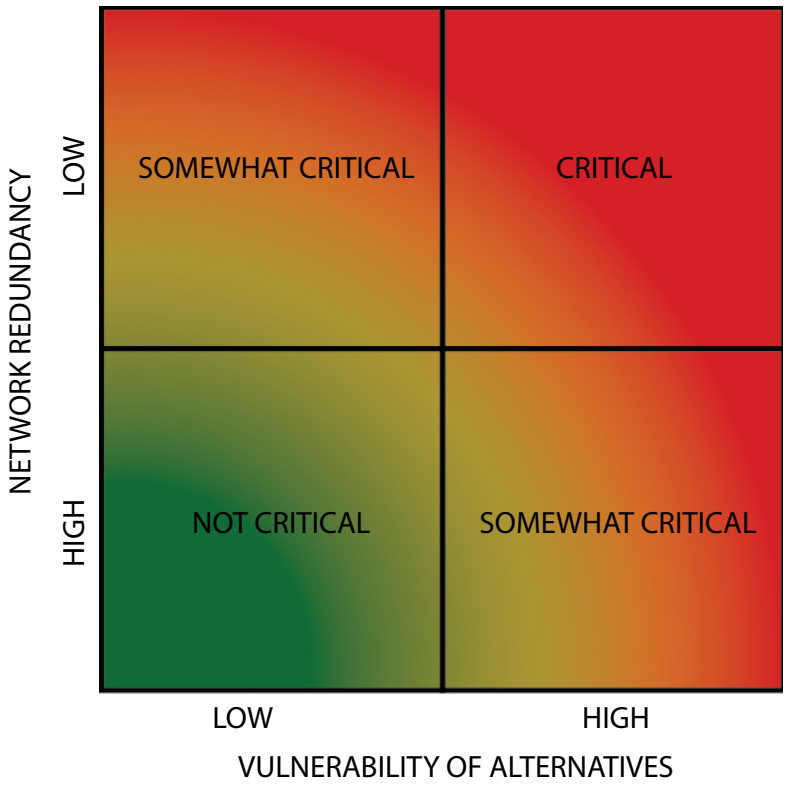

Figure 3. Relationship between Criticality, Redundancy and Vulnerability

Transportation professionals understand that vulnerability, redundancy and criticality are interrelated. Despite widespread use, traffic volumes (or proxies), are not a sufficient metric by which to assess criticality and, at a minimum, route redundancy needs to be considered in conjunction with volume measures. Several approaches to quantifying criticality that account for traffic volumes and the redundancy inherent in the network are based on modeling the total travel delay caused when the capacity of a road segment or link is disrupted or removed (*17–21*). Phase II of the FHWA's Gulf Coast study (*22*) also used this approach but only assessed the criticality of a small set of "representative" links that are unlikely to accurately capture the full topology of the network. Actual networks are far larger and more complex than the three bridges shown in Figure 2 (there are thousands of road links in a medium sized city). This is further complicated because surface highways are owned by different agencies and transit and non-motorized infrastructure may provide valuable redundancy that is yet to be fully accounted for. In general, the rating of criticality may be the weakest link in the common five-step framework and the one for which local and state cooperation is most essential.

Selecting and executing adaptation actions (step 5) is the process of identifying, choosing and implementing actions that will reduce the vulnerability of the transportation system to climate threats. It is useful to further divide adaptation actions into either procedural or infrastructure adaptation actions. Looking at adaptation actions through this lens reveals that many process

adaptation actions, such as improving communications procedures, data monitoring or including climate risk in the resiliency planning process, can be undertaken even with considerable uncertainty about the magnitude of climate threats and the specific vulnerabilities that they will cause. In contrast, infrastructure adaptation actions are considerably more costly and require greater certainty in terms of vulnerability or criticality to implement with confidence. AASHTO (*1*), FHWA (*22*) and NCHRP (*23*) synthesis reports all suggest that because process adaptations generally have more modest implementation requirements than infrastructure adaptations, they represent low hanging fruit for climate adaptation efforts.

Agencies across the United States differ not only because of the different weather threats and system designs but in terms of their capacity for and engagement in adaptation planning. The web-based survey designed for this paper used the 5-step framework as a means to assess the capacity of, and potential differences in capacity between, state and local agencies.

Integrating Local and Regional Agencies into Adaptation Planning

While the states and federal government provide approximately 70% of all surface transportation funding (*24*), towns, municipalities and counties own more than 75% of all road miles and nearly 50% of all bridges in the United States (*25*). Consequently, many of the effects of extreme weather events impact locally owned and managed transportation infrastructure. Numerous entities are involved with transportation planning and infrastructure management at the sub-state level. These entities frequently have overlapping jurisdictions and responsibilities and are very different in size and resource level. These entities include 3,033 counties (*26*), 36,011 cities and towns (*26*), port and transit authorities, as well as transportation planning organizations – 393 MPOs alone (*27*). Local governments and transportation authorities own considerable infrastructure but may be limited in geographic extent or focus on a single transportation mode, conditions that limit the ability of these agencies to undertake broader adaptation planning.

Planning organizations, including MPOs, rural planning organizations and other regional planning and economic development bodies, frequently have a relatively broad geographic reach based on development or travel patterns. Their jurisdictions can cross state boundaries and these agencies often function as a liaison between city, town, state and federal agencies. Additionally, many MPOs are integrated within councils of government, regional planning commissions, or other regional entities with land-use planning, economic development, and disaster recovery responsibilities. This integration can be beneficial for adaptation planning. Consequently, MPOs offer some advantages as a sub-state locus of adaptation planning even though they do not own transportation infrastructure in most cases. The FHWA has sought to engage MPOs through its climate adaptation pilot projects (*13*–*15*) and by sponsoring a series of webinars presented by AMPO (*28*). In 2008, AMPO convened a conference on climate change that included some discussion of adaptation measures (*29*). Several multi-county partnerships, such as the Southeast Florida Regional Climate Change Compact, and individual MPOs are

undertaking climate assessments that include adaptation components (*30*–*33*). In addition, the California DOT has issued a guide on how to incorporate adaptation in regional transportation plans (*34*).

