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Bush School Capstone Course Support: The Regional Impact of Climate Change on Transportation Infrastructure and Decision Making

Eric Lindquist

Research Report SWUTC/09/476660-00010-1
Project Title: Bush School Capstone Course Support:
The Regional Impact of Climate Change on Transportation Infrastructure and Decision Making

Performed in cooperation with the
Southwest Region University Transportation Center

Institute for Science, Technology and Public Policy
Bush School of Government and Public Service
Texas A&M University
College Station, TX 77843-4350

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Executive Summary

The Master of Public Service and Administration program at Texas A&M's Bush School of Government and Public Service requires that all second year graduate students participate in a two semester Capstone course. These courses represent the practical culmination of the degree program and are based on a real world research experience. For the 2008-09 school year, one of these Capstone efforts focused on the significant impact climate change will have on infrastructure and decision making in the Houston-Galveston area. Attention has recently shifted from the impact of transportation on climate to a focus on adaptation to potential climate stressors of sea level rise, increased frequency and magnitude of storms and severe weather events, and changes in precipitation and temperature. The Houston-Galveston Area Council (H-GAC) recognized this situation and agreed to support a Capstone class and project focusing on these issues. The Capstone report is included in this SWUTC report as Appendix A.

The starting point for this project was the suggestions for future research found in two recent reports on the nexus between transportation and climate change: the TRB Special Report 290, "The Potential Impacts of Climate Change on U.S. Transportation" (Transportation Research Board 2008), and the US Climate Change Science Program study, "The Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I" (Savonis, et al, 2008). Adaptive measures that have been suggested in these reports as needing further study include operational responses design strategies, including design and building infrastructure to more robust standards, new infrastructure investments, and new thinking on transportation planning and land use controls. In addition, just prior to the start of the course, the H-GAC published a report from its Foresight Panel on Environmental Effects (Houston-Galveston Area Council 2008). This report also focused on the potential impacts of climate change on the H-GAC region. The Capstone class reviewed the Foresight Panel report and, with the support and input from the H-GAC, decided to include the report findings and suggestions in its research. The students conducted content and review analysis of existing studies and designed and implemented an interview protocol which was targeted at H-GAC constituent agencies and staff. The final report for the H-GAC is included here as Appendix A. The results of the research were presented to the H-GAC on May 11, 2009. The final project report was submitted to the client on September 3, 2009. The report is available on the Bush School website: http://bush.tamu.edu/research/capstones/

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Disclaimer

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Acknowledgment

The authors recognize that support for this research was provided by a grant from the U.S. Department of Transportation, University Transportation Centers Program to the Southwest Region University Transportation Center.

Bush School Capstone Course Support: The Regional Impact of Climate Change on Transportation Infrastructure and Decision Making

The Master of Public Service and Administration program at Texas A&M's Bush School of Government and Public Service requires that all second year graduate students participate in a two semester Capstone course. These courses represent the practical culmination of the degree program and are based on a real world research experience. For the 2008-09 school year, one of these Capstone efforts focused on the significant impact climate change will have on infrastructure and decision making in the Houston-Galveston area. Attention has recently shifted from the impact of transportation on climate to a focus on adaptation to potential climate stressors of sea level rise, increased frequency and magnitude of storms and severe weather events, and changes in precipitation and temperature. The Houston-Galveston Area Council (H-GAC) recognized this situation and agreed to support a Capstone class and project focusing on these issues.

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This Capstone course had eight Master of Public Service and Administration students enrolled (second year students). Capstone course research projects are traditionally student designed and implemented in conjunction with the client agency, all under the direction of an MPSA faculty member or adjunct. These courses are rigorous in scope and involve significant interaction with the client, for the negotiation of the research question, deliverables, and time line, and with relevant stakeholders in the study area. Faculty direction for this Capstone was provided by Dr. Eric Lindquist, the Associate Director of the Institute for Science, Technology and Public Policy in the Bush School of Government and Public Service at Texas A&M University. Dr. Lindquist previously taught two sections of the Bush School Capstone course and has been active in climate change and transportation research for the past several years.

References

Houston-Galveston Area Council. 2008. Foresight Panel on Environmental Effects Report. Houston, TX: H-GAC.

Savonis, Michael J., Virginia R. Burkett, Joanne R. Potter. 2008. Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I Synthesis and Assessment Product 4.7 Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. (sr290)). Washington, D.C.: U.S. Department of Transportation.

Transportation Research Board. 2008. Potential impacts of climate change on U.S. transportation. Washington, D.C.: TRB.

Appendix A

Adaptation to Climate Change in the Houston-Galveston Area: Perceptions and Prospects: A Report to the Houston-Galveston Area Council

Adaptation to Climate Change in the Houston-Galveston Area: Perceptions and Prospects

A Report to the Houston-Galveston Area Council

The Bush School of Government and Public Service
Master of Public Service and Administration
CAPSTONE Project 675-605
May 2009

The Bush School of Government and Public Service
Master of Public Service and Administration
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Adaptation to Climate Change in the Houston-Galveston Area: Perceptions and Prospects

A Report to the Houston-Galveston Area Council

Presented to the
Houston-Galveston Area Council
May 11, 2009

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ABSTRACT

Communities around the world are discovering that the impacts of climate change may be more significant than previously thought. Therefore, communities need to look at their public infrastructure's resiliency to climate change impacts. Areas that have the ability to plan and adapt to changes in the environment could save money, lives, and area resources. There are many questions associated with climate change, adaptation, and resiliency, however, which need to be explored at the regional scale. In response to this situation, the Houston-Galveston Area Council (H-GAC) created a panel that examined the impacts of climate change in the Houston-Galveston region. In 2008, this H-GAC "Foresight Panel on Environmental Effects Report" outlined the effects of climate change and made adaptation recommendations for regional constituents. This Capstone project and report were initiated between the Bush School of Government and Public Service, Texas A&M University, in order to explore in more detail some of the issues and questions raised during the Foresight Panel process. The objectives of this Capstone project were to further consider the impacts of climate change in the area and the utility of adaptation as an alternative solution, and to examine the responsiveness of the constituents to the Foresight Panel Report.

CHAPTER 1 - INTRODUCTION

Communities around the world are discovering that the impacts of climate change may be more significant than previously thought. Therefore, communities need to look at their public infrastructure's resiliency to climate change impacts. Areas that have the ability to plan and adapt to changes in the environment could save money, lives, and area resources. However, there are many questions associated with climate change, adaptation, and resiliency, which need to be explored at the regional scale.

In response to this situation, the Houston-Galveston Area Council (H-GAC) created a panel that examined the impacts of climate change in the Houston-Galveston region. In 2008, this H-GAC "Foresight Panel on Environmental Effects Report" outlined the effects of climate change and made adaptation recommendations for regional constituents. The objectives of this Capstone project were to further consider the impacts of climate change in the area and the utility of adaptation as an alternative solution, and to examine the responsiveness of the constituents to the Foresight Panel Report.

This report will first provide a general description of the Houston-Galveston Area Council and a brief overview of the Houston-Galveston region. Then it will provide an overview of climate change, followed by specific hazards for the H-GAC region. Next, it will discuss the impacts of climate change on public infrastructure, list local government responsibilities, and provide basic guidelines for a risk assessment approach to planning for adaptation to climate change. It will also discuss federal funding trends and opportunities. This report also includes a description of the design and implementation of a stakeholder survey and a discussion of the survey findings. Finally, the report presents policy recommendations based on the project research.

General Description

The Houston-Galveston Area Council (H-GAC) is a Regional Planning Commission, a voluntary association of local governments in a 13-county area in southeast Texas (About H-GAC 2008). These counties cover over 12,500 square miles and are home to over 5.7 million people. The 13 counties are: Austin, Brazoria, Chambers, Colorado, Fort Bend, Galveston, Harris, Liberty, Matagorda, Montgomery, Walker, Waller, and Wharton.

Regional Planning Commissions were established by the Texas Legislature for the purpose of "…mak[ing] studies and plans to guide the unified, far-reaching development of a region, eliminate duplication, and promote economy and efficiency in the coordinated development of a region" (Texas Local Government Code, Sec. 391.001, 2007). H-GAC serves as a forum for local governments to cooperate in solving area-wide problems and also has planning programs in areas such as economic development, community enhancement, disaster response, environmental protection, and many other areas of region-wide concern.

Additionally, H-GAC serves as the metropolitan planning organization (MPO) for an eight-county region: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller. Federal law requires that MPOs be established in any urban area with a population of at least 50,000 in order to provide for the development of an integrated transportation system (Metropolitan Planning Organizations 2005). In its capacity as an MPO, H-GAC is responsible for the area's Regional Transportation Plan, a comprehensive, long-range plan which identifies transportation projects needed to keep up with population growth between now and 2035 (About H-GAC 2008). H-GAC is also responsible for the Transportation Improvement Program, a four year plan identifying regional transportation priorities.

As part of its regional planning responsibilities, and in response to recent reports by the U.S. Department of Transportation, the Intergovernmental Panel on Climate Change (IPCC), and others, H-GAC has begun to consider strategies which local governments can use to adapt to the effects of climate change.

H-GAC recently established the Foresight Panel on Environmental Effects, composed of experts on climate change and infrastructure planning; in 2008 this panel produced a report which made a variety of recommendations to local governments regarding climate change adaptation strategies.

The Houston-Galveston Area Council's Region

The H-GAC's 13 counties span an area along the northwest coast of the Gulf of Mexico approximately 146 miles long and stretching inland 150 miles. The region spans the Western Gulf Coastal Plain, South Central Plains, East Central Plains, and Blackland Prairie ecoregions. Elevation ranges from sea level to 1000 feet above sea level. Precipitation in the area averages as little as 16 inches in the Northwestern regions to 45 inches in the Southeastern portions. Terrain ranges from flat wetlands to rolling hills to well drained prairies. Agricultural activities in the H-GAC area include forestry, cropland, and cattle. Figure 1 shows the borders of the H-GAC region.

Public Infrastructure

Public infrastructure consists of the assets controlled by the local government that are necessary for the area's homes and businesses to function. These taxpayer-funded structures, roadways are all vulnerable to climate change impacts. In order to prevent catastrophic damage from climate change impacts, decision makers must assess the common public infrastructure features across all jurisdictions.

Transportation

Interstates are highways specifically designated as part of the Eisenhower National System of Interstate and Defense Highways (U.S. Climate Change Science Program & Subcommittee on Global Change Research [CCSP], 2008). Arterials connect major cities, recreational areas, and other travel destinations. Collectors connect local roads and smaller cities to arterials, and local roads are low-volume and provide access to homes and other private property. The Houston metropolitan area contains 137 miles of interstates, 2,414 miles of arterials and other freeways, 1,409 miles of collectors, and 11,597 miles of local roads. A total of 104,390 vehicle-miles are traveled over these roads each day (U.S. Department of Transportation 2009).

The H-GAC region also includes nearly 6,600 bridges. The following chart details the number of bridges in each of H-GAC's counties (Table 1) (Bridge Division, Texas Department of Transportation, 2007). On-system bridges are administered by TxDOT and are generally funded by federal and state funds. Off-system bridges are the responsibility of local governments.

