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Examining the Effects of Transportation Governance on Infrastructure Adaptation to Climate Change

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1. Introduction and Project Objectives

Transportation agencies across the United States are faced with the challenge of effectively adapting infrastructure to withstand the predicted effects of climate change. This challenge is magnified by a nationwide funding shortage, uncertainty about impacts, and a limited (but growing) body of information regarding best practices. The literature on transportation infrastructure adaptation is weak in terms of strategies for undertaking improved planning. The work presented here seeks to help fill that gap. This report discusses research efforts and presents findings regarding the influence of transportation governance structures and mechanisms on infrastructure adaptation to climate change. This work is a continuation of research that began in 2009 as part of our ongoing efforts in climate change resiliency through the Research on Adaptation to Climate Change (RACC) project. Several different research topics and methodologies have contributed to the results.

Due to the varied nature of the research undertaken on this subject, this report is organized by specific projects and papers. While some have a fairly unique focus, others share a significant amount of overlap. The interdisciplinary nature of this research aligns well with the complex system spire's emphasis on social complexity, and it also is well aligned with the UVM TRC's focus on network resiliency, adaptive governance, and climate change.

Over the past two years, our work on this subject, with the support of the UVM TRC, has resulted in the creation of one database, five papers in various stages of acceptance and/or review at peer-reviewed journals, one grant proposal, and two conference presentations (at the 2015 Annual Meeting of the Transportation Research Board and the 2015 Conference of the American Society for Public Administration).

2. Database: Bridge Funding in Vermont and Maine, 2000-2015

Although this database has not been published, it is currently accessible for use by the UVM TRC and associated researchers. The database was first constructed by TRC GRA Tiyasha De Pinto; Anna Schulz expanded the database and revised/updated some earlier work for accuracy.

2.1 Background

While many transportation agencies are beginning to discuss the importance of adapting infrastructure to climate change, it is unclear whether funding is actually being allocated for that purpose. Both to help calibrate models and provide a snapshot of funding priorities, we constructed a database that has entries for every planned bridge project undertaken in Vermont and Maine from 2000-2015.

2.2 Methodologies

The first step in building this database was the acquisition of funding documents for the states involved. For Vermont, the most detailed funding documents proved to be yearly Capital Programs published by VTrans. For Maine, the Capital Programs lacked detail about project funding breakdown, so Statewide Transportation Improvement Programs were used instead. The two plan types are closely related yet do have distinct differences: Capital Programs are more representative of the budget, while STIPs are a plan for committing federal funds. Capital Programs also tend to operate on the state fiscal year, while STIPs align with the federal fiscal year. In the case of both plan types, specific projects often fall behind schedule or are delayed for another year. As a result, some projects can reappear in plans for several consecutive years even if they are not actually active, which leads to funds being overcounted. Capital Programs are also produced annually, while STIPs are produced biennially.

The Capital Programs and STIPs were used to build a project database that included all available information about a given project. For the purposes of this research, only bridge and culvert projects were included. VTrans divides its projects into specific programs: those projects belonging to the “Interstate Bridges”, “State Highway Bridges”, and “Town Highway Bridges” categories were included in the database. For plans produced in 2006 and later, maintenance projects were segregated into a separate “Bridge Maintenance” category; those were included as well.

MaineDOT does not subdivide bridge projects into program classes as neatly as VTrans. While Maine STIPs do include a “Bridge Replacement and Rehabilitation” funding source category, many additional bridge projects are typically funded through other sources, such as “Interstate Maintenance.” To create a database comparable to the assembled for Vermont, Maine projects were selected if their descriptions explicitly stated that they were bridge or culvert projects. Bridge or culvert projects that were listed as part of another, larger project were not included due to the inability to determine how much funding was allocated to the different portions of the project. Because STIPs are only produced every two years, odd years typically include fewer projects. Several project listings contained discrepancies between funding allocation breakdowns and projects totals, many of which were considered to be clerical errors. For those projects, the totals were updated to reflect the sum of the allocated funding sources.

The resulting database has an entry for every bridge or culvert project that has appeared in Vermont Capital Programs or Maine STIPs in the past fifteen years, complete with all available funding data, location information, and a brief description.

2.3 Results and conclusions

Given that this is a database, the results and conclusions depend largely on context and method of analysis. At the broadest level, Vermont is steadily investing more into bridges, while Maine has seen much more sporadic investment.

3. Paper: The emergence of attractors under multi-level institutional designs: agent-based modeling of intergovernmental decision making for funding transportation projects

This paper was published in the international journal *AI & Society: Knowledge, Culture, and Communication* (published online 11 December, 2013). Asim Zia and Chris Koliba authored the paper; Anna Schulz provided edits in the review stage.

3.1 Background

In multi-level governance networks, policy systems are influenced by varying distributions of power and authority among federal, state, regional, and local levels. To better understand the theory and practice around governance relative to the field of transportation, we undertake the following research question: *how do intergovernmental institutional rules set by federal, state, and regional government agencies generate and sustain basins of attraction in funding infrastructure projects?* Modeling these arrangements and associated factors has the potential to reveal patterns regarding socioeconomic and infrastructure development. In this paper, we introduce our work on a pattern-oriented, agent-based model (ABM) that was developed to simulate real-life transportation policy implementation processes at the federal, state, regional, and local levels. The ABM compares a baseline governmental scenario with alternative structures (based on the use of different rules) and examines how that influences finances. Calibrating the ABM required inputting data gathered from focus groups, interviews, and analysis of current policies and programs. In this paper, we used the ABM to focus on how different power and authority structures between transportation actors (including government at multiple levels) affect roadway project prioritization procedures and funding allocations.

3.2 Methodologies

Multiple steps--from gathering data to building the model--were required to obtain the results published in this paper.

3.2.1 Data collection

We conducted both in-depth interviews and focus groups with a number of stakeholders, including local government officials, CCRPC (MPO) staff and board members, staff from other Vermont RPCs, Vermont Agency of Transportation (VTrans) officials, Federal Highway Association (FHWA) representatives, USDOT officials, federal and state senate office representatives, and local nonprofits and NGOs. Both the focus groups and the interviews were recorded and transcribed, then analyzed for relevant themes.

To better understand how roadway projects are selected, we acquired project prioritization procedures for the state, the MPO, and other RPCs. Because transportation funding is increasingly limited, in any given year there are far too many potential projects to actually fund, so states and MPOs are forced to prioritize the most important ones. Each state does this differently. Vermont's project prioritization procedures can be found in Table 1, below. After acquiring the project prioritization procedures, we assessed all of Vermont's Capital Programs from 1998-2011. Capital Programs, which are essentially to-do lists, include all of the projects that have been prioritized and selected for funding. We pulled the roadway projects out of each year's Capital Program and created a funding database (like the bridge funding database described earlier in this document). This database enabled us to compare the observed priorities with the stated prioritization procedures and to look at funding patterns across space and time.

Table 1. Transportation project prioritization procedures in Vermont.

<table>
<tr><th></th><th colspan="2">State Level</th><th colspan="4">Regional Level</th></tr>
<tr><th></th><th>SDOT Criteria</th><th></th><th colspan="2">Chittenden County</th><th colspan="2">Other Counties</th></tr>
<tr><th>Project Class</th><th></th><th>Wt.</th><th>MPO Criteria (applied across all classes)</th><th>Wt.</th><th>RPC Criteria since 2006</th><th>Wt.</th></tr>
<tr><td rowspan="4">Roadway</td><td>Highway system*</td><td>.40</td><td rowspan="31">Economic vitality

Safety and security

Accessibility, Mobility and connectivity

Environment, Energy and Quality of life

Preservation of Existing System

Efficient System Management</td><td rowspan="31">.166 @</td><td rowspan="31">The impact of the project on congestion and mobility conditions in the region

The availability, accessibility and usability of alternative routes

The functional importance of the highway or bridge as a link in the local, regional or state economy

The functional importance of the facility in the social and cultural life of the surrounding communities.

Conformance to the local and regional plans

Local support for the project.</td><td rowspan="31">Ranked by priority from 1 (being the highest) to 5 (being the lowest)</td></tr>
<tr><td>Cost per vehicle mile*</td><td>.20</td></tr>
<tr><td>Regional priority</td><td>.20</td></tr>
<tr><td>Project momentum</td><td>.20</td></tr>
<tr><td rowspan="3">Paving</td><td>Pavement condition index*</td><td>.20</td></tr>
<tr><td>Benefit/cost*</td><td>.60</td></tr>
<tr><td>Regional priority</td><td>.20</td></tr>
<tr><td rowspan="8">Bridges</td><td>Bridge condition*</td><td>.30</td></tr>
<tr><td>Remaining life*</td><td>.10</td></tr>
<tr><td>Functionality*</td><td>.05</td></tr>
<tr><td>Load capacity and use</td><td>.15</td></tr>
<tr><td>Waterway adequacy & scour suscept.</td><td>.10</td></tr>
<tr><td>Project momentum</td><td>.05</td></tr>
<tr><td>Regional input and priority</td><td>.15</td></tr>
<tr><td>Asset-benefit cost factor</td><td>.10</td></tr>
<tr><td rowspan="7">Bike/ Pedestrian</td><td>Land use density</td><td>.20</td></tr>
<tr><td>Connectivity to larger bike/ped network</td><td>.10</td></tr>
<tr><td>Multi-modal access</td><td>.05</td></tr>
<tr><td>Designated downtown/village center</td><td>.05</td></tr>
<tr><td>Project cost</td><td>.20</td></tr>
<tr><td>Regional priority</td><td>.20</td></tr>
<tr><td>Project momentum</td><td>.20</td></tr>
<tr><td rowspan="5">Traffic operations</td><td>Intersection capacity*</td><td>.40</td></tr>
<tr><td>Accident rate</td><td>.20</td></tr>
<tr><td>Cost per intersection volume*</td><td>.20</td></tr>
<tr><td>Regional input and priority</td><td>.20</td></tr>
<tr><td>Project momentum</td><td>.10</td></tr>
<tr><td rowspan="4">Park and ride</td><td>Total highway and location*</td><td>.40</td></tr>
<tr><td>Cost/parking space</td><td>.20</td></tr>
<tr><td>Regional Input priority</td><td>.20</td></tr>
<tr><td>Project momentum</td><td>.20</td></tr>
</table>

***denotes Asset Management System**

3.2.2 Structuring the ABM

The ABM was structured to simulate the intergovernmental decision-making processes that result in project funding. The ABM, which is pattern-oriented, generates emergent patterns based on the Capital Program database. It has a nested scheme: a state agent contains ten nested RPCs, which collectively contain 600 nested municipalities, which contain transportation projects as their own agent class. USDOT is modeled as a dummy parameter due to the fact that (a) it allocates funds but is not involved in prioritizing projects; and (b) we are focused on the state scale. The user can modify the parameter to indicate how much funding is available in a given year. Figure 1 displays the structure of the ABM. Twenty-seven different input parameters were used to calibrate the model. Most of those parameters have uniform or triangular probability distributions, meaning that the model is stochastic and its base and each run is a unique realization chosen from the random probability distributions. The ABM calculates yearly resource flows from the state to smaller jurisdictions.