Given the different capacities of agencies involved in local and regional transportation issues and the overlap of responsibilities with adaptation implications, no single local or regional agency is ideally positioned to conduct all of the steps in the adaptation planning process individually. Instead, engaging different agencies in different steps of the process is likely to maximize the overall effectiveness and avoid inefficient replication of effort. It is possible that the exact role of these agencies will vary from area to area depending on the resources and capacity of agencies, and that the state agency will have to play a larger role in economically depressed or rural areas outside the jurisdiction of transportation planning organizations.

A recent Georgetown Climate Center report of community case studies makes a strong case for a significant role for citizens and non-governmental organizations in the process of planning for adaptation in the transportation system (*35*). Community groups have been included in stakeholder processes to evaluate assets criticality (*34*) as well as to define adaptation goals and evaluate adaptation options (*36*). Additional work is needed to understand the appropriate role of these groups.

Proposed roles for state, regional and local agencies in each of the five steps of the adaptation framework are shown in Table 1. The asset inventory step is logically the responsibility of the agency that owns the infrastructure. Agency personnel are frequently in contact with their own assets and some degree of condition monitoring is inherent in maintenance responsibilities. As at the state level (*2*), resource constraints are the largest challenge to asset inventory and smaller agencies may have more staffing challenges and less sophisticated database management capabilities. Since asset inventory ultimately feeds the vulnerability and criticality assessments, asset inventories across agencies need to be maintained in a way that allows for integration. States may have to take a leadership role in developing standards for asset inventories. These standardizations may need to cross state lines given metropolitan areas, travel patterns and supply chains, suggesting a potential national role in standard development.

Detailed climate threat assessment requires considerable technical expertise as well as decisions about what scenarios ought to be considered. Developing the technical expertise to conduct climate assessment at multiple levels would be duplicative and is beyond the typical scope of a local agency. Moreover, the determination of what emissions scenarios ought to be considered is a social decision, reflecting the degree of risk tolerance of the society. Both of these factors suggest that climate threat assessment should be conducted at the state level. In many cases, the most relevant climate threats may vary from one part of the state to another in which case threat assessment will need to be regionally specific. For example, determining the threat of riverine flooding due to increased precipitation intensity might include hydrological modeling, which is best undertaken at the level of watersheds. Once the climate threats have

been assessed, this information needs to be passed on to local and regional agencies for planning and infrastructure design purposes.

Table 1. Adaptation Planning Role for Local Infrastructure

Component	Primary Responsibility	Notes
Inventory and Monitor Assets	Local/infrastructure owning agency	State agencies will need to provide technical support and guidance to ensure inventory asset databases maintained by local agencies can be integrated with one another.
Assess Climate Threats	State	For large states or topographically diverse states, climate threats can vary at the sub-state level and threat assessment will need to be regionally specific. Unified assessment of climate threats will reduce replicated efforts and ensure that consistent climate scenarios are used by all agencies.
Evaluate Vulnerability	Local/infrastructure owning agency	Varies based on type of threat and condition of infrastructure
Rate Asset Criticality	State or MPO/RPO	The criticality of specific infrastructure depends on network characteristics and is fundamentally cross jurisdictional and cross modal. The exact scale of analysis and appropriate boundaries, especially for non-metropolitan areas, are not yet clear.
Select and Execute Adaptation Actions	Infrastructure adaptations – owning agency Procedural adaptations – all agencies.	Owning agencies will undertake infrastructure adaptation, in consultation with funding agencies, using guidance developed at the state or national level.

The vulnerability assessment for specific infrastructure can be conducted by the agency that owns that infrastructure. Although the vulnerability of infrastructure can be conducted town by town at the local level, it is essential to recognize that the vulnerability of all infrastructure in a given region needs to have been accurately assessed for any one agency to accurately evaluate criticality, because criticality is dependent on the vulnerability of alternative routes (across modes) regardless of asset ownership.

The criticality assessment phase may be especially prone to duplication or error since criticality should ideally be evaluated with a complete, multi-modal representation of the full regional network. This means that criticality is dependent on inventory and vulnerability inputs from agencies at all levels across the region. Depending on the size of the state and planning organization, this analysis might be conducted by the state or by the MPO/RPO but it should not be limited based on infrastructure ownership. Criticality in surrounding rural areas might best be incorporated into metropolitan analysis due to access needs. Criticality assessment is a large challenge for adaptation planning for agencies of all types. Because criticality assessment requires further methodological development, the most effective means of implementation are yet to be established.

The execution of adaptation actions includes both changes to infrastructure and adaptations to agency processes. The agency that owns the infrastructure will likely execute the infrastructure adaptation in consultation and collaboration with funding agencies. Prioritization should include overall importance to the regional network regardless of asset ownership.

Integrating local and regional agencies into adaptation planning in coordination with state agencies is not straightforward and has the potential to derail the implementation of even the best adaptation policies. Different agencies have different roles and the partnerships will likely vary from region to region. This institutional topic alone is worthy of considerable focus.

The CAPS Survey

In order to better understand the differing capabilities and levels of engagement in adaptation planning at state and local transportation agencies a short online questionnaire was designed for distribution to planners and other transportation professionals. The survey content was selected based on the findings in a prior NCST-funded white paper project (2).

Survey Execution

The CAPS survey was implemented by our partner, Resource Systems Group (RSG) Inc., using rSurvey, their online survey platform. The survey was “open link,” allowing invited respondents to share the survey link. The open link did not prevent people from completing the survey multiple times. Possible duplicates were flagged by RSG Inc. and one possible duplicate response was deleted.

The survey link was distributed by email to approximately 500 individuals who worked at state Departments of Transportation (DOT) and Metropolitan Planning Organizations (MPO) in the U.S. The team reached out directly to contacts at universities and agencies to ask individuals to forward the link to planners in their region. Mid-survey the effort was repeated in regions with low response rates. The link was also available to members the National Association of Development Organizations (NADO) and the National Association of Regional Councils (NARC) to promote the survey to their members. Individuals invited to participate in the survey were

encouraged to think of others who might be appropriate respondents for the survey and to forward the link to them. In total, 154 complete and valid survey responses were received. Given the open nature of the link and participant recruitment, it is impossible to quantify a response rate.

