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Transportation Planning, Policy and Climate Change: Making the Long-Term Connection

Final Report

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16. Abstract

Climate change and variability will have significant impacts on the future mobility of the population in this country. Previous research has found that the transportation sector is not considering adaptation as a solution to these potential impacts. Further, results from a current Southwest Region University Transportation Center (SWUTC) project — Climate Change/Variability Science and Adaptive Strategies for State and Regional Transportation Decision Making — suggest that state and regional transportation planners are not integrating climate change science into their decision and planning processes. This runs counterintuitive to the traditional long-range focus of the planning process. There are several reasons for this situation, including uncertainty in regard to climate science, lack of resources, other problems that require short-term attention, a lack of understanding of the problem, and the desire to avoid the issue as too political. This UTCM project develops a greater understanding of decision and policy processes in regard to climate change and adaptation. Coastal areas in particular are seen as vulnerable to climate change and variability, and thus comprise the regional focus of this study. From a temporal perspective we are interested in adaptation to abrupt climate change (discrete climate events such a hurricane or storms) as well as longer-term incremental changes traditionally associated with global warming.

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Transportation Planning, Policy and Climate Change: Making the Long-Term Connection

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Final Report

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EXECUTIVE SUMMARY

Climate change and variability will have significant impacts on the future mobility of the population in this country. Recent studies, however, have found that the transportation sector in general is not considering adaptation as a solution to these potential impacts. Further, results from a current SWUTC project — *Climate Change/Variability Science and Adaptive Strategies for State and Regional Transportation Decision Making* — suggest that state and regional transportation planners are not integrating climate change science and impacts into their decision and planning processes (Lindquist 2010). This runs counterintuitive to the traditional long-range focus of these planning processes, however. Findings from the earlier study suggest several reasons for this situation, including: uncertainty in regard to climate science, lack of resources, other problems that require more short-term attention, a lack of understanding of the problem, and the tendency to avoid the issue as being too political. These findings raised additional questions that this UTCM project sought to explore and address in more detail, particularly the concern about uncertainty and the lack of resources for transportation decision and policy makers.

Concerns and issues raised in the SWUTC study presented an opportunity to build on this previous and related ongoing research and develop a greater understanding of decision and policy processes, not only in regard to climate change and adaptation, but to other long-range planning issues that may be in conflict with climate change scenarios. Coastal areas in particular are seen as vulnerable to climate change and variability, and will comprise the regional focus of this study. From a temporal perspective we are also interested in adaptation to abrupt climate change (discrete climate events such as hurricanes or storms) as well as longer-term incremental changes traditionally associated with global warming.

The objectives of this project are:

- Update and expand the research on climate change from the transportation planning and policy perspective, particularly in regard to adaptation to potential impacts from climate change.
- Identify best practice and planning scenarios that provide more understandable linkages and communication processes between science findings, projections and models and the relevant stakeholders and decision makers in the transportation field.
- Provide a reference source on the current state of transportation and adaptation to climate change.

Our approach in this project was to, first, update and review the available research and material on transportation and adaptation to climate change; and second, to identify, if possible, best practices or viable examples of successful integration of climate change into transportation planning and decision making as well as attention to adaptation as a solution to potential impacts from climate change. Prior research, both U.S. and international is summarized in the SWUTC report (Lindquist 2010) and is not included here. We conducted an extensive literature search for

recent material related to these issues in the United States, as well as research conducted abroad. We categorized the material across a range of issues all relating to our primary focus on the nexus between transportation policy and planning, climate change, and adaptation. These categories included the following and are found in the report Appendix:

- General Climate Change and Adaptation
- Climate Change and Planning
- Climate Change and Transportation
- Case Studies (climate change and transportation)
- Climate Change and Governance
- Coastal Studies

In addition, this report focused on the Houston-Galveston, Texas, region for a case study of a coastal area. Several recent studies on this area are reviewed here. The reports and research summarized in this section indicate that the area is somewhat aware of the potential impacts from climate change and stakeholders are willing to at least move in the general direction of climate change and adaptation integration. However, the insistence that climate change was strictly an environmental issue (as opposed to public health or natural systems) raises the question of broader acceptance of the issue. From the transportation sector perspective, this aggregate research suggests that the Houston-Galveston region warrants continued observation as a potential test bed for policy change and integration of climate science and factors in the decision making processes.

The literature and available guidance, best practices and case studies related to climate change and the transportation policy domain is slim but growing incrementally. This lack of guidance and relevant research is frequently cited as the main constraint in integrating climate change into the transportation planning and decision processes. Tools and information are slowly becoming available to the transportation community and decision makers, but not as rapidly as the general debate and concern for climate change issues. However, much of this available research is circular in nature, relying on a few studies and similar reports (such as the U. S. Climate Change Science Program report or the TRB 290 report) without adding much new research and systematic assessments of what decision makers and transportation planners actually need and at what scale and scope. Climate scientists are currently shifting their focus from the large global climate models to a more regional scale of emphasis. This shift will provide opportunities to link regional planning and policy making initiatives with advances in regional climate science. It will be necessary for transportation planners, sub-national governmental agencies and institutions, and academia to follow suit and integrate more formally with the climate science community.

Capacity issues are also significant in the current discussion of climate change and transportation. To focus on the issues of climate change and adaptation as a viable alternative solution in transportation planning requires more than an environmental focus. Climate change as an issue or problem goes beyond the narrow environmental definition as it includes other sectors and stakeholders than a traditional state or local transportation agency may have experience in dealing with. This is also related to the question of governance for climate change. In response to capacity and governance issues, the U.S. Government Accountability Office recently published a report on the need to enhance the capacity of MPOs to address

transportation planning issues and capacity problems. According to the report, MPOs were having difficulty meeting federal requirements and responsibilities. Much of the problem is associated with the lack of capacity at smaller MPOs, and with general challenges such as a lack of resources, authority, and technical expertise. The report does, however, suggest that an opportunity exists to address these challenges in the upcoming reauthorization process, which should be considered in Congress in 2011 (United States, Government Accountability Office, 2009).

The Houston area example illustrates the importance of communication and education in regard to generating support and acceptance for climate change, first, as an issue, and second as a problem that needs to be dealt with in a systematic manner. Communicating science to decision makers and making sure they understand the implications, probabilities and alternative solutions is a significant task, and one for which many regional agencies may not be prepared. Also, as one of the few research efforts to directly address regional level stakeholders and decision makers, the Capstone study (Bjune, et al 2009) illustrates the continued resistance to climate change as a general issue or scientific concept. The transportation policy domain will have to address this situation as new climate science becomes available, as resistance to the issue continues, and as funding at all levels of government becomes scarce and resource availability for addressing any transportation problem declines.

Although the transport policy domain is slowly and incrementally moving in the direction of climate change and policy integration, with the publication of guidance and case examples, there is much room for improvement, particularly on the issues of capacity for policy making, regional planning and policy making, and governance for climate change and changing global environment. The main barrier may be a lack of understanding of how transportation policy actually works at the sub-national levels in regard to such a conflictual issue as climate change and how it competes for attention and resources with more traditional transportation problems. Continued research and attention on the constraints, barriers, as well as opportunities, to addressing the potential impacts of climate change on transportation in this country will remain a critical issue for further study.

TRANSPORTATION PLANNING, POLICY AND CLIMATE CHANGE: MAKING THE LONG-TERM CONNECTION

PROBLEM

Climate change and variability will have significant impacts on the future mobility of the population in this country. Recent studies, however, have found that the transportation sector in general is not considering adaptation as a solution to these potential impacts. Further, results from a current SWUTC project — *Climate Change/Variability Science and Adaptive Strategies for State and Regional Transportation Decision Making* — suggest that state and regional transportation planners are not integrating climate change science and impacts into their decision and planning processes (Lindquist 2010). This runs counterintuitive to the traditional long-range 3focus of these planning processes, however. Findings from this study suggest several reasons for this situation, including: uncertainty in regard to climate science, lack of resources, other problems that require more short-term attention, a lack of understanding of the problem, and the tendency to avoid the issue as being too political. These findings raised additional questions that this UTCM project sought to explore and address in more detail, particularly the concern about uncertainty and the lack of resources for transportation decision and policy makers. If transportation decision makers are not concerned with climate change, why not, and will this situation continue even as climate change is recognized as a significant threat to the health and mobility needs of society, and its infrastructure? Can the question of uncertainty in regard to climate science be resolved as an issue as far as policy makers are concerned? What other long-range issues are considered more significant to planners and policy makers?

Concerns and issues raised in the SWUTC study presented an opportunity to build on this previous and related ongoing research and develop a greater understanding of decision and policy processes, not only in regard to climate change and adaptation, but to other long-range planning issues that may be in conflict with climate change scenarios. Coastal areas in particular are seen as vulnerable to climate change and variability, and will comprise the regional focus of this study. From a temporal perspective we are interested in adaptation to abrupt climate change (discrete climate events such as hurricanes or storms) as well as longer-term incremental changes traditionally associated with global warming. This project also addressed the Coast-to-Coast Mobility focus area of the UTCM research portfolio, as vulnerable coastal infrastructure can be considered potential chokepoints within the national transportation system. In addition, it also addressed the Congestion Management and Mitigation Focus area, as disruptions caused by climate change may have significant impacts on long-term mobility in affected areas.