Rail

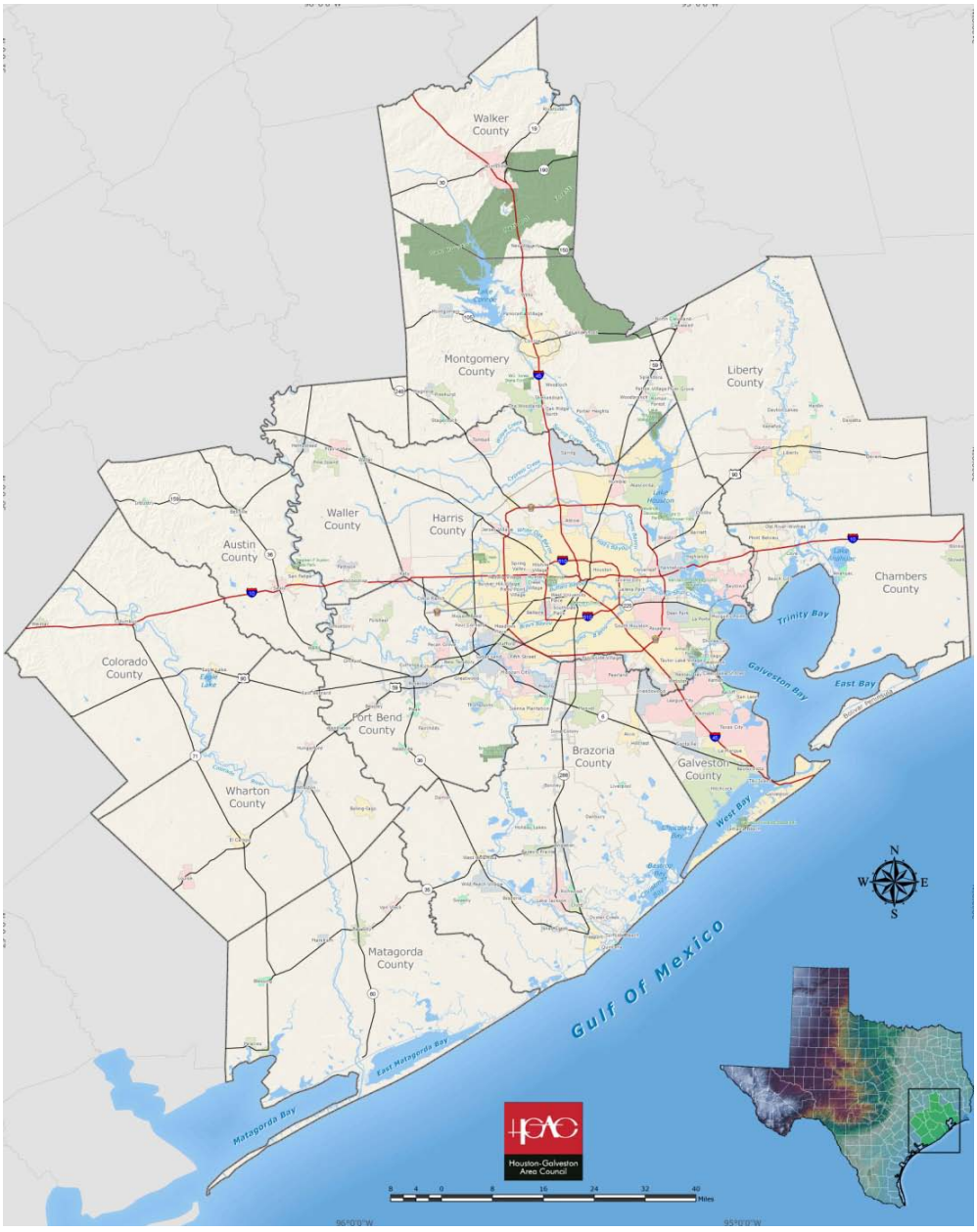
Within the eight county region for which H-GAC serves as an MPO, approximately 800 miles of mainline track support 2,200 trains per week (Texas Department of Transportation, 2007). These railways include 21 miles of bridges and 1,200 grade crossings. Of those 2,200 trains, all but 5% pass through Houston. According to TxDOT, the region's freight volume is expected to double by 2025 (Texas Department of Transportation, n.d.).

Water Management and Solid Waste

Storm water management and drainage is especially relevant to the issue of climate change because of its role in flood prevention. Storm water management is the responsibility of organizations such as Houston's Storm Water Management Program, the Harris County Flood Control District, and Galveston County Consolidated Drainage District. Wastewater treatment plants remove contaminants from water, allowing the water to be reused. The City of Houston operates 40 wastewater treatment plants, in which 277 million gallons of water are treated per day (City of Houston, 2009). The H-GAC region produces more than 8 million tons of waste each year (A. Boyers, personal communication, October 12, 2009). In

2007 the region had roughly 162 million tons of solid waste capacity; many of these sites are located within potential flood zones (TCEQ, Waste Permits Division, 2008).

Figure 1. Map showing H-GAC area with county boundaries and major roads



Source: H-GAC

Table 1. H-GAC Region Bridges

County	Number of Bridges (On-System)	Structurally Deficient	Functionally Obsolete	Number of Bridges (Off-System)	Structurally Deficient	Functionally Obsolete	Total
Austin	104	0	15	97	18	9	201
Brazoria	273	1	20	73	43	270	346
Chambers	112	4	20	18	1	1	130
Colorado	151	1	20	95	9	8	246
Fort Bend	230	3	21	307	12	75	537
Galveston	187	1	31	96	6	11	283
Harris	1591	3	385	1769	23	792	3360
Liberty	136	3	9	40	5	8	176
Matagorda	87	0	12	99	3	3	186
Montgomery	255	0	14	178	18	30	433
Walker	114	3	9	27	4	0	141
Waller	124	0	11	64	9	2	188
Wharton	175	2	13	194	17	10	369
						Total:	**6596**

Population and Economic Setting

Factors affecting a region's vulnerability to climate change effects are not limited to geographic features. Socioeconomic conditions, demographics, and other factors which influence a region's capacity to respond to climate change can be "equally if not more important than biophysical hazards in dictating the potential for harm" (Preston et al., 2008, 3).

Preston et al. found that social indicators commonly used in assessing climate change vulnerability generally center around an affected population's access to resources, equity, level of health, and political influence (2008, 17). Specific indicators include income, income inequality, poverty, race/ethnicity, age, and population projections. Appendix B provides indicators of the H-GAC region's social vulnerability.

Appendix C provides a List of Acronyms that are used in the report; Appendix D provides a list of Definitions used in the report.

CHAPTER 2 - CLIMATE CHANGE IMPACTS AND THE H-GAC

Climate change refers to any significant change in measures of climate (such as temperature, precipitation or wind) lasting for an extended period (decades or longer) (EPA, 2007). While there has been much debate in the past 20 years over the causes of climate change, scientific organizations have documented statistically significant changes that have occurred due to climate change. The National Oceanic and Atmospheric Administration's (NOAA) State of the Climate Report and the National Aeronautics and Space Administration's (NASA) Surface Temperature Analysis indicate that the average atmospheric temperature has increased by about 1.2 – 1.4ºF (equivalent to 0.77 degrees Celsius) since 1900 (NOAA website, 2008). In 2007, the IPCC released a Fourth Assessment Report, which explains observed changes in the Earth's climate and expected impacts on natural and built systems of continued warming. Figure 2 provides a summary of the impacts of increasing temperatures. As we can see, the damaging impacts of climate change are only in their beginning stages.

We recognize that this is an intense political issue for many individuals, groups, and communities. The debate surrounding climate change should not affect the research of this capstone. It was not the purpose of this study to determine the cause of climate change, but to look at the evidence provided by scientific organizations and determine how the effects of climate change should alter the decision making process among officials with authority over public infrastructure. The documented changes in climate are the starting points for the impacts on public infrastructure. However, because climate change impacts are estimated predictions, researchers and decision makers must be cautious with results that predict with high levels of certainty. Therefore, our research synthesizes a large literature review focusing on the trends in climate change impacts to predict their impact on public infrastructure.

Climate Change for the H-GAC Region

This section discusses the historic climate trends for the region and then focuses on specific hazards due to climate change in the H-GAC region. It is important, when making planning and policy decisions, to have an understanding of the impacts of climate change on the specific region and planning topic. Additional information can be found in the Texas Climate Initiative and in the Foresight Panel on Environmental Effects Report released in 2008; both provide planners with an excellent starting point and include links to much more detailed data.

Overview of Texas Climate

The Texas coastal region is a warm, wet, low lying region that experiences the impacts of a warm ocean every summer during hurricane season. Subsidence, which is the sinking down of ground usually from compaction or removal of subsurface minerals or groundwater, exacerbates the low mean elevation that is already vulnerable to flooding during tropical storms and heavy rain events. Therefore, as sea levels rise, these vulnerabilities will be magnified. Furthermore, the predicted hotter summer temperatures will stress many aspects of the built environment, requiring more maintenance to sustain a safe working and living situation (Kafalenos et al., 2008).

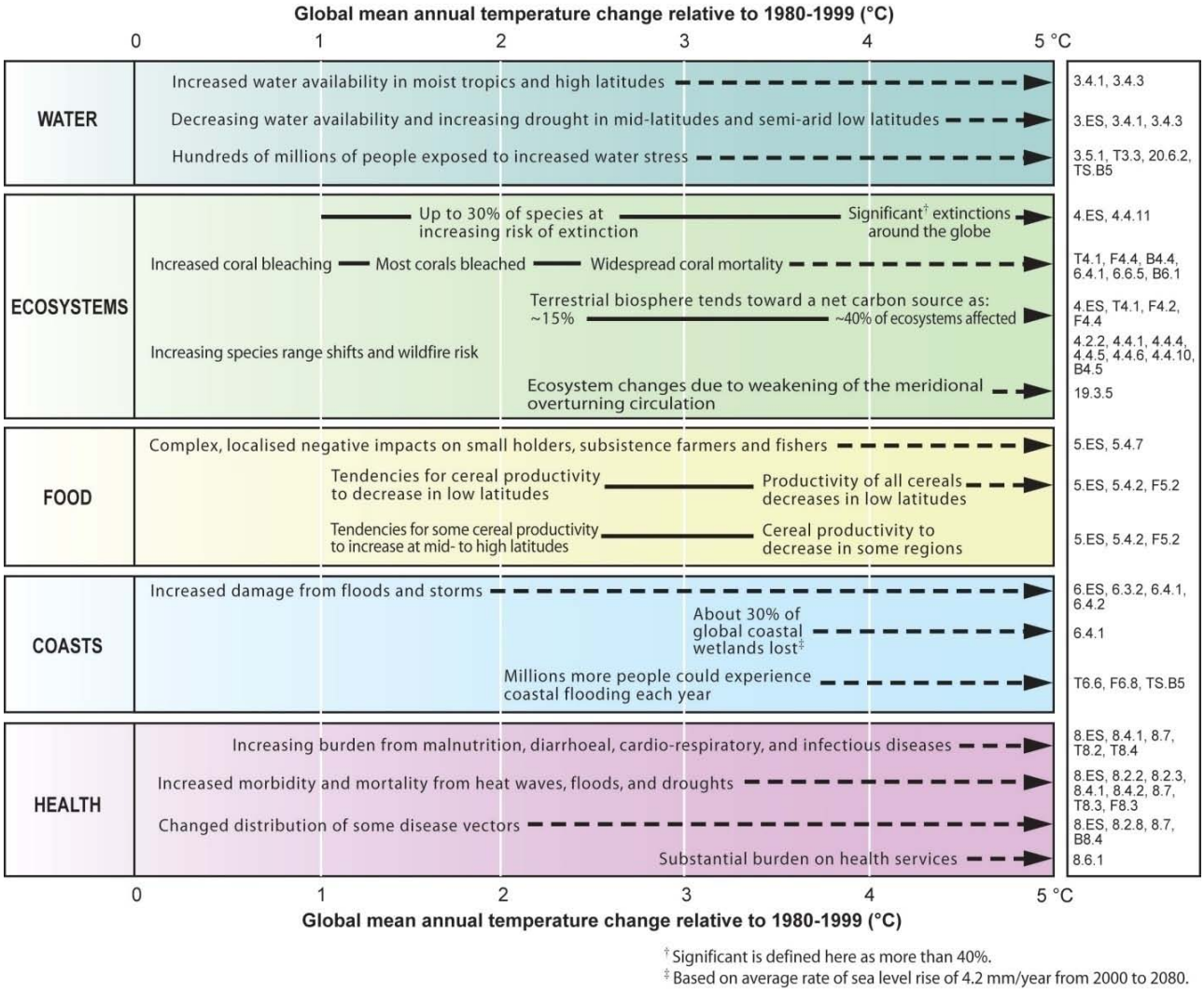
It is important to remember that the scientific data supporting climate change is being enhanced and refined continuously; however, the data associated with specific regions is less certain than the data available at the global scale. The information in this section is the latest information available for the state of Texas.

Temperature

Historic temperature records in Texas show that warming and cooling periods have occurred. The overall trend for the state shows that temperatures are rising; the H-GAC region has experienced a warming trend observed from 1901 to 2000 of 0.4 – 0.9°F (Nielsen-Gammon, 2008). Models have been run for the

entire state to attempt to predict temperatures in the future at 20 year intervals. These models show that without drastic human intervention and no natural phenomena to decrease temperatures, the state could expect a 0.56°C rise by 2010, 1.12°C by 2030, and 1.94°C increase by 2050 – only 40 years from now (Nielsen-Gammon, 2008). The devastating impacts of these temperature changes can be seen in Figure 2 and include 30% of species at an increased risk of extinction, decreasing human health conditions, and more damaging storm systems.

Figure 2. Summary of climate change impacts at incremental temperatures increases



Source: IPCC AR4

Precipitation

Predicted global changes in precipitation cannot easily be summed up. Dr. Gerald North, a Texas A&M University climatologist, explains that over the next century, global rainfall patterns will move toward the poles, increasing the rainfall toward those areas (2008). However, different regions of the globe will be impacted differently. During the last century, in the H-GAC region there was an increase in precipitation; however, climatologists are uncertain what caused this trend or if the trend will continue or reverse (Nielsen-Gammon, 2008). Climatologists suggest that while overall precipitation for the state will decrease, certain areas of Texas will see increased rainfall (Nielsen-Gammon, 2008). North suggests that

west Texas will become more arid and that east Texas will experience more precipitation, effectively bisecting the state at the I-35 corridor (Texas Parks and Wildlife Department, 2008).

As previously mentioned it is very difficult to say with certainty the expected changes for the H-GAC region. Climatologists predict that historic rain patterns will change and droughts will last longer. When rainfall does occur it will potentially be heavier, leading to more frequent flooding.

Drought

Droughts are expected to increase throughout Texas as a result of increased air temperatures (Nielsen-Gammon, 2008). Even in areas of normal or high levels of rainfall, evaporation will be more rapid, offsetting any gains from precipitation. Furthermore, changing weather patterns are predicted to include longer periods between rain events, also contributing to the likelihood of drought (Nielsen-Gammon, 2008). This combination will lead to normal dry periods similar to that of the 1950's drought, which is used by the Texas Water Development Board as the drought of record to plan state water consumption needs (North, 2008).