The survey consisted of 14 multiple choice or open-ended questions. It was open from May 20-June 30, 2015. In addition to the multiple choice survey content outlined in Table 2, respondents were asked about their primary role at the agency, their agencies' professional development needs related to transportation planning and whether or not they would be will to discuss workforce development needs with staff from the FHWA's Northeast Transportation Workforce Center at the University of Vermont. Pop-up definitions were provided for the elements of the adaptation planning framework introduced above: "inventorying infrastructure," "assessing climate threats," "evaluating vulnerability," "rating criticality" and "executing adaptation actions." Options were randomized and choices for "don't know", "unsure", "not applicable" and "other/specify" were provided. For the two questions on climate threats at the top of Table 2, respondents could select any subset of the 12 threats listed in the right-hand column of the Table. For the third question on climate threats, only the options selected as threats in the first question were provided to each respondent to reduce burden.

Table 2. Outline CAPS Content

What climate trends and related events pose a threat to the transportation infrastructure in your region? **Which of the following climate threats is your agency CURRENTLY preparing for?** **How vulnerable is your region's transportation system to each of the following threats? (scale of 0-10)**	1. Increased total precipitation or precipitation intensity 2. Flooding 3. Erosion 4. Landslides, rockslides, slope failures 5. Increased heat extremes/heat waves 6. Increased freeze/thaw cycles 7. Thawing permafrost 8. Increased run-off from changes in snow/glacial melt 9. Sea level rise 10. Drought 11. Electrical service disruptions 12. Wildfires
Which of the following types of institutional or procedural changes has your agency implemented as part of adaptation planning?	1. Hiring additional staff 2. Adding staff with different skills than existing staff 3. Developing new interagency relationships/communication procedures 4. Creating programs to address climate adaptation/including climate threats in planning procedures 5. Training 6. Developing hazard mitigation and emergency response plans 7. Creating or improving data collection and/or analysis procedures 8. Modifying maintenance schedules and practices
Which of the following types of INFRASTRUCTURE ADAPTATIONS have been undertaken in your region?	1. Infrastructure hardening (e.g. reinforcing or resizing infrastructure, altering designs to reduce vulnerability to climate threats) 2. Adding protective infrastructure (e.g. dikes or berms) 3. Infrastructure relocation 4. Infrastructure abandonment 5. Increasing network redundancy 6. Adding natural areas or green infrastructure to protect existing assets
On a scale of 0-10, rate the adequacy of each of the following for your agency's overall adaptation planning efforts.	1. Financial Resources 2. Infrastructure Design Guidance 3. Human Resources – Number of Staff 4. Human Resources – Knowledge Base of Existing Staff
Please rate the availability and quality of the TECHNICAL TOOLS for each of the following adaptation steps. (scale 0-10)	1. Inventorying infrastructure 2. Assessing climate threats 3. Evaluating asset vulnerability 4. Rating asset criticality 5. Selecting and executing adaptation actions
Which training resources does your agency use for staff professional development?	1. In-house training department 2. Local community college 3. College/University 4. State DOT technical center 5. Technical center 6. Consultants 7. Conferences 8. Other, please specify

Survey Respondents

The survey response was relatively large, with 154 respondents from transportation and planning agencies at all levels. Responding agency types are summarized in Figure and

Table 3. The geographic distribution of respondents is shown in Figure 5. In some cases, as many as 3 individuals responded from the same agency. In this paper, some results are reported with the planner as the unit of observation and others are reported by agency. Though the survey was designed for planners with all levels of adaptation experience, it is likely that the responses are biased towards agencies that are more active in adaptation planning. Responses from a total of 149 planners from 137 agencies are used in the analysis of agency capacity. These respondents were categorized as working for either a local/regional agency (110) or state agency (39). Five respondents from airports, non-profits and federal agencies are not considered in the analysis of agency capacity but are included in the analysis of workforce development needs.

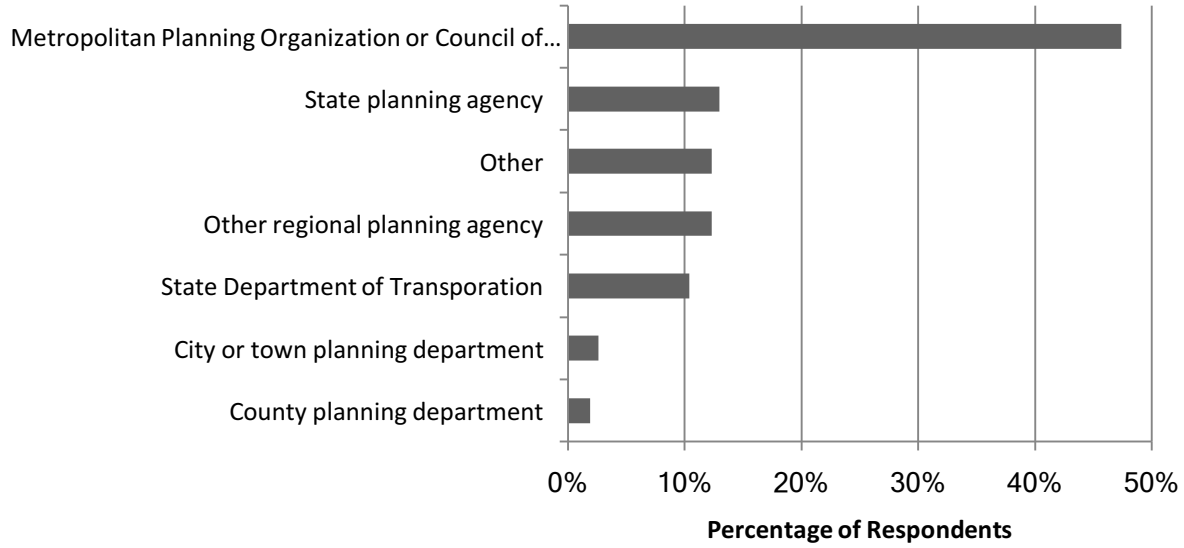

Figure 4. CAPS Respondents by Agency Type

Table 3. "Other" Agencies Represented (n=19)

Number of Respondents	Type of Agency
5	Transit Agency or System
4	Local Public Works or Planning Department
3	Combined MPO and Regional Planning Agency
2	Non-profit
1	Airport
1	Port Authority
1	Toll Agency
1	Transportation Authority
1	FHWA

The "other" category of respondents included those listed in Table 1.