The objectives of this project are:

- Update and expand the research on climate change from the transportation planning and policy perspective, particularly in regard to adaptation to potential impacts from climate change.

- Identify best practice and planning scenarios that provide more understandable linkages and communication processes between science findings, projections and models and the relevant stakeholders and decision makers in the transportation field.
- Provide a reference source on the current state of transportation and adaptation to climate change.

APPROACH AND METHODOLOGY

This research was designed to follow and supplement the SWUTC Project *Climate Change/ Variability Science and Adaptive Strategies for State and Regional Transportation Decision Making* (Lindquist 2010). This previous project developed a baseline understanding of the current policy responses to climate change/variability at the state and regional levels of transportation decision making. Through a series of interviews and surveys, this project found that few state and regional agencies were integrating climate change as a factor in decision making and planning. Specific findings from the report include:

- Politics and public opinion play and will continue to play important roles in these agencies moving toward the integration of climate change as a decision factor.
- Lack of direction, suggested primarily as a lack of any top down federal – state relationship, has impeded progress on understanding and responding to the climate change – transportation nexus.
- Respondents stressed the need for downscaled, state- and regional-level data on climate change impacts and probabilities. This needs to be communicated to the climate science community, as does specific transportation-related data needs.
- Coastal area respondents appear to be better informed and engaged in the climate change issue. This may be a factor of the proximity to vulnerable coastlines and sea- level rise stressors. However, this suggests that the other climate change stressors of temperature and precipitation variation may be more difficult to visualize or communicate effectively.
- Adaptation as an alternative solution that can be considered and developed at the state and regional levels is gaining only slight attention from planners and decision makers. This was identified in the interview process, and not in the formal survey or content analysis. The adaptation suggests that despite recent movement toward including climate change as a factor, the consideration of adaption responses will be even slower.

The current UTCM project reported here moves the discussion and these findings one step further along in our understanding of the connections between climate change impacts and response from the transportation policy and planning domain.

Our approach in this project was to, first, update and review the available research and material on transportation and adaptation to climate change; and second, to identify, if possible, best practices or viable examples of successful integration of climate change into transportation planning and decision making as well as attention to adaptation as a solution to potential impacts from climate change. Prior research, both U.S. and international is summarized in the SWUTC

report (Lindquist 2010) and is not included here. We conducted an extensive literature search for recent material related to these issues in the United States, as well as research conducted abroad. We categorized the material across a range of issues all relating to our primary focus on the nexus between transportation policy and planning, climate change, and adaptation. These categories included the following:

- General Climate Change and Adaptation
- Climate Change and Planning
- Climate Change and Transportation
- Case Studies (climate change and transportation)
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The most significant and primary examples are discussed in the Findings section of this report, while additional material is presented as an extensive annotated bibliography in the Appendix.

In addition to this review, we also focused our attention on the Houston-Galveston area as an illustration and case study. This region was selected as a result of our recent participation in other relevant research projects that contributed to our understanding of the complexities associated with the integration of climate change science in decision making at the sub-national level of governance in this country.

Finally, we conclude the report with a summary and recommendations for further consideration and research. As the issue of climate change is still very much in the news, new information is coming out daily that can be viewed from the perspective of the transportation policy and planning domain. It will be important to continue this stream of inquiry as this issue evolves and new science comes to light.

FINDINGS

This section of the report summarizes a sample of the most significant reports and research from the updated literature review and analysis. The remainder of the literature is annotated in the Appendix. The final component of the Findings section is a brief summary of the climate change policy and planning activities in the Houston-Galveston, Texas, area and an aggregate list of findings and suggestions for further research based on these activities.

General Climate Change

While the issue of climate change in general has inspired an enormous body of research and commentary, this report focuses on a smaller subset of this material, the adaptation literature. It is important, however, to understand the current situation in regard to science, politics, public understanding and acceptance, in regard to climate change as a general issue.

Many of the recent reports summarized here drew upon a small number of sources, including the IPCC reports from 2001 and 2007 (Intergovernmental Panel on Climate Change 2001; 2007), as well as the Gulf Coast study and assessment produced through the U.S. Climate Change Science Program (U. S. Climate Change Science Program 2008). It is anticipated that future research on the nexus between climate change and transportation planning and policy will continue to rely on such resources as it may be too expensive to conduct original primary climate science specifically for transportation research efforts.

In 2008, the IPCC determined that a new assessment, the Fifth Assessment Report (AR5) would be prepared and published in September 2013 (www.ipcc.ch). The emphasis of the AR5 will be more focused on adaptation in the past, as well as the socio-economic implications of climate change and regional issues. This report, and its broader emphasis on non-physical science issues and problems, will provide a significant framework for future transportation and climate change research and policy.

Transportation and Climate Change Adaptation

Compared to the issue domains of public health or agriculture, the transportation policy domain has been slow to pay attention to climate change in general from an adaptation perspective. Most of the attention has been on mitigating the impacts of transportation on the environment. Even the recent *TR News* issue is dominated by the mitigation side of the climate change/ transportation nexus (Transportation Research Board 2010). This section considers the current state of research and attention on the link between transportation and climate change adaptation and its implications on transportation planning and policy.

The Transportation Research Board (TRB), a division of the National Research Council, is the major supporter and advocate for transportation research and innovation in the United States. As such, they are a primary source of information, through various reports and journals, for the transportation planning and policy community. For example, the annual "Critical Issues in Transportation" series reports on the most pressing issues in transportation and their potential impact on the economy and other sectors. In the 2009 edition (Transportation Research Board 2009), one of the broad critical issues is "energy, environment and climate change." Unlike in previous years, where the focus has been on emissions reduction and mitigation, the 2009 update does include adaptation as an issue:

"…the transportation sector must begin adapting to the consequences of change – for example, by inventorying assets that are vulnerable to more frequent flooding and wind damage; using probabilistic models ion planning for upgraded designs; and contributing the research needed to revise design standards and operational practices in flood-prone areas." (4)

The 2009 update references an earlier TRB research publication, Special Report 290 (National Research Council 2008) as the source for this statement. This report, which focused on the "consequences of climate change or infrastructure and operations of U.S. transportation" (2008, 1), represents a definitive statement of the acceptance of the probability of climate change as a

significant factor for transportation in the U.S. It summarizes the science of climate change and the five most probable changes that will require responses form the transportation community:

- Increases in very hot days and heat waves
- Increases in Arctic temperatures
- Rising sea levels
- Increases in intense precipitation events
- Increases in hurricane intensity

Based on findings from the 2007 IPCC and National Research Council reports on climate change, and work done by the USGCRP on Gulf Coast (U. S. Climate Change Science Program), TRB 290 does include consideration of adaptation options, specifically operational responses, the use of technology to monitor extreme climate changes, best practice sharing among transportation decision makers, design changes in response to climate change impacts, integration of climate change as a factor in transportation planning and land use decision making, and the encouragement of regional and multi-state institutional and organizational responses to climate change. As a resource document and statement of the current state of understanding in regard to the transportation-climate change nexus, this report will serve as a framework for transportation decision makers at all levels of government and can be considered as firm foundation for subsequent work in this area.

While it includes attention to adaptation, TRB 290 provides only an introduction to the issue. For further insight, TRB 299, a focused report of adaption research relevant to transportation stakeholders, delves deeper into this policy alternative. This report is annotated here in the Appendix.

In addition to the Transportation Research Board, other organizations and interests have produced transportation-climate change documentation and research recently. In particular, the American Association of State Highway and Transportation Officials (AASHTO) published a *Primer on Transportation on Climate Change* in 2008. This report focuses primarily on the impact of transportation on the climate (emissions) and not adaptation. It does provide an overview of the current climate science, an inventory of potential impacts from climate change on transportation (derived in part from the TRB 290), and a list of potential approaches to reducing vehicle miles traveled and greenhouse gas emissions (American Association of State Highway and Transportation Officials 2008).

Another, similar, report was produced by the transportation consulting firm, ICF International, Report, with a focus on climate change integration into transportation planning (ICF International 2008). Through content analysis, interviews and an assessment of the typical long-range transportation planning process, this report provides more operational detail and guidance than the summary report from TRB and AASHTO. The report provides little guidance in regard to adaptation, however, primarily because the agencies surveyed for the report are doing little, if anything, on this issue. This is consistent with other reports reviewed here (Lindquist 2010).

The question of climate change and transportation in a coastal context is addressed most systematically in the U.S. Climate Change Science Program's (2008) report on the impact of

climate change on transportation along the U.S. Gulf Coast. This assessment, which was a collaborative research project with the United States Geological Survey and the U.S. Department of Transportation, involved a systematic assessment of the potential impacts from climate change on transportation along the U.S. Gulf Coast. One of the unique attributes of this report, in contrast to the summary and review reports above, was the inclusion of original and focused climate science research on the Gulf Coast area. This was integrated with transportation data and information, and socio-economic data to develop a comprehensive regional perspective on the issue. Chapter 5 of the report includes an extensive assessment of how to incorporate climate change factors into transportation planning. (For process background and a general guide to transportation decision making in the United States, see Office of Planning, Federal Highway Administration, 2009). A conceptual framework is provided which focuses on the factors of exposure (to climate change), vulnerability, resilience, and adaptation. The report also stresses the importance of including risk as a factor in transportation planning, primarily as it can be allied to the questions of uncertainty in the climate science available for decision and planning purposes. Conclusions from the report direct attention to the significant issues and research questions that need to be addressed, including:

- Planning timeframes and the need for transportation planners to extend their planning horizons beyond the 20-30-year timeframe to better correspond to the potential impacts from climate change.