Hurricanes

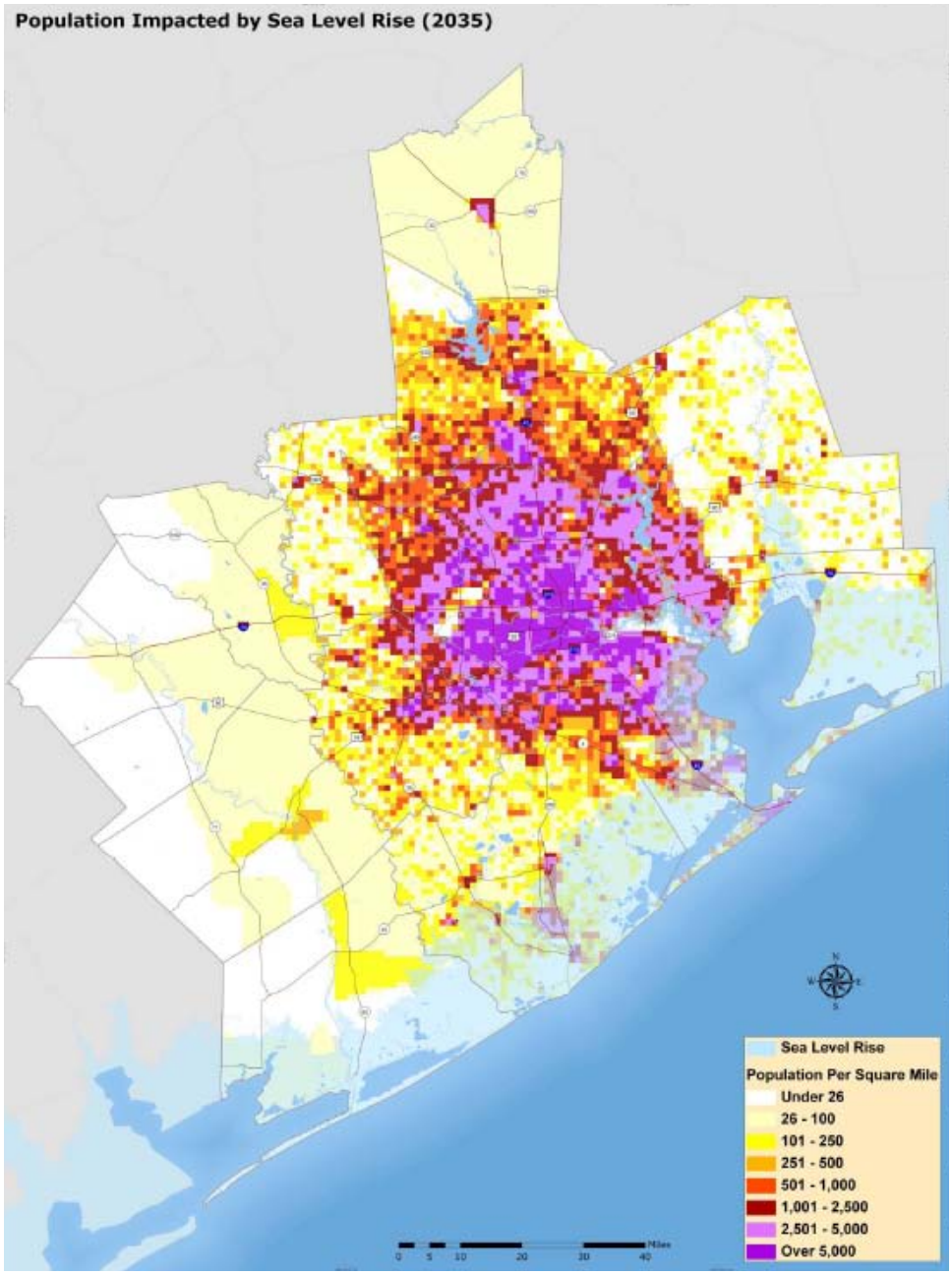
As with precipitation, scientist point out that it is difficult to predict with high certainty the trends of extreme weather events, such as hurricanes. Throughout its history Texas has been hit by several hurricanes. Additionally, "major hurricanes pass within 75 miles of any given coastal location about once every 25-46 years" (Nielsen-Gammon, 2008, 14). A major hurricane is defined as a category 3 or higher and having wind speeds of at least 111mph (NOAA, National Hurricane Center, 2009). Even though major hurricanes are infrequent, severe damage can be caused by a weaker, slower moving storm, such as Tropical Storm Allison, and as witnessed last year by Hurricane Ike. It is important to understand that several factors are involved in tropical storm formation and development. One of those factors is warm ocean water, and as sea temperatures increase it is likely that hurricane intensity will also increase (Montagna, Brenner, Gibeaut, & Morehead, 2008).

Sea Level

Sea levels are projected to rise worldwide from the melting of large glaciers and the thermal expansion of ocean waters (IPCC, 2007). Within the next 50 to 100 years the Texas coast is expected to experience a rise of 0.6 to 1.9 feet, and when accounting for subsidence, changes could be as much as 3 feet in some areas (Figure 3) (CCSP, 2008; Montagna et al., 2008). This change in sea level, coupled with increased rain and drought, is predicted to have significant erosion impacts on Texas barrier islands (Montagna et al., 2008). This significantly limits the habitats for species living between the land and the sea (Science Daily, 2005).

These physical and societal characteristics greatly affect the different counties' varying levels of vulnerability to climate change, and they have perhaps also contributed to citizens' perspectives on climate change in differing ways in each county. According to the Houston Area Survey, which is conducted by Rice University and measures the opinions of residents in nine of H-GAC's counties, 63.0% of the public believes as of 2008 that the United States is spending too little money improving and protecting the environment, compared to 4.1% which believes the country is spending too much ("Houston Area Survey" 2008). Additionally, 51.3% believes that global warming is a "very serious" threat, along with 28.6% which believes that it is a "somewhat serious" threat.

Figure 3: Impacts of sea level rise on H-GAC region



Source: H-GAC Foresight Panel on Environmental Effects Report

Climate Change's Overall Impact on Public Infrastructure

Several reports have been developed by both academics and public officials studying the impact of climate change on public infrastructure. The following section summarizes some of the reports that outline public infrastructure vulnerabilities to climate change impacts, as well as some of their general findings that might also be applicable in the H-GAC area.

Climate Impacts Group

The Climate Impacts Group in Washington State has released a report, with one chapter alone focusing on storm water control. The report discusses in detail the method used to study historical average precipitation in three large coastal cities in the Pacific Northwest. Then the researchers try to extrapolate the observed data into expectations for future precipitation in order to make recommendations for improvements to storm water systems. The conclusions of the report show that in some study areas, precipitation appears to be increasing; while in other areas, future precipitation levels remain uncertain. However, findings regarding storm water infrastructure "suggest that concern over present design standards is warranted and that some adaptation to changing conditions is already probably prudent." (Rosenberg et al., 2009)

Sydney Coastal Council Group

The Sydney Coastal Council Group (SCCG) in Australia also conducted research looking at climate change scenarios and potential impacts on various natural and built systems. They used the data available in several IPCC reports to assess potential impacts on public infrastructure in their 15-council study region. Of those, all 15 will experience the impacts of climate change to some degree. Based on the data, the SCCG determined that projected sea level rise will have consequences for the low lying regions (Preston et al., 2008). Furthermore, the SCCG states that when combined with storms, "extreme rain events, run-off, and flooding are likely to increase the need for storm water management and flood protection" (Preston et al., 2008). Additionally, areas with greater urbanization will experience a greater impact from rising temperatures than more rural areas because of the heat-sink effect (Preston et al., 2009).

International Institute for Environment and Development

Another study was conducted looking at sub-Saharan Africa's urban water resources. The author uses data from the IPCC to draw his conclusions and recognizes that uncertainty in predicting future weather patterns is of concern; however, water managers must consider the possibility of longer drought periods and more powerful, intense storm events when developing water needs plans (Muller, 2007). The report explains that costs of wastewater treatment will increase when water levels are low, and that costs of road maintenance associated with storm water run-off and flooding will increase; both scenarios should be estimated in planning budgets (Muller, 2007). The report also indicated that flood risks are increased for low lying areas along the coast and should be taken into consideration when developing future land use and infrastructure plans (Muller, 2007).

Transportation Research Board

In 2008, the Transportation Research Board, a non-profit focused on research and education about the U.S. transportation system, released a Special Report (SR290) describing the impacts of climate change on the United States transportation system. The report looked at all predictions of climate change and how each scenario would impact transportation. SR290 clearly states that "all modes of transportation will be impacted" by climate change. A complete table describing potential impacts for the Gulf Coast is included in Appendix A. Impacts relevant to the H-GAC area are listed here briefly:

- Hot days could cause thermal expansion on bridge joints and paved surfaces and pavement integrity could be compromised leading to traffic-related rutting, and liquid asphalt migration.
- Roads, rail lines, and airport runways in low lying areas will be inundated by the combined effects of sea level rise and storm surge.
- Increased flood events will intensify erosion of the road base and bridge supports, and will reduce clearance under bridges. Pipelines could experience scouring and damage from flooding.

- Extreme rain events will increase flooding of roadways, rail lines, and runways and lead to road washout, damage to rail-bed support structures, and land/mud slides.
- Port facilities will experience higher tides and storm surges.
- Hurricanes may become more frequent and grow in intensity, leading to a greater probability of infrastructure failures.

US Department of Transportation – Gulf Coast Study

Another report released in 2008 focused on the Gulf Coast specifically. Similar to SR290, this report was commissioned to study the expected impacts of climate change on transportation and related infrastructure in the Gulf Coast region. The Gulf Coast study explains that the overall increase in average temperature of ≅ 2.7°F will have some effect, but the increase in the number of days each year above 90°F will have a larger impact on transportation infrastructure (Kafalenos et al., 2008). The report states that maintenance on roads, rail, vehicles, facility buildings, and structures will increase as the number of hot days increases.

Additionally, the report takes into consideration the impact of higher temperatures on human workers and passengers of public transportation, stating that energy demands will be increased to account for cooling needs (Kafalenos et al., 2008). Extreme rain events are expected to increase as a result of climate change, and runoff from individual events could be sufficient to require bridges to be raised and culvert sizes to be increased (Kafalenos et al., 2008). Sea level rise has the potential to interrupt truck and rail shipping throughout the Gulf Coast region, especially when ports are considered. A two foot rise in sea level would affect 137 miles of I-10 between Houston and New Orleans (Kafalenos et al., 2008). Hurricane intensity and frequency may increase with climate change, and as witnessed by recent hurricanes Katrina, Rita, and Ike, transportation infrastructure will likely be severely damaged by storm surges, wind, heavy precipitation, and erosion (Kafalenos et al., 2008).

Economic Impacts of Climate Change

There is a lot of uncertainty surrounding the potential economic impacts of climate change. Some economists argue that small increases in temperature (2° - 4°F), accompanied by increased rain will have the aggregate impact of increasing economic output (Mendelsohn, 2003). This is because the agriculture and forestry industries will benefit from longer growing seasons and more rainfall. Under scenarios with slightly warmer temperatures and less precipitation however, the net aggregate impact will be a negative one, with agriculture and forestry still receiving some positive benefits but not enough to offset the costs needed to sustain coastal systems and public infrastructure. Finally, in scenarios with a large temperature change (>7.5°F), and regardless of increases or decreases in precipitation, the net aggregate impact across all industries and services is negative (Mendelsohn, 2003). Following are some areas of infrastructure that will need monetary investments to respond to the impacts of climate change.

Energy

Energy demand is expected to increase in the future as a result of climate change. Buildings will increase their energy demands an estimated 20% during peak hours throughout the traditionally hotter months (Hazleton, 2008). Increased demand will require new energy infrastructure to meet growing needs. Hazleton estimates the cost of new “climate change” infrastructure constructed between today and 2050 to be between $21 to $45 billion dollars (2008). These increased costs are for statewide projected energy needs and are based on current energy supply ratios. New technologies or increased energy efficiencies in homes and buildings are not taken into consideration in these reports; both could decrease the amount of needed energy in the future, thus decreasing estimated costs (Hazleton, 2008).

Increased demand is not the only vulnerability in the H-GAC electricity grid; storms have costly impacts on energy systems as well. From 1994 to 2004, the average cost of storm damage to electric utilities in

the United States was roughly $49 million hurricane/tropical storm, with the most expensive storm damage totaling $890 million (Hazleton, 2008). Hurricane Ike's estimated damage to public utilities was estimated by CenterPoint Energy to be between $350 million and $500 million.