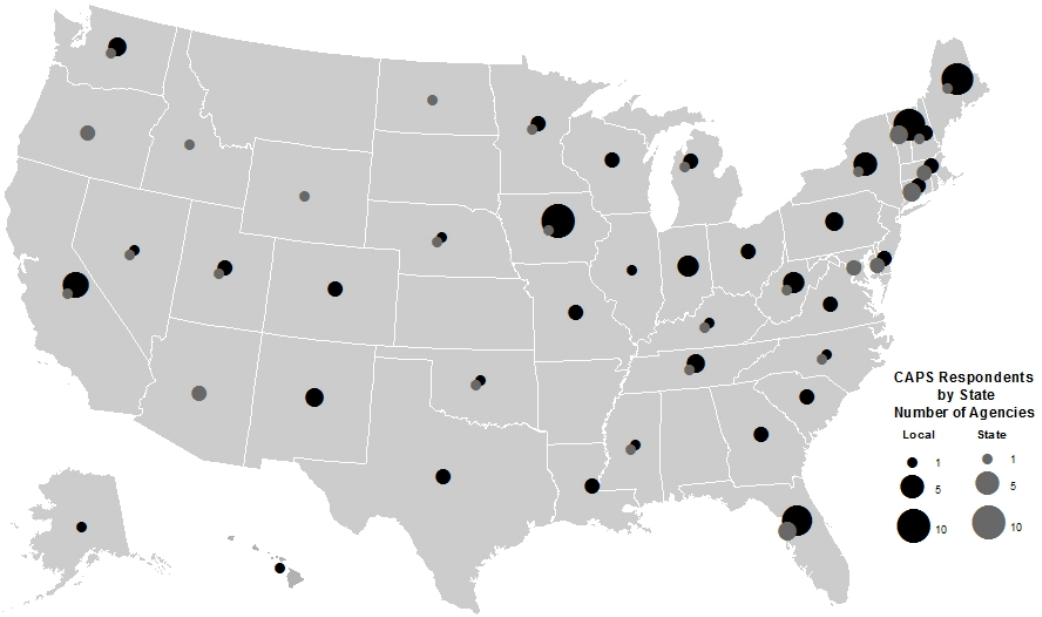

Figure 5. Respondents by State and Agency Type

Agency Capacity

Preparation Levels

One key element of this research is the identification of state and local agencies that are actively preparing for all of the threats facing their region and those agencies that still face a preparation gap. We define a preparation gap as any instance when a planner indicates his or her agency's region is exposed to a particular climate threat but then indicates the agency is not

yet preparing for that threat. Table 4 presents the percent of the planners who responded that a particular threat posed a risk to transportation in their region. On average, each planner indicated their region was facing 5 threats. Threats specified as "other" by respondents included hurricanes, wind, earthquakes, ice storms, sink holes, and tornadoes. Table 4 also shows the proportion of planners in at-risk areas that reported their agencies were preparing for a particular threat. Values less than 100 in columns 3 and 5 indicate a preparation gap for that threat. Table rows are ordered based on the percent of local agency planners in at-risk regions who indicated that their agency was preparing for the threat. Although the percent of at-risk agencies preparing for each threat is ordered similarly between state and local agencies, in almost all cases the proportion of state agencies preparing for each threat is higher. Core to the research question in this paper was to determine if whether the preparation gap differed between state and local agencies. Although local planners were more likely to indicate their agency was not yet preparing for a threat in their region, most differences were not statistically significant.

Table 4. Regional Threats and Agency Preparedness

Potential Threats	State Agency Planners (N=39)		Local/Regional Agency Planners (N=110)	
	Percent At Risk	Percent Preparing[1]	Percent At Risk	Percent Preparing[1]
Sea level rise	51.3	75.0	24.5	70.4
Flooding	94.9	70.3	88.2	62.9
Increased precipitation totals/intensity	71.8	**64.3**	70.0	**45.5**
Erosion	64.1	52.0	47.3	42.3
Landslides, rockslides, slope failures	61.5	**79.2**	34.5	**42.1**
Drought	46.2	16.7	33.6	35.1
Thawing permafrost	2.6	0.0	2.7	33.3
Electrical service disruptions	38.5	46.7	39.1	23.3
Wildfires	48.7	36.8	28.2	22.6
Increased run-off from snow/glacial melt	15.4	**50.0**	13.6	**20.0**
Increased freeze/thaw cycles	53.8	28.6	43.6	18.8
Increased heat extremes/heat waves	59.0	17.4	44.5	16.3

[1] Refers to the percent of *at-risk agencies* that are preparing for each threat
*bold indicates statistical difference between state and local based on Phi statistic at the 0.1 significance level.

Binary logistic regression models were used to assess predictors of whether an agency had a preparation gap. Explanatory variables tested included the planners' assessments of:

1. adequacy of financial resources for adaptation efforts (scale of 0-10);
2. regional infrastructure vulnerability (scale of 0-10);
3. adequacy of tools for assessing asset vulnerability (scale of 0-10);
4. adequacy of their agency's staffing level for adaptation efforts (scale of 0-10);
5. adequacy of their agency's staff knowledge for adaptation efforts (scale of 0-10);
6. number of threats identified by the planner (0-12); and
7. dummy variable if the agency was local.

Due to sample size, models were not estimated for all threats (Table 5). Observations were weighted by zip code in order to account for multiple responses from the same agency (120 agencies had only one respondent, while others had 2 or 3 each). Local agencies were more likely to face a preparation gap only for erosion and landslide threats. Whether or not a planner indicated their agency was preparing for a threat most often related to the level of vulnerability of the region's infrastructure to that threat. As would be expected, higher levels of financial resources and staffing and greater confidence in vulnerability assessment tools were also associated with an increased preparation rate. The Nagelkerke R^2 provides a general measure of the amount of variance between observations. Models are not strong for predictive purposes but show surprisingly high R^2 values given small sample sizes and limited predictor variables. This suggests a larger sample of similar data might be useful for targeting educational or professional development efforts. The general lack of a gap between state and local agencies may be due to a sample bias. Perhaps more active local agencies completed the survey. In some cases, it might be outside the scope of an agency's mission to pursue preparation for a threat. Clarification of these limitations is recommended.