- Need for an intermodal and connectivity focus in regard to assessing transport vulnerabilities along the Gulf Coast.

- Need for integrating climate change into research and attention on existing ecological and weather-related impacts.

At this time, ICF International is leading a Phase 2 follow-up study which is focusing on the Mobile, Alabama, region as a second case study.

Finally, for the most part adaptation plays a limited role in the reports summarized above. This is in part due to the overall policy dominance and attention in this country to mitigating the potential impacts, and to the transportation policy domain's focus on greenhouse gas emissions and the transport impacts on climate and the environment. A recent TRB report addresses this situation and does address the question of adaptation from a transportation perspective (National Research Council 2009). The report, which focuses on both mitigation and adaptation, states that in addition to a lack of understanding of the effectiveness of transport-related measures to mitigate greenhouse gas emissions and energy use:

"Also not well understood are the policies and practices that should be considered for **adapting** the transportation system to changes in precipitation, flooding, storm surges, and wind loadings that are likely to occur in the future as climate changes. The cost of **adapting** infrastructure is high, as is the uncertainty about the timing, magnitude, and location of the risks (2)."

Of primary significance from this report is the chapter (derived from a commissioned paper by McNeil, 2009) on adaptation research and development. Reiterating the climate science and

potential impacts from climate change from previous reports, this chapter does shed new light on the importance of adaption as a transportation policy response to the potential impacts. The main findings from the chapter suggest, first, a need for decision tools for state and local decision makers to make informed decision about policy alternatives. The second spotlighted the need to include stakeholders and end-users in the adaptation research agenda for transportation policy and planning efforts.

For an expanded general discussion of adapting to climate change, see the National Academies of Science (2010) Report in Brief on adaptation.

Case Studies of Climate Change and Transportation: Houston-Galveston, Texas

There are currently limited examples or case studies available on actual applied climate change adaptation activities in the U.S. The U. S. Climate Change Science Program assessment report (2008) summarized above is one exception, and there are several states and MPOs initiating efforts at integrating climate change as a factor in planning and decision making. One of the more active regions in the U.S. in this regard is found in the Houston, Texas (and surrounding cities) region of the Texas Gulf Coast. The Houston area was included in the U. S. Climate Change Science Program Gulf Coast assessment as the primary case study for the research effort. While the complete assessment and findings of the Houston-Galveston case can be found in the Assessment report, it is summarized here as it provided a framework for two subsequent studies summarized below.

The USGCRP report chose the Houston-Galveston area for its regional case study and designed and conducted in-depth interviews with a sample of decision and policy makers in the region in late 2006 – early 2007. The interviews focus on three primary areas of interest:

- Interviewees' perspectives on climate change as a general issue,
- Decision and planning processes the interview respondents were involved with,
- Utility and usefulness of the original research and scenarios prepared for the assessment project (see U. S. Climate Change Science Program, 2008 pages 5-10).

The interview findings stressed three categories of issues. First, climate change was recognized by the respondents as an important issue, but not one that was being considered or integrated into planning processes at that time. Climate change data was not being used, either, in decision making. Second, while the climate data and scenarios presented to the respondents was of interest, it was generally considered to be at a temporal scale that was of little use. Respondents wanted more localized climate information and projections. Third, in regard to respondent perceptions of individual climate factors, storm frequency and magnitude was of primary importance. Considering the proximity of the study area to the Gulf Coast, this was to be expected. The other factor perceived as important was sea level rise, another proximity concern for the region. The overall findings from the interviews stressed the lack of available information for integrating climate change into transportation planning and adaptation efforts as well as the lack of any top-down pressure from the federal government for broad range or major policy changes (U. S. Climate Change Science Program 2008).

Following the completion of the U. S. Climate Change Science Program assessment research, the Houston-Galveston Area Council, the Regional Planning Commission for the area covering 13 counties and 5.7million people, convened a Foresight Panel to "develop recommendations for local governments to adapt to potential changes in the region's climate and associated environmental effects" (Houston-Galveston Area Council, Foresight Panel 2008). Building on the CCSP approach, findings and climate scenarios, the Panel focused on the three broad issues of human health and safety, public infrastructure, and natural systems. The specific recommendations will not be summarized here, but the transportation-related recommendations included the following:

- Improve intergovernmental coordination and cooperation, including those associated with transportation.
- Use alternative paving products, in response to probable higher temperatures associated with climate change.
- Avoid new developments in flood-prone areas
- Avoid construction in areas subject to sea level rise
- Consider appropriateness of different modes of transportation
- Consider a longer-term vision of infrastructure needs than currently in use
- Use the H-GAC as a tool to assist local governments with climate change planning activities (Houston-Galveston Area Council, Foresight Panel 2008 5-7).

These suggestions were also considered within a framework of vulnerability assessment, as a first step towards understanding regional vulnerabilities to potential climate change risks. The final section of the report provides a summary of the potential climate impacts on the three broad issues that the Panel discussed. The report was finished and presented in December 2008.

As a result of the efforts of the Panel and the report, the H-GAC contracted with the Bush School of Government at Texas A&M University to design and implement a study on the perception of climate change of its constituent agencies and institutions. The study, which was conducted as one of the second year Master of Public Service and Administration program Capstone courses, also considered adaptation to climate change impacts as a research question (Bjune, et al 2009; see the online report for research methods, specific findings and recommendations). Through content analysis and interviews, the study found that, first, the Foresight Panel Report had not been given much consideration, even if the issues addressed in the report were of interest to respondents. Second, interview respondents frequently directed the interviewer to the environmental department or contact in the specific agency. Third, many of the individuals contacted for an interview responded negatively in general to the concept of climate change, citing the political nature of the issue as well as a general mistrust of the science and personal doubt of climate change as actually occurring. Finally, even with the emphasis on vulnerability assessments in the panel report, the Capstone study did not find evidence that these were being implemented, or even considered, by the H-GAC constituent agencies.

Recommendations from the Capstone study focused on efforts or initiatives that H-GAC could implement to move the region toward an awareness of the potential impacts from climate change and measures to adapt to these impacts. Recommendations emphasized two broad areas – education of the regional stakeholders about climate change, impacts and adaptation alternatives,

and developing or identifying funding mechanisms for stakeholders to conduct localized research or risk and vulnerability assessments as first steps toward integrating climate as a factor in decision making.

Taken as an aggregate of Houston regional perceptions and opportunities, the reports and research summarized above indicate that the area is somewhat aware of the potential impacts from climate change and stakeholders are willing to at least move in the general direction of climate change and adaptation integration. However, the insistence that climate change was strictly an environmental issue (as opposed to public health or natural systems, as addressed in the Foresight panel report) raises the question of broader acceptance of the issue. From the transportation sector perspective, this aggregate research suggests that the Houston-Galveston region warrants continued observation as a potential test bed for policy change and integration of climate science and factors in the decision making processes. Once the USDOT Gulf Coast Phase 2 study of Mobile, Alabama, is complete, these two regional coastal assessments will provide a solid framework for future policy making and planning.

Climate Change and Governance

The final section of literature reviewed for this report focuses on the issue of governing for climate change adaptation and policy change, in general. This is an understudied issue in the United States, yet is of significant concern in other regions of the world. In a recent World Bank working paper, Meadowcroft (2009) states that issues of societal impact, scientific uncertainty, equity issues and the long time frame associated with climate impacts, and ultimately the global implications for responding and adapting, all interact and raise difficulties for existing governmental structures and institutions. The United Nations International Human Dimensions Programme on Global Environmental Change (IHDP) is addressing this issue and associated concerns such as financing, water, and food security. The general issue of governing for climate change and sustainability draws attention to the interactions among a wide variety of stakeholders across different scales and temporal dimensions. As Moser (2009) states, responding to the consequences of climate change impacts involves a "rapidly and profoundly changing social-environmental context," and:

"Those involved in organizing, shaping, steering and implementing these efforts will have to navigate and manage a system made up of multiple actors with a variety of interests, capacities, and challenges often spanning several sectors" (31).

The interactions she describes goes beyond a typical intergovernmental approach applied in the policy and social sciences as it includes additional actors, such as non-profit and non-governmental agencies and the business sector. This may be a new and challenging world in which transportation planning and decision making is forced to operate in. It raises the question of how the transport sector interacts with other sectors such as agriculture and health, to name only two areas significantly involved with climate change issues and adaptation responses.