Storm Water Management

The H-GAC area is well-versed in diverting storm water runoff into ditches and channels to mitigate flooding. However, according to the Houston Storm Water Management Program (SWMP) flooding is a problem for the region as a result of its topography. The area floods easily, because it is at low elevation with a flat terrain; large rainfall events first fill the built drainage system and then inundate the road system as a secondary drain route (SWMP, n.d.). Climate change will likely increase the intensity of precipitation in the H-GAC region, necessitating a reassessment of the drainage system to prevent frequent flooding. Furthermore, as the cities grow and develop, more natural land area is covered with pavement, increasing the likelihood of flooding due to the loss of absorptive land areas (Preston et al., 2008). Costs associated with flooding in southeast Texas in 1998 totaled $1 billion dollars for each event of between 10-20 inches of rainfall (NOAA, National Climatic Data Center, 2009). In 2001, Tropical Storm Allison dumped 36 inches of rainfall, flooding the Houston Metropolitan area at a cost of $4.8 billion dollars (NOAA, NCDC, 2009).

Transportation Infrastructure

The 2005 hurricane season imposed public and private costs of more than $100 billion across the Gulf Coast (Kafalenos et al., 2008). The cost of rebuilding roads, bridges, and utilities, as estimated by the Louisiana Recovery Authority was over $15 billion (Kafalenos, 2008). Louisiana is currently working on elevating a section of Highway 1 and a bridge that crosses Bayou LaFourche; the bridge project alone is estimated to cost $161 million (Kafalenos et al., 2008). As more people move to the coast, a transportation infrastructure that is able to withstand the impacts of higher temperatures, extreme precipitation, and increased storm events must be developed. As the amount of damage from these storms have shown, storm damage to infrastructure will be very expensive and will require improvements to the detailed planning that incorporates potential impacts from larger storm surges, extreme rain events, and hotter temperatures.

Predicted Impacts on Public Infrastructure in the H-GAC Region

Climate change is expected to impact both cities and rural areas in various ways, and in order to address specific predicted impacts, it is important to think in terms of vulnerability (Hitchcock, 2008). Flooding due to climate change may be the most critical long-term problem for the H-GAC area, partially due to the problem of larger and more frequent extreme weather conditions (i.e. hurricanes). As sea levels rise and storm activity increases, coastal areas will flood more frequently. Because of differences in individual characteristics, including proximity to the coast, elevation, and drainage capabilities, different locations within the H-GAC region experience varying levels of risk for flooding. Additionally, many important public facilities are located within potential flood zones, increasing the public's risk. Public facilities that are farther inland are not immune to rising water levels, as we saw in the case of Tropical Storm Allison. Larger and more intense storms are rapidly increasing in frequency and are a primary concern for many of the residents and users of public infrastructure in the H-GAC area.

The impacts on public infrastructure are critically important, and were developed by the Foresight Report, the IPCC, and the Gulf Coast study (CCSP, 2008). For a more detailed description of the various types of public infrastructure, as well as the specific risks associated with each type, refer to the Foresight Panel on Environmental Effects Report. This entire report is available at their website: http://www.h-gac.com/go/environmentaleffects.

CHAPTER 3 - FUNDING AND RISK ASSESSMENT ISSUES FOR ADAPTATION

This chapter focuses on two critical issues related to climate change adaptation: funding and risk assessment. Both of these issues can contribute to the development of possible approaches for initiating climate change adaptation solutions in the H-GAC area. First, we consider federal funding trends and mechanisms that may provide support for adaptation solutions or projects. Second, we include a brief discussion of risk assessment as a possible tool or perspective for integration into infrastructure and transportation planning and policy. In addition, we provide a list and examples of organizations and states that are actively engaged in the climate change and adaptation discussion and provide a brief introduction to their activities.

Federal Transportation Funding Trends – 1992-Present

Traditionally, funding has not been made available for specific resiliency measures in at-risk areas. Funding priorities have often evolved over the past two decades along the lines of political priorities. Significantly though, the last two funding reauthorizations have taken climate change into account. However, the goal has been to fund climate change mitigation rather than adaptation or resiliency. We believe that funding for adaptation can be pushed as a policy initiative, as many civic and local/regional government organizations and even the U.S. Department of Transportation have been engaging in a dialogue regarding resiliency. This section will describe the recent history of federal funding trends for transportation infrastructure. Additionally, it outlines several organizations' resiliency and adaptation efforts and lists some of the entities that should be encouraged to join the conversation. These lists are by no means exhaustive, but should be viewed as a significant portion of the funding opportunities available to H-GAC and similar organizations.

The federal government provides roughly 40% of Texas' transportation funding, with the remaining 60% of funds coming from state taxes, transportation user fees, and bond revenues. According to the Texas Legislative Budget Board's budget estimates for the 2010-2011 Biennium, the federal government would be providing $6.25 billion in transportation funding for the two year period (Legislative). This amount does not include any funding provided through economic stimulus bills. The structure of federal funding in Texas has changed significantly over the past twenty years, and each authorization round has focused on different priorities. Transportation infrastructure adaptation will in most cases be a very expensive undertaking. Additionally, when adaptation measures are seen as being driven by "climate change," the funding of resiliency projects may prove to be controversial in Texas due to the political debate surrounding climate change. As a result, we feel it is best to focus efforts at the federal level, as there is both the capacity and the political climate to designate funds for climate change adaptation. Below is a brief history of the structure of past transportation authorizations and the priorities that have received designated funding.

Intermodal Surface Transportation Efficiency Act (ISTEA) – 1992-1997

ISTEA, which authorized $155 billion, was passed in 1991 and reflected a change in thinking after the Interstate Highway System had been largely completed. ISTEA shifted the focus from a funding system that focused primarily on highway transportation to one that looked more comprehensively at intermodal transportation. It sought to link highway, rail, air, and marine transportation into a more efficient transportation system that would allow the United States to compete globally. ISTEA brought with it a number of new programs that shifted federal and state funding priorities.

ISTEA established the Interstate Maintenance (IM) program to provide maintenance funds for the Interstate Highway System. Funds for preventative maintenance were provided on a large scale, as upkeep rather than expansion of the highway system became the priority. ISTEA also established the Congestion Mitigation and Air Quality (CMAQ) program which had the goal of funding projects that are

aimed at reducing transportation-related emissions. This was the first time that federal transportation legislation seriously took environmental concerns into account. Funding was aimed towards public transportation and transit solutions, such as fixed guideway, bike lanes, and carpooling, as well as clean fuel alternatives.

ISTEA also created the Surface Transportation Program (STP) which gave states and municipalities increased flexibility in how they could spend federal highway dollars. STP dollars, although derived from the Highway Trust Fund (HTF), were able to be used for a wide range of projects including public transportation facilities, bridges on public roads, and transit capital projects. This flexibility gave more power to local governments to determine how federal dollars could best be spent locally. This also meant the opportunity for more stakeholder involvement, and it set the tone for public input from groups including environmentalists, historic preservation societies, and the general public.

Transportation Equity Act for the 21st Century (TEA-21) – 1998-2003

TEA-21, which authorized $218 billion, was passed in 1998 and was groundbreaking in its own right, as it mandated a guaranteed funding level for the authorization period, and it set a formula whereby states would receive a more equitable share of their contributions to the Highway Trust Fund. A so-called "firewall" was set which meant that Congress had to appropriate a guaranteed amount of $198 billion over the six years, tying it directly to the HTF. This floor for federal transportation funding meant that the bulk of transportation dollars no longer had to compete with other priorities in the General Fund. (Department of Transportation: TEA-21, 1998)

TEA-21 also contained a "minimum guarantee" provision, which meant that each state would receive at least 90.5% of its contributions to the Highway Trust Fund. While this did not apply to the federal Transit Account, it was good news for Texas. Historically, Texas had contributed far more to the HTF than it had received back. During the period that ISTEA was in place, Texas' average rate of return was $0.77 for every dollar it contributed to the Fund.

Beyond funding guarantees, TEA-21 also focused on other national priorities. TEA-21 emphasized safety through initiatives including drunk driving regulations, seat belt campaigns, and truck safety programs. And in the midst of the welfare reform movement, TEA-21 contributed with provisions meant to expand opportunity. The act sought to create opportunities by training workers, providing Job Access and Reverse Commute grants for low income individuals, and by establishing the Disadvantaged Business Enterprise Program, which set goals for minority participation in transportation projects. TEA-21 also continued to focus on the environment through the expansion of CMAQ programs, alternative fuels, and tax-free transit benefits to promote public transportation (Department of Transportation: TEA-21, 1998).

Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) – 2005–2009

Passed in 2005, and with guaranteed funding set at $244.1 billion, SAFETEA-LU is the largest investment in transportation in U.S. history. It focuses on a number of priorities, but climate change adaptation is not one of them. It does however gradually increase the rate of return that Texas receives from its contributions to the Highway Trust Fund. For 2008 and 2009, Texas is guaranteed to receive a 92% relative rate of return, increased from the 90.5% established by TEA-21. (Federal Highway Administration, 2005)

Also of great importance is the emphasis that SAFETEA-LU placed upon innovative financing. Understanding that public revenues were not meeting transportation funding needs, this legislation encouraged the attraction of private investment through several mechanisms. A summary of three initiatives from FHWA follows:

1. Private Activity Bonds – SAFETEA-LU expands bonding authority for private activity bonds by adding highway facilities and surface freight transfer facilities to a list of other activities eligible for

exempt facility bonds. These bonds are not subject to the general annual volume cap for private activity bonds for State agencies and other issuers, but are subject to a separate national cap of $15 billion.

2. Transportation Infrastructure Finance and Innovation Act (TIFIA) – The TIFIA program provides federal credit assistance to nationally or regionally significant surface transportation projects, including highway, transit and rail. To encourage broader use of TIFIA financing, the threshold required for total project cost is lowered to $50 million ($15 million for ITS projects). Additionally, eligibility is expanded to include public freight rail facilities or private facilities providing public benefit for highway users, intermodal freight transfer facilities, access to such freight facilities, and service improvements to such facilities, including capital investment for intelligent transportation systems (ITS).
3. State Infrastructure Banks (SIBS) – The SIB program allows states to establish infrastructure revolving funds eligible to be capitalized with federal transportation funds authorized for fiscal years 2005-2009. This program allows states to increase the efficiency of their transportation investment and significantly leverage federal resources by attracting non-federal public and private investment.

SAFETEA-LU's other priorities included programs aimed at reducing congestion, support for regional initiatives, safety improvements and environmental initiatives. However, SAFETEA-LU also funded a number of research programs, studies, and grants geared towards new and innovative ideas in transportation, including resilient technologies such as improved pavements and bridges. The Surface Transportation-Environmental Cooperative Research Program (STEP) is one such program, whose stated goal is "to improve understanding of the complex relationship between surface transportation, planning and the environment" (FHA, 2005). This program provides $16.9 million per year (through FY2009) to fund cooperative research based on stakeholder involvement. Each year STEP solicits input regarding lines of research, making this program a potential resource to grow the body of knowledge surrounding resiliency planning. Another provision of SAFETEA-LU allows states to obligate surface transportation funds for training and other educational activities at 100% federal share.

Federal Transportation Funding Trends – The Future

SAFETEA-LU expires on September 30, 2009. The next round of the federal transportation authorization is currently gearing up, and H-GAC has the opportunity to cooperate with other organizations to make climate change adaptation a priority, especially in the Gulf Coast region. There are a number of organizations that understand the importance of federal funding for climate change resiliency, and they are working hard to promote it as part of the dialogue. As previously mentioned, the heated debate over climate change has opened a policy window that allows significant funding to be diverted to programs dedicated to climate change adaptation – if the necessary support can be brought together. Due to the non-political nature of MPOs, H-GAC must look for sources of funding other than political action committees and other political groups.

Risk Assessment as a Component of an Adaptation Strategy

This section considers the importance of a risk assessment for climate change impacts in the H-GAC region. Additionally, basic recommendations for conducting a risk assessment, also known as a Hazard and Vulnerability Assessment (HVA), will be given. With the information collected by the HVA, the estimated consequences, probability, and resulting risk of specific climate change impacts to infrastructure can be calculated. This information can then be used to develop detailed plans for adaptation as well as benchmarks for improvement. Without preliminary assessments, benchmarks can be unreasonable or unremarkable. Only after common HVAs are conducted across all regions can benchmarks be set to address each area.

Public infrastructure is often underappreciated until it is unavailable. After Hurricane Ike in 2008, some areas of the H-GAC region went three weeks or more before power was restored. This illustrates the vulnerability associated with this region and its public infrastructure. Before adaptation measures can be implemented, the infrastructure that needs protection must be identified, its importance to public and government operations must be prioritized, and any hazards that could potentially cause damage should be identified.

When identifying and assessing infrastructure, it is important to look for those assets that are most vulnerable and would cause the largest amount of disruption if they were damaged or lost. Along the Gulf Coast, this could include the electric grid, local water resources, bridges or roadways, drainage systems and canals, or ports and refineries.

Identifying Hazards

Before a risk assessment can be completed, it is vital to have a clear understanding of all potential hazards that are present in a region. In this case, it will also include any hazards that may result from climate change.

Vulnerability is defined in terms of the capacity of individuals and social groups to respond to, cope with, recover from, or adapt to any external stress imposed on their livelihoods and well-being (Kelly & Adger, 2000). Those communities that have a higher level of vulnerability should be among the first to implement resiliency plans and processes. This is especially true for communities in low lying or coastal regions, as they are the most prone to experience an early and increased exposure to hazards.