Table 5. Binary Logistic Regression of Whether an Agency is Preparing for a Threat their Region Faces

Preparing for Threat (Y = 1)			Odds Ratio (bold if significant at 0.10)						
Vulnerability to threat	N	R^{2*}	Resources Financial	Adequacy of Tools for Vulnerability Assessment	Resources # of staff	Resources Staff Know-ledge	# of threats	Local Agency	Vulner-ability to threat
Sea level rise	43	0.57	1.35	1.45	0.72	1.18	0.67	0.07	**2.67**
Flooding	114	0.16	1.20	**1.17**	0.99	1.09	1.03	1.00	1.19
Precipitation	90	0.34	1.16	1.09	**1.34**	1.05	**1.36**	0.38	**1.26**
Erosion	68	0.42	**1.45**	**1.34**	**0.77**	1.23	1.16	**0.16**	**1.66**
Landslides	56	0.26	1.20	1.05	0.87	1.26	1.04	**0.19**	1.30
Drought	50	0.31	0.98	0.94	0.99	1.13	1.12	0.96	**1.44**

*Nagelkerke

Adequacy of Resources and Tools

The planners' assessment of the adaptation resources and tools is reported in Table 6. Resource sufficiency was measured on a scale of 0-10 where 0 was insufficient and 10 was sufficient. Ratings were relatively low in all four cases with high standard deviations. The adequacy of financial resources had the lowest average rating. There were no significant differences between state and locals but a higher percentage of locals selected unsure. The possibility that respondents were biased towards the most active agencies makes these low ratings even more concerning.

Table 6. Planner Ratings of Resources and Tools (Scales 0-10)

		All		State		Local	
		Mean	SD	Mean	SD	Mean	SD
Sufficiency of Resources	Financial Resources	3.1	2.7	3.0	2.6	3.2	2.8
	Infrastructure Design Guidance	4.8	2.7	5.1	2.7	4.7	2.7
	Human Resources: Number of Staff	4.1	2.7	4.1	2.6	4.1	2.7
	Human Resources: Knowledge Base of Existing Staff	5.1	2.5	4.9	2.7	5.1	2.4
Adequacy of Tools	Inventorying and monitoring transportation assets	6.9	2.2	7.4	2.2	6.8	2.2
	Assessing climate threats	4.7	2.7	5.1	2.6	4.6	2.8
	Evaluating asset vulnerability	5.0	2.5	5.4	2.5	4.8	2.5
	Rating asset importance or criticality	5.2	2.5	5.5	2.6	5.1	2.5
	Identifying and executing adaptation actions	4.1	2.5	4.2	2.6	4.0	2.5

A similar rating scheme (Table 6) was used for the technical tools for each of the five planning steps. In this case, 0 indicated no tools available and 10 indicated excellent tools available. In general, the tools for step 1, inventorying assets, are rated highest. Tools for steps 2 through 4 are moderately rated and tools for step 5, implementation, are lowest. Tools are on average rated lower by local agency planners but the differences between state and local were not

statistically significant as measured using two-sample Student's t-tests. Again, the overall low ratings are concerning given the presumed high activity level of the responding agencies.

Adaptation Actions

Planners were also asked if their agency had pursued a range of procedural adaptation actions and infrastructure changes. The results in Table 7 show the percent of agencies that are undertaking each action, weighted by zip code to account for agencies with multiple respondents. Overall, procedural changes are more common than infrastructure changes. Among infrastructure changes, most are design related. This is consistent with the lower cost of procedural changes discussed previously. We would expect if the survey was repeated in a few years that more agencies would report taking adaptation actions, including more infrastructure changes.

New data collection, communication procedures, plans and trainings are the most common adaptation actions. Changing data collection practice was the single most common action. Few agencies have added overall staff or new skill sets. We again would look for these percentages to increase over time. In almost all cases, a higher proportion of the state agencies have undertaken adaptation actions compared to local agencies. Without knowing the bias in the agencies responding it is difficult to assess if this measures a slight lag for local agencies overall. We suggest that local agencies may have been biased towards those leading in the adaptation area and that overall local agencies may lag more than suggested by these numbers. Of particular note are the 20% of local agencies that report no procedural changes compared to 0% of state agencies.

Table 7. Adaptation Actions

		% of State Agencies	% of Local Agencies
Institutional or Procedural Changes	Hiring additional staff	6.5	4.9
	Adding staff with different skills than existing staff	3.2	8.8
	Developing new interagency relationships/communication procedures	**58.1**	**38.2**
	Programs for climate adaptation/planning procedures	45.2	30.4
	Training	32.3	28.4
	Developing hazard mitigation/emergency response plans	48.4	48.0
	Creating/improving data collection/analysis procedures	**67.7**	**41.2**
	Modifying maintenance schedules and practices	**20.0**	**8.8**
	Other	16.1	6.9
	None	**0.0**	**19.6**
Infrastructure Changes	Infrastructure, altering designs	**51.6**	**29.4**
	Adding protective infrastructure	26.7	14.7
	Infrastructure relocation	12.9	13.7
	Infrastructure abandonment	9.7	7.8
	Increasing network redundancy	16.1	19.6
	Adding natural areas or green infrastructure to protect existing assets	**19.4**	**39.2**
	Other	9.7	5.9
	None	12.9	11.8
	Unsure	16.1	19.6

*bold indicates statistical difference between state and local based on a Phi statistic at the 0.1 significance level.

Workforce Development Needs

Several recent studies point to the need for continuing education of current planners and transportation professionals regarding climate adaptation as well as education about climate adaptation for transportation leaders, the public and future employees(*3*, *37*, *38*). The 2012 National Transportation Workforce Summit organized by the Council of University Transportation Centers (CUTC) resulted in a report and framework that articulates the transportation workforce challenges including an aging workforce, lack of new entrants and advancing technology (*39*). Various U.S. Department of Transportation programs have addressed workforce issues including the Transportation Development Education Pilot Programs (TEDPP), the Garrett Morgan Program and others with emphasis on specific audiences. In Fall 2014 the FHWA awarded grants to five universities for development of regional surface transportation workforce centers, each part of a new National Network for the Transportation Workforce (*40*). The Transportation Research Center at the University of Vermont was designated the Northeast Transportation Workforce Center (NTWC) and has

among other goals, a focus on workforce development related to climate adaptation. For this reason, the CAPS included several questions relating to agency staffing, knowledge base of current employees and training.