Other studies have focused on the governance issue, including Dernbach, et al (2010) with its assessment of the need for further state involvement in a national (U.S.) climate change policy effort. They contend that the de facto state leadership role needs to be institutionalized and used

as a framework for a comprehensive national level strategy and policy. The Pew Center on Global Climate Change also addresses this situation in a 2008 paper focusing on the dynamic interaction between the state and federal levels of government and how they should share responsibility for this policy domain (Litz 2008). Although the paper only addresses emissions and mitigation strategies, the general framework and concept can be applied for adaptation alternatives. Gore and Robinson (2009) provide a contrasting perspective which suggests that the state and municipal levels of government are really the only option for moving forward on climate change policy A related question about how to mainstream climate change policy in a coherent manner within and across existing administrative structures, is considered in a report from the Prime Minister of Finland's Office (2009). (For an extensive perspective on the question of finance and climate change adaption, see Persson, et al, 2009)
The research in the United States concerning how to govern for climate change, and the implications for the transportation policy domain, is in its infancy. This is one area where further research is needed and the transportation community has much to gain by interacting with the broader earth system governance community. For further information on earth system governance and the most recent research, see the following websites:

The Urbanization and Global Environmental Change project at Arizona State University

http://www.ugec.org/

The United Nations IHDP program

http://www.ihdp.unu.edu/

The Earth Systems Governance office at Lund University, Lund, Sweden

http://www.earthsystemgovernance.org/

CONCLUSIONS AND RECOMMENDATIONS

The literature and available guidance, best practices and case studies related to climate change and the transportation policy domain is slim but growing incrementally. This lack of guidance and relevant research is frequently cited as the main constraint in integrating climate change into the transportation planning and decision processes. Tools and information are slowly becoming available to the transportation community and decision makers, but not as rapidly as the general debate and concern for climate change issues. However, much of this available research is circular in nature, relying on a few studies and similar reports (such as the U. S. Climate Change Science Program report or the TRB 290 report) without adding much new research and systematic assessments of what decision makers and transportation planners actually need and at what scale and scope. Climate scientists are currently shifting their focus from the large global climate models to a more regional scale of emphasis. This shift will provide opportunities to link regional planning and policy making initiatives with advances in regional climate science. It will be necessary for transportation planners, sub-national governmental agencies and institutions, and academia to follow suit and integrate more formally with the climate science community.

Capacity issues are also significant in the current discussion of climate change and transportation. To focus on the issues of climate change and adaptation as a viable alternative solution in transportation planning requires more than an environmental focus. Climate change as an issue or problem goes beyond the narrow environmental definition as it includes other sectors and stakeholders than a traditional state or local transportation agency may have experience in dealing with. This is also related to the question of governance for climate change. In response to capacity and governance issues, the U.S. Government Accountability Office recently published a report on the need to enhance the capacity of MPOs to address transportation planning issues and capacity problems. According to the report, MPOs were having difficulty meeting federal requirements and responsibilities. Much of the problem is associated with the lack of capacity at smaller MPOs, and with general challenges such as a lack of resources, authority, and technical expertise. The report does, however, suggest that an opportunity exists to address these challenges in the upcoming reauthorization process, which should be considered in Congress in 2011 (United States, Government Accountability Office, 2009).

The Houston area example illustrates the importance of communication and education in regard to generating support and acceptance for climate change, first, as an issue, and second as a problem that needs to be dealt with in a systematic manner. Communicating science to decision makers and making sure they understand the implications, probabilities and alternative solutions is a significant task, and one for which many regional agencies may not be prepared. Also, as one of the few research efforts to directly address regional level stakeholders and decision makers, the Capstone study (Bjune, et al 2009) illustrates the continued resistance to climate change as a general issue or scientific concept. The transportation policy domain will have to address this situation as new climate science becomes available, as resistance to the issue continues, and as funding at all levels of government becomes scarce and resource availability for addressing any transportation problem declines.

Although the transport policy domain is slowly and incrementally moving in the direction of climate change and policy integration, with the publication of guidance and case examples, there is much room for improvement, particularly on the issues of capacity for policy making, regional planning and policy making, and governance for climate change and changing global environment. The main barrier may be a lack of understanding of how transportation policy actually works at the sub-national levels in regard to such a conflictual issue as climate change and how it competes for attention and resources with more traditional transportation problems. Continued research and attention on the constraints, barriers, as well as opportunities, to addressing the potential impacts of climate change on transportation in this country will remain a critical issue for further study.

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APPENDIX – ANNOTATED BIBLIOGRAPHY

Climate Change and Adaptation General Literature

2008

United States Government Accountability Office Report to Congressional Requesters. (May, 2008). *Climate Change: Expert Opinion on the Economics of Policy Options to Address Climate Change.* GAO-08-605.

Outline
Greenhouse gas emissions levels in the atmosphere and the effect on climate could have potentially serious environmental and economic impacts in the United States and abroad. Because of these potential implications, Congress asked the GAO to obtain experts' opinions on 1) actions that Congress might consider to address climate change and what is known about costs, benefits, and uncertainties of these actions; and 2) the strengths and weaknesses of policies or actions to address climate change.

Methods
GAO collaborated with NAS to identify and recruit experts with experience analyzing the economic effects of climate change policies. NAS recruited 25 experts that work on economics of climate change with expertise in agriculture, environmental, and natural resource economics. They then reviewed relevant climate change literature and federal agency documents and met with agency officials from EPA, DOE, NOAA, USDA and NASA. The Delphi method was used, which is an iterative and controlled feedback approach. Two web-based questionnaires were used – the first gathered opinions, the responses which were then used to create a second round of questions. Of the 25 experts, 18 responded to both questionnaires, and their responses are summarized in this report.

Findings/Recommendations
All of the experts agreed that Congress should consider establishing a price on greenhouse gas emissions using a marked-based mechanism by 2015, but differed in the type and stringency of that mechanism. Eight preferred cap and trade; seven preferred tax on emissions; and three preferred cap and trade without a safety valve. R&D, adaptation, and international negotiations and assistance were also considered important. The panelists assessed the costs and benefits, provided cost estimates, and assessed strengths and weaknesses (and administrative burden) of different policy options (namely cap and trade vs. a tax on emissions or a hybrid of both).

2007

Adger, W.N., S. Argawala, M.M.Q. Mirza, C.Conde, K. O'Brien, J. Pulhin, R. Pulwarty, B. Smit and K. Takahashi. 2007: Assessment of adaptation practices s, options, constraints and capacity. *Climate Change 2007: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, eds. Cambridge University Press, Cambridge, UK, 717-743.

Outline
Chapter 17 of the Fourth IPCC Assessment Report is an assessment of the knowledge and practice on adaptation since the Third IPCC report (TAR). This literature review focuses on "climate change adaptation practices and processes, determinants and dynamics of adaptive capacity, and opportunities and constraints of adaptation."

Methods
Literature review.

Findings/Recommendations
This article concludes that "there has been significant documentation and analysis of emerging adaptation practices" since the TAR. The adaptation worldwide has been a part of broader social and development initiatives. The article also notes limitations of adaptation, posed by financial, cultural, technological, institutional, and cognitive constraints related to the "magnitude and rate of climate change." Different regions and communities differ greatly in their ability to respond to climate change and implement adaptation procedures, and the policy and planning processes should take these differences into account in the design and implementation of climate change adaptation. Specifically, "high priority should be given to increasing the capacity of countries, regions, communities, and social groups to adapt to climate change in ways that are synergistic with wider societal goals of sustainable development.

In addition, there are significant challenges for researchers trying to understand the process by which adaption is occurring and will occur, and in identifying areas where government can intervene. Further research is needed to monitor progress on adaptation and to assess the effects of measures being implemented. Research is also needed on the "resilience of socio-ecological systems to climate change…and on the economic and social costs and benefits of adaptation measures" (market and non-market). Information on economic growth and employment is also lacking.

2007

IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, eds. Cambridge University Press, Cambridge, UK, 7-22.

Outline
"This Assessment is of current scientific understanding of the impacts of climate change on natural, managed and human systems, the capacity of these systems to adapt and their vulnerability(8)." It incorporates new knowledge gained since the Third Assessment.

Methods
Literature review.

Findings/Recommendations
By evaluating recent studies, the study showed that:
• Natural systems are affected by climate change
• Effects on hydrological systems are occurring
• Terrestrial biological systems are affected
• Trends toward earlier "greening" of vegetation are occurring
• Changes in marine and freshwater biological systems are associated with rising water temperatures
• The uptake of anthropogenic carbon since 1750 has led to the ocean becoming more acidic.

Much more evidence has accumulated over the past five years to indicate that changes in many physical and biological systems are linked to anthropogenic warming. These studies have some limitations; however, "the consistency between observed and modeled changes in several studies is sufficient to conclude with high confidence that anthropogenic warming over the last 3 decades has had a discernible influence on many physical and biological systems. (8)"

The study lists key findings regarding projected impacts as well as findings on vulnerability and adaptation. The study also looks at the impacts on different regions of the globe.

Since the TAR, "confidence has increased that some weather events and extremes will become more frequent and more widespread. (8)"

The study also assesses current knowledge about responding to climate change and how to increase adaptive capacity to diminish risks associated with climate change. Still, many important questions are left to be answered, and further research is needed.

2007

Nicholls, R.J., P.P. Wong, V.R. Burkett, J.O. Codignotto, J.E. Hay, R.F. McLean, S. Ragoonaden and C.D. Woodroffe, 2007: Coastal systems and low-lying areas. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, eds. Cambridge University Press, Cambridge, UK, 315-356.

Outline
This chapter of the Fourth Assessment Report "presents a global perspective on the impacts of climate change and sea-level rise on coastal and adjoining low-lying areas, with an emphasis on post-2000 insights.(318)"

Methods
Literature Review.