When identifying hazards, it is important to specify the changing conditions that are relevant to the region (Smit et al., 2000). While it is agreed that the impact of climate change will be large, there is uncertainty as to the exact type and degree of expected impacts. As Tol observes, “The uncertainty about the impact of climate change is known to be large because climate change itself is rather uncertain in its magnitude and regional patterns…” (2002).

This makes adaptation especially difficult for planners and engineers, as they prefer to have as much information as possible available for plan development and implementation. While the scale of hazards resulting from climate change is not known in detail, what is known is that there will be no new threats. Rather, currently experienced hazards (flood, drought, tropical storms) will be exacerbated. The benefit of no new hazards is that planners do not have to invent new protection systems, nor wait for greater knowledge and detail of threats and hazards to begin their planning.

Because the hazards of climate change will be similar to many which are already experienced, planners have the ability to begin planning based on current best practices. There are already well-established methods for land use planning that can be drawn from, and there exists a strong knowledge base among engineers regarding shoreline protection. If planners start now, using methods and systems already known to them, they can extend and expand current systems to meet future needs.

Risks in Urban Areas

Urban areas have an advantage over other areas in implementing adaptation methods due to their ability to mobilize more resources and their access to large tax bases and government funding. Conversely, though, several features of modern cities exacerbate climate change risks and increase vulnerability. These factors include a greater amount of paved area that causes heavy run-off, reduction of green spaces that facilitate rain water absorption, centralized power sources, increased development in flood plains or sloped areas, and “far-stretched supply lines combined with just-in-time shipping practices [that] can result in shortages of needed goods when transportation is disrupted by extreme weather” (Clean Air Partnership, 2007, p. 3; see also IPCC, 2007; Tol, 2002; Kelly, 2000).

Risks in Coastal/Low-Lying Communities

Coastal and low-lying communities can be large urban areas or smaller communities located near rivers and bayous or along the coastline. While these communities may be more familiar with extreme weather or have systems in place to mitigate flood damage, their vulnerability will be greatly increased in coming years by increased flood events.

A combination of increased size and frequency of tropical storms may quickly overwhelm current water management systems, including levees and dikes. Additionally, the threat of rising sea level is a very large concern. New Orleans and The Netherlands are examples of communities and countries constantly struggling to survive while residing below sea level. While these examples may be at greater risk with the predicted 1 – 3 meter sea level rise, nearly all coastal communities will be impacted by this increase (IPCC, 2007). The eastern coast of the United States, Florida, Louisiana, and Texas are especially at risk of large amounts of land loss should a significant rise be experienced. In addition to rising sea levels and increased tropical storms, coastal areas can expect erosion, loss of beaches and dunes, larger sediment deposits in shipping canals, more extreme tidal cycles, and further inland inundation by storm-surges (Clean Air Partnership, 2007; IPCC, 2007; Tol, 2002).

Risks in Island Communities

Not only are mainland communities at risk, but island communities are at an increased risk from the impacts of climate change. Island communities have similar risks as both urban and coastal/low-lying areas. They typically have lower evaluations and higher population densities and as sea levels rise they have increasingly smaller areas for retreat. The IPCC reports that “sea-level rise is already affecting coastal infrastructure, coastal populations and increasing the pressure on scarce land resources” (2007).

Assessing Risk

Risk is the potential for an unwanted outcome resulting from an event as determined by its likelihood and the associated consequences. Simply stated, risk is influenced by the nature and magnitude of a threat, the vulnerabilities to that threat, and the consequences that could result. It is important to note that common definitions, scenarios, assumptions, metrics, and processes are necessary to ensure that risk assessments contribute to a shared understanding among various regional partners.

Risk assessment for any scenario is a function of consequence, vulnerability, and threat, as defined below. It is important to think of risk as influenced by the nature and magnitude of the threat, the vulnerabilities to that threat, and the consequences that could result:

$R = f(C, V, T)$

1. Consequence (C): The effect of an event; reflects the level, duration, and nature of the loss resulting from the incident.
2. Vulnerability (V): Physical feature or operational attribute that renders an infrastructure open to exploitation or susceptible to a given hazard.
3. Threat (T): Natural occurrence or action that has the potential to harm life, operations, the environment, and/or property. For the purpose of calculating risk, threat is generally estimated as the likelihood that a hazard will manifest itself (TEEX, 2008).

Risk assessments consider all three components of risk and are conducted on assets, systems, or networks, depending on the characteristics of the infrastructure being examined. Once the three components of risk have been assessed for one or more given assets, systems, or networks, they must be integrated into a defensible model to produce a risk estimate.

Recognizing that many risk assessment methodologies are under development and evolve in a dynamic environment, the core criteria for risk assessment methodologies serve as a guide for future adaptations. The basic analytic principles ensure that risk assessments are:

1. Documented: The methodology and the assessment must clearly document what and how information is used to generate risk estimates. The types of decisions that the risk assessment is designed to support and the timeframe of the assessment (e.g., current conditions versus future operations) should be given.
2. Defensible: The risk methodology must logically integrate its components, making appropriate use of the professional disciplines relevant to the analysis, as well as be free from significant errors or omissions. Uncertainty associated with consequence estimates and confidence in the vulnerability and threat estimates should be communicated.
3. Complete: The methodology should assess *consequence, vulnerability*, and *threat* for every defined risk scenario and follow the more specific guidance for each of these as given in the subsections that follow (Lindell et al., 2006).

All risk is assessed with respect to a specific scenario or set of scenarios. Simply put, the risk scenario answers the question "The risk of what?"(Tol, 2002). All consequence, vulnerability, and threat estimates are specific to the risk scenario. When developing scenarios for a risk assessment of a relatively fixed system, an important first step is to identify those components or critical nodes where potential consequences would be highest and where protective measures and resiliency strategies can be focused.

The risk scenario also identifies the potential source of harm. In the case of natural hazards, the risk scenario must include the type and magnitude of the hazard (e.g., a Category 5 hurricane or an earthquake of 6.5 on the Richter scale). Finally, the scenario must identify the conditions that are relevant to calculating consequence, vulnerability, and threat. The U.S. Department of Homeland Security (DHS) uses reasonable worst-case conditions to assess terrorism risks because intelligent adversaries can choose circumstances where targets are vulnerable and consequences are maximized (DHS, 2008). The concept of "worst case" (that combination of conditions that would make the most harmful results be the ones that occur) is moderated by reason.

Scenarios should not be merged in such a level of complexity as to include numerous unlikely conditions, unless the focus of the contingency and other planning is on extremely rare events (e.g. a terrorist attack during a category 5 hurricane following a significant HAZMAT incident) (Lindell et al., 2006). Neither should scenarios be based simply on average conditions. Each type of infrastructure will have the different characteristics needed to accurately describe reasonable worst-case conditions, such as a stadium's maximum capacity, the storage volume of a particularly hazardous material at a chemical facility, or the height and duration of a high water level at a dam.

The comparative risk assessment criteria for consequences can be divided into three main categories:

1. Public Health and Safety: Effect on human life and physical well-being (e.g. fatalities, injuries/illness).
2. Economic: Direct and indirect economic losses (e.g. cost to rebuild infrastructure, cost to respond to and recover from disaster, and long-term costs due to environmental damage).
3. Governance/Mission Impact: Effect on government's or industry's ability to maintain order, deliver minimum essential public services, ensure public health and safety, and carry out national related missions and functions.

A full-consequence assessment takes into consideration all of the consequence criteria. However, estimating potential indirect impacts requires the use of numerous assumptions and other complex variables. An assessment of all categories of consequence may be beyond the capabilities available for a given risk assessment. Nevertheless, a minimum assessment should focus on the two most fundamental impacts: the human consequences and the most relevant direct economic consequences.

Climate Change and Adaptation: Illustrations from Organizations and States

The following section provides brief introductions to the activities and approaches of other organizations and states that are actively involved in climate change. These organizations may be useful resources or partners as the H-GAC moves toward adaptation as a strategy and policy.

Transportation and Climate Change Clearinghouse (TCCC)

The Transportation and Climate Change Clearinghouse is the U.S. Department of Transportation's focal point for information regarding climate change and transportation. It is part of the DOT's Center for Climate Change and Environmental Forecasting, whose mission is to provide technical expertise through strategic research, as well as to propose solutions through policy analysis, partnerships, and outreach (TCCC, 2009). The TCCC is designed to be a forum for the transportation community to discuss issues, organize and share knowledge. The "Climate Exchange" is a forthcoming online project by TCCC based around a knowledge exchange site where information can be shared regarding modeling, analysis, adaptation, and state, regional, and federal actions and policies.

ICLEI – Local Governments for Sustainability

International Council for Local Environmental Initiatives (ICLEI) is an international organization made up of more than 1,000 local and national governments and planning organizations working toward a more sustainable future (ICLEI website). In 2007 ICLEI released *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments*. The Guidebook was designed to be used by decision makers at the local, regional or state government level to prepare for and adapt to climate change. It helps the official understand the science, determine their area's vulnerability, conduct a risk assessment, improve existing plans, and implement new plans to become a more resilient and sustainable community (Snover et al., 2007).

Climate Impacts Group

The Climate Impacts Group (CIG) was mentioned previously in this report discussing stormwater drainage. CIG is an interdisciplinary research group located at the University of Washington that studies the potential impacts of climate change (CIG, 2009). Their approach is to look at natural and social science research to understand how the natural world is changing and how people are responding to those changes. With this information CIG partners with local planners and policy makers to help them interpret climate change science to make better regional adaptation decisions (CIG, 2009; Snover et al., 2007). CIG's focus is on the Pacific Northwest but its research has been used by community planners worldwide for mitigation and adaptation planning, and is included in the ICLEI guidebook (CIG website).

State of Alaska

Governor Palin established the Climate Change Sub-Cabinet in 2007 to prepare and implement a statewide climate change strategy. The Sub-Cabinet's Adaptation Advisory Group is at the fore of adaptation strategies in the United States, and has already developed plans to relocate three villages, with 160 more villages identified by the Army Corps of Engineers as endangered by coastal erosion. The Sub-Cabinet is tasked with building a knowledge base of the effects of climate change in Alaska, developing measures and policies to prepare communities, and to provide guidance as to how Alaska can participate regionally and nationally to address climate change. One such collaboration is the Western Climate Initiative, started by the governors of Arizona, California, New Mexico, Oregon, and Washington, and joined by Alaska and others in order to address some of the challenges of climate change (State of Alaska, 2009).

State of California

Governor Schwarzenegger recently signed an executive order mandating a Climate Adaptation Strategy to be presented by the state's Climate Action Team by June 30, 2009. This executive order also requires

that all state agencies planning construction projects in areas vulnerable to sea level rise consider sea level scenarios for 2050 and 2100 in order to assess each project's potential vulnerability and to increase resiliency. The California Climate Change Center is also very actively involved in researching adaptation strategies and in proposing policies (California Climate Change Research Center, 2009).

State of Florida

Florida's Action Team on Energy and Climate Change is tasked with developing strategies to address climate change adaptation, public sector planning and investment, and organizing the government for action. The Florida Climate and Energy Commission authorized the 2007 report, *Florida's Resilient Coasts: A State Policy Framework for Adaptation to Climate Change* which looked at policy options for:

- Land use planning and building regulation
- Water supply and delivery
- Transportation and infrastructure
- Conservation of natural lands and marine life
- Beaches and beach management
- Extreme events: emergency preparedness and response

(Century Commission for a Sustainable Florida, 2007)

Keene, New Hampshire

The city of Keene, New Hampshire has worked since 2000 to mitigate climate change. It is a member of ICLEI – Local Governments for Sustainability and has developed a Local Action Climate Plan focused on mitigation. In 2007 Keene developed a plan for adapting to current and potential climate change impacts. Keene's goal in developing its manual, *Adapting to Climate Change: Planning a Climate Resilient Community*, is to enhance the city's resiliency to climate change - based on ICLEI's Climate Resilient Communities Program - and to serve as an example for other communities to develop their own adaptation strategies (City of Keene, 2007).

State of Maryland

Maryland's Climate Action Plan, produced by the Maryland Commission on Climate Change, looks extensively at adaptation strategies to decrease the vulnerability of the state's coastlines to the impacts of climate change. The Adaptation and Response Working Group (ARWG), co-chaired by the Department of Natural Resources and the Department of Planning was tasked with developing a comprehensive strategic framework, and their report includes sections on shoreline management and state response mechanisms to sea level rise. The Action Plan also focuses on federal and state cooperation, including promoting federal legislation that addresses adaptation (Maryland Commission on Climate Change, 2008).

State of Oregon

Oregon's Global Warming Commission has responsibility for adaptation, and the Governor's Climate Change Integration Group (CCIG) was formed to develop a strategy for adaptation. This group focused on processes and policies for government, private industry, and the public in its report, *A Framework for Addressing Rapid Climate Change*, released in January 2008**.** The CCIG developed its framework with regard to the overall planning process, focusing not just on infrastructure, but on the natural, human services, economic systems, and built systems (State of Oregon. CCIG, 2009).