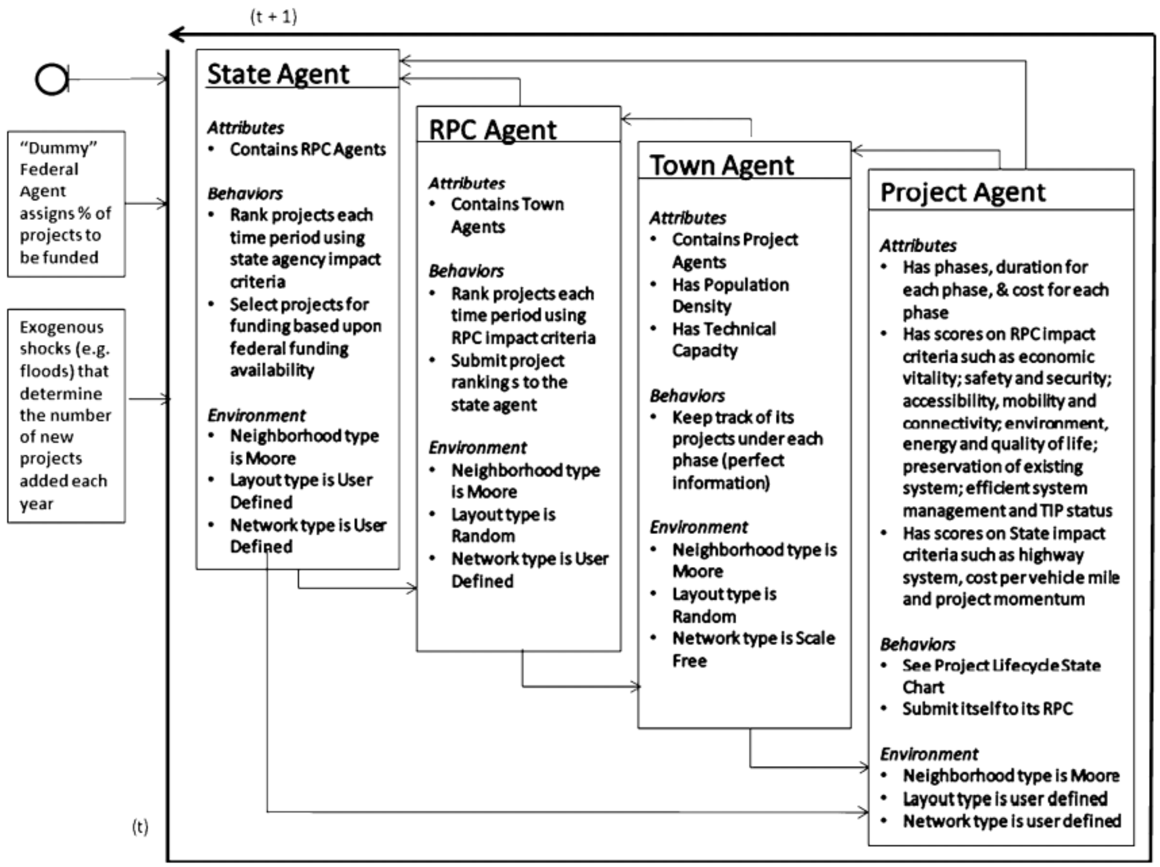

Figure 1. Internal structure of the ABM

3.2.3 Experimental Simulations

We ran the model for six different experimental scenarios. These scenarios and their weighting systems are outlined in Table 2. Scenario 1, the baseline scenario, gave relatively little weight to regional priority compared to Scenario 2, which approximated an alternative intergovernmental institutional design that focused much more on regionalization than on highway system condition. Scenario 3 weighted cost effectiveness very heavily, while Scenario 4 had a high percentage of funded projects. Scenario 5 reduced federal funding and Scenario 6 was indicative of a situation in which exogenous shocks like floods raised the number of new projects per year.

Table 2. Parametric values for alternative scenarios

	Weight on regional priority	Weight on highway system	Weight on cost per vehicle mile	Weight on project momentum	Percentage of projects to be funded yearly	Number of new projects each year
Scenario 1 (baseline)	0.2	0.4	0.2	0.2	0.1	30
Scenario 2 (regionalization)	0.5	0.1	0.2	0.2	0.1	30
Scenario 3 (cost-effective)	0.2	0.1	0.5	0.2	0.1	30
Scenario 4 (funding flux)	0.2	0.4	0.2	0.2	0.3	30
Scenario 5 (sequestration)	0.2	0.4	0.2	0.2	0.05	30
Scenario 6 (sequestration and shocks)	0.2	0.4	0.2	0.2	0.05	40

3.3 Results and Conclusions

Despite the differences between the differences between scenarios, there were consistently some RPCs that attracted relatively large funding amounts, indicating basins of attraction. We identified two major patterns: first, the ABM is very tied to the exogenous parameter of funding availability. Second, there is variability in the success rate across the scenarios and those differences may point to equity and efficiency trade-offs in policy outcomes.

The scenario runs enabled us to make a few preliminary conclusions. First, if regional considerations are weighted more heavily, a phase change will result, meaning that the basins of attraction will switch. Second, shifting power from state to regional governments may result in a more equitable regional funding distribution. Changes in the institutional design cause major changes in which towns receive funding for which projects.

While this paper focuses on modeling and thereby presents an abstraction of reality, there are important implications from this work. Notably, our experimental simulations using the ABM indicate that the current institutional configuration of state and regional-level governments generates basins of attraction in funding for transportation infrastructure. Additionally, these basins privilege certain towns and regions over others, and that level of privilege can increase under certain scenarios (including funding sequestration and exogenous shocks). While weighting the cost effectiveness of projects may not shift the basins, weighting regional priorities may indeed do so. As such, various actors may be able to alter institutional structures to modify the basins of attraction and subsequently shift funding allocations.

In further research, the ABM may be extended beyond the “roadway” project to include others, such as the “bridges” class. GIS could also be incorporated to make the model more spatially explicit. We hope to extend the model to additional states pending the incorporation of additional empirical data.

4. Paper: Establishing Performance Priorities: Regional Variation and the Role of Collaborative Capacity in MPOs

This paper is under review at the journal *Urban Affairs Review.* Asim Zia, Chris Koliba, Jack Meek, Erin Flynn, and Anna Schulz authored the paper.

4.1 Background

Emergent governance networks pose unique performance management challenges. In the transportation field, federal and state governments, which provide sustaining base funding to smaller governance networks, are faced with the difficulty of monitoring performance to appropriately allocate funds. In this paper, we analyze responses from a 2009 Government Accountability Office survey of all 380 Metropolitan Planning Organizations (MPOs) in the United States. We use the data to test two hypotheses:

(1) *Both the administrative and collaborative capacities of MPOs and network organizations affect MPO prioritization of performance measures; and*

(2) *Various complex contextual factors, such as the size of the population served by the MPO and whether it is located in a multi-state area and/or an air quality non-attainment district, affect the selection of which performance measures are used: MPOs across the United States do not assign equal weights to performance measures.*

MPOs are major actors in planning and executing transportation plans and policies. In various regions, they are structured differently and have unique relationships to regional governance networks. Fragmented institutional governance structures have, at times, resulted in reduced collective action and collaboration. There is increasing interest in how collaboration influences the definition of performance measures, the collection of performance data, and the integration of that data into organizational management. MPOs provide one avenue through which to examine the impacts of collaboration on performance management.

4.2 Methodologies

4.2.1 Data Collection

This study relies on data from a 2009 GAO survey of all 381 MPOs in the US. The 45-question survey had an 85% response rate and is available to the public online. The survey was taken by MPO directors or their designees and asks about factors that shape MPO structure and function. Table 3 provides an overview of the variables examine in the survey as well as the mean scores among respondents and the standard deviation.

Table 3. Descriptive statistics

Table 1. Descriptive statistics

Variable	Symbol	N	Min	Max	Mean	Standard Deviation
Contextual complexity variables						
TMA urban (>200K)	CC1	327	.00	1.00	.45	.498
Multi-state area	CC2	327	.00	1.00	.12	.328
Located within an air quality non-attainment or maintenance area	CC3	328	.00	1.00	.50	.501
Air quality non-Attainment area and <200K	CC1*CC3	327	.00	1.00	.3242	.4687
Administrative structure variables						
Independent organization	AS1	328	.00	1.00	.18	.385
Part of a regional council/council of governments	AS2	328	.00	1.00	.38	.486
Part of a county government	AS3	326	.00	1.00	.1319	.3389
Part of a city government office	AS4	326	.00	1.00	.1902	.393
Descriptive performance measures variables						
Project implementation	DPM1	310	.00	1.00	.4323	.4961
Travel demand model accuracy	DPM2	297	.00	1.00	.2357	.4251
Transportation system safety	DPM3	310	.00	1.00	.4613	.4993
Transportation system reliability	DPM4	307	.00	1.00	.4430	.4975
Transportation system accessibility	DPM5	310	.00	1.00	.4419	.4974
Transportation system security	DPM6	301	.00	1.00	.1561	.3636
Compliance with federal and state rules	DPM7	320	.00	1.00	.7938	.4052
Satisfaction among local stakeholders	DPM8	315	.00	1.00	.8540	.3537
Satisfaction among general public	DPM9	317	.00	1.00	.6593	.4746

Extent of coordination and stakeholder involvement	DPM10	319	.00	1.00	.6771	.4683
Measure of public participation	DPM11	317	.00	1.00	.4606	.4992
Level of highway congestion	DPM12	311	.00	1.00	.5209	.5003
Air quality	DPM13	282	.00	1.00	.3723	.4842
Mobility for disadvantaged populations	DPM14	311	.00	1.00	.4309	.4960
Condition of transportation network	DPM15	314	.00	1.00	.4873	.5006
Normative performance measure variables						
Project implementation	NPM1	324	.00	1.00	.7222	.4486
Travel demand model accuracy	NPM2	318	.00	1.00	.5818	.4940
Transportation system safety	NPM3	323	.00	1.00	.7523	.4323
Transportation system reliability	NPM4	320	.00	1.00	.7344	.4423
Transportation system accessibility	NPM5	319	.00	1.00	.7179	.4507
Transportation system security	NPM6	310	.00	1.00	.4032	.4913
Compliance with federal and state rules	NPM7	323	.00	1.00	.7121	.4535
Satisfaction among local stakeholders	NPM8	319	.00	1.00	.9216	.2691
Satisfaction among general public	NPM9	319	.00	1.00	.8715	.3352
Extent of coordination and stakeholder involvement	NPM10	320	.00	1.00	.8031	.3982
Measure of public participation	NPM11	319	.00	1.00	.6928	.4620
Level of highway congestion	NPM12	317	.00	1.00	.7161	.4516
Air quality	NPM13	285	.00	1.00	.5368	.4995
Mobility for disadvantaged population	NPM14	318	.00	1.00	.7516	.4327
Condition of transportation network	NPM15	314	.00	1.00	.7803	.4147
Collaborative capacity variables						
Stakeholder representation on MPO Board	COC1	328	.00	12.00	4.5122	2.5425
External collaborative capacity	COC2	328	.00	100.00	44.7866	21.9686
Technical capacity variables						
In-house capacity for generating travel forecasts	TC1	328	.00	1.00	.4451	.4977
Using a travel demand model	TC2	328	.00	1.00	.9360	.2451
Capacity challenge variables						
Lack of funding	CCH1	326	.00	4.00	2.6840	1.1508

Competing priorities	CCH2	322	.00	4.00	1.9752	1.1731
Obtaining public input	CCH3	321	.00	4.00	2.2991	1.0417
Lack of flexibility	CCH4	317	.00	4.00	1.8486	1.2638
Lack of ability to find local match	CCH5	324	.00	4.00	2.2006	1.3213
Fiscal constraints	CCH6	327	.00	4.00	2.5719	1.1378
Limited authority	CCH7	312	.00	4.00	2.3942	1.0914
Limitations in TDM capacity	CCH8	317	.00	4.00	1.7634	1.0984
Data limitations	CCH9	321	.00	4.00	2.0436	1.0237
Coordination with land-use agencies	CCH10	321	.00	4.00	1.6168	1.0721
Coordination with other regions	CCH11	311	.00	4.00	1.0161	.9348
Coordination with state DOT	CCH12	326	.00	4.00	1.4448	1.1156
Lack of trained staff	CCH13	322	.00	4.00	1.5497	1.1269

4.2.2 Variables and Operationalization

We focused on questions that offered insight relative to three main areas: (1) performance, (2) contextual complexity, and (3) collaborative capacity. With respect to performance, we examined questions regarding:

- The MPO's current use and valuation of performance measures,
- The level of importance MPO directors ascribe to certain performance measures, and
- The MPO's level of technical and collaborative capacity.

With respect to contextual complexity and collaborative capacity, we coded the questions for the following five variables:

- Contextual complexity,
- Administrative structures,
- Descriptive and normative performance measures,
- Collaborative and technical capacities, and
- Capacity challenges.

We developed logistic regression models that use contextual complexity, administrative structure, technical capacity, collaborative capacity, and capacity challenges as independent variables. Figure 2 is a graphical representation of our framework.