Findings/Recommendations
The understanding of the implications of climate change for coastal systems and low-lying areas has increased substantially since the TAR. Six climate policy messages are explained by this review:

1. Coasts are experiencing the adverse consequences of hazards related to climate and sea level.
2. Coasts will be exposed to increasing risks, including coastal erosion, over the coming decades due to climate change and sea-level rise.
3. The impact of climate change on coasts is exacerbated by increasing human-induced pressures.
4. Adaptation for the coasts of developing countries will be more challenging than for coasts of developed countries due to constraints on adaptive capacity.
5. Adaptation costs for vulnerable coasts are much less than the costs of inaction.
6. The unavoidability of sea-level rise, even in the longer term, frequently conflicts with present-day human development patterns and trends.

The most appropriate response to sea-level rise for coastal areas is a combination of adaptation to deal with the inevitable rise, and mitigation to limit the long-term rise to a manageable level.

2007

Klein R.J.T., S. Huq, F. Denton, T.E. Downing, R.G. Richels, J.B. Robinson, F.L. Toth, 2007: Inter-relationships between adaptation and mitigation. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* M.L. Parry, O.F. Canziani, J.P. van der Linden and C.E. Hanson, eds. Cambridge University Press, Cambridge, UK, 745-777.

Outline
This chapter identifies and explores four types of inter-relationships between adaptation and mitigation:
• Adaptation actions that have consequences for mitigation;
• Mitigation actions that have consequences for adaptation;
• Decisions that include trade-offs or synergies between adaptation and mitigation; and
• Processes that have consequences for both mitigation and adaptation.

Methods
Literature Review.

Recommendations/Conclusions
This review finds that:

1. Effective climate policy aimed at reducing the risks of climate change to natural and human systems involves a portfolio of diverse adaptation and mitigation actions.
2. Decisions on adaptation and mitigation are taken at different governance levels and inter-relationships exist within and across each of these levels.
3. Creating synergy between adaptation and mitigation can increase the cost-effectiveness of actions and make them more attractive to stakeholders, including potential funding agencies.
4. It is not yet possible to answer the question as to whether or not investment in adaptation would buy time for mitigation.
5. People's capacities to adapt and mitigate are driven by similar sets of factors which represent a generalized response capacity that can be mobilized for both adaptation and mitigation.

More well-documented studies at the regional and sectoral level are still needed.

2007

IPCC, 2007: Summary for Policymakers. *In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller eds. Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA.

Outline
This chapter describes progress being made in understanding the human and natural drivers of climate change, observed climate change, climate processes and attribution, and estimates of projected future climate change.

Methods
Literature Review.

Conclusion/Recommendations
The report finds that greenhouse gas emissions including carbon dioxide, methane, and nitrous oxide have increased as a result of human activities since 1750. The increases are primarily due to fossil fuel use and land-use change, and agriculture. The warming of the global climate system is unequivocal, as evidenced by observations of increases in global average air and ocean temperatures, melting snow and ice, and rising sea levels. Long-term changes in climate have been observed, including changes in Arctic temperatures and ice, changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather systems; however, some aspects of climate have not been observed to change. Information gathered from paleoclimatic studies has suggested that the warmth of the last half century is unusual in at least the last 1,300 years. Most of the observed increase in average global temperatures can be attributed to the observed increase in anthropogenic greenhouse gas concentrations. Human influence can be extended now to other aspects of climate such as ocean warming, average temperatures, temperature extremes and wind patterns. Projections indicate that for the next two decades, a warming of .2^{o}C per decade can be expected – if all concentrations of greenhouse gasses had been constant at 2000 levels, a further warming of .1^{o}C would be expected, and if greenhouse gas emissions continue at or above current rates, this would cause further warming and larger changes in the global climate system. Since the TAR, there is a higher confidence in these observations and predictions.

2007

Berger, E. (2007, January 22). Climate scientists feeling the heat. *The Houston Chronicle*. Retrieved from http://www.chron.com.

Outline
This article begins by discussing the tensions between scientists and the public regarding climate change, implying that the science community may have overblown the science of global warming in order to sell the public on it. The author then goes on to explain that computer models are not perfect in their predictions for future warming. Finally, young scientists sometimes feel pressure from older peers as well, and the article implies that scientists may feel compelled to hide their research findings if it contradicts the climate change consensus.

2009

USGCRP, 2009: Regional Climate Impacts: Southeast. *In: Global Climate Change Impacts in the United States* [Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, eds. Cambridge University Press, 2009.

Outline
This document details past warming and future predictions for climate change impacts in the Southeast United States. Since 1970, the average annual temperature has risen by 2^{o}F. Models predict continued warming in all seasons and an increase in the rate of warming. In addition, models predict less precipitation in winter and spring; hurricane strength has also increased, correlated with an increase in sea surface temperature. The intensity of Atlantic hurricanes is likely to increase, along with rising sea levels, which is the most serious consequence expected from climate change. Projected increases in air and water temperatures will cause heat-related stresses for people, plants, and animals such as increased illness and death, decline in forest growth and crop yield, increased buckling of pavement and railways, decreased oxygen in waters leading to fish kills and loss of species diversity, and decline in production of cattle and other livestock. Decreased water availability may affect the region's economy and natural systems, and disruptions to various ecosystems. All of these effects may also affect the quality of life in this region.

2009

USGCRP, 2009: Executive Summary. *In: Global Climate Change Impacts in the United States* [Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, eds. Cambridge University Press, 2009.

Outline
This report synthesizes information from a wide variety of scientific assessments and recently published research to summarize what is known about the observed and projected consequences of climate change in the United States. The report combines analysis of impacts on various sectors such as energy, water, and transportation at the national level with an assessment of key impacts on the specific regions of the United States.

Key Findings:

1. Global warming is unequivocal and primarily human-induced.
2. Climate changes are under way in the United States and are projected to grow.
3. Widespread climate-related impacts are occurring now and are expected to increase.
4. Climate change will stress water resources.
5. Crop and livestock production will be increasingly challenged.
6. Coastal areas are at increasing risk from sea-level rise and storm surge.
7. Threats to human health will increase.
8. Climate change will interact with many social and environmental stresses.
9. Thresholds will be crossed, leading to large changes in climate and ecosystems.
10. Future climate change and its impacts depend on choices made today.

Climate Change and Planning

2003

Chapin, F. S., Rupp, T. S., Starfield, A. M., DeWilde, L.-o., Zavaleta, E. S., Fresco, N., et al. (2003). Planning for resilience: modeling change in human-fire interactions in the Alaskan boreal forest. *The Ecological Society of America* , 255-261.

Outline
This article uses a modeling approach to understand policy impacts on regional sustainability and applies the approach to wildfires in the interior of Alaska.

Methods
The author developed a model to test understand the challenges and policy implications of regional sustainability. The goals of the model was to develop possible scenarios of future changes to Alaska's fire regime and then fire managers can recognize the long-term consequences of different fire policies.

Recommendations/Suggestions
The paper describes the possible long-term effects that changes in ecosystem services can have on society. This model could be used to prepare other responders to changes in the ecosystem due to climate change. It could assist in understanding the impacts of climate change policy on cultural, demographic and socioeconomic factors.

March 2006

Berke, P., & Campanella, T. (2006). Planning for Postdisaster Resiliency. *The Annals of the American Academy*, 192-207.

Outline
The paper focuses on the planning for resiliency after a catastrophe and the possible barriers to planning for federal and state governments. The paper discusses the benefits of planning and its relationship to resiliency.

Methods
The authors analyzed various case studies on planning and look in-depth at planning for Hurricanes Katrina and Rita. The paper examines and compares the resiliency of Gulf Coast communities after the hurricanes.

Recommendations/Suggestions
This paper illustrates challenges that federal and state government face in planning and resiliency. These challenges need to be considered for climate change mitigation and planning. One suggestion is to look at federal government standards for critical land-use principles because land use was a problem in planning coordination.

February 2009

Connell, D. J. (2009). Planning and its Orientation to the Future. *International Planning Studies* , 85-98.

Outline
The article examines the relationship between planning and its orientation to the future from a socio-historical perspective. The article examines the emergence of planning as a social phenomenon in relation to society's break from a traditional to a modern experience of the future.

Methods
The author draws upon non-planning literature about society's orientation to the future and compares or links it to planning theory literature. The author focuses on the relationship between the function of planning, its orientation to the future, and society's orientation to the future.

Recommendations/Suggestions
This article could be useful in understanding how society focuses on planning for the future. It can explain the collective action challenges of planning and mitigating for climate change.

Climate Change Case Studies

2005

Pablo, S., Anderson, W., Mahal, V., and Lakshmanan, T. (2005). Impacts of flooding and climate change on urban transportation: A system-wide performance assessment of the Boston Metro Area. *Science Direct*.

Summary
The paper assesses the impact of climate change on the system-wide performance of transportation networks using the Boston Area as a case study. The results from the case study indicate almost a doubling in delays and lost trips. These impacts are significant, but probably not large enough to justify a major effort for adapting the physical infrastructure to anticipated climatic conditions. The paper focuses on transportation disruption rather than infrastructure damage.

Methodologies
The paper integrates projected changes in land use, demographic and climatic conditions into the urban transportation modeling system to explore the relative impacts of global warming on the system performance due to additional riverine and coastal flooding. The methodology is based on modeling and data resources from metropolitan areas in the United States and other countries.