New Orleans/Louisiana Parishes

Following Hurricane Katrina, there was a statewide push to implement new programs and policies to better prepare Louisiana communities for future disasters. One of the ways individual parishes are

attempting to become more resilient is by enacting policies that will save and restore Louisiana's coastal wetlands, which serve as a protective buffer for populated areas, both residential and commercial. Twenty-seven parishes and cities have joined together to form Parishes Against Coastal Erosion (P.A.C.E).

P.A.C.E. plans to partner with other organizations to implement policies from the Coastal Wetlands Planning, Protection and Restoration Act passed by the U.S. Congress in 1990. Some of the main strategies to combat coastal wetland erosion are watershed management, such as river diversion and improved drainage, and structural watershed repair. The local governments comprising P.A.C.E. are collaborating with the U.S. Army Corps of Engineers, the Departments of Interior, Commerce, Agriculture, and the EPA to fund this massive engineering project that aims to protect Louisiana's wetlands (P.A.C.E. website).

New York City- PlaNYC

PlaNYC was initiated by New York City Mayor Michael Bloomberg in 2006 when he asked city residents to generate ideas for six major policy areas: land, water, transportation, energy, air, and climate change (City of New York, PlaNYC, 2009).

PlaNYC's climate change aspect seeks to impact three areas: infrastructure, public and community health, and planning and policy. It consists of three main initiatives. First, PlaNYC created a citywide strategic planning process to assess the risks, costs, and potential solutions for adapting to climate change. Second, PlaNYC created an interagency task force (NYC Climate Change Task Force) to protect vital infrastructure by building climate change into the long-term capital planning processes. The task force is charged with creating an inventory of existing at-risk infrastructure, such as tunnels, airports, subways, power plants, etc. It seeks to analyze and prioritize the components of each system and develop adaptation strategies by designing new guidelines for the construction of new, and the refitting of old public infrastructure. Finally, the plan requires that the city work with community stakeholders in vulnerable neighborhoods to develop site-specific protection strategies.

Miami, Florida - Miami-Dade Climate Change Advisory Task Force

In July 2006, the Miami-Dade County Board of County Commissioners passed an ordinance that created the Miami-Dade Climate Change Advisory Task Force (CCATF) (Miami-Dade County Climate Change Advisory Task Force, 2008). The task force was charged with identifying potential climate change impacts to Miami-Dade County and providing recommendations regarding mitigation and adaptation measures. The task force made several recommendations in areas including scientific research, greenhouse gas reduction, built environment, natural systems, the economy, health, and intergovernmental affairs.

The built environment section focuses on adaptation rather than mitigation efforts. One recommendation from this section requires all county agencies and entities that receive county funding for significant infrastructure or built investments to assess climate change impacts on the agency's/entity's responsibilities. Another recommendation from this section is to expand the mission and resources of the County's Office of Sustainability to provide a central agency for climate change information, monitoring, analysis, and benchmarking.

The next section deals with recommendations for natural system adaptation. One of the recommendations calls for increased funding and resources for the county's land acquisition and management programs, to acquire all undeveloped lands needed for restoration purposes. The next section covers economic, social, and health adaptation, which is important, as Miami-Dade County continues to grow into one of the most populous counties in the U.S. The task force recommended that the Miami-Dade County Comprehensive Development Master Plan be revised to include a new policy to restrict land use in areas that would be at risk from sea level rise and associated impacts within the next 50 years, per the CCATF Science Committee's *Statement on Sea Level in the Coming Century* report.

The final section deals with intergovernmental affairs. One of the recommendations from this section is to conduct a survey of Miami-Dade municipalities to gauge their level of knowledge and engagement in climate change issues, learn about their activities, and begin the creation of an intergovernmental network in which members work together on adaptation and mitigation issues.

In addition to the activities of the Miami-Dade County Climate Change Advisory Task Force, the county has also partnered with the Center for Clean Air Policy (CCAP): Urban Leaders Adaptation Initiative. The CCAP, an independent think tank, focuses on infrastructure and land use decisions that can affect local adaptation efforts.

San Francisco, California - Climate Change Strategy for the San Francisco Bay

According to the Climate Change Strategy for the San Francisco Bay Region Report, four local agencies need to play a coordinated role to address the impacts of sea level rise. The responsibilities of these agencies include land use planning, transportation, flood protection, and ecosystem protection and development. The San Francisco Bay Conservation and Development Commission (BCDC) was formed to act as a mediator between state and city officials in California, with the policy goal of preventing the San Francisco Bay area from shrinking further as a result of development along its banks.

The BCDC is currently working on an eight-year program to help prepare and adapt to the potential impacts of climate change. In year one of their plans, the BCDC will prepare a detailed map of the areas around the Bay that are likely to be inundated by sea level rise within the next 50 years. In years two and three, the Association of Bay Area Governments (ABAG) will determine the economic value of all resources within the area likely to be flooded, the cost of protecting high-value resources, and the cost of removing or relocating lower-value resources. In years four and five, the BCDC will prepare a plan for the Bay that will protect the most important natural and man-made resources from inundation and enhance the biological productivity of the Bay estuary. Finally, in years six through eight, each local bay front government will prepare a sea level rise protection program that identifies needed levees and other infrastructure, a relocation and resource enhancement program, and a sustainability program that will offset greenhouse gas emissions from new development (San Francisco Bay Conservation and Development Commission, 2007).

American Association of State Highway and Transportation Officials (AASHTO)

The American Association of State Highway and Transportation Officials, in their latest report regarding the upcoming transportation appropriation, did not discuss climate change adaptation as a priority for transportation funding. Instead, the focus was on the need to fund transportation infrastructure to make United States' industry more competitive internationally. In light of the current economic downturn, it is likely that this, rather than climate change adaptation, will be a recurring theme.

CHAPTER 4 - INTERVIEWS AND RESEARCH METHODOLOGY

In the wake of Hurricanes Rita and Ike, stakeholders in the Houston-Galveston region have become more attuned and concerned with the growing threat of climate change impacts. Because this is a global concern, many feel that the effects of climate change will not be felt for years to come. Local governments are thus left to cope with the potential climate change impacts in their communities for the foreseeable future. In order to understand of this situation and to develop strategies and policies for local government response to this issue, information must be gathered directly from local decision makers.

To this end it was determined, in consultation with the H-GAC, that in depth interviews with local officials would be the most efficient way to gather this information. This methodology would allow us to target critical decision makers who have the most direct influence over regional policy decisions. Additionally, H-GAC's Foresight Panel recommendations were targeted toward a specific list of decision makers who would be able to utilize the information for resiliency efforts. The intent of these interviews was to build on the work already conducted by the Foresight Panel. This section of the report outlines the design and implementation methodology for the survey and the findings.

H-GAC Constituent Interviews

Purpose of the Interviews

The primary objective of the interview process was to determine the level of knowledge and interest in climate change, in general, from these H-GAC constituents and decision makers, and their understanding and interest in climate change adaptation, in particular. In addition, with the knowledge that the H-GAC had recently distributed the Foresight Panel Report to government officials and policy makers throughout the region, another objective of the interviews was to determine the amount of attention the recommendations had received and to measure, if possible, the responses to the report.

We also focused on local governments' organizational responses to recommendations from a non-binding regional planning organization. We hoped to discover the needs of local governments regarding funding, technical assistance, and the authority needed to address potential climate change impacts.

Interview Design

A telephone interview guide was designed following Institutional Review Board (IRB) requirements and guidelines. The survey instrument is included in Appendix E. Two students were present for the interviews, one to conduct the interview and one to take notes. No audio recordings of the interviews were taken and the responses have been kept confidential.

Target Population

The stakeholders we targeted for our interviews were the same as those targeted for the dissemination of H-GAC's Foresight Panel study findings and report. This group included elected officials and staff at various levels of government in the study region. The initial contact list was obtained from the H-GAC and was supplemented with additional contacts derived from a review of regional organizations that might be interested andinvo0vled in responding to climate change impacts. Once the contact list was generated an initial telephone contact was made with potential respondents in order to schedule the interviews. If the contact was unavailable or was not interested in participating, we requested a second name from the same organization. We also queried the contact in regard to the Foresight Panel report. If the contact had passed on the report to someone else we attempted to interview that individual. Our initial contact list had 49 individuals, representing 23 different entities within the H-GAC jurisdiction

Perspectives on Climate Change

In order to introduce the topic of climate change adaptation, the initial questions asked to our respondents were about their understanding and perceptions of climate change and its potential impact on their immediate area and jurisdiction. Because most of the interest, and knowledge disseminated, about climate change has focused on mitigation – how to stop it and reverse its effects – our interviews included a definition of adaptation, as well as some illustrations of adaptation responses in order to provide direction to the interview.

We also queried respondents about the sources of information regarding climate change that were driving, or would potentially, drive, policy or even informal discussions. This information was solicited to enable us to determine how climate change information was currently being used in the decision making process, if at all.

Considering the reality in which local government officials operate and the political pressures that are exerted in their direction, we were also interested in ascertaining the competition between political and scientific input into decision making. For example, do political pressures outweigh scientific ones?

H-GAC Relations

The relationships between local governments and the H-GAC were also recognized as being an important factor for the future development and implementation of climate change adaptation policies or solutions. With this in mind, the survey included an open-ended section in which we sought to explore these relationships. We inquired about the relationship in general to determine if regular contact is kept between H-GAC and the local government. We then ask specifically about the adaptation recommendations they received a few weeks prior in the Foresight Panel Report. These responses sought to identify possible implementation and funding hurdles that would become relevant in any eventual planning and implementation stages of adapting to climate change in the region.

Adaptation to Climate Change

The interview then asked a series of open ended questions about the effects of climate change in that respondent's immediate jurisdiction or area of responsibility, and specifically about any plans that the organization had discussed or put in place to respond to these effects. Questions would specifically target the respondent's knowledge regarding public infrastructure resiliency to such damaging effects as hurricanes, floods, and extreme temperatures and precipitation events. We also asked how responsive some of the strategies were (if any were in place) during Hurricanes Ike and Rita. We then linked the adaptation issues with H-GAC's goal of providing support to local governments for climate change adaptation and queried respondents if there had been discussion yet or are plans in place to implement the Foresight Panel's recommendations.

Measurement and Data Analysis

Due to the open-ended nature of our questions, primarily qualitative analysis was conducted with the responses we received. Open-ended responses allow for a wider array of answers, ensuring that those local government respondents that we interviewed were not restricted in the information and insight they could provide. The questions were, however, set up to give an affirmative or negative response, followed by an explanation. This would allow for efficient coding and simple computational measures to provide a snapshot of responses as a whole.

Each individual answer was broken down, and all similar responses (similarity of responses will be determined by group consensus) were grouped into categories. With a small sample size, as represented by our research, qualitative methods allowed for more response options for the respondents as well as richer detail and interpretation. A low variance of responses among these categories should highlight common issues that local governments share in the region.

Findings and Observations

We conducted 16 complete interviews, ranging in duration from 15 minutes to an hour. We attempted to make at least 3 attempts to schedule an interview before either striking the contact from the list or identifying another contact within the same agency and department, if possible.

Our requests for interviews from the contact list encountered a high refusal rate. The primary reasons given for refusal focused on the general political nature and tensions surrounding climate change as an issue. Respondents did, however, inform us that specific sections of the Foresight Panel report – those which concerned a wider range of issues and not solely climate change – were of significant interest to respondents.

First, the general reaction to our research in the initial contact process was negative. Ten percent of the contacts refused outright to speak with our research group members and offered a myriad of explanations. These responses ranged from a disinclination to speak with "green folks" (despite the fact that we identified ourselves as students and never claimed to take one side or the other on the politics of climate change) to referring us to their agency's "environmental department," claiming that his/her department had nothing to do with climate change.

Second, the responses of those we contacted revealed significant doubt about the existence of climate change – and therefore also about its effects. This was a fairly consistent response throughout the interview process. Most respondents we interviewed regarded climate change in general – and the recognition of climate change impacts – as a low priority issue at the local government level. We recognized this as a potential political problem for adaptation, since the majority of respondents informed us that their climate change impact information came from general knowledge or from media sources such as television. They acknowledged a lack of scientific data used in decision-making, which was often due to the cost of producing the necessary studies. We also found that local governments' definitions of "sustainability," "resilience," and "adaptation" varied significantly, with internal evaluations of sustainability usually concluding with positive results.

Despite a relative unfamiliarity with the Foresight Panel report (both as an official report as well as the content in the report) among many of those interviewed, the issues addressed in the report were issues that local governments were already concerned about. The four climate change impact areas of concern in H-GAC's report included increased magnitude and frequency of storms, rising sea levels, changes in regional rainfall, and temperature fluctuations. These same four areas were each identified by at least one respondent as something that concerned their agency/government, and they reported that steps were being taken to address those concerns. Due to the recent impacts of Hurricanes Ike and Rita, extreme storm events were by far the most pressing issue on the minds of our respondents. Following at a distant second, sea level rise was also a concern, due to the low-lying geography of the area's coastal plain. The more inland located respondents were more concerned with rainfall and temperature changes.