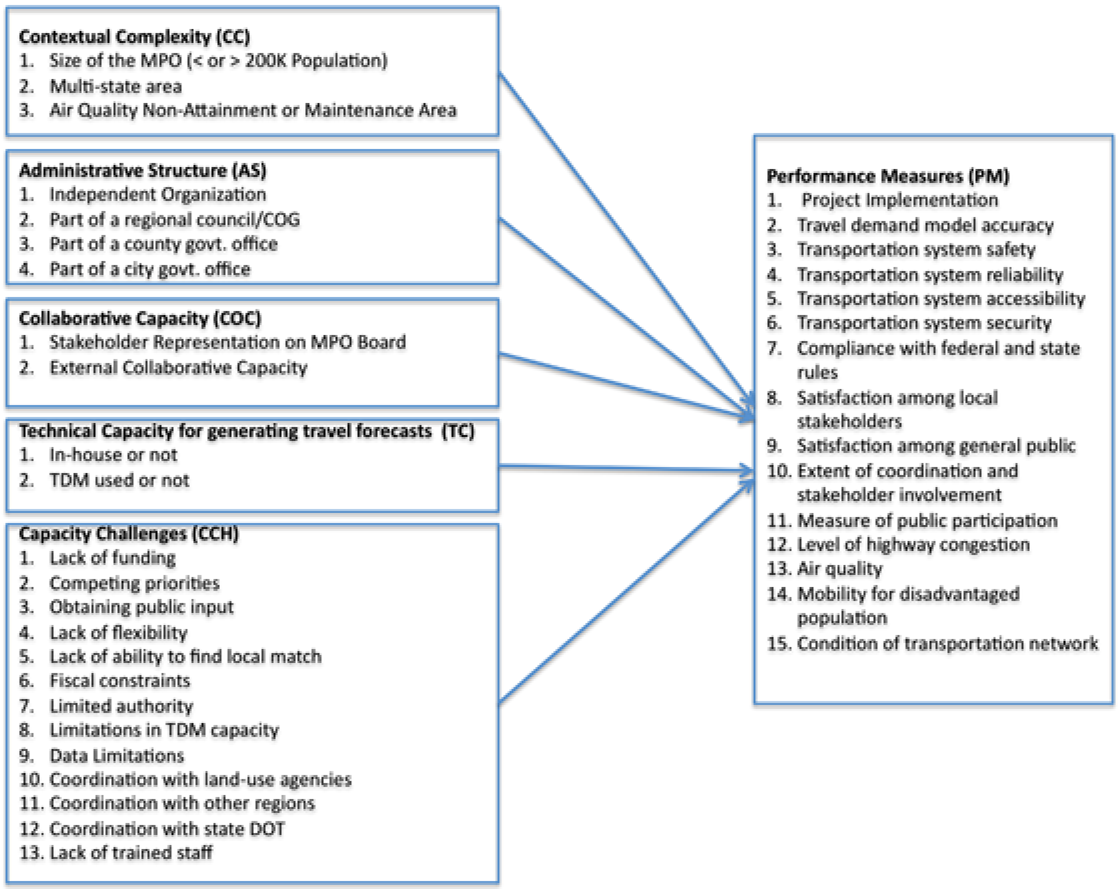

Figure 2. Logistic regression model design

Respondent prioritization of 15 performance measures (descriptive and normative) were used as binary response variables in 30 binomial logistic regression models.

4.3 Results and Conclusions

We found that both the size of a community in which and MPO is located and the collaborative capacity of an MPO both have significant effects on the choice of performance measures. Technical capacity and administrative structures exert influence as well, as do additional capacity challenges such as lack of funding and shortage of staff. In our analysis we focused on descriptive performance measures in an effort to consider actual MPO practices, rather than perceptions about desirable performance measures.

For our first hypothesis, which posited that administrative and collaborative capacity both influence which performance measures an MPO selects, we examined both internal and external collaborative capacity. For the internal component, we found that as stakeholder representation on an MPO board increases, they are more likely to prioritize the condition of the transportation network as a performance measure and less likely to prioritize satisfaction among local stakeholders. External collaboration also exerts influence over the prioritization of performance measures. To be more precise, we found that as an MPO's collborative capacity increases by 1%, that MPO is:

- 1% more likely to prioritize the condition of the transportation network and transportation system accessibility;
- 2% more likely to project implementation, transportation system safety, transportation system reliability, air quality, mobility for disadvantaged populations, compliance with federal and state rules, satisfaction amongst the general public, and measure of public participation;
- 3% more likely to travel demand model accuracy, transportation system security, and extent of coordination and stakeholder involvement; and
- 4% more likely to prioritize satisfaction among local stakeholders.

These findings enable us to confirm our first hypothesis.

Our second hypothesis was that complex contextual factors influence an MPO's selection of performance measures and that MPOs across the US weight measures differently. We employed small to medium sized MPOs in air quality attainment areas as the base group. Relative to that group, large (greater than 200,000 people) MPOS in air quality attainment areas are:

- 62% less likely to prioritize project implementation; 65 % less likely to prioritize transportation system safety;
- 67% less likely to prioritize transportation system accessibility;
- 65% less likely to prioritize the extent of coordination and stakeholder involvement and
- 68% less likely to prioritize the condition of the transportation network as performance measures.

In air quality *non-attainment* areas, small- or medium-sized MPOs are, relative to their air quality attainment counterparts:

- 56% less likely to prioritize project implementation;
- 61% less likely to prioritize mobility for disadvantaged populations;
- 142% more likely to prioritize level of highway congestion; and
- 1417% more likely to prioritize air quality as performance measures.

These findings allow us to confirm our second hypothesis: size and other contextual factors influence the prioritization of performance measures.

Finally, we also examined the effect of MPO capacity on administrative challenges. Table 4 summarizes those findings.

Table 4. MPO capacity challenges and implications

MPO Capacity Challenge	Priority Implication
MPOs with in-house capacity for generating travel forecasts are:	56% less likely to prioritize satisfaction among the general public 43% less likely to prioritize the level of highway congestion as performance measures
MPO's listing lack of funding as a major challenge are:	80% more likely to prioritize travel demand model accuracy, 47% more likely to prioritize transportation system safety, 56% more likely to prioritize transportation system reliability, 37% more likely to prioritize transportation system accessibility, 73% more likely to prioritize satisfaction among the general public, 76% more likely to prioritize extent of coordination and stakeholder involvement, 35% more likely to prioritize the measure of public participation, 49% more likely to prioritize the level of highway congestion, 74% more likely to prioritize air quality, and 35% more likely to prioritize the condition of the transportation network as performance measures
MPOs that rank *competing priorities* as a major challenge are:	25% less likely to prioritize transportation system safety, 28% less likely to prioritize transportation system reliability, 25% less likely to prioritize transportation system accessibility, 29% less likely to prioritize satisfaction among the general public as performance measures.
MPOs that listed *coordination* with state DOTs as a major challenge are:	33% less likely to prioritize project implementation, 36% less likely to prioritize travel demand model accuracy, 35% less likely to prioritize transportation system safety, 34% less likely to prioritize transportation system reliability, 24% less likely to prioritize transportation system accessibility, 35% less likely to prioritize compliance with federal and state rules, and 24% less likely to prioritize level of highway congestion as performance measures
MPOs that listed *shortage of trained staff* as a major challenge are:	43% less likely to prioritize project implementation, 35% less likely to prioritize extent of coordination and stakeholder involvement, 44% less likely to prioritize level of highway congestion, and 32% less likely to prioritize both travel demand model accuracy and transportation system reliability as performance measures

Overall, an MPO's collaborative capacity, contextual complexity, size, and capacity challenges all appear to exert influence over the prioritization of performance measures. Given these variations, we recommend that federal government agencies, such as the Federal Highway Administration (FHWA), Department of Transportation (DOT), or others, do not attempt to impose uniform performance measures across the spectrum of MPOs. Instead, it may be practical to generate weighting schemes on performance measures to fit MPOs of different sizes and capacities. Another implication of the research presented here is that MPOs have a real need for improved capacity to better able the use of performance measures in network contexts. Additionally, given the important and beneficial ramifications of collaboration, our research suggests that it would be prudent to investigate in more detail how to develop collaborative capacity in particular as an avenue toward improved performance management.

5. Paper: Integrating Sustainability with Transportation Asset Management Processes: Governance of Intergovernmental Decision-Making on Prioritizing Transportation Projects

This paper is under review at the journal *Public Works Management and Policy*. Asim Zia, Chris Koliba, Erin Flynn, and Anna Schulz authored the paper.

5.1 Background

The research presented in this paper evaluates the decision-making processes of state and regional transportation agencies regarding project prioritization. As transportation agencies are faced with an abundance of potential projects and limited funds with which to complete those projects, they are forced to select only a small subset. This paper employs the state of Vermont as a case study and examines the processes through which projects are prioritized for inclusion in the Statewide Transportation Improvement Program (STIP). STIPs are federally mandated documents produced by all states and are essentially to-do lists of projects.

Different agencies employ many different sets of criteria and prioritization schemes to appropriately select projects. Many rely to at least some degree on asset management systems, which typically assess the economic trade-offs between investing in different projects. Presently, most asset management systems and/or programs skew toward prioritizing projects that preserve the current transportation system. Additionally, a tendency to focus on economic efficiency has led to some concerns over the consideration of other important factors, such as environmental sustainability. “Stovepiping,” or a lack of horizontal overlap between projects o project phases, is another concern

Here, we assess the following two hypotheses: first, the criterion of “system preservation” is a dominating factor in the selection of projects, and second, environmental sustainability-related criteria are under-emphasized in the selection of projects. To test these hypotheses, we statistically model prioritization processes for a 5-year period in Vermont and evaluate the probability of projects being funded according to certain characteristics.

5.3 Methodologies

5.3.1 Qualitative research and process mapping

Our research was informed by focus groups, interviews, and analysis of prioritization data from both the Chittenden Country MPO (CCMPO, which is alternately referred to as CCRPC in other papers covered in this report) and the Vermont Agency of Transportation (VTrans). Our focus groups and interviews were conducted in the fall of 2010 with multiple stakeholders, including local government officials, CCMPO staff and board members, VTrans officials, FHWA and USDOT officials, federal and state senate office representatives, and local NGOs. The resultant information enabled us to develop a schematic representation of the prioritization process with its many actors and steps, as seen in Figure 3.

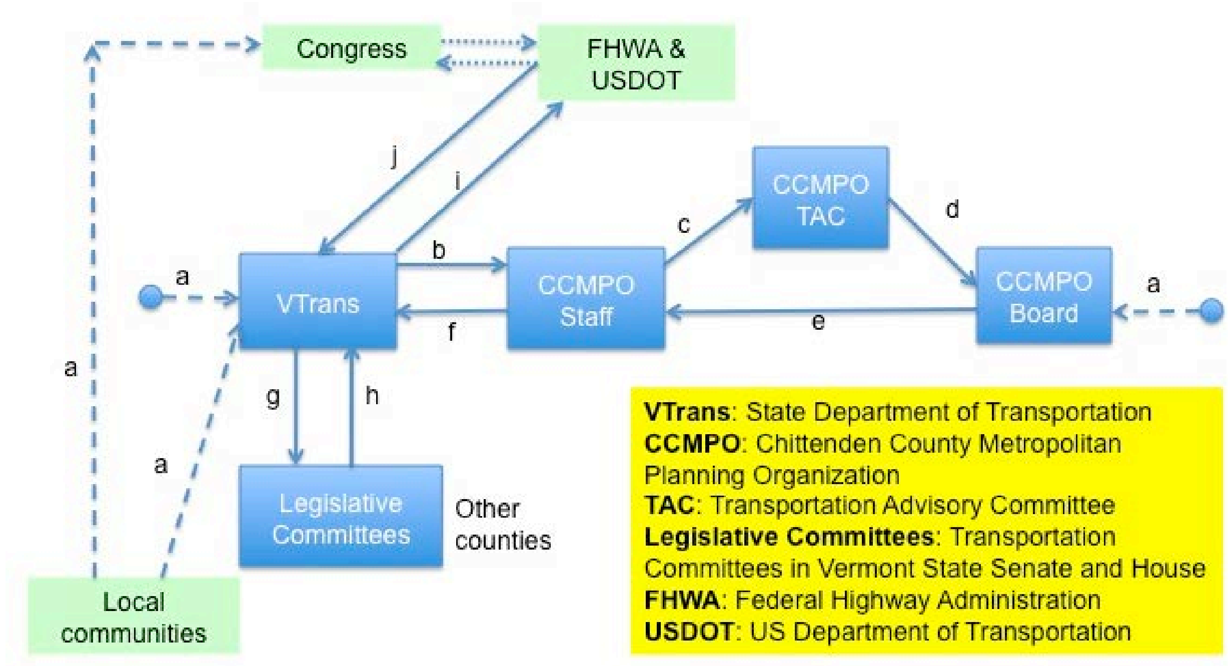

Figure 3. Prioritization relationships in Vermont

As shown in Figure 3, projects either initiate at the community level or are identified by agencies, and a subset of those projects are accepted as "legitimate" by VTrans. If they are in Chittenden County and fall under CCMPO jurisdiction, they are evaluated by CCMPO staff, who assign a score to each project based on the following criteria: economic vitality; safety and security; accessibility, mobility and connectivity; environment, energy and quality of life; preservation of existing system; efficient system management; and TIP status. CCMPO's Transportation Advisory Committee (TAC) accepts or modifies the scores before passing them along to the board. After reaching consensus on the scoring, CCMPO subjects a project list to VTrans (this is called a Transportation Improvement Program, or TIP, which is similar to a localized STIP). VTrans incorporates these projects into the STIP along with the projects selected from other regions.

5.3.2 CCMPO prioritization

Both VTrans and CCMPO categorize transportation projects into six classes: (1) roadways; (2) traffic operations; (3) paving; (4) park & ride; (5) bridge; and (6) bicycle/pedestrian. Due to data limitations at the time this initial study was conducted, we were forced to limit our statistical analysis to roadways and traffic operations listed in the CCMPO TIPs and VTrans STIPs from 2006-2010, but the study could be extended to the other classes as well. It could also be extended to more states.