Significance
This report focuses on the possible damages to the transportation sector from flooding caused by climate change. The results could illustrate to other cities the harmful effects that climate change can have on infrastructure and transportation, especially the impacts on major commuter routes. Furthermore, the different scenarios could assist cities in adaption and mitigation plans. Finally, the impact could be more severe in other U.S. cities because Boston is already heavily built and there will not be much change in urban infrastructure and the transportation network is not too vulnerable to extreme events.

2005

Kirshen, P., Ruth, M., & Anderson, W. (2005). Interdependencies of urban climate change impacts and adaptation strategies: A case study of Metropolitan Boston USA. *Springer Science*, 105-122.

Summary
This paper analyzes the interdependencies of the impacts of climate change and adaptation strategies on infrastructure system in Boston. The authors found that taking actions before 2050 results in less total adaptation and impacts costs to the region than taking no action.

Methodology
A stakeholder group was formed and consisted of 30 multi-level government officials, members of non-governmental organizations, and representatives from private industry to identify issues of regional concerns and on the ground data. A modeling of the period 2000 to 2100 was used to analyze the performance of many of the critical infrastructure systems in Metro Boston.

Significance
The authors developed an adaptation matrix that describes any negative impacts on energy, health, transportation, river flooding, sea-level rise, water supply, and water quality caused by climate change in any one system. The results show that an effective adaptation action in one system also lessens climate change impacts in another system. For example, plans that improve water quality could also improve water supply, health, and the environment. Further research could be conducted to analyze the benefits and effectiveness of the paper's adaptation actions and its effect on climate change.

2008

Houston-Galveston Area Council. (2008). *Foresight Panel on Environmental Effects Report.* Houston.

Summary
The Houston-Galveston Board of Directors formed a panel to develop recommendations for local governments to adapt to climate and environmental changes in the region. The panel included experts in environmental and infrastructure planning. The purpose of the panel was to compile recommendations that local governments could use to adapt to potential effects of climate change. The panel forecasted the following as potential climate change effects that could occur by 2100: "average annual temperature rise of two to seven degrees Fahrenheit, sea level rise of two to five feet, increased intensity and frequency of extreme weather events (such as hurricanes and tropical storms), similar annual precipitation levels; however, occurring in more frequent and intense storms, interspersed with longer dry periods" (2).

Methodology
The panel used climate change models to project the possible environmental impact on the region and also to project the timeframe the effects would occur. Models were "global or hemispheric in scale" and the climate change scenario was based on the U.S. Department of Transportation's *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study Phase 1* (2).

Significance
The panel concluded that climate change in the Houston-Galveston area could have potential effects on human and natural environments such as heat-related illness, air quality, disease, and public safety. It compiled recommendations for local governments based on the following broad goals: "protect human health, protect property, protect natural environment, increase efficiency of operations, reduce need for vehicular transportation and reduce urban heat island effect" (5). It came up with a list of 25 recommendations for assisting local government in adapting to climate change. The panel suggests that local governments should first focus on "strategies that focus on existing operations and standards for new buildings and infrastructure" (3).

2008

The Oregon Department of Transportation. (2008). *Sustainability Plan Volume 1: Setting the Context.* Salem.

Summary
This report is a multi-year sustainability plan that "provides the overall vision and rationale" for the state's future sustainability projects (2). This volume of the sustainability plan focuses on the "context for considering sustainability and introduces the focus areas that will be used to incorporate sustainability into agency operations and transportation system-related activities" (5). The main objectives for this report are on the following areas: sustainability in Oregon, sustainability and transportation, sustainability planning at Oregon Department of Transportation, and the introduction to the focus areas. These focus areas consist of health and safety, social responsibility, environmental stewardship, land use and infrastructure, energy/fuel use and climate change, material resource flows, and economic health.

Significance
This report is an expansion of a previous Oregon sustainability plan and ODOT worked to implement the three main actions: renew the vision of a balanced, multimodal transportation system that includes sustainability considerations, implement the Oregon Transportation Investment Act, and develop an ODOT maintenance yard Environmental Management System. ODOT seems to be aggressively formulating and implementing sustainability plans. This volume is updated and attempts to provide a "more strategic and comprehensive approach for incorporating sustainability in the agency and in its management of the statewide transportation system" (13).

2009

Gore, C., and Robinson, P. (2009). Local Government Response to Climate Change: Our Last, Best Hope? *Changing Climates in North American Politics* , 137-158.

Summary
The article examines local governments' response to climate change in North America and "identifies the political and practical forces at work in local governments" (137). The authors found four factors that are involved in local actions. First, local governments are members of networks that promoted climate change response such as national, regional and international entities. Second, citizens look to their local government for action on local environmental issues. Third, local governments are concerned about "their international reputation and take action to demonstrate leadership" (138). Fourth, local governments are aware of the "interrelationship among social, economic, and environmental issues when making decisions about the physical form and social and economic quality of urban regions" (138). The article provides an overview of the federal structure of Canada, the U.S., and Mexico and how local governments operate within the structure.

Methodology
Qualitative research on the federal structure of the governments in North America and how local governments work within the structure.

Significance
Many North American municipal governments are well equipped to play an important role in national climate change mitigation and adaptation. "Municipalities are central actors in emerging multilevel climate change governance in North America" (155). State and federal governments have been slow to support local governments and offered "inconsistent support," but local governments have the ability to be policy leaders and play an important role in climate change governance.

2009

Mintrom, M., & Norman, P. (2009). Policy Entrepreneurship and Policy Change. *The Policy Studies Journal* Vol. 37, No. 4 , 649-667.

Summary
This article examines policy entrepreneurship as an explanation of policy change and shows how "policy entrepreneurship can be understood within more encompassing theorizations of policy change: incrementalism, policy streams, institutionalism, punctuated equilibrium, and advocacy coalitions" (649).

Methodology
The authors conducted a literature review on policy entrepreneurship in relation to policy change. They refer to the works of Baumgartner and Jones, Kingdon, Crowley, Teodoro, and other political scientists.

Significance
The article discusses how the concept of policy entrepreneurship is yet to be broadly integrated within the analyses of policy change. The authors offer two options for future research: "there is a need for closer study of the motivations and strategies used by policy entrepreneurs and more study of the interactions between policy entrepreneurs and their specific policy contexts" (661). They mention that more research could be conducted in conceptual development and empirical testing concerning policy entrepreneurship.

2009

Natt, W. (2009, March 25). Adapting to climate change: Livable Houston Initiative. *Houston Tomorrow*.

Summary

The newspaper article discusses the recommendations on climate change and infrastructure planning. The Houston-Galveston Area Council formed a group of experts in 2007 “to develop recommendations for local governments to adapt to potential changes in the region’s climate and associated environmental effects.” The recommendations included forming mutual aid agreements between communities, plans for water and energy conservation, and efforts at stormwater retention and heat island mitigation. Furthermore, recommendations were made for future growth such as reevaluate building codes in high-risk areas, preserve existing green infrastructure, establish green building standards, develop compact, livable communities and assess priorities and strategies for reinvestment, recovery, and reconstruction following potential climate change-related disasters. The audience was receptive to the recommendations from the experts and that the report emphasizes a “new way of thinking” about climate change.

Climate Change and Transportation

1995

Owens, S. (1995). Transport, land-use planning and climate change. *Journal of Transport Geography* Vol. 3, No. 2 , 143-145.

Summary
The article reviews a recent publication of new transportation planning in the United Kingdom. The author summarizes the importance of land-use planning and the connections between transportation and the environment. The author states that land-use planning is "relevant to climate change because land-use patterns influence mobility and the amount of movement has important implications for greenhouse emissions" (143). The new policy demonstrates the increase public awareness of climate change and its possible impact of travel time. The author suggests the need for a coherent policy framework and policies aimed at reducing the environmental impacts on traffic should include land-use planning.

Significance
The new policies in the UK link land-use planning, transport, climate change and how decisions made locally are connected to the global environment. The new policy demonstrates the more widespread shift in thinking and "new receptiveness for older ideas and policy prescriptions" for transportation policy and climate change.

2008

Schalch, K. (2008, March 11). Studies: Climate Change Threatens U.S. Roadways. *National Public Radio*.

Summary

The National Research Council issued a warning to the transportation sector that it will become increasingly more vulnerable to floods and sea-level rise. The council predicts “60,000 miles of highways, major airports, low-lying tunnels and ports” will be impacted. It estimates the damage to the infrastructure and the cost of revamping the transportation sector could cost hundreds of billions of dollars.

Significance

The National Research Council predicts major damage to the transportation sector due to climate change. The council is calling for major policy changes at all levels of government to limit the damage.

2008

Burkett, Virginia R., Potter, J. R., & Savonis, M. J. (2008). *Impacts of Climate Variability and Change on Transportation Systems and Infrastructure–Gulf Coast Study.* US Climate Change Science Program.

Summary
This report analyzed the potential impacts climate change could have on the transportation sector in the Gulf Coast. The goals of the report were to determine "whether climate and ecological data could be usefully employed in the analysis; identify and implement an assessment approach; and provide an overview of the potential impacts" (6-1). The report concluded that six trends in climate and coastal change: relative sea level rise, storm activity, average temperature increase, temperature extremes, precipitation change and extreme rainfall events.