We also found that risk assessments (for climate change impacts) were not being used in a majority of the respondents' jurisdictions. Most local government respondents stated they conducted risk assessments of their public infrastructure, but they were not considering the potential impacts of climate change in these assessments.

Overall, we observed that the target audience of H-GAC's Foresight Panel report paid relatively little attention to the document, despite having had the report available for approximately four weeks. Because of its clear focus on climate change impacts, personal doubts and the political debate caused many of these officials to pass the report on to other individuals without the same level of decision-making influence (such as environmental departments). Fortunately however, many of the actions and recommendations defined in the report as "resiliency efforts" are being independently evaluated at the local level. These decisions are being made without the climate change framework or context, but they

may have similar effects. Despite the seeming lack of enthusiasm for climate change reports, nearly all respondents answered that they would welcome H-GAC assistance with research and planning. However, they also state they would be uncomfortable with mandates. When asked if they would accept additional funding that included strings attached as a mechanism of enforcement, a majority of respondents agreed to such an arrangement.

Limitations of the Survey

The limitations of our research are common to similar small sample size studies that rely on interviews as an information-gathering tool. Another limitation includes the sharing of responsibility and overlapping jurisdictions in many of these areas. For example, attitudes on climate change adaptation may be different in the City of Houston from public servants in the Harris County offices – and each might feel it is the other's responsibility, or even the state's responsibility.

Differences in opinions may not lie along jurisdictional boundaries alone, but also may form along rifts between elected officials and non-elected public servants. Each group has certain responsibilities they must prioritize, and these priorities may or may not line up with the policies recommended in the report, or even with climate change as an issue they should be concerned with and responding to. Any research in this area may be limited if one or both groups decide that climate change adaptation is a low priority. Our research also may be different dependant on election year cycles, fiscal year priorities, or budget availability.

Finally, our open-question format is limited due to recall problems. We wanted to avoid prompting the respondents and not give them a false set of ideas or steer them in any direction over another – but it is entirely possible that the respondents did not know about resiliency or related programs that actually existed in their area. When asking open ended questions, there is also always a possibility that respondents will intentionally or unintentionally mislead us. These limitations are consistent with other, similar, studies and should in no way diminish the utility and validity of our findings.

Recommendations

In this section we outline our recommendations based on the findings and research.

Remarket how climate change is perceived; focus on security and public safety

One of the largest problems we discovered in our research for this report was that a number of respondents did not understand the implications of climate change, felt it was out of their jurisdiction, or were uninterested in discussing it in general. It was discovered that many respondents based their opinion or position on information from television media or from informal information sources, rather than scientific ones, with many respondents wary of "climate change" as a concept.

It is therefore the recommendation of this report that H-GAC attempt to remarket or re-brand climate change among both community leaders and citizens. H-GAC should make an effort to change the perception of climate change from one of a strict environmental focus, to a more scientifically-based assessment that is security and safety motivated. Not only would this help different communities have a similar level of understanding about the issues, but it would also create an atmosphere where constituents would be more likely to support adaptation projects within their communities.

By shifting the emphasis from who is responsible for climate change, green house gases and mitigation issues to instead providing an assessment that is focused on the increased frequency and severity of storms, for example, climate change will become relevant. Rebranding climate change towards adaptation will better enable H-GAC to encourage communities to implement those systems and projects which will establish resiliency to the changes expected for the region.

Focus on constituent education

Along with rebranding, H-GAC should be involved in providing education, information, and facts to constituents in support of their planning processes. By providing communities with facts, H-GAC will give community leaders and managers the tools and knowledge that is needed to provide the proper protection to their citizens. Included in this should be education about adaptation systems and resiliency projects that communities can implement during disaster recovery. While many of the communities in the H-GAC region continue to recover from Hurricane Ike, now is the time to begin the implementation of resiliency. Communities should not rebuild on pre-impact standards, but rather should rebuild to stronger standards. It is during recovery and reconstruction that resiliency implementation is the cheapest to put into action; no new projects have to be undertaken, instead those projects focused on rebuilding should simply apply resiliency practices into their construction.

To help communities begin to adapt, it is recommended that H-GAC begin a campaign of adaptation systems education. Many systems provide overlap coverage and can in fact provide resiliency against several natural hazards. The implementation of resiliency projects that are currently underway should not only consider the threat of immediate hazards, but should incorporate long term hazards as well. The overall cost of the projects will not be affected by much, but by building better-planned projects, communities will be protected now and in the future.

Promote a regional viewpoint on climate change

The next recommendation for H-GAC is to try and establish one recognized position regarding climate change within the region. Currently, constituents have varying positions and perspectives on what climate change is and what the effects of it will be in the region. Our report recommends that the H-GAC should seek to define a consensus position throughout member communities so that planners and elected officials alike have a common end goal. During our research and survey, we discovered that a number of officials and managers had different definitions for climate change, had a range of stances regarding climate change, and had diverse long term strategies (ranging from none to complex).

For this reason our research shows that H-GAC would benefit from trying to reach a consensus regarding climate change, in order to provide a framework for a common strategic goal for all planners and officials. If the Houston-Galveston area is to be properly prepared for what current climate change models suggest, it is critical that the entire area have the same perspective. To accomplish this we encourage the use of educational seminars and conferences for elected and top officials to provide education about climate change, what to expect, and what steps they can take to implement adaptation for their community.

Highlight academia as a source of adaptation knowledge

Scientific information about climate change is very familiar in academia. However, in doing the survey, we found that many local governments don't have a clear picture about what climate change is and what actions could be taken to adapt and mitigate its effects. In fact, many local governmental leaders' main source of information about climate change is from media sources such as television. While the media can be a good source of information for understanding climate change, it is not sufficient for local governments to design and implement adaptation plans. Hurricane Ike had an enormous impact on the Houston-Galveston area, with one result being that planning for hurricanes has become a significant issue for local governments. Here is an opportunity for partnerships with the academic community, as a variety of scholars have already participated with stakeholders in the area on climate change adaption and mitigation planning and modeling.

Offer workshops and other support opportunities to involve and educate stakeholders

Before local governments can begin implementing adaptation measures to protect the region's public infrastructure, they must identify the infrastructure that most needs protection as well as the potential hazards. Most respondents did say that they had conducted some kind of hazard vulnerability assessment of their public infrastructure; however, these were general assessments and not related to climate change. Not one of these HVAs had been informed by any scientific data regarding climate change, and all were conducted independently.

To the extent possible (given financial and personnel constraints), H-GAC should partner with member governments to conduct a risk assessment for that government's public infrastructure. H-GAC could provide expertise related to climate change and risk assessment, and the local government could provide access to information about its particular infrastructure.

If providing individual risk assessments is not possible, H-GAC should conduct a workshop to educate any interested members about the hazards associated with climate change and provide guidance on conducting their own risk assessments.

Work with other organizations to support funding adaptation at the federal level

Federal transportation funding priorities have shifted over the past twenty years. Funds have been aimed towards activities such as congestion mitigation, passenger safety, welfare to work initiatives, emissions reduction, and research. This variance shows that there is some leeway to program some federal funds towards activities that have gained national attention. A focus on federal funding is necessary as both the scope of funding is more readily available at the federal level, and the political climate more conducive to funding adaptation activities.

We recommend that H-GAC work with partner organizations nationwide to encourage the funding for climate change adaptation as a part of the next federal appropriations bill. There are numerous communities across the country that are dealing with the effects of climate change and increased storm activity. We feel that the policy window is open at this time to push resiliency planning as a policy initiative.

The Department of Transportation has begun to recognize that emissions reduction is not enough to stop climate change and that communities will have to begin planning for adaptation. The USDOT's Transportation and Climate Change Clearinghouse is a newly created forum for organizations involved with this issue to both learn from each other but also to organize to influence policy. Additionally there are a number of other organizations devoted to this issue as well as states that have begun planning for climate change adaptation.

We recommend that H-GAC reach out to these organizations and become more involved with the policy debates and funding issues surrounding the next federal transportation appropriation. Currently adaptation activities are not listed among the priorities of the Obama Administration's 2010 Transportation Budget, despite the devastating hurricanes and flooding nationwide that has occurred in the past several years.

H-GAC, as an organization which represents an area of the country that has been directly impacted by destructive storm activity has an opportunity to play a leading role in bringing adaptation to the table as an issue for discussion. Hurricanes Ike and Rita have opened this policy window, and the request for federal adaptation funding should be framed in light of the need to plan for increased storm activity, as well as the other potential impacts.

Houston Area Survey

Public support is critical for decision makers in making tough or potentially politically risky decision. Climate change as an issue is certainly one which can make public officials hesitant about taking

action without ensuring significant public support. Recently, however, surveys and studies conducted in the Houston-Galveston area have shown shifts in public opinion regarding climate change.

As previously mentioned, the Houston Area Survey shows that 80% Houston area residents (in nine of H-GAC's thirteen counties) believe that climate change is at least a somewhat significant threat to the resident's way of life, and that 63% of Houston area residents believe that more money should be spent on preparing for the impacts of climate change. These results should be discussed more between H-GAC and the decision makers of the Houston-Galveston area. We recommend that H-GAC pass these results onto the local government officials, putting these programs in perspective. While local government officials may be hesitant to act because of the political firestorm around climate change, the results of this survey will shift their focus to their constituents – and not to the positions staked out by ideologues.

Changing the mindset of climate change is a crucial first step to changing the attitudes toward evaluating climate change impacts in the decision making process. Without providing some political cover for the local government officials, they are unlikely to change their policies toward a more adaptive resiliency strategy.

Conclusions

In the opinion of this Capstone group, the Foresight Panel recommendations were sensible and based on sound scientific evidence. The packaging and delivery of the message, though, as well as the political issues surrounding the topic of climate change, deterred many local leaders from being receptive to the recommendations. We believe repackaging the report recommendations to be less focused on climate change as an environmental issue and more focused on safety and common sense precautions would better reach the intended audience.

H-GAC could also increase local governments' receptiveness toward the recommendations by providing resources related to scientific research on the subject. H-GAC should work to bring all local governments onto the same page regarding climate change, partnering with local governments to assess the risks in their areas, and assisting them in obtaining funding for climate change adaptation.

While climate change politics bring many of the impacts to light on the national stage, they preclude many local agencies from being engaged or from considering H-GAC's recommendations – that is, many public officials want to stay away from such a "hot button" issue. Contrary to the results of the Houston Area Survey, public officials in the H-GAC region believe that constituents have not been "sold" on the idea of climate change enough to give them enough political cover to fully embrace the idea. As a long term issue, climate change is not a regular part of the decision making process at the local level – although many of the impacts of climate change are. Because of this, local governments are willing to work with planning organizations on specific impact issues, but are reluctant to tackle them all as a comprehensive response to "climate change."

These important issues show that there is a lot of work to be done in the realm of climate change adaptation in the Houston-Galveston area. While there is some resistance, changes in communication between H-GAC and local governments can make a significant and positive impact on promoting climate change adaptation in the Houston-Galveston area.

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ANNEX 5-1A **Potential Climate Changes, Impacts on Land Transportation, and Adaptation Options**

	Impacts on Land Transportation (Highways, Rail, Pipeline)		Adaptation Options		
Potential Climate Change	Operations and Interruptions	Infrastructure	Changes in Operations	Changes in Infrastructure Design and Materials	Other
Temperature: increases in very hot days and heat waves	Limitations on periods of construction activity due to health and safety concerns; restrictions typically begin at 29.5°C (85°F); heat exhaustion possible at 40.5°C (105°F) Vehicle overheating and tire deterioration	Impacts on pavement and concrete construction practices Thermal expansion on bridge expansion joints and paved surfaces Impacts on landscaping in highway and street rights-of-way Concerns regarding pavement integrity, e.g., softening, traffic-related rutting, migration of liquid asphalt; sustained air temperature over 32°C (90°F) is a significant threshold Rail-track deformities; air temperature above 43°C (110°F) can lead to equipment failure	Shifting construction schedules to cooler parts of the day	Development of new, heat-resistant paving materials Greater use of heat-tolerant street and highway landscaping Greater use of continuous welded rail lines	

(continued)

ANNEX 5-1A *(continued)* Potential Climate Changes, Impacts on Land Transportation, and Adaptation Options

	Impacts on Land Transportation (Highways, Rail, Pipeline)		Adaptation Options		
Potential Climate Change	Operations and Interruptions	Infrastructure	Changes in Operations	Changes in Infrastructure Design and Materials	Other
Temperature: decreases in very cold days	Regional changes in snow and ice removal costs and environmental impacts from salt and chemical use (reduction overall, but increases in some regions) Fewer cold-related restrictions for maintenance workers	Decreased utility of unimproved roads that rely on frozen ground for passage	Reduction in snow and ice removal Extension of construction and maintenance season Shortening of season for use of ice roads		
Temperature: increases in Arctic temperatures		Thawing of permafrost, causing subsidence of roads, rail beds, bridge supports (cave-in), and pipelines Shorter season for ice roads	Shortening of season for use of ice roads Lengthening of potential construction season Increased use of sonars to monitor streambed flow and bridge scour	Use of insulation in the road prism Use of different types of passive refrigeration schemes, including thermosiphons, rock galleries, and "cold culverts"	Relocation of sections of roads and rail lines to more stable ground