For each project class, CCMPO calculates an expected value function (CCMPO_EV) for each project included on the TIP, as shown in Equation 1:

$$CCMPO\_EV (Project_i) = \sum_{j=1} w_j . X_j \quad \text{[Equation 1]}$$

Where there are i=1,2…N projects and j=1,2….M criteria. Each project is evaluated qualitatively on seven criteria (M=7), denoted by X_j on an ordinal scale from 1 to 10. All seven criteria are weighted equally:

$$\sum_{j=1} w_j = 70 \text{ and } w_1=w_2=w_3=w_4=w_5=w_6=w_7$$

Table 5 shows descriptive statistics for CCMPO_EV, its natural log transformation (Ln_CCMPO), and seven criteria scores (X_j) from that were assigned to roadway projects. Standard errors are shown in brackets. The year 2007 see a higher number of projects and the mean expected value hovers between 46.08 ± 5.41 and 50.53 ± 6.20 out of a maximum score of 70. Economic vitality as a criterion appears to receive consistently high scores, while system preservation appears to receive relatively low scores.

Table 5 CCMPO Prioritization Scores: Descriptive Statistics for Roadway Projects

	2007 N= 24	2008 N=15	2009 N=15	2010 N=18
Expected Value	46.08 (5.41)	49.06 (6.01)	50.53 (6.20)	47.22 (9.21)
Ln(Expected Value)	3.82 (.12)	3.88 (.124)	3.91 (.12)	3.84 (.21)
Economic Vitality	7.41 (2.48)	8.53 (1.95)	9.06 (1.66)	8.38 (2.17)
Safety and Security	6.37 (2.22)	8.00 (1.46)	8.00 (1.46)	7.72 (1.52)
Accessibility, Mobility and Connectivity	6.70 (2.40)	7.60 (2.41)	7.86 (2.19)	7.27 (2.53)
Environment, Energy and Quality of Life	6.25 (2.57)	5.80 (2.75)	5.80 (2.75)	5.72 (2.86)
Preservation of Existing System	4.62 (2.42)	5.06 (2.81)	5.20 (2.75)	5.05 (2.55)
Efficient System Management	6.29 (1.80)	7.40 (1.80)	7.40 (1.80)	7.00 (1.87)
TIP Status	8.41 (2.56)	6.66 (3.90)	7.20 (4.05)	6.55 (4.43)

Likewise, Table 6 displays scoring for the Traffic Operations category of projects, which sees a much smaller number of overall projects in any given year.

Table 6 CCMPO Prioritization Scores: Descriptive Statistics for Transport Operation Projects

	2007 N=10	2008 N=6	2009 N=5	2010 N=5	2007-2010 N=26
Expected Value	48.5 (5.46)	50.00 (7.32)	47.4 (5.12)	47.6 (6.02)	48.42 (5.55)
Ln(Expected Value)	8.2 (3.32)	3.90 (.15)	3.85 (.11)	3.85 (.13)	3.87 (.12)
Economic Vitality	6.70 (1.76)	7.16 (1.6)	7.00 (.00)	7.00 (.00)	6.92 (1.29)
Safety and Security	7.80 (2.25)	8.00 (1.54)	6.80 (2.48)	6.8 (2.48)	7.46 (2.13)
Accessibility, Mobility and Connectivity	5.70 (1.63)	5.83 (2.04)	7.80 (2.16)	7.4 (2.5)	6.53 (2.08)
Environment, Energy and Quality of Life	5.5 (1.84)	7.50 (2.73)	6.00 (2.23)	6.00 (2.23)	6.15 (2.22)
Preservation of Existing System	7.00 (2.05)	7.00 (2.75)	6.6 (.89)	6.00 (2.64)	6.84 (1.82)
Efficient System Management	7.60 (2.22)	7.83 (2.48)	7.2 (1.78)	7.2 (1.78)	7.5 (2.02)
TIP Status	8.2 (3.32)	6.66 (5.16)	6.00 (5.47)	7.2 (4.38)	7.00 (4.46)

CCMPO and the nine other RPCs send their ranking orders to VTrans. At the time of this study, VTrans assigns a 20% weight to regional priority, while the remaining 80% are derived from asset management systems and expert input. Equations 2 and 3 show the criteria breakdown and weights used by VTrans for generating VTrans_ExpectedValue (score) for roadway and traffic operation project classes, respectively:

VTrans_EV (Roadway Projects) = (0.4)* Highway System Score + (0.2)* Cost Per Vehicle Mile + (0.2)* Regional Priority + (0.2) Project Momentum [Equation 2]

VTrans_EV (Traffic Operation Projects) = (0.4)* Intersection Capacity + (0.2)* Accident Rate + (0.2)* Costs per Intersection Volume + (0.2)* Regional Priority + (0.1) Project Momentum [Equation 3].

The scoring structures used in both of these equations are derived from the VTrans asset management system and engineering economic analysis. Regional priority for each project class is derived from local rankings, as discussed above, and project momentum is assigned through qualitative observation. In 2009 and 2010, VTrans added a 10% weight for projects that were supporting the development of “designated downtowns.”

5.3.3 VTrans prioritization

Descriptive statistics for VTrans roadway and traffic operation project expected values can be found in Table 7 and Table 8, respectively.

Table 7. VTrans Roadway Project Scores from 2007-2010: Descriptive Statistics

	2007 N=73	2008 N=61	2009 N=60	2010 N=61
Expected Value	48.15 (15.864)	50.07 (13.103)	49.82 (13.662)	50.36 (14.709)
Ln(Expected Value)	3.80 (.443)	3.88 (.289)	3.86 (.351)	3.87 (.329)
Highways System	20.808 (9.984)	20.721 (9.510)	21.050 (9.826)	20.820 (10.044)
Cost/vehicle mile	11.041 (5.397)	11.508 (5.793)	10.900 (5.780)	11.016 (5.895)
Regional priority	9.643 (6.947)	10.721 (6.802)	9.633 (7.192)	10.557 (6.714)
Momentum	6.658 (4.808)	7.115 (5.410)	7.066 (5.590)	6.820 (6.412)
Designated Downtown			1.166 (3.237)	1.148 (3.213)

At the state level, VTrans prioritizes approximately 60 to 70 roadway projects per year. Traffic operation projects at the state level range from 14 to 21 per year. The VTrans expected value hovered between 48-50% of points for roadway projects and 48-54% of points for traffic operation projects.

Table 8. VTrans Traffic Operations Project Scores from 2007-2010: Descriptive Statistics

	2007 N=21	2008 N=17	2009 N=16	2010 N=14
Expected Value	54.00 (14.832)	49.29 (12.883)	48.88 (9.415)	50.43 (8.916)

Ln(Expected Value)	3.96 (.263)	3.86 (.275)	3.87 (.209)	3.90 (.192)
Intersection Capacity	n/a	16.941 (6.713)	16.500 (6.673)	17.143 (6.163)
Accident Rate	n/a	5.588 (6.820)	5.313 (3.860)	5.714 (3.852)
Cost per Intersection Volume	n/a	9.294 (5.429)	7.125 (5.932)	6.286 (5.539)
Region	n/a	13.294 (7.647)	15.250 (5.310)	16.286 (4.762)
Momentum	n/a	4.176 (2.877)	4.688 (2.915)	5.000 (3.258)

We found that only 40-50% of CCMPO ranked projects are included by VTrans in the same fiscal year. To gain further insight, we estimated a binomial regression model that used probability of project selection by VTrans as a binary dependent variable and CCMPO_EV as an independent variable. To test the effects of CCMPO scoring on environmental and system preservation criteria on the VTrans_EV we estimated log-linear regression models. These log-linear models regress the natural log of VTrans_EV against CCMPO scores for each of the seven criteria.

5.3 Results and Conclusions

The binomial regression model results can be found in Table 9. Over the years examined, Vtrans selected 44.29% of CCMPO-prioritized roadway projects and 46.15% of traffic operation projects. The Nagelkerke R^2 for roadway projects is slightly lower (5.1%) than for transportation projects (25.0%). A higher CCMPO_EV increases the probability of selection by VTrans for inclusion in the STIP by 5.9% for roadways and 15.8% for traffic oeprations. Overall higher CCMPO_EV tends to increase its inclusion in the STIP project prioritization process by VTrans; but this does not completely explain the variation in the observed data.

Table 9. Predicting the Likelihood of VTrans Selection with a Logistic Regression Model: Dependent Variable is VTrans_Selection

	Roadways N=70	Traffic Operations N=26
CCMPO_EV	B= 0.057* S.E.= 0.036 EXP(B)= 1.059*	B= 0.147* S.E.= 0.078 EXP(B)= 1.158*
Constant	B=-2.95* S.E.=1.74 EXP(B)= 0.052*	B= -7.16* S.E.= 3.83 EXP(B)= 0.001*

Nagelkerke-R^2	5.1%	25.0%
% Correctly Predicted	62.9%	57.7%

Next, we regress the natural log of VTrans_EV for the VTrans selected projectsagainst CCMPO criteria scores, testing whether projects ranked high on system preservation criterion or environment/sustainability criterion by CCMPO are also ranked high by the VTrans scores. The results of these regressions are presented in Table 10.

Table 10. Predicting VTrans Prioritization from 2007-2010 Pooled Data with CCMPO Criteria: Dependent Variable is Ln(VTRANS_EV)

	Roadways N=31	Traffic operations N=12
Economic Vitality	-.155*** (.041)	Excluded#
Safety and Security	-.036 (.032)	-.084** (.031)
Accessibility, Mobility and Connectivity	.113** (.043)	.032 (.017)
Environment, Energy and Quality of Life	-.076*** (.019)	Excluded#
Preservation of Existing System	.073*** (.019)	.073** (.023)
Efficient System Management	.007 (.030)	.001 (.021)
TIP Status	.003 (.014)	Excluded#
Year	.077** (.034)	.06 (.03)
Constant	-150.962** (67.76)	-116.99 (64.95)
Adjusted R^2	67.1%	61.1%
F-test	8.65***	4.45**

Note. Excluded# variables are constants or have missing correlations.
*Significant at 90%; ** Significant at 95%; *** Significant at 99%.

We estimate that both of the log-linear regression models presented in Table 10 have a relatively high Adjusted R^2 at 67.1% and 61.1% for roadway and traffic operation projects, respectively. *We find that higher scores on “system preservation” by CCMPO significantly raises the VTrans_EV by 7.3% for both roadway and traffic operation projects. In contrast, higher* *scores on “environment, energy and quality of life” by CCMPO significantly decreases the VTrans_EV by 7.6% for roadway projects.* This effect is not significant for traffic operation projects, probably due to their low adverse environmental effects across the board (for which reason the variable is excluded from the model). These findings confirm our hypotheses for the roadway projects.

We also find that projects ranked high on “accessibility, mobility and connectivity” are likely to increase VTrans_EV by 11.3% for roadway projects. Surprisingly, we find that the roadway projects that scored high on “economic vitality” by CCMPO significantly reduce the VTrans_EV by (15.5%). Similarly, for traffic operation projects, we find that the projects scored high on “safety and security” are likely to reduce VTrans_EV by 8.4% of points (significant effect at $p<0.05$). Both of these unexpected findings require additional research to aid in explaining the observed phenomena.

In conclusion, we found “system preservation” to have a statistically significant effect on asset management system-generated project prioritization scores in the state of Vermont. To the contrary, projects that CCMPO scores better on environmental sustainability are under-prioritized by VTrans’ asset management system generated scores. These findings point to the need to modify the governance of intergovernmental decision-making processes for prioritizing transport projects; at present, sustainability considerations are not seriously integrated with transport asset management and investment decision-making processes. We recommend that the scores generated from the state asset management systems explicitly incorporate and weigh the criteria of environmental and social impacts of transportation projects. This would enable future asset management systems to appropriately integrate a broader spectrum of criteria for transportation investment decisions.

6. Paper: Scale and Intensity of Collaboration as Determinants of Performance Management Gap in Polycentric Governance Networks: Evidence from a National Survey of MPOs

This paper is slated for publication following final edits for a special edition of the journal *Politics and Policy*. Asim Zia, Chris Koliba, Jack Meek, and Anna Schulz authored the paper.

6.1 Background

Many multi-level public-public and public-private inter-organizational partnerships are characterized as “governance networks.” Presently, more work is needed to understand how performance management systems are institutionalized within governance networks. Given the tendency toward distributed power and the presence of multiple actors, performance management systems and larger accountability regimes face unique challenges in the frame of governance networks. The scale of a governance network, both in terms of its jurisdictional reach and its level of collaboration, plays a unique role in performance assessment.

Performance measurement is a difficult task across many sectors; it becomes more complicated when networks span sectors and levels. Measuring performance often involves data collection and analysis, then typically some sort of process by which that analysis is incorporated into future action. Assumptions shape which data are collected and how heavily different areas of performance are weighted relative to each other. We argue that too little attention is paid to the development of process measures, the distribution of authorities, and the collaborative and technical capacities found within multi-level governance networks.