Implications for Human Resource Development

Survey respondents were asked to indicate which institutional or procedural changes their agency implemented as a part of climate adaptation planning. Beyond technical procedures, 31.2% were undertaking training, while just 5.2% were adding additional staff with 7.8% adding staff with different skills than existing staff.

Respondents rated on a 0 (low) to 10 (high) scale the adequacy of their agency's number of staff to address climate adaptation challenges and work. Results in Figure 6, indicate a rather broad distribution of rating of adequate staff numbers with a mean rating on the scale of 4.2.

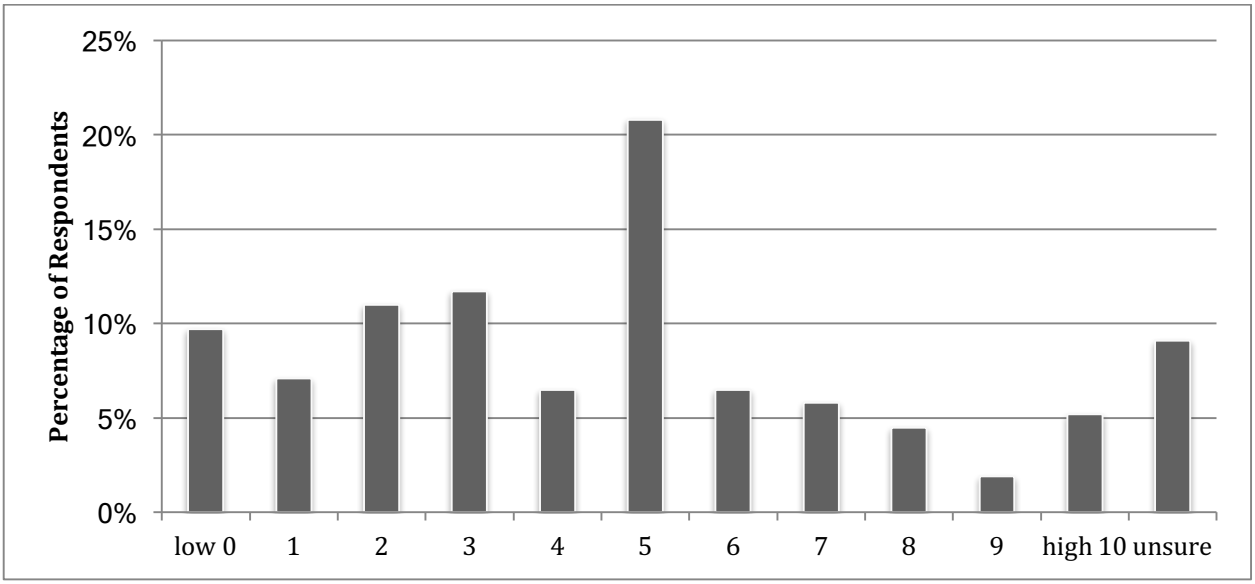

Figure 6. Number of Staff Adequate for Climate Adaptation Efforts (n=154, mean=4.2)

Respondents also rated, on the same scale, the adequacy of current agency staff's knowledge base concerning climate adaptation. Results in Figure 7 show a similar broad distribution regarding general adequacy of knowledge base around the mean score of just 5.1.

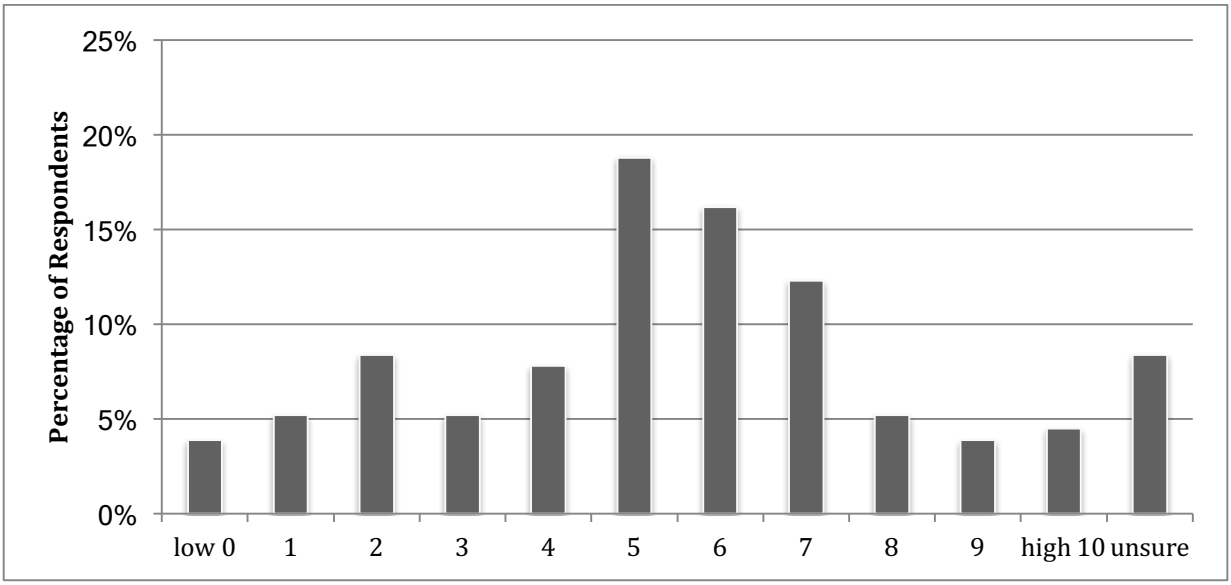

Figure 7. Knowledge Base of Existing Staff Adequate for Climate Adaptation Efforts (n=154, mean = 5.1)

The general response indicates that responding agencies had neither the number of staff needed, nor the incumbent skills required to address the questions and issues of climate adaptation in their current and future work.

Workforce Development Needs

In an open-ended question, respondents were asked to briefly describe their agency's professional development needs related to adaptation planning. 90 of the 154 (58%) respondents replied to this question. The responses were analyzed and coded using HyperResearch qualitative analysis software.

Of the 90 respondents, 20% indicated no workforce development needs for climate adaptation planning. Some respondents simply answered "none" but others gave explanatory comments. Most often the lack of need was because either 1) there was no acceptance or focus on climate change in the state, 2) the agency faced more important or urgent issues, or 3) training was already being designed or underway for adaptation planning.