Methodology
The study used historical data on the natural environment, made climate models, estimated emission scenarios and compiled well-established literature on climate impacts.

Significance
The report outlines possible impacts on transportation infrastructure in the Gulf Coast area. The report lacks the ability to predict that exact impact of climate change because of the uncertainties in modeling but rather gives a broad assessment of the long-term impact. The authors suggest that the "safety impacts associated with climate impact deserve further in-depth analysis" (4-56).

Climate Change and Governance

2009

Biermann, F., Betsill, M. M., Gupta, J., Kanie, N., Lebel, L., Liverman, D., et al. (2009). Earth System Governance: Science and Implementation Plan of the Earth System Governance Project. *Earth System Governance Project Report No. 1* , 144.

Summary
The Earth System Governance Project is a new long-term research program developed under the International Human Dimensions Programme on Global Environmental Change. This book elaborates on the concept of earth system governance and on the central questions, methods and processes of a global research effort. The plan is organized into five problems. The first section explains the architecture of earth system governance including the emergence, design, and effectiveness of governance systems. The second outlines the agents that drive earth system governance and those that need to be involved. The third analyzes the adaptiveness of earth system governance. The fourth section examines the accountability and legitimacy of governance. The fifth, analyzes how the earth system governance can reach interdisciplinary conceptualizations and definitions of allocation and access. Finally, the book contains chapters of crosscutting themes, case studies, policy relevance, and the future process of earth system governance.

Methodologies
The research program will employ qualitative social science methodology, develop databases, and use theoretical frameworks and research design from social sciences. Furthermore, it will use modeling in the fields of qualitative, agent-based, game theory or scenario development. Finally, the book examines case studies that would likely play a central role in the study of earth science governance.

Significance
Further research on the governance project can determine if the project is effective and worthwhile in providing long-term governance solutions. It will also show if integrated systems of governance can support a co-evolution of nature and human societies that leads towards sustainable development.

2008

Litz, F. T. (2008). Toward a Constructive Dialogue on Federal and State Roles in U.S. Climate Change Policy. *Pew Center on Global Climate Change* , 1-36.

Summary
This paper evaluates possible approaches to a climate change from strong federal action to strong state action. It examines different scenarios to which responsibility is shared between federal and state governments and where action is required at both levels. The author contends that federal action is necessary to achieve significant pollution reductions and to establish uniformity across the country. States' role would be to work as policy innovators, on-the-ground implementers, and policy drivers. The first section summarizes the roles for state and federal government in climate change policy. The second section explains the climate change actions taken by states and issues resulting from state action. The third section summarizes ways the state policy can be affected by federal action. The fourth section examines the state and federal partnership established under the Clean Air Act, as it relates to the division of federal and state responsibility. The fifth section outlines three possible approaches to comprehensive nationwide climate change action, taken into account the challenges and benefits of each option. The final section offers key conclusions for the continuing climate change dialog.

Methodologies
The author researched state climate change programs, federal climate change actions, and the Clean Air Act. He also analyzed the nature of the climate change problem as it relates to local, state, federal, and international entities.

Significance
The article provides helpful insights on the roles of federal and state governments in climate change action. It outlines possible approaches that the federal government could take to implement a comprehensive climate change plan. It recognizes how state governments are important in policy implementation, but asserts that the federal government should be the leader in the climate change debate.

General Adaptation

2008

The Federal Government of Germany. Federal Cabinet. 17 December 2008. *German Strategy for Adaptation to Climate Change*.

Outline
"This strategy creates a framework for national adaptation to the impacts of climate change and establishes a transparent and structured medium-term process which, in conjunction with relevant actors, will progressively ascertain actions needs, define appropriate objectives, identify and resolve conflicts of objectives, and develop and implement potential adaptation measures (1)"
"The long-term objective of the Adaptation Strategy is to reduce the vulnerability and maintain and improve the adaptability of natural, social, and economic systems."

Method
Federal Cabinet report on Germany's Adaptation Strategy

Findings/Recommendations
The strategy addresses a broad and varied range of possible adaptations. The impacts of climate change, as well as adaptation options for 13 fields of life, environment, and business are described. The report takes into account various scenarios and climate models and provides a comparative evaluation of four regions in Germany that are especially sensitive to climate change. The regional planning with regard to adaptation is an integration of regional policy and planning, physical development planning, and population protection. The strategy also considers climate change impacts on developing countries, and how development policies address adaptation needs. The report concludes with a discussion of the next steps on Adaptation Strategy, which focuses on an 'Adaptation Action Plan' from the Federal Government, to be presented in March 2011.

2008

Horstmann, Britta. 2008. Framing Adaptation – a Challenge for Building Institutions. *IOP Conference Series: Earth and Environmental Science* 6 (48).

Objective
To define core characteristics of the conceptual frame of adaptation

Method
Analysis of the framing of adaptation within the UNFCC, scientific discourse, and development policy and practice

Findings/ Recommendations
The report analyzes how the UNFCC, scientific discourse, and development policy and practice define adaptation to climate change. The author concludes that the definition of adaptation is still very broad and should be addressed by defining the problem in a context-specific way to find an appropriate solution. The core characteristics of adaptation framing that are considered concept-inherent are: differentiating between adaptation and development; the conceptual adaptation frame for funding mechanisms, process orientation and country-drivenness; strengthening context-specific information and analysis; and addressing uncertainty and responsibility. Based on those core characteristics, the report generates questions for use in creating context-specific definitions of adaptation:
•Adaptation to what? (climate-related stimuli),
•Who or what adapts? (characteristics of system),
•How does adaptation occur? (attributes, forms, types of adaptation),
•On what time scale and on what spatial scale is adaptation being addressed?
•How should uncertainty and responsibility in adaptation be addressed? All of these issues are considered in relation to institute building for the purpose of addressing adaptation to climate change.

2008

Koomen, Eric, Willem Loonen, Maarten Hilferink. 2008. “Climate-Change Adaptations in Land-Use Planning; A Scenario-Based Approach” in *The European Information Society*, 261-282. Springer Berlin Heidelberg.

Objective
To describe scenarios projected by the *Land Use Scanner*

Method
The *Land Use Scanner* is fed possible socio-economic and climatic changes to simulate future land use in various scenarios.

Findings/ Recommendations
The paper describes scenarios the researchers created, and the variables used to create them, using the *Land Use Scanner*. The scenarios can be used in future research on adaptation and mitigation measures in the Netherlands. Potentially, the adaptation and mitigation measures could be fed back into the *Land Use Scanner* for analysis. The study is part of a larger research program, *Climate Changes Spatial Planning*, and the scenarios created in this study are closely related to and can be used in other projects happening within the program.

2009

Cruce, Terri L. 2009. “Adaptation Planning – What U.S. States and Localities are Doing.” Working paper, Pew Center on Global Climate Change.

http://www.pewclimate.org/docUploads/state-adapation-planning-august-2009.pdf
Objective
This paper focuses on adaptation plans and actions in progress by state and local governments.

Method
Description of adaptation plans at the state level and local level within the United States

Findings/ Recommendations
The paper identifies different levels of adaptation plans at the state level, with a map indicating which states have adaptation plans that are complete or in process and which states have recommended adaptation plans in their climate action plans. After the map is a table listing the details of the previously mentioned states’ adaptation plans. The paper highlights the efforts of King County, Washington as a leader for adaptation planning on the local level and points to efforts in New York City, Seattle, and Portland, Oregon to address climate change. The role of non-governmental organizations in cities’ adaptation planning is also discussed. The paper then focuses on actions taken by the state and local governments that address specific impacts of climate change but are not being specified as adaptation planning.

2009

Giddins, Anthony. 2009. The Politics of Adaptation. In *The Politics of Climate Change*, 162 – 181. Malden, MA: Polity Press.

Objective
This chapter defines adaptation and examines its relevance in Europe, developing countries, and with the insurance industry.

Method
Analysis of adaptation in Europe, a case study from the UK, adaptation and the insurance industry, and adaptation in the developing world

Findings/Recommendations
The author provides definitions for a variety of terms related to adaptation, including pro-active adaptation, vulnerabilities, resilience, and adaptive capacity. The discussion of adaptation in Europe includes a description of climate changes that are currently happening or possibly could happen, as well as current and proposed adaptation activities. A case study of floods in the UK is included. As for the role of insurance in adaptation planning, the author believes the insurance industry must not back away in the face of increased natural disasters, but instead, work with governments to figure out ways to expand insurability. Finally, the author notes that poor countries are most vulnerable to consequences of severe weather events, which climate change will most likely increase. Possible adaptation strategies for developing countries and a description of preventive adaptation actions taken by Bangladesh are provided.

2009

Glick, Patty, Amanda Staudt, Bruce Stein. 2009. A New Era of Conservation: Review of Climate Change Adaptation Literature. National Wildlife Federation.

Objective
This literature review summarizes recent science on climate change adaptation in the context of natural resource management and fish and wildlife conservation.