In this paper, we study the performance management issues faced by MPOs in the US. MPOs are often seated within multi-level, polycentric governance networks and therefore present a unique real-world context for the study of performance management. They have inter-modal transportation planning responsibilities that must be conducted according to varying time horizons. As such, their performance measures must not only capture conventional efficiency measures, but also broader social, economic, and environmental impacts of regional transportation planning choices. Many factors are at stake, including energy consumption, air quality, impact on natural resources, safety, neighborhood integrity, employment, and economic output. The Intermodal Surface Transportation Efficiency Act (ISTEA) requires MPO performance management systems to measures outcomes relative to environmental, economic, and social consequences.

Our earlier research indicated that MPOs aggregate the preferences of local governments, particularly with respect to project prioritization, and transmit those preferences to state DOTs. Per federal legislation, MPO governing bodies must have elected or appointed representation from local governments, as well as representatives from regional FHWA and state DOTs. They typically have many other stakeholders involved in the governance process as well. Because they forge so many vertical and horizontal ties, MPOs have a unique capacity to collect, report and use performance measurement data. Whether performance measures are established according to user or stakeholder demand or initiated as a top-down approach by MPOs may have influence over how accountability regimes are constructed and used. Interagency collaboration can be beneficial for accountability and performance management, so increased collaborative capacity at MPOs could have positive results. A variety of actors can not only collect and report performance measures, but also employ those measures to inform project prioritization and program implementation.

This study examines how the size of an MPO and its ability to collaborate impact the collection and use of performance measurement data. Again, we use a 2009 Government Accountability Office (GAO) survey of all 381 MPOs to provide our primary data. Our study examines whether an MPO's scale and intensity of collaboration across vertical (federal, state and local governments) and horizontal (regional planning commissions, businesses, citizen advocacy) stakeholder groups influences performance management gaps. We posit that the variability in how MPOs use and value performance data contributes to a "performance management gap." We define the performance management gap as the statistical distance between the values ascribed to performance measures (normative performance measures) and the current practices for measuring performance (descriptive performance measures). We test two hypotheses:

(1) Small scale MPOs have a significant performance management gap compared with large scale MPOs in the US; and
(2) The performance management gap is inversely affected by the scale of MPOs as polycentric governance networks; that is, larger-scale MPOs with higher scale and intensity of collaboration have a smaller performance management gap.

6.2 Methodologies

The GAO survey asks MPO directors or their designees to respond to 45 questions regarding a variety of factors that shape an MPO's structures and functioning. For this study, we focus on the set of questions that specifically relate to the MPO's spatial scale, their scale and intensity of collaboration with other agencies and stakeholders, the operational challenges that MPOs face, and the performance management gap. Table 11 provides descriptive statistics for the variables that measure these constructs.

Table 11. Descriptive statistics

Variable	Symbol	N	Min	Max	Mean	Standard Deviation
SPATIAL SCALE						
TMA Urban (>200K)	SS1	327	0	1	.45	.498
Multi-state area	SS2	327	0	1	.12	.328
Located within an air quality non-attainment or maintenance area	SS3	328	0	1	.50	.501
Air Quality Non-Attainment Area and >200K	SS1*SS3	327	.00	1.00	.3242	.4687
SCALE & INTENSITY OF COLLABORATION						
FHWA Board Member	SC1	328	0	1	.43	.495

FHWA Committee Member	SC2	328	0	1	.55	.498
FTA Board Member	SC3	328	0	1	.32	.466
FTA Committee Member	SC4	328	0	1	.41	.492
StDOT Board Member	SC5	328	0	1	.79	.406
StDOT Committee Member	SC6	328	0	1	.76	.430
State Env. Agency Board Member	SC7	328	0	1	.16	.366
State Env. Agency Committee Member	SC8	328	0	1	.47	.500
Transit Operator Board Member	SC9	328	0	1	.59	.492
Transit Operator Committee Member	SC10	328	0	1	.76	.426
Local Govt. Elected Board Member	SC11	328	0	1	.95	.222
Local Govt. Elected Committee Member	SC12	328	0	1	.48	.500
Local Govt. Non-elected Board Member	SC13	328	0	1	.48	.501
Local Govt. Non-elected Committee Member	SC14	328	0	1	.78	.417
Other Regional Authority Board Member	SC15	328	0	1	.38	.487
Other Regional Authority Committee Member	SC16	328	0	1	.59	.493
Environmental Advocacy Org. Board Member	SC17	328	0	1	.05	.209
Environmental Advocacy Org. Committee Member	SC18	328	0	1	.34	.476
Business Advisory Groups Board Member	SC19	328	0	1	.13	.335
Business Advisory Groups Committee Member	SC20	328	0	1	.45	.499
Citizen Participation Groups Board Member	SC21	328	0	1	.10	.305
Citizen Participation Groups Committee Member	SC22	328	0	1	.56	.497
Private Sector Board Member	SC23	328	0	1	.13	.338
Private Sector Committee Member	SC24	328	0	1	.48	.500
Other Officials Board Member	SC25	328	0	1	.19	.392
Other Officials Committee Member	SC26	328	0	1	.20	.402
Intensity of Collaboration Index	ICI	328	.00	100.00	44.7866	21.9686
OPERATIONAL CHALLENGES						
Lack of funding	CC1	326	.00	4.00	2.6840	1.1508
Competing Priorities	CC2	322	.00	4.00	1.9752	1.1731
Obtaining public input	CC3	321	.00	4.00	2.2991	1.0417
Lack of flexibility	CC4	317	.00	4.00	1.8486	1.2638
Lack of ability to find local match	CC5	324	.00	4.00	2.2006	1.3213
Fiscal Constraints	CC6	327	.00	4.00	2.5719	1.1378
Limited authority	CC7	312	.00	4.00	2.3942	1.0914
Limitations in TDM Capacity	CC8	317	.00	4.00	1.7634	1.0984
Data limitations	CC9	321	.00	4.00	2.0436	1.0237
Coordination with land-use agencies	CC10	321	.00	4.00	1.6168	1.0721
Coordination with other regions	CC11	311	.00	4.00	1.0161	.9348
Coordination with state DOT	CC12	326	.00	4.00	1.4448	1.1156
Lack of trained staff	CC13	322	.00	4.00	1.5497	1.1269
PERFORMANCE MEASURE GAP						
Project Implementation	PMG1	306	-4.00	4.00	.6503	1.55509
Travel Demand Model Accuracy	PMG2	287	-3.00	4.00	.9826	1.52016
Transportation System Safety	PMG3	305	-4.00	4.00	.7115	1.39855
Transportation System Reliability	PMG4	299	-4.00	4.00	.7926	1.44838
Transportation System Accessibility	PMG5	301	-4.00	4.00	.7143	1.43228
Transportation System Security	PMG6	285	-4.00	4.00	.7333	1.50788
Compliance with federal and state rules	PMG7	315	-3.00	4.00	-.1556	1.24073
Satisfaction among local stakeholders	PMG8	306	-3.00	4.00	.1895	1.02590
Satisfaction among general public	PMG9	308	-3.00	3.00	.4610	1.10747
Extent of coordination and stakeholder	PMG10	311	-3.00	4.00	.3312	1.12864

involvement						
Measure of public participation	PMG11	308	-4.00	4.00	.4708	1.27713
Level of highway congestion	PMG12	300	-4.00	4.00	.4700	1.52869
Air quality	PMG13	245	-4.00	4.00	.5224	1.97227
Mobility for disadvantaged populations	PMG14	301	-4.00	4.00	.6379	1.31089
Condition of transportation network	PMG15	300	-4.00	4.00	.7433	1.44837

6.2.1 Spatial Scale

We consider three variables relative to spatial scale:

Population (SS1): Per responses to Question #28 about population, MPOs for over 200,000 were coded as having a large population; the rest were coded as having a small or medium-sized. Of the respondents in this survey, 45% of MPOs are large and the remaining 55% are small or medium-sized.

Area of Representation (SS2): Question #3 enabled us to code SS2 (whether the MPO represents a multi-state area). Of the sample (N=327), 12% represent multi-state areas. Multi-state areas could complicate rules and governance.

Air Quality Non-Attainment Area (SS3): Question #6 provided SS3: whether states are in air quality non-attainment areas. 50% of the MPOs are located in air quality non-attainment areas. We generated an interaction term between size (SS1) and air quality non-attainment (SS3): 32.42% of MPOs in the sample are large (TMA>200K) *and* located in air quality non-attainment areas.

6.2.2 Scale of Collaboration

MPOs are required to collaborate with a variety of other institutional actors. MPO boards are often comprised of representatives from local governments, state DOTs, and federal agencies. One way to assess the scale of their external collaboration may be the measure the number of vertical and horizontal stakeholders on MPO's governing boards and committees.

Question #4 in the survey asked: "which of the following types of officials are members (including both voting and non-voting) of your MPO's board…?" Respondents were provided with a list of 12 stakeholder groups: FHWA, FTA, State DOT, State or local environmental agency, transit operator, local government (elected), local government (non-elected), other regional agency, environmental advocacy organizations, business advocacy groups, citizen participation groups, and private sector. A thirteenth category of "other stakeholders," was asked as an open-ended question. Analysis of this open-ended question reveals that these "other stakeholders" are typically represented by local universities, port authorities, freight industry, FAA, US Air Force, school districts and airport authorities. The survey respondents were also asked which of the 13 stakeholder groups were represented on their technical advisory committees. We used their responses to measured 26 binary variables [SC1….SC26] regarding scale of collaboration across vertical and horizontal stakeholders.

6.2.3 Intensity of Collaboration Index (ICI)

To measure intensity of collaboration we used Question #8, which asks, "how, if at all, does your MPO coordinate its planning activities with the following types of organizations?" Respondents received a list of 10 organizations: Federal DOT (FHWA and FTA), state DOT, city and county entities, adjacent MPOs, councils of government/regional council, regional transit operators, environmental agencies, air quality organizations, regional civic organizations, and advocacy groups. Respondents reported whether coordination took place through committee representation (to which we assigned a weight of 4), regular meetings (weight of 3), regular correspondence (weight of 2), solicitation of input/feedback on an ad-hoc basis (weight of 1) or does not coordinate (weight of 0). If an MPO coordinates with an organization type through all four coordination mechanisms, it will get an ICI score of 10, if none then 0. Since the respondents reported for 10 different organization types, each MPO's ICI is measured on a scale from 0 to 100. The mean ICI is 44.78% points with a standard deviation of 21.96% points.

6.2.4 Operational Challenges

The survey asked respondents to indicate the extent to which their MPO faces specific operational challenges. Many of these challenges are common among networked organizations. We used Question #27 to measure operational challenges. It asks, "in your opinion, how much of a challenge, if any, do the following issues present for your MPO in carrying out the federal requirements for transportation planning?" and then lists 13 issues (variables CC1-CC13 in Table 11). Respondents assessed them on a likert scale: very great challenge (coded as 4), great challenge (3), moderate challenge (2), some or little challenge (1) and no challenge (0). Lack of funding appears to provide the greatest challenge, while coordination with other regions is the least challenging.

6.2.5 Use and Valuation of Performance Measures and the Estimation of Performance Management Gaps

The survey identified performance measures along the following parameters: the extent to which project implementation evaluations were conducted; travel demand models were used; the safety, accessibility and security of the regional transportation system; the level of compliance with federal and state rules; local stakeholder and general public satisfaction; the extent of coordination with stakeholders; measures of public participation; levels of traffic congestion; air quality and mobility for disadvantaged populations; and assessments of the condition of the regional transportation network.

We attempt to assess both descriptive and normative performance measures. Question #37 asked, "To what extent, if at all, does your MPO use the following indicators to evaluate its effectiveness?" Respondents were provided with a list of 15 performance measures and were asked to select one answer from "very great extent, great extent, moderate extent, some or little extent to no extent and no basis to judge". Question #38 asked, "Regardless of your individual answers to question 37, from your perspective, how useful, if at all, could the following indicators be for evaluating the effectiveness of MPOs?" Respondents were provided with the same list of 15 performance measures and were asked to select an answer: very useful, useful, moderately useful, of some or little use, of no use, and no opinion or no basis to judge. Question #37 provides insight into descriptive measures (those actually used) and question #38 provides insight into normative measures (those desired to be used or presumed to be valuable). Figure 3 illustrates the differences between descriptive and normative performance measures according to the survey responses (responses have been recoded on a binary scale; those with a higher score are more commonly used and/or more commonly valued).

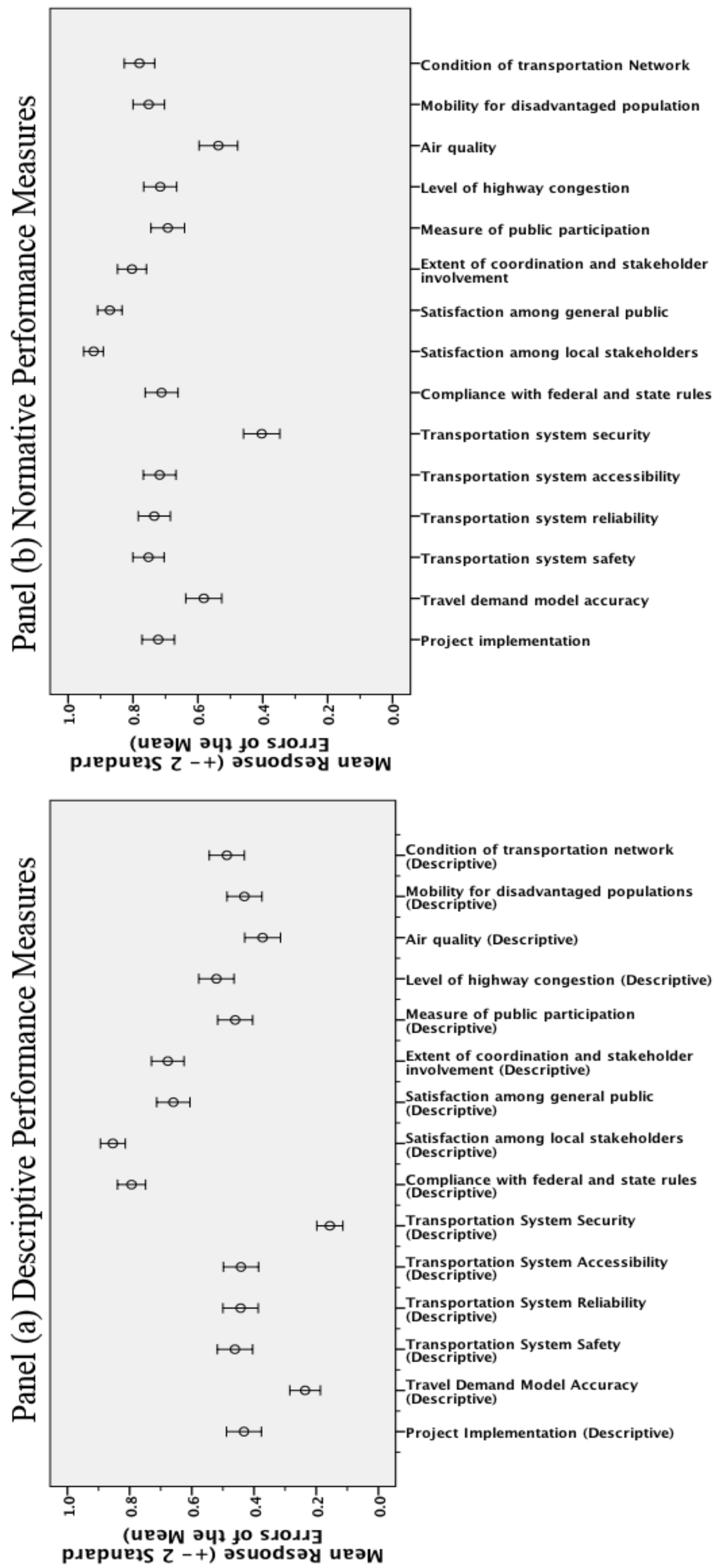

Figure 3. Descriptive vs. normative performance measures

In this paper, we define the performance management gap as the statistical distance between descriptive performance measures (those currently used) and normative performance measures (those ascribed high value). Figure 4, a box plot of performance management gap variables, shows that measures such as travel demand model accuracy are perceived to have a higher performance management gap, while variables such as satisfaction among local stakeholders have a smaller gap.

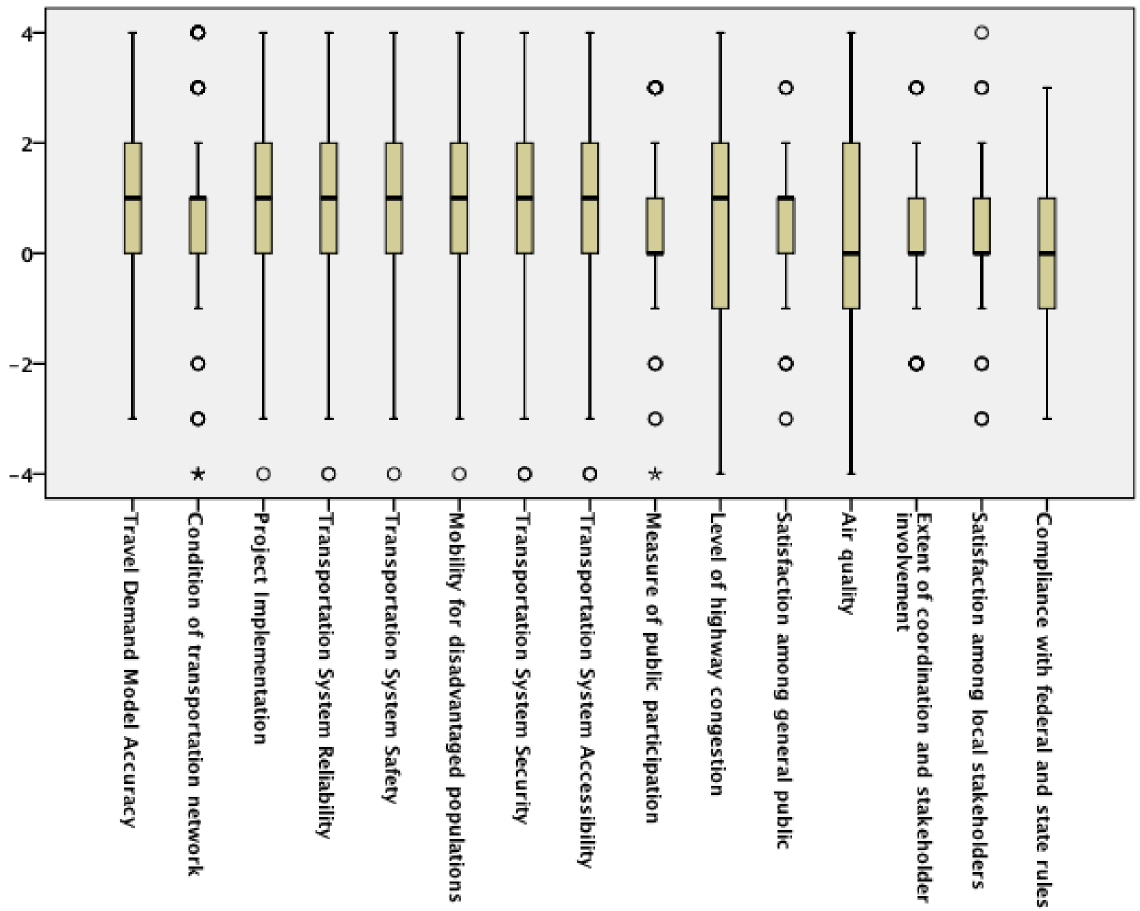

Figure 4. Performance management gap variables (positive values represent a higher gap)

We contacted several MPOs in Maine and Vermont and requested short interviews to help ground our findings. Rob Kenerson, director of the Bangor Area Comprehensive Transportation System (BACTS), and Tom Reinauer, director of the Kittery Area Comprehensive Transportation System (KACTS) provided what insight they could. Both MPOs are very small and cited funding limitations as a major contributor to the use and valuation of performance measures.

To test our hypotheses, we estimated fifteen OLS regression models that use spatial scale, the scale and intensity of collaboration and operational challenges as independent variables to explain the variation in the performance management gap for each of the fifteen performance indicators.

6.3. Results and conclusions

Table 12 illustrates our findings.

Table 12. Results from OLS regression models. Standardized coefficients (effect sizes) with * shows significance with 10%; ** shows significance with 5% and *** shows significance with 1% Type I probability error.

	Project Implementation	Travel Demand Model Accuracy	Transportation System Safety	Transportation System Reliability	Transportation System Accessibility
TMA Urban (>200K)	.129	.324**	.127	.152	.095
Multi-state area	.056	-.038	-.019	.022	-.068
Located within an air quality non-attainment area	.060	.245**	.142	.135	.193*
Air Quality Non-Attainment Area and >200K	-.042	-.413**	-.076	-.070	-.097
FHWA Board Member	-.172	.029	.094	.135	.051
FHWA Committee Member	-.074	-.052	-.163	-.095	-.176*
FTA Board Member	.248**	-.061	.010	-.106	.002
FTA Committee Member	.090	.065	.166	.178*	.171*
StDOT Board Member	.049	.078	.049	.014	.137
StDOT Committee Member	-.069	-.106	.133	-.070	.100
State Env. Agency Board Member	-.101	-.014	.025	.007	.030
State Env. Agency Committee Member	.080	-.170*	.019	-.126	-.076
Transit Operator Board Member	-.077	-.125	-.086	-.076	-.089
Transit Operator Committee Member	.192*	-.060	.091	.126	-.010
Local Govt. Elected Board Member	-.006	-.029	.027	-.004	-.008
Local Govt. Elected Committee Member	.029	.055	.031	-.017	.064
Local Govt. Non-elected Board Member	.040	.063	-.014	-.035	.040
Local Govt. Non-elected Committee Member	-.142	.054	-.035	-.001	.003
Other Regional Authority Board Member	-.054	.128*	-.028	-.039	-.041
Other Regional Authority Committee Member	.040	.122	-.068	.030	.041
Environmental Advocacy Org. Board Member	-.058	.043	.024	.016	.103
Environmental Advocacy Org. Committee Member	-.027	.095	-.032	-.062	-.019
Business Advisory Groups Board Member	.026	.026	.021	.135	-.061
Business Advisory Groups Committee Member	.007	-.071	.052	-.086	-.068
Citizen Participation Groups Board Member	.037	-.066	.051	.015	-.018
Citizen Participation Groups Committee Member	.003	-.030	-.054	.044	-.037
Private Sector Board Member	-.018	.006	.000	.032	.136
Private Sector Committee Member	-.170*	-.117	-.053	.017	.005
Other Officials Board Member	-.007	-.117*	-.020	-.072	-.032
Other Officials Committee Member	-.020	.160**	-.034	.021	-.008

Intensity of Collaboration Index	-.237***	-.204**	-.211**	-.190**	-.224**
Lack of funding	-.061	-.047	-.121	-.185**	-.088
Competing Priorities	-.042	-.109	.057	.124	.085
Obtaining public input	.019	.045	.007	-.059	-.042
Lack of flexibility	.007	.011	-.136	-.078	-.135
Lack of ability to find local match	-.019	-.007	-.007	-.130	-.150*
Fiscal Constraints	.102	.059	.055	.107	.140*
Limited authority	-.014	-.115	-.016	-.036	-.027
Limitations in TDM Capacity	-.271**	-.104	-.173*	-.190**	-.139
Data limitations	.233	.097	.190*	.063	.140
Coordination with land-use agencies	.004	-.031	.001	.138*	.078
Coordination with other regions	.068	-.172**	.013	.014	.007
Coordination with state DOT	.169**	.193**	.064	.102	.076
Lack of trained staff	-.035	.099	.037	.116	.085
N	254	239	251	246	249
R^2	23.3%	27.1%	19.2%	24.7%	25.0%

For the first hypothesis (that smaller MPOs have a bigger performance management gap than do larger MPOs), the evidence is mixed once we control for air quality, multistate areas, and other variables. To illustrate this, consider the measure “travel demand model accuracy.” Large MPOs located in air quality *attainment* areas have a statistically significant (p<0.05) higher performance management gap for travel demand model accuracy than small MPOs that are also in air quality attainment areas. But small MPOs in air quality *non-attainment* areas have a higher performance management gap for TDM accuracy than their larger counterparts. There continue to be unexpected results across several different variables.

Regarding our second hypothesis (the performance management gap is inversely affected by the collaborative scale of MPOs), intensity of collaboration does appear to generally limit the performance management gap. The standardized coefficient for the intensity of collaboration index is statistically significant (p<0.05) for 11 out of 15 performance indicators. Two indicators are marginally significant (p<0.1).

The implications of these findings are potentially significant: if MPOs aim to decrease their performance management gaps, one strategy could be to increase their intensity of collaboration with both vertical and horizontal stakeholders. Our limited qualitative research suggested that the small scale of their MPOs necessitates both vertical and horizontal collaboration to accomplish basic initiatives. Expectations, culture around performance, and standards-setting may play major roles in the presence and size of performance management gaps. More qualitative research is warranted to explain and contextualize these findings.

7. Paper: Adapting Bridge Infrastructure to Climate Change in Vermont: Planning Practices and Recommendations

This paper is under review at the journal *Mitigation and Adaptation Strategies for Global Change*. Anna Schulz, Asim Zia, and Chris Koliba authored the paper.

7.1 Background

Federal and state-level agencies are faced with the challenge of effectively employing data to inform planning processes in the face of climate change. Transportation agencies are being forced to consider methods of adaptation to the projected impacts, not just mitigation of those impacts. Se level rise, precipitation changes, and more extreme weather are just some of the impacts anticipated to affect transportation infrastructure. At present, transportation policies do not typically accomplish adaptation objectives. This paper uses Vermont as a case study and employs multiple methods to recommend policy alternatives that encourage adaptation.

Although climate adaptation is a global concern, effects vary regionally and locally, meaning that approaches will likely need to be tailored to smaller scales. The US transportation governance structure is very hierarchical: federal, state, sometimes regional, and local agencies operate in a nested system. At present, local and state agencies are largely pursuing adaptation initiatives on their own. Vermont makes an interesting case study for its recent experiences with disaster and rebuilding.

In August of 2011 Tropical Storm Irene caused an estimated $250 million of damage to transportation infrastructure in Vermont alone. Approximately 500 bridges and nearly 1,000 culverts were damaged. The disaster spurred VTrans to formalize its stance on climate change adaptation; it released a white paper outlining opportunities and roadblocks alike. Federal funding bills have done little to address climate adaptation. Due to the disparate nature of the approaches being taken, additional research is needed to identify adaptation practices.

This paper seeks to build on prior research and literature. It examines current practices, project prioritization procedures, and allocated funding trends in Vermont, then employs geospatial analysis to make recommendations. We seek to provide insight toward two research questions: first, are New England states undertaking planning and implementation practices to adapt transportation infrastructure, specifically bridge infrastructure, to the threats posed by climate change? Second, which local jurisdictions' bridge infrastructure is vulnerable to flooding risk in the face of climate change and should be targeted for bridge adaptation funding? The state of Maine is also discussed to provide context, but data limitations precluded a full comparative case study between the two states.

7.2 Methodologies

7.2.1 Interviews and qualitative research

The first stage relied on interviews to provide background information on existing adaptation practices. Eleven individuals from seven different organizations contributed insight either via phone or email. Online data mining and an extensive literature review also provided context.

7.2.2 Project prioritization procedure assessment

Next, state project prioritization procedures were assessed for the inclusion of adaptation-specific components. These procedures tend to be publicly available, at least in large part, and can vary dramatically between MPOs and between states.

7. 2.3 Funding allocation analysis

Our research required the compilation funding data dating. We acquired from VTrans Vermont's Capital Programs from 2000-2015. Maine's Capital Programs provide little details; the best available funding plans were Statewide Transportation Improvement Programs (STIPs). Capital Programs are more representative of the budget, while STIPs are a plan for committing federal funds. In both plans, projects can fall behind, which can cause them to reappear in plans for several consecutive years even if they are inactive, which leads to data inaccuracies. Capital Programs are produced annually; STIPs are produced biennially. Using the Capital Programs and STIPs, we built a project database that included all available information about a given project. This research focuses solely on bridge and culvert projects.

7.2.4 Geospatial analysis

The fourth and final stage of research involved preliminary exploration with geospatial analysis. Due to limited data availability, this stage of analysis was conducted only for Vermont. Most data used is publicly available online through the Vermont Center for Geographic Information (VCGI); the only data not available there is the Vermont Bridge Funding Table noted earlier in this report. The bridge funding data was linked with geospatial data to map funding relative to other attributes. Steep slopes and high precipitation were used as proxy variables for risk and were mapped by town as well. To provide context regarding the risks relative to population, we also mapped income and population. Table 13 provides additional background on the data used.

Table 13. Spatial analysis data overview

Name	Data Type	Source	Scale/ Resolution	Publication Date	Attributes Used
Vermont RPC, County, and Town Boundaries	Polygon	VCGI	Various	2012	Names and spatial boundaries of RPCs, counties, and towns
VTrans Bridge and Culvert Inventory	Point	VCGI/VTrans	1:5,000 & GPS	2014	Long and short structures: town

					name and count
USGS National Elevation Dataset 30m	Raster	VCGI/USGS	30 meters	2002	Elevation (feet)
Mean annual precipitation data for Vermont (1971-2000)	Raster	VCGI/NRCS	800 meters	2008	Precipitation (inches)
Vermont Town Population Stats, 1790 - 2000	Polygon	VCGI/UVM Center for Rural Studies	1:5,000	2014	Estimated 2008 population
Vermont Town Economic Stats	Vector digital	VCGI/UVM Center for Rural Studies	1:5,000	2004	Estimated 2008 average annual wages
Vermont Bridge Funding Table	Table	UVM Transportation Research Center	N/A	Unpublished; compiled in 2014	N/A

7.3 Results and Conclusions

7.3.1 Current practices

VTrans is embarking on limited adaptation initiatives. Post-Irene Capital Programs do refer to resiliency and adaptation. Notably, a partnership with the Vermont Agency of Natural Resources (ANR) has led to changes in stream crossings: new structures must be built to at least bank full width. This mandate was established largely for the benefit of aquatic organisms but has had the effect of improving flow capacity in floods and storms. Anecdotal reports indicate that structures built to bank full width are much less likely to fail (N. Wark, VTrans, unpublished data). Maine, like Vermont, has width requirements for stream crossings. All Priority 1 roads must have crossings at least 1.2 times bank full width and smaller roads require permits for any crossings not built to bank full width (J. Gates, MaineDOT, unpublished data). Adaptation is not an explicit a part of Maine's primary transportation planning documents: none of the terms "adaptation," "resilience," or "climate change" appear in the most recent STIP or work plan. The political leadership in Maine has likely contributed to the state's slow movement on adaptation. Recently, however, with the help of FHWA grant funding, MaineDOT began a vulnerability study to assess climate risks posed to transportation infrastructure.

7.3.2 Project Prioritization Procedures

At the state DOT level, both Vermont and Maine fail to include adaptation-specific criteria. Vermont's current project prioritization scheme assigns points quantitatively based on a project's ability to meet certain criteria and is based on asset classes. VTrans does indeed direct funding explicitly toward bridges and list criteria, such as scour, that can be associated with resilience, but it does not explicitly mention adaptation or resilience. MaineDOT employs a less quantitative scheme. It divides roadways into five Highway Corridor Priority (HCP) classes and identifies three different customer service levels (CSLs): safety, condition, and service. Projects are given report card style grades, A-F. A group of experts makes the final choices based on these grades. This could be both positive and negative: while it allows for flexibility, it also allows for political interference. The criteria employed by MaineDOT do not explicitly incorporate adaptation components.

7. 3.3 Funding allocations

Figures 4a and 4b provide a snapshot of bridge and culvert funding allocations in Vermont and Maine from 2000-2015, derived from the new database. Note: the funding information presented here represents planned—not actual—spending.

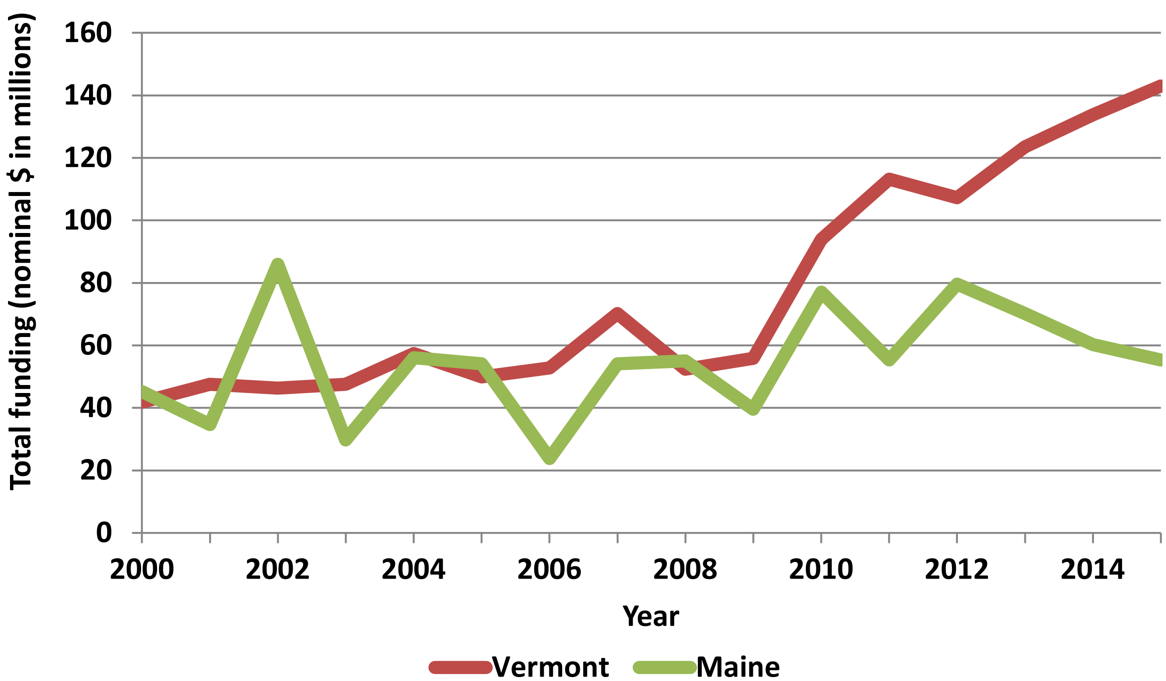

Figure 4a. Planned bridge spending in Vermont and Maine, 2000-2015 (standard deviation is 35.5 for Vermont, 17.6 for Maine)

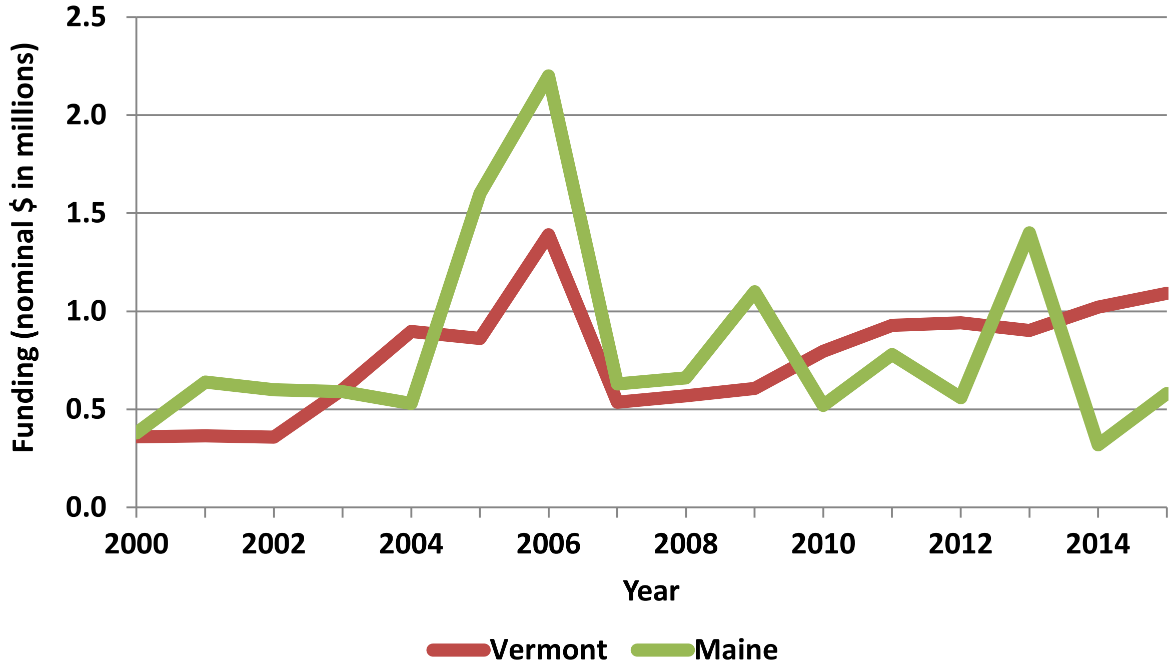

Figure 4b. Mean funding per bridge/culvert project in Vermont and Maine, 2000-2015 (standard deviation is 0.29 for Vermont, 0.50 for Maine)

In general, the funding trend in Vermont is more consistent than in Maine, though neither have consistent mean per project funding. Absolute allocations in terms of total yearly funding have seen a steady increase in Vermont since 2010. The database used here is currently being used to build an agent based model to simulate the changes in the expected funding projections with and without adaptation to climate change scenarios, similar to the roadways model presented earlier in this report. Further research is needed to quantify the damages anticipated due to funding shortages in the coming decades.

7.3.4. Geospatial analysis

The geospatial analysis presented here is a preliminary foray into the research possibilities associated with linking funding data to spatial bridge data. Time and data constraints forced us to limit our analysis to Vermont; we have not ventured into Maine. In Vermont, the mean number of bridges in a town is just under 20 and the mean funding for state-level bridges over the fifteen-year period examined is $5,787,080 per town (the mean federal funding per town is $4,430,248). Precipitation and slope were also mapped to act as proxy variables for risk: the mean average annual precipitation for any given town is 46 inches and the mean terrain slope is 8.1 degrees.

Figure 5 displays average annual precipitation levels in Vermont. Elevation and precipitation are clearly related.

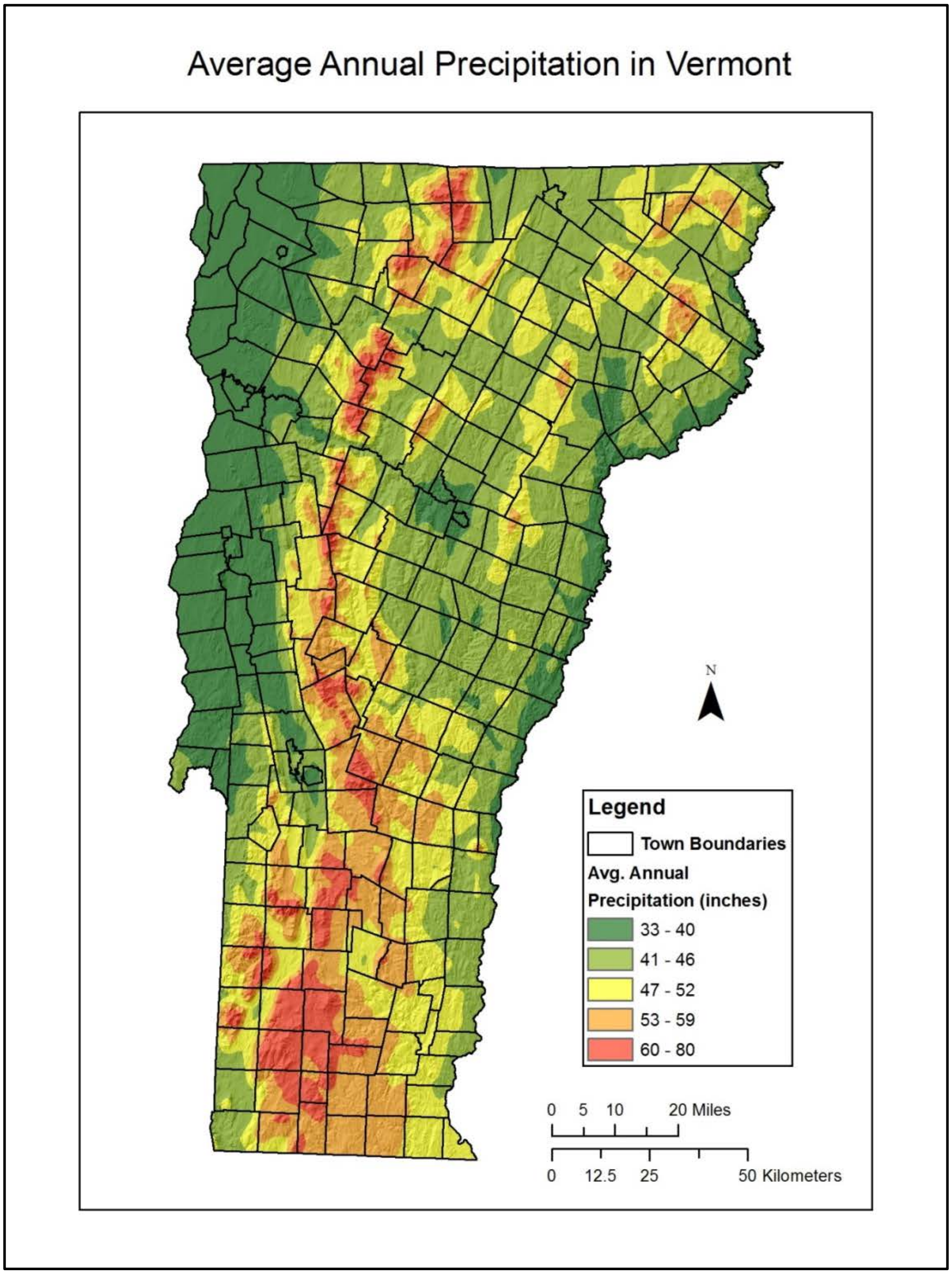

Figure 5. Average annual precipitation in Vermont

Figure 6 shows both cumulative 15-year bridge funding and total bridge count, both by town. Several towns with at least a dozen state-level bridges have received no bridge funding since the year 2000, while many more have received $2.5 million or less. Towns with a high number of bridges and very low amounts of funding may have more vulnerable structures.

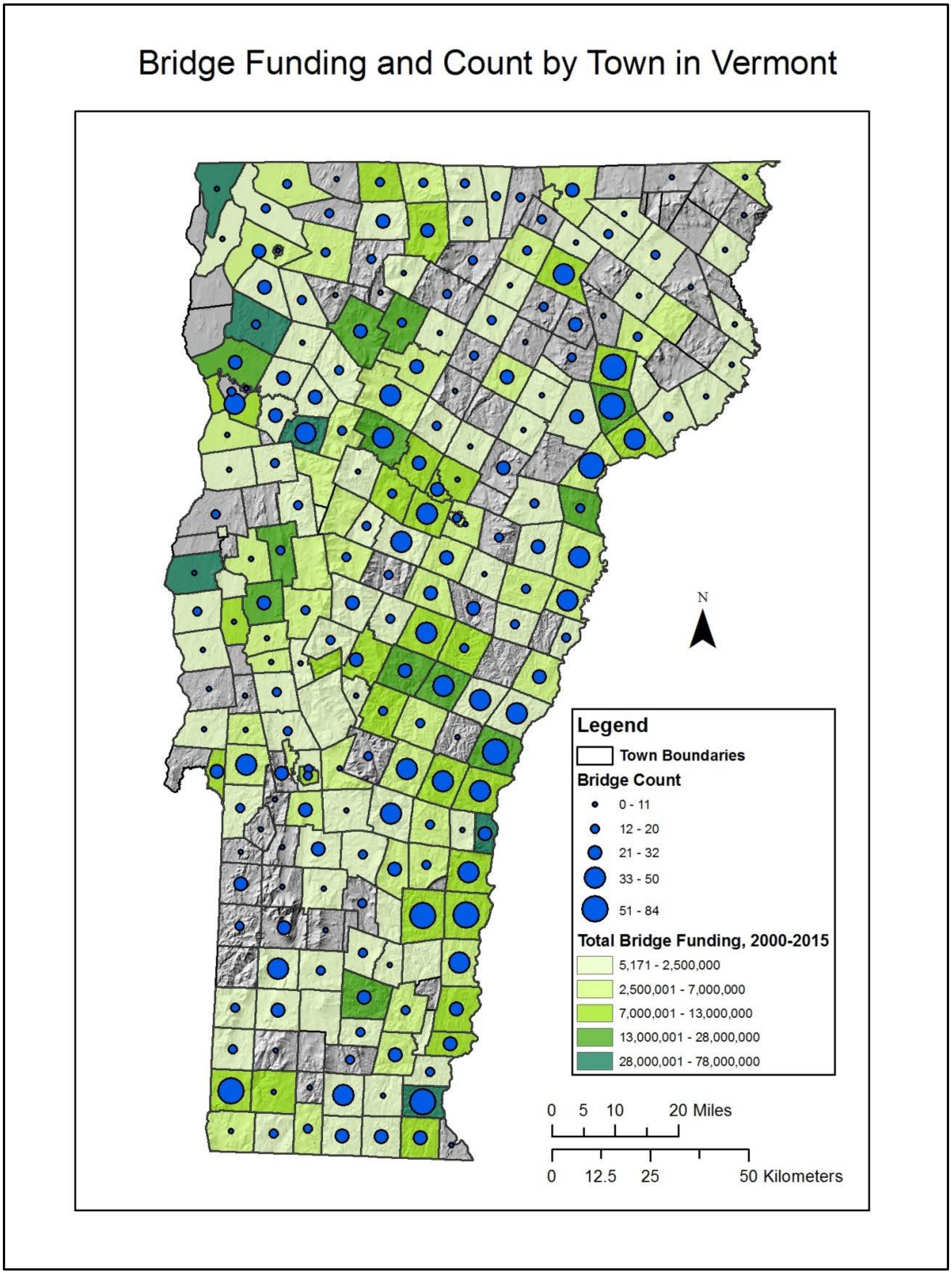

Figure 7. Cumulative bridge funding, 2000-2015, and total number of bridges, by town

To assess vulnerability, we isolated towns with: higher than mean bridge counts, slope, and precipitation and lower than mean funding levels. We identified nine towns deemed to be most vulnerable according to that basic assessment: Granville, Bridgewater, Plymouth, Wallingford, Ludlow, Manchester, Sunderland, Newfane, and Halifax. When evaluated for income, all nine towns had below-average incomes (mean annual wages being $28,617 statewide). Their populations, however, were also below average, indicating that bridge failures might be less disruptive than in more populous locations. Figure 8 identifies those towns.

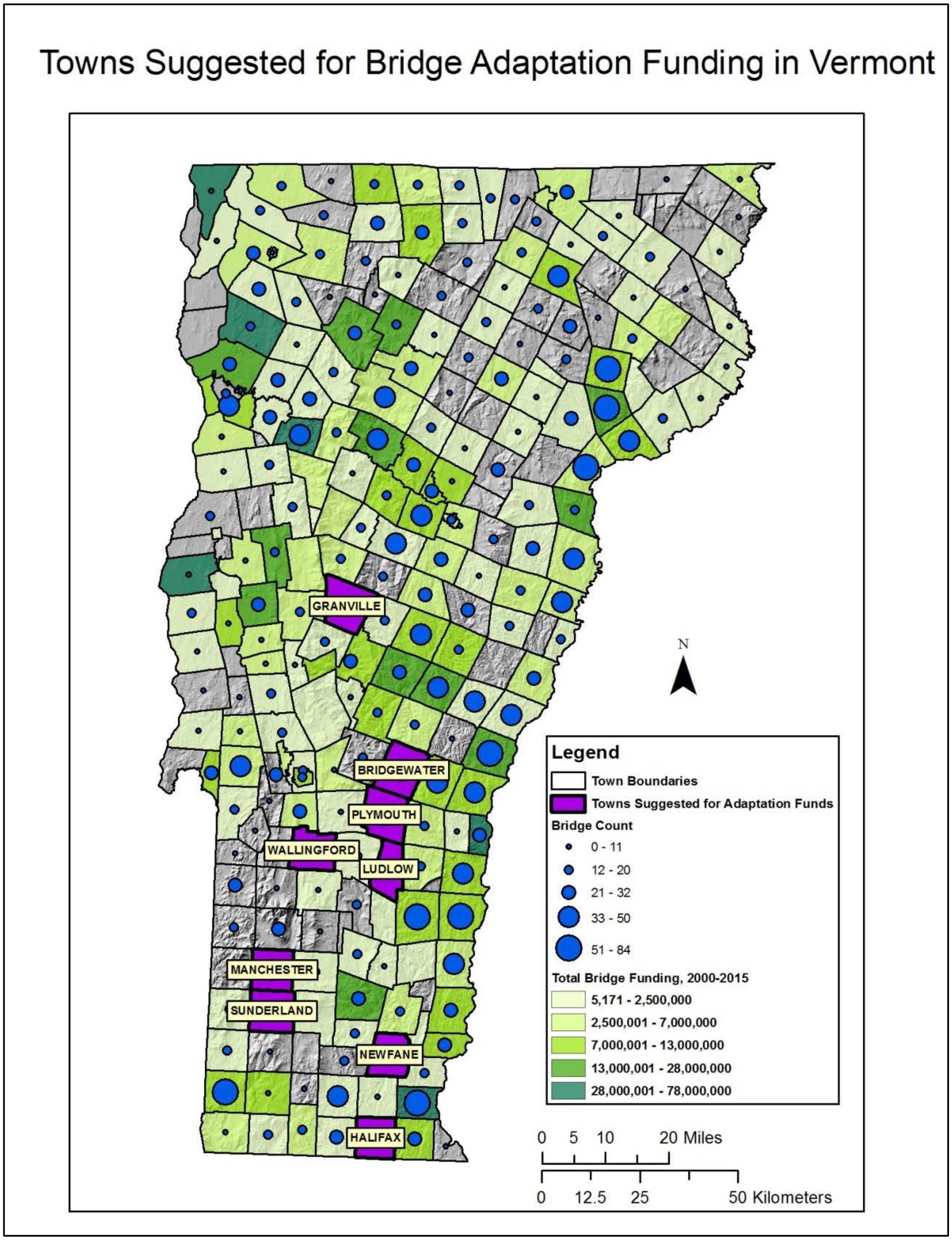

Figure 8. Towns suggested for adaptation funds

It should be noted that the mapping undertaken here is rudimentary: many additional factors would need to be assessed to provide a more accurate picture of risk. Traffic corridors, soil types, bridge age, river locations and flow patterns, and flooding history are just a few variables that could be important. Additionally, this analysis is limited to state-level bridges, but local bridges would ideally be included as well.

7.3.5 Conclusions

Despite the increasing body of knowledge about the future impacts of climate change, transportation agencies in Vermont are undertaking only limited adaptation actions. The nearby state of Maine appears to be lagging as well, though additional research would be beneficial. State agencies and MPOs, with their unique ability to assess threats at the state level, are uniquely poised to undertake adaptation planning. Linking funding data with existing spatial data may provide a novel way to assess risk and target limited funds to the most vulnerable areas.