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Climate change adaptation as an organizational system in transportation infrastructure organizations: Identifying processes and institutional elements

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1. Introduction

Climate change resiliency and adaptation have become a larger focus of the transportation industry and research efforts over the past decade. As increasing numbers of scientists and practitioners acknowledge that even with mitigation the planet will experience certain unavoidable levels of climate change, discussions have begun to transition from mitigation to resilience (IPCC, 2015). While the questions of how much and when are still debated, the transportation field has progressed from the study of mitigating greenhouse gas (GHG) emissions to estimating climate change impacts, vulnerability to impacts, and the current emphasis on adaptation. According to the United States Department of Transportation (DOT), adaptation should now be an equal consideration to mitigation (USDOT, 2014).

Many transportation infrastructure agencies, particularly state DOTs, cities, and Metropolitan Planning Organizations (MPOs), have therefore created or are in the process of creating climate change adaptation strategies and plans. However, despite the policy recommendations and an increase in research, attention to and implementation of adaptation is still relatively low (EEA, 2014).

Concurrently, research frameworks are emerging that focus on incorporating climate change into existing processes within an agency (FHWA, 2008; Meyer et al., 2010a; Schmidt and Meyer, 2009). USDOT policy guidance is for state DOTs to incorporate climate change adaptation into nearly all of their existing processes, including risk and asset management, long-term planning, and operations and maintenance (USDOT, 2014). However, even with this emerging focus, there is a lack of understanding and guidance about how DOTs implement climate change within and across organizational processes.

In 2009, the barriers to climate change adaptation were found to be the need for tools to assess vulnerability, uncertainty about asset criticality, and limited funding (Plumeau and Lawe, 2010). Since then, many tools have been developed and new methods proposed, eliminating or reducing some of those barriers. While the tools, methods, and frameworks cover a wide range of solutions, there is a lack of understanding of the organizational implications of climate change adaptation and only a moderate understanding of executing adaptation action (Dowds and Aultman-hall, 2015). This research moves beyond a focus on tools to study the organizational barriers to adaptation by examining climate change adaptation as an organizational management issue for agencies such as local/city government, state DOTs, and MPOs.

This research takes the first step in developing an organizational framework for climate change adaptation that links existing transportation management processes to the development of a climate change adaptation program. This project determines the most important and urgent factors that agencies implementing climate change adaptation should address. These factors, to be later incorporated into an organizational model, are identified through a literature review. They are validated and ranked by industry and academic experts in a Delphi survey.

2. Background

2.1. Climate change adaptation and transportation

Climate science shows our climate has already changed, certain levels of additional change are unavoidable, and those changes may be even greater depending on our mitigation efforts in the future (IPCC, 2015; USGCRP, 2014). Research also shows that all types of infrastructure, including roads, airports, seaports, rails, tunnels, and bridges are vulnerable to extreme weather events and coastal flooding, as well as gradual changes in temperature and precipitation (Humphrey et al., 2008; IPCC, 2015; Meagher et al., 2012; Meyer et al., 2010b). These climate stressors have the potential to accelerate infrastructure deterioration, increase severe damage and failures, decrease safety, and increase traffic, all of which will have an economic impact in addition to the direct

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impact on infrastructure and its users (Melillo et al., 2014; Nemry et al., 2012).

As knowledge about vulnerability increases, transportation agencies need to transition from assessing vulnerabilities to addressing them (Savonis et al., 2014). Much of the initial work on adaptation has focused on either very local action (Burch, 2010) or national policy-making (Jotzo, 2010) and is not specific to transportation infrastructure (Berkhout et al., 2006; Bollinger et al., 2014; Liso, 2006).

Many industry sectors, including transportation, have completed economic modeling of the impact and adaptation costs (Chinowsky et al., 2013). This quantification is an important tool for economists and policy-makers, but there are limitations to economic modeling for climate change adaptation, and more detailed sector-specific research is required to enable local adaptation action (Jotzo, 2010). Not providing the appropriate scale and type of research can lead to a pattern where organizations include adaptation into planning and policy documents but do not take any action as a result (Berrang-Ford et al., 2011).

As priorities move from policy to producing measurable results and action, the focus should also move from the national to local level (Bulkeley and Betsill, 2010; Burström and Korhonen, 2001). Therefore, there is a need for studies that are unique to specific organizations (MacArthur et al., 2012). In the case of transportation in the United States, this means shifting focus to specific agencies, such as city transportation departments, state DOTs and MPOs.