Method
Literature review

Findings/Recommendations
The literature review finds that challenges to adaptation planning and implementation include lack of information about future climate conditions, difficulty planning with that type of uncertainty, lack of management and policy options, and inadequate funding and capacity, along with institutional barriers. Overall, five principles emerged from the literature review:
•Reduce other, non-climate stressors
• Manage for ecological function and protection of biological diversity
• Establish habitat buffer zones and wildlife corridors
• Implement "proactive" management and restoration strategies
•Increase monitoring and facilitate management under uncertainty

Finally, the authors propose a conceptual framework for developing and implementing adaptation strategies. This framework includes six parts:
• Select conservation targets
• Assess climate-change impacts and vulnerabilities of those targets
•Evaluate management options
• Develop management response
• Implement management and monitoring strategies
• Review and revise

2009

McEvoy, Darren, Kate Lonsdale, Julia Rawlins, Sarah Lindley, Jochen Hinkel, Maria Falaleeva. 2009. Adaptation in the Urban Environment: A Story of Process and Outcome. *IOP Conference Series: Earth and Environmental Science* 6 (33).

Objective
This paper analyzes the adaptation agenda of three different cities and develops an adaptation 'ladder' to conceptualize the adaptation process.

Method
An analysis of case studies using information gathered from local experts and stakeholders and academic literature.

Findings/Recommendations
This paper reviews case studies in the cities of London, Manchester, and Berlin in order to analyze each city's progress in adaptation to climate change. The authors noted the following two main barriers that hinder the ability to determine adaptation 'best practices: 1) Much of the 'on the ground' adaptation activities are not labeled as adaptation, but rather as detached, single issues, and 2) Adaptation is a complex issue that happens at different spatial scales and involves both public and private actors.

The authors also devised an adaptation ladder with five rungs to demonstrate the dynamic process of adaptation, namely: 1) risk perception, 2) individual and organizational willingness to respond, 3) building adaptive capacity, 4) learning to adapt, and
5) sustaining action in the longer term.

2009

McNeil, Sue. 2009. "Adaptation Research Programs and Funding." Paper prepared for Transportation Research Board. http://onlinepubs.trb.org/onlinepubs/sr/SR299Adaptation.pdf

Objective
"This paper presents a proposed research program and activities to assist transportation agencies, owners and users to adapt to climate change as outlined in (but not limited to) Transportation Research Board (TRB) Special Report 290: *Potential Impacts of Climate Change on U.S. Transportation*."

"…the proposed research program is structured around information sharing, stakeholder involvement and support tools for all levels of government and public and private sector stakeholders (1)."

Method
Developed criteria for research projects, literature review of already completed research, explored current adaptation actions and existing research programs, and identified research projects needed

Findings/ Recommendations
The paper presents a proposed research program created to address the following climate changes that will affect the transportation industry: temperature changes, sea-level rise, precipitation changes, and increasing intensity of storms. This program is based on a review and potential linkage to current research and initiatives happening in the United States. and abroad, as well as integration with Transportation Research Board Special Report 290. The assumptions and criteria used to develop this program are detailed in the paper. Three categories of research provide the structure for the research program: foundational research, applied research, and support functions. Subcategories exist under foundational and applied research, and within each subcategory, research projects are proposed for various sectors. The paper details the issues, objective, research, and timeframe of each research project proposed.

2009

Parry, Michael, Nigel Arnell, Pam Berry, David Dodman, Samuel Fankhauser, Chris Hope, Sari Kovats, Robert Nicholls, David Satterthwaite, Richard Tiffin, Tim Wheeler. 2009. *Assessing the Costs of Adaptation to Climate Change: A Review of the UNFCCC and Other Recent Estimates*. London: International Institute for Environment and Development and Gratham Institute for Climate Change.

Outline
This report evaluates the cost estimation of adaptation to climate change made by the UNFCCC and other studies to determine strengths and weaknesses of the studies, as well as provide suggestions for future assessments. This report is not meant to provide new or different cost numbers for adaptation, but rather assess costs estimates put forth by other studies.

Methods
Assessment of the UNFCCC study and other adaptations estimates

Findings/Recommendations
The UNFCCC and other studies have underestimated the cost of adaptation to climate change by not including some sectors in estimates (such as ecosystems, energy, manufacturing, retail, and tourism), including only partial costs for other sectors, and overlooking current adaptation deficits. 'Adaptation deficits' refers to the current lack of necessary investment in certain sectors that would cause adaptation investment to be insufficient. This report details the strengths and weaknesses of previously estimated adaptation costs by sector (agriculture, forestry, and fisheries; water supply; human health; coastal zones; infrastructure; ecosystems). The authors recommend that future studies provide a choice range of costs for varying amounts of impact and also provide more analysis of the costs of residual impacts that adaptation may not avoid.

2009

Persson, Asa, Richard J.T. Klein, Clarisse Kehler Siebert, Aaron Atteridge, Benito Muller, Juan Hoffmaister, Michael Lazarus, Takeshi Takama. 2009. *Adaptation Finance Under a Copenhagen Agreed Outcome*. Stockholm: Stockholm Environment Institute.

Objective
"This report presents options for overcoming obstacles and reaching an agreement on adaptation financing as part of a Copenhagen Agreed Outcome."

Method
The research framework addresses the questions of how adaptation financing should be *delivered* to countries, how adaptation financing should be *governed*, and how adaptation financing should be *generated* – in that order. The order of questions is purposefully reversed from the more typical order, which would put generation of funds first, followed by governance, then delivery. The authors hope to provide a new perspective by re-ordering the sequence of questions.

Findings/Recommendations
The report gives six overarching recommendations with regard to adaptation financing:

1. An agreement on adaptation finance is crucial to the success of the Copenhagen negotiations.
2. Uncertainty about the investment and financial flows needed for adaptation should not be used as an excuse for not acting decisively.
3. Decisions about the implementation of adaptation activities are the responsibility of individual Parties, based on their national circumstances.
4. The allocation of adaptation finance to developing countries must be guided by an assessment based on agreed, objective, and measurable criteria.
5. A substantial degree of consolidation of international adaptation funding streams is required to ensure an efficient, fair, and flexible disbursement process.
6. A multiplicity of sources will be necessary to provide adequate levels of funding to meet current and future adaptation needs in developing countries.

Climate Change and Coastal Issues

2009

Davidson, Margaret A., director. 2009. *Coastal Services* 12 (6).

Objective
Provide examples of what states and localities are doing to address impacts of climate change

Method
Bimonthly trade journal for coastal managers

Findings/Recommendations
The publication includes a short article on smart growth of coastal and waterfront areas that can increase a community's resilience to weather and climate hazards. Next is an article about Delaware's use of new technology known as Lidar, which can be used to create high-resolution topographic maps. These maps are then used in natural hazard planning to create inundation maps, provide data for flood and storm surge modeling, and create an early flood-warning system. The article about North Carolina looks at how hurricanes in the '90s, especially Hurricane Floyd, have strengthened the state's resilience toward natural disasters and provides a detailed description of the North Carolina's hurricane manual that includes emergency construction permits, response coordination, mapping programs, buyout programs, and fisherman relief. The publication also includes an article about a design competition in San Francisco that addresses the rising sea level in the San Francisco Bay.

2008

Dean, Cornelia. 2008. Government Reports Warn Planners on Sea-Rise Threat to U.S. Coasts. *New York Times*, March 12.

Objective
Describe reports released by the U.S. government about the potential impacts of coastal flooding

Method
Newspaper article describing recent reports by the U.S. government

Findings/Recommendations
The article describes reports recently released by the National Research Council, as well as two studies from a multiagency effort led by the Environmental Protection Agency, that all indicate rising sea levels and coastal flooding from climate change are major threats to infrastructure and natural features. The reports are intended to encourage policy makers and transportation planners to start addressing this issue now. Vulnerabilities in certain regions of the country, such as the east coast and gulf coast, are profiled in the reports, with an emphasis on transportation issues.

2009

Fahey, Kitty, ed. 2009. *Coastal Connections* 7 (5).

Objective
Provide tools for coastal resource managers

Method
Bi-monthly publication

Findings/Recommendations
The publication notes that print articles addressing climate change adaptation have sharply increased in the previous couple of years and quotes an expert who says that adaptation planning, not just mitigation, is necessary to address impacts from climate change. The rest of the publication focuses on what coastal professionals can do to begin adaptation planning. The NOAA Coastal Services Center's Coastal Climate Adaptation website is described in detail as a resource for coastal professionals. Additionally, the publication, *Local Strategies for Addressing Climate Change*, is mentioned as a resource for descriptions of tools, programs, and projects already being implemented to address climate change issues.

2008

Jacob, John S., Stephanie Showalter. 2008. “The Resilient Coast: Policy Frameworks for Adapting the Wetlands to Climate Change and Growth in Coastal Areas of the Gulf of Mexico.” Texas Coastal Watershed Program.
http://www.rpts.tamu.edu/urban-nature/publications/documents/ResilentCoastWetlands-sm.pdf

Objective
Promote the use of inundatable lands for the creation of wetlands lost to sea level rising

Method
Analysis of current policy regarding wetland protection

Findings/Recommendations
The authors look at current state and federal legislation regarding protecting wetland areas, noting that these laws do not protect dry land that could be used for the creation of future wetlands to replace those lost due to rising sea levels. The authors state that, “[i]nsuring the availability of inundatable land is the single most important thing that can be done to insure the presence of salt marsh wetlands as sea level rises,” and they propose actions that can be taken by state and local governments to accomplish this, including the idea of rolling easements. They look to the Texas Open Beaches Act as an example of how rolling easements might work.

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