For the remaining 80 % of respondents, thematic categories of comments related to workforce development needs are listed in Table 8. (Note that some respondents had answers that included two or more themes).

Table 8. CAP Workforce Development Needs

Theme	Number of Responses
Need specific training topics	55
Need resources	19
Need training for planners	8
Need a Community of Practice	6
Need local climate data and scenarios	4

The most frequently mentioned specific training in adaptation planning was introductory or basic (and low cost) seminars in climate change and planning (n=17). Along with this came the request to understand the risks and benefits along with cost analysis of climate adaptation planning (n=9) and the technical tools available to help with planning (n=5). Beyond these topics, other responses included: more specific requests for a focus on inland assets, learning how to identify valuable assets, how to assess environmental areas, how to assess vulnerability, sea level rise planning and training for emergency management staff. Help with policy development and coordinating the planning process with other agencies was also a need for specific workforce development efforts.

Resources specifically needed for climate adaptation planning included funding, staff and time. Many agencies felt understaffed to undertake this work, or needed new staff with new skills in transportation or planning. Some respondents made particular mention of the need for workforce development in climate adaptation planning for planners and not just engineers. As one respondent mentioned:

> *Since we are a planning and not an implementing agency, there is a need for professional development within our agency as well as implementing agencies.*

Some respondents expressed the desire for a Community of Practice to learn from and work with those who are in neighboring states or regions of the country. This extended to learning from the best practices of others, reviewing model plans and reports as well as guidance from state and federal agencies. Agencies were interested in engaging with and having access to climate data and forecasts that were specific to their region. This included new sources of data and guidance in how to use that data.

Sources for Professional Development

Respondents were also asked to select all sources of professional development used by their agency for climate adaptation knowledge and skill development. Figure 8 shows results to this question.

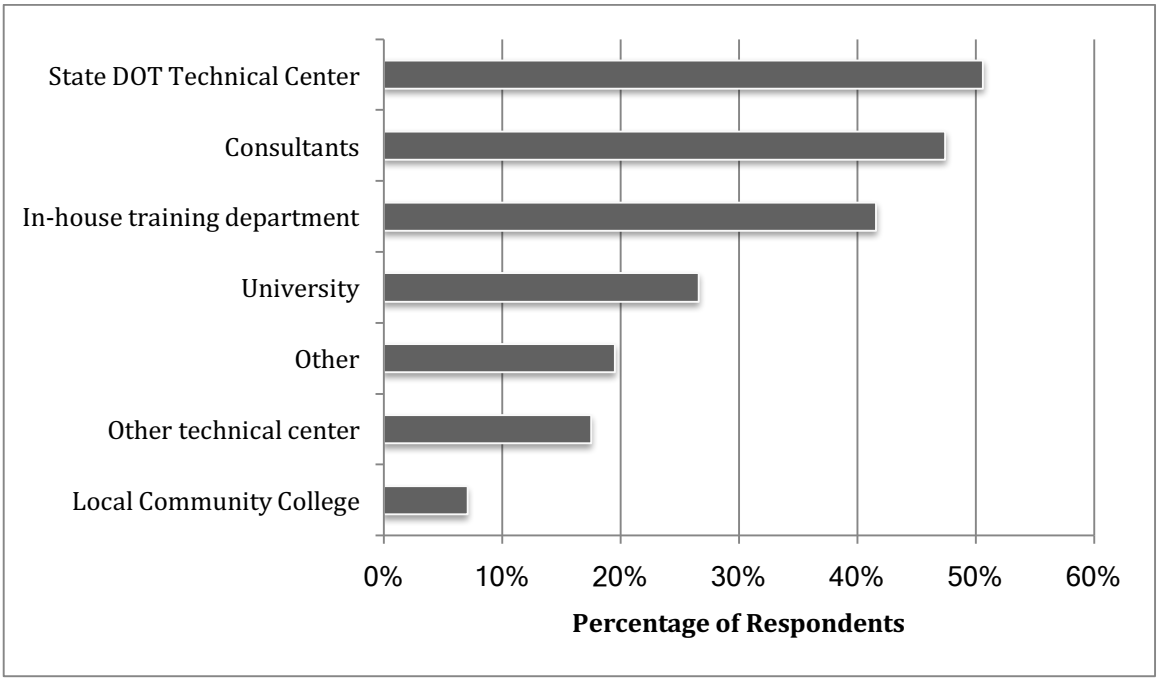

Figure 8. Sources for Staff Professional Development (n=154)

Respondents who included the "other" category primarily mentioned online learning or research, particularly webinars offered by FHWA and other federal agencies. Partnerships with other regional agencies (such as Conservation Districts or Emergency Management) were also included.

Workforce Development Discussion

The results of this initial look at workforce development needs for climate adaptation planning points to a broad spectrum of issues and challenges to be addressed. While this survey was limited in scope, it does provide a good starting point for understanding the variety of preparations currently being undertaken in adaptation workforce efforts and factors that are necessary to support this process.

To further explore this, a brief limited review of current (July 2015) web-based job postings at the Association of Metropolitan Planning Organizations (www.ampo.org) and the National Association of Development Organizations (www.nado.org) found a total of 46 current openings at organizations across the county. In a key phrase search under qualifications and responsibilities for reference to climate change, greenhouse gases or emergency planning and mitigation, four of the 46 posting has such a reference with only one referring directly to climate change. A more comprehensive look at how open positions at all types of transportation planning organizations are, or are not, referencing either conceptual links to climate adaptation as a responsibility area, or have identified specific skill or qualification

categories necessary to address the needs of agencies in response to climate adaptation is warranted in future research.

It is clear that most, but not all, of the organizations surveyed have undertaken preparations for staff development in climate adaptation seriously and were actively engaged in specific actions or seeking to build capacity. The survey further surfaced a set of supports that if put in place would help agencies move forward in their planning and capacity building. These include adequate funding for training and planning activities, availability of a continuum of training and education opportunities, establishment of communities of practice for ongoing learning and collaboration, and access to education resources through online learning technologies.