While implementation and barriers of climate change adaptation are less understood at this level (Burch, 2010), the amount of research on particular frameworks and methods for climate change adaptation has increased. Rowan et al. utilize a sensitivity matrix to incorporate a wide range of climate stressors (Rowan et al., 2013). Meyer and Weigel (2011) and Wall et al. (2007) suggest an adaptive management approach that, among other steps, includes vulnerability assessment, risk appraisal, and cost analysis and can be applied to a wide range of infrastructure assets (Meyer and Weigel, 2011). Meyer et al. detail how asset management can be used to address climate change adaptation (Meyer et al., 2010a). Other recommendations expand on the asset management approach by specifically suggesting a risk-based asset management approach (O'Har, 2013), which aligns well with the Fixing America's Surface Transportation (FAST) Act requirement for risk-based asset management (114th Congress and Congress, 2015).

While each approach and framework are different, one thing they have in common is that they all focus on a process. In some cases, it is a process that already exists within transportation agencies, in others the framework develops an entirely new process specific to climate change adaptation. These studies add to the body of knowledge and expand the set of tools available to infrastructure managers. However, they often isolate adaptation within one project or process or create an entirely new process outside of what organizations already perform.

2.2. Climate change adaptation and organizations

The former Secretary of Transportation, Ray LaHood, stated that "climate change adaptation should be integrated into core policies, planning, practices, and programs" (LaHood, 2011) and the USDOT "strongly encourages consideration of potential climate change impacts in the transportation planning process." (USDOT, 2014) USDOT further states that "mainstreaming consideration of climate in all activities related to planning, constructing, operating and maintaining transportation infrastructure and providing transportation services can ensure that resources are invested wisely and that services and operations remain effective." (USDOT, 2014).

Incorporating climate change adaptation into existing transportation processes is consistent with literature suggesting that the implementation of adaptation is more likely if it is consistent with existing programs that are already designed for non-climatic stresses and integrated into policy strategies (Burch, 2010; O'Riordan and Jordan, 1999; Yohe, 2001).

Much of the research on processes, institutions, and barriers to climate change implementation is non-transportation specific. Research in other public infrastructure industries, such as water resources or land management, can help pre-identify certain elements as potential barriers (Archie et al., 2014). However, these approaches typically take an industry-wide stakeholder perspective, rather than examining a single organizational actor. When examining organizations, it has been shown that it is not a lack of capacity but a facilitation of resources and institutional barriers that keep organizations from climate change action (Burch, 2010).

Despite the USDOT policy recommendations, there are relatively few cases examining the incorporation of climate change adaptation into organizations, including one detailed study in New York (Major et al., 2011). Many of the case studies and publications are project-based, often focusing on singular pilot projects and not ongoing project development. FHWA has completed a regional project on this topic, but it focused on land use and scenario planning, not specifically on climate change adaptation in DOTs (FHWA, 2014). USDOT anticipates a publication on the integration of climate change adaptation, but it focuses only on coastal highways (USDOT, 2015). There is a need for more rigorous and in-depth study of the organizational implications of climate change adaptation, particularly on the organizational change necessary to implement adaptation processes in transportation agencies.

2.3. Organizational modeling

The literature review and Delphi study conducted for this paper are part of a larger research goal to model the organizational aspects of climate change adaptation in transportation agencies. This requires combining organizational change and process development into a single framework. Based on their flexibility and focus on general process and institutional environments, organizational maturity modeling is an effective framework for this goal. On a broad level, "maturity models describe the development of an entity over time. This entity can be anything of interest: a human being, an organizational function, etc." (Klimko, 2001) A maturity model is a structure that describes the elements of a process at different stages of development. It provides separation between stages of development, and describes means for advancing from one stage to the next (Pullen, 2007). Many of the first maturity models were based on quality process improvement (Crosby, 1983) and the Capability Maturity Model (CMM) (Paulk et al., 1993). While many maturity models are based on these models and their principles, the method has expanded into a wide range of industries (Wendler, 2012).

Maturity models and the concept of maturity are not new to the transportation, construction, and engineering industries. For example, a maturity model was used to examine the level of asset management formalization in infrastructure management (Zeb et al., 2013). The approach was also used to study institutional architecture for Transportation Systems Operation and Maintenance (TSOM). (TRB, 2011).

The organizational maturity framework is used in this research as it examines processes of the organization that will support an overall climate change adaptation program. Formalizing these processes of climate change adaptation allows agencies to quantify and compare management practices to a benchmark, determine existing capabilities, strengths, and weakness, and identify best practices (Zeb et al., 2013; Zephir et al., 2011).

During the early stages of a topic's research and implementation, a maturity model can also provide a roadmap for organizations to guide decision-making and investment. It formalizes roles and responsibilities without focusing on particular individuals in an organization (Bate, 1998) and identifies elements needed to change or create a new organizational culture (Chinowsky et al., 2007). Climate change adaptation includes inherent uncertainty, and a maturity model limits process uncertainty and variability by controlling outputs, tasks, or behaviors (McBride, 2010). These characteristics apply to the case of climate change adaptation in transportation agencies, which makes the maturity