Temperature: later onset of seasonal freeze and earlier onset of seasonal thaw	Changes in seasonal weight restrictions Changes in seasonal fuel requirements Improved mobility and safety associated with a reduction in winter weather Longer construction season	Reduced pavement deterioration resulting from less exposure to freezing, snow, and ice, but possibility of more freeze–thaw conditions in some locations	Relaxation of seasonal weight restrictions Shortening of season for use of ice roads		
Sea level rise, added to storm surge	More frequent interruptions in travel on coastal and low-lying roadways and rail service due to storm surges More severe storm surges, requiring evacuation	Inundation of roads and rail lines in coastal areas More frequent or severe flooding of underground tunnels and low-lying infrastructure Erosion of road base and bridge supports Bridge scour Reduced clearance under bridges Loss of coastal wetlands and barrier shoreline Land subsidence		Elevation of streets, bridges, and rail lines Addition of drainage canals near coastal roads Elevation and protection of bridge, tunnel, and transit entrances Additional pumping capacity for tunnels	Relocation of sections of roads and rail lines inland Protection of high-value coastal real estate with levees, seawalls, and dikes Strengthening and heightening of existing levees, seawalls, and dikes Restriction of most vulnerable coastal areas from further development Increase in flood insurance rates to help restrict development

(continued)

ANNEX 5-1A *(continued)* **Potential Climate Changes, Impacts on Land Transportation, and Adaptation Options**

	Impacts on Land Transportation (Highways, Rail, Pipeline)		Adaptation Options		
Potential Climate Change	Operations and Interruptions	Infrastructure	Changes in Operations	Changes in Infrastructure Design and Materials	Other
					Return of some coastal areas to nature
Precipitation: increase in intense precipitation events	Increases in weather-related delays Increases in traffic disruptions Increased flooding of evacuation routes Disruption of construction activities Changes in rain, snowfall, and seasonal flooding that affect safety and maintenance operations	Increases in flooding of roadways, rail lines, and subterranean tunnels Overloading of drainage systems, causing backups and street flooding Increases in road scouring, road washout, damages to railbed support structures, and landslides and mudslides that damage roadways and tracks Impacts on soil moisture levels, affecting structural integrity of roads, bridges, and tunnels	Expansion of systems for monitoring scour of bridge piers and abutments Increase in monitoring of land slopes and drainage systems Increases in monitoring of pipelines for exposure, shifting, and scour in shallow waters Increases in real-time monitoring of flood levels Integration of emergency evacuation procedures into operations	Protection of critical evacuation routes Upgrading of road drainage systems Protection of bridge piers and abutments with riprap Increases in culvert capacity Increases in pumping capacity for tunnels Addition of slope retention structures and retaining facilities for landslides Increases in the standard for drainage capacity for new	Greater use of sensors for monitoring water flows Restriction of development in floodplains

		Adverse impacts of standing water on road bases Increases in scouring of pipeline roadbeds and damages to pipelines		transportation infrastructure and major rehabilitation projects (e.g., assuming a 500-year rather than a 100-year storm)	
Precipitation: increases in drought conditions for some regions	Increased susceptibility to wildfires, causing road closures due to fire threat or reduced visibility	Increased susceptibility to wildfires that threaten transportation infrastructure directly Increased susceptibility to mudslides in areas deforested by wildfires	Vegetation management		
Precipitation: changes in seasonal precipitation and river flow patterns	Benefits for safety and reduced interruptions if frozen precipitation shifts to rainfall, depending on terrain	Increased risk of floods from runoff, landslides, slope failures, and damage to roads if precipitation changes from snow to rain in winter and spring thaws			
Storms: more frequent strong hurricanes (Category 4–5)	More debris on roads and rail lines, interrupting travel and shipping More frequent and potentially more extensive emergency evacuations	Greater probability of infrastructure failures Increased threat to stability of bridge decks Increased damage to signs, lighting fixtures and supports	Emergency evacuation procedures that become more routine Improvements in ability to forecast landfall and trajectory of hurricanes	Changes in bridge design to tie decks more securely to substructure and strengthen foundations	Strengthening and heightening of levees Restriction of further development in vulnerable coastal locations

(continued)

ANNEX 5-1A *(continued)* **Potential Climate Changes, Impacts on Land Transportation, and Adaptation Options**

	Impacts on Land Transportation (Highways, Rail, Pipeline)		Adaptation Options		
Potential Climate Change	Operations and Interruptions	Infrastructure	Changes in Operations	Changes in Infrastructure Design and Materials	Other
		Decreased expected lifetime of highways exposed to storm surge	Improvements in monitoring of road conditions and issuance of real-time messages to motorists Improvements in modeling of emergency evacuation	Increases in drainage capacity for new transportation infrastructure or major rehabilitation projects (e.g., assuming more frequent return periods) Removal of traffic bottlenecks on critical evacuation routes and building of more system redundancy Adoption of modular construction techniques where infrastructure is in danger of failure Development of modular traffic features and road sign systems for easier replacement	Increase in flood insurance rates to help restrict development Return of some coastal areas to nature

County	Population	% Under Age 18	% Over Age 64	Future Pop. Projection*	Mean Household Income	Median Household Income	% Unemployed (in labor force)	% Below Poverty Level (last 12 months)
Austin	26,172	25.0	15.0	32,713	66,809	51,141	3.0	9.0
Brazoria	284,363	27.9	9.0	429,708	74,322	58,583	3.6	11.2
Chambers	28,384	25.7	9.1	48,787	64,214	56,080	3.4	12.1
Colorado	20,558	23.2	18.8	24,779	54,052	38,167	2.7	15.4
Fort Bend	484,948	28.4	6.4	419,832	96,583	76,635	4.4	8.2
Galveston	279,604	25.9	11.0	266,550	67,971	51,885	4.8	13.2
Harris	3,854,254	28.8	7.7	5,842,290	70,693	48,604	5.1	16.9
Liberty	74,917	26.0	10.7	123,673	51,225	41,369	4.4	14.0
Matagorda	37,176	27.7	13.6	48,652	51,667	39,123	5.5	25.6
Montgomery	393,363	27.5	9.2	717,467	84,166	62,367	4.2	11.3
Walker	64,111	16.8	9.4	78,293	41,949	29,817	4.7	24.6
Waller	35,207	25.1	9.6	75,902	55,281	40,187	4.4	23.6
Wharton	40,947	27.1	13.6	50,962	51,950	39,966	3.3	14.8
State of Texas	23,385,340	27.7	10.0	35,761,165	64,452	46,248	4.4	16.9

County	% Black/African-American**	% Hispanic	% White**	% Other	% with no HS Diploma (over 25)	% with Bachelor's Degree or higher
Austin	9.9	19.9	68.9	1.3	19.2	16.4
Brazoria	10.1	25.4	58.9	5.6	17.4	24.5
Chambers	11.1	15.3	72.1	1.5	16.1	13.7
Colorado	-	-	-	-	25.8	16.5
Fort Bend	20.6	23.3	40.5	15.6	12.8	37.9
Galveston	14.2	20.5	60.8	4.5	15.1	25.4
Harris	18.2	37.9	37.2	6.7	23.5	27.0
Liberty	12.5	14.0	71.8	1.7	30.2	7.5
Matagorda	11.8	35.5	49.0	3.7	27.8	13.7
Montgomery	4.5	16.9	75.6	3.0	15.4	27.9
Walker	22.8	15.3	59.3	2.6	22.5	15.8
Waller	26.1	23.2	49.1	1.6	23.1	17.3
Wharton	14.1	34.8	49.8	1.3	25.6	14.1
State of Texas	11.3	35.5	48.3	4.9	21.4	24.7

Statistics from: "2005-2007 American Community Survey 3-Year Estimates" (http://factfinder.census.gov)
*Projections from: http://txsdc.utsa.edu/cgi-bin/prj2008totnum.cgi (more detailed statistics and explanations available at the site)
**Non-Hispanic

APPENDIX C. LIST OF ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
ABAG	Association of Bay Area Governments
ARWG	Adaptation and Response Working Group
BCDC	San Francisco Bay Conservation and Development Commission
CCAP	Center for Clean Air Policy
CCATF	Miami-Dade Climate Change Advisory Task Force
CCIG	Climate Change Integration Group
CMAQ	Congestion Mitigation and Air Quality
CCRI	Climate Change Research Initiative
DHS	Department of Homeland Security
EPA	Environmental Protection Agency
HAZMAT	Hazardous Material
H-GAC	Houston-Galveston Area Council
HTF	Highway Trust Fund
HVA	Hazard and Vulnerability Assessment
IM	Interstate Mandate
IPCC	Intergovernmental Panel on Climate Change
ISTEA	Intermodal Surface Transportation Efficiency Act
ITS	Intelligent Transportation Systems
LRA	Louisiana Recovery Authority
MPO	Metropolitan Planning Organization
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
PACE	Parishes Against Coastal Erosion
PlaNYC	Plan New York City
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act
SIBS	State Infrastructure Banks
STEP	Surface Transportation-Environmental Cooperative Research Program
STP	Surface Transportation Program
SWMP	Houston Storm Water Management Program
TCCC	Transportation and Climate Change Clearinghouse
TEA-21	Transportation Equity Act for the 21st Century
TIFIA	Transportation Infrastructure Finance and Innovation Act
TxDOT	Texas Department of Transportation

APPENDIX D. DEFINITIONS

Adaptation: Adjustment in natural or *human systems* in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation:

Anticipatory adaptation – Adaptation that takes place before impacts of *climate change* are observed. Also referred to as proactive adaptation.

Autonomous adaptation – Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or *welfare* changes in *human systems*. Also referred to as spontaneous adaptation.

Planned adaptation – Adaptation that is the result of a de-liberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state.

Climate Change: Climate change refers to any change in *climate* over time, whether due to natural variability or as a result of human activity. This usage differs from that in the *United Nations Framwork Convention on Climate Change (UNFCCC)*, which defines 'climate change' as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global *atmosphere* and which is in addition to natural climate variability observed over comparable time periods'.

Extreme weather event: an event that is rare within its statistical reference distribution at a particular place. Definitions of "rare" vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile. By definition, the characteristics of what is called extreme weather may vary from place to place. An extreme *climate* event is an average of a number of weather events over a certain period of time, an average which is itself extreme (e.g., rainfall over a season).

Mitigation: An *anthropogenic* intervention to reduce the anthropogenic forcing of the *climate system*; it includes strategies to reduce *greenhouse gas sources* and emissions and enhancing *greenhouse gas sinks*.

Public infrastructure: Infrastructure is commonly defined as the various components of the built environment that support modern society. H-GAC lists: Transportation, Water Management, Solid Water, and the Built Environment.

Resilience: The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change.

Risk: potential for an unwanted outcome resulting from an incident, event, or occurrence, as determined by its likelihood and the associated consequences.

Vulnerability: Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of *climate change*, including *climate variability* and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its *sensitivity*, and its adaptive capacity.

APPENDIX E. CAPSTONE FINAL INTERVIEW GUIDE

Introduction

"I am from the George Bush School of Government and Public Service at Texas A&M University, and we are studying the regional impact of climate change on public infrastructure in the Houston-Galveston area. We are focusing specifically on local government resiliency and adaptation to climate change.

This project is funded by the Southwest Region University Transportation Center at Texas A&M University and is sponsored by the Houston Galveston Area Council.

Should you choose to participate in our interview, your answers will remain confidential. The University releases no information as to how any particular individual answers. You can refrain from answering any questions that make you feel uncomfortable, and you can end the interview at any time.

[Get full contact information. Ask the interviewee for residency, length of residency, occupation/expertise, and training]

Perspective on Climate Change and Variability: Problems & Solutions

In an open-ended format and without prompting, solicit R's perception(s) of climate change, in general, the range of short and long-term climate impact problems facing his/her state or immediate region (for MPO respondents)

The following are some definitions that should be presented to the R:

- Adaptation can be defined as: as adjustments in natural or human systems in response to climate change conditions or effects
- Adaptive responses can also be categorized into three main types:
  - Protect (measures to preserve the transportation infrastructure in its existing location and condition)
  - Accommodate (measures to adjust to climate change impacts such as raising a roadbed)
  - Retreat (abandon existing facilities)

Specific lead-in questions should be: "What is your perception on climate change in general? What is your perception of climate change as a potential problem for public infrastructure? What is your perception of adaptation in response to potential climate change impacts on public infrastructure?"

This may be followed by more directed questions:

- "In your opinion, are there climate impacts that need, or will need attention in your area?"
- Is climate change currently being discussed as a potential problem in your area of responsibility?
- If yes, by whom? If no, why not?
- What are the potential impacts presented by climate change in this area? [prompt for sea level rise, changes in precipitation, changes in temperature, and increased frequency and magnitude of storms]
- What data describes these impacts (probe for metrics, especially performance metrics)?
- Where will these impacts be most evident (generalized or localized, location, distribution)?
- When do you see these impacts occurring (now, constant, seasonal, occurring only under