Funding

Many of the barriers to adequately planning for climate adaptation can be connected to lack of funding, which translates to a shortage of resources in staff, time and knowledge, which contributes to a competition with other priorities. If climate adaptation planning is to be a national priority in transportation, than adequate funds must be made available at all levels to support this effort. As respondents noted:

> *We have nothing in place right now and no resources to pay for training.*
>
> *There are no resources set aside for climate change planning. Our needs would be fundamental: staff and funding.*

Continuum of Workforce Development Training

Workforce development trainings and resources need to be designed and offered across a continuum from the basics of climate change and adaptation to advanced offerings including tools and technical planning. It was clear that some respondents were just beginning to explore climate change as an issue to address, while others were fairly well along in their understanding but needed specific tools and applications. It would also be a benefit to design training that was as local and regional as possible for maximum applicability by agencies. These ideas were expressed by respondents as:

> *Basic seminars on all aspects.*
>
> *Training on an overview standpoint and on specific tools that could be used.*

DOT needs professional training on all aspects of adaptation planning. This includes identifying critical assets, describing climate and extreme weather threats, assessing vulnerability, and especially, identifying and selecting adaptation strategies.

The five-step transportation adaptation framework put forward by Dowds and Aultman-Hall (*2*) could serve as the core of this continuum, with additional training steps added explaining the

basics of climate change and necessity for adaptation planning. The continuum in fact, may be more appropriately thought of as a matrix, offering similar topics and content, but for different audiences including planners, engineers, governmental leaders and the interested public. This should include not just technical information but also organizational development information for regional leaders that could enhance interagency cooperation. While this framework provides a model that can be applied equally in any state, content could be adjusted to the specific regional climate adaptation issues and needs.

Communities of Practice

Professional communities of practice (CoP), where planning and transportation professionals can learn from each other, share problems, solutions and build a network can have a profound impact on organizational outcomes (*41*). In a pilot program that brought together state DOT professionals from three adjoining states, one particular outcome participants endorsed was the network building, information and resource sharing from learning and working with colleagues (*42*). Developing and facilitating regional CoPs would help meet and sustain some of the climate adaptation workforce needs expressed by respondents.

> *We need to be educated on the topic and study best practices from other state DOTs and MPOs.*
>
> *I am continually looking for resources to use in assisting me in adaptation planning. Applicable technical reports from federal and state transportation agencies, other agencies' climate change adaptation plans, and webinars are of great interest to me.*

Use Learning Technologies

Given resource constraints in time, funding and staff, offering high quality but accessible and low cost workforce development options is necessary. Many respondents were accustomed to accessing training via webinars, online learning and for searching online for reports and information. The TRB and many professional organizations, as well as institutions of higher education, have developed robust systems for offering webinars and this is an excellent avenue for offering adaptation planning workforce development or hosting CoP.

Conclusions

Climate adaptation and resiliency planning is important for state and local transportation agencies. The five-step common framework presented here is useful for identifying barriers to implementation and for facilitating opportunities for interregional and interagency cooperation. However, more data and policy discussions are needed regarding the roles for different agencies. Particular attention must be paid to asset criticality rating which cannot be conducted in isolation by either the local or the state agency since it must account for the network redundancy and vulnerability of both state and local infrastructure.

Results of the online CAPS indicate many commonalities among agencies but give some indications that local agencies may be lagging behind their state counterparts. Responses from state agency personnel generally indicated a smaller preparation gap for all threats and a higher percentage of agencies undertaking both procedural and infrastructure adaptations. Nonetheless, the differences between the individual agencies surveyed were greater in most cases than the overall average difference between state and local agencies. Many of these patterns were not statistically significant. If, as we hypothesize, agencies that are more engaged and knowledgeable in climate adaptation planning were more likely to respond to the survey, the discrepancy between local and state agencies may be larger than found here. Missing agencies may include those without resources, political support or that are unware of climate threats in their region. Future research needs to find and assess all local agencies and ensure they are able to provide appropriate adaptation and resiliency planning in their region.

A substantial preparation gap existed for all identified threats. Between 0-80% of agencies are preparing for a given threat in their region. Modeling confirmed that whether an agency was preparing for a threat was related to many factors including financial resources, technical tools, staffing and agency type (state versus local). Surprisingly few of the planners in the survey indicated that their agencies were pursuing adaptation actions. As expected, more adaptation actions were procedural rather than infrastructure adaptations. However, 20% of local agencies indicated no procedural actions and 12% of all agencies indicated no infrastructure actions. This points to a need to track actions over time and ensure that identified barriers are reduced and that other significant barriers to action implementation are not present but unmeasured. Future surveys should also seek to understand which types of actions and preparation are reasonable within a given agency's mission.

Tools and resources, especially staff time, are clearly barriers to adaptation efforts. Both state and local agency respondents assessed many adaptation tools and resources as lacking. Among adaptation tools, asset inventorying tools are rated substantially higher than other tools but only rated an average of 6.9 out of 10. All other tools were rated between 4.1 and 5.2 out of 10 with tools for identifying and executing adaptation actions requiring the most improvement. The number of staff was cited as the most limiting resource. Given that the adequacy of the tools for four of the five steps in adaptation process had an average rating below 5.5 on a 0-10 scale, there appears to be a clear need to advance or develop better tools for agency use.

Given the significant infrastructure owned by local agencies, both local and regional agencies have an important role to play in adaptation planning. Unfortunately, the comprehensive understanding of which local agencies are currently able to engage in adaptation efforts is limited. We suggest that the criticality of any asset cannot be accurately assessed without knowledge of the entire regional network system, regardless of ownership, and the vulnerability of all constituent assets. Climate adaptation planning is a complex, challenging endeavor and must address threats that vary considerably by region. Therefore all agencies within a region have a stake in ensuring all agencies are adequately resourced and active in the adaptation efforts appropriate for the region.

Respondents in the study affirmed that workforce development is an important part of advancing adaptation planning. More work is needed in examining the workforce development needs of transportation agencies by factors such as region and type of organization. In addition, a higher level of specificity of the skills and qualifications is needed to inform development of new training, new hires, and educational curriculum that prepares the future workforce. This overview is useful in establishing an initial set of recommendations that can be used as a foundation for addressing adaptation planning workforce development needs and can be applied in planning organizations as well as educational and training institutions as the more specific content continues to evolve. These recommendations are 1) Provide additional funding, 2) Develop a continuum of adaptation planning workforce capacity building offerings, 3) Develop Communities of Practice and 4) Make use of online learning technologies for workforce development offerings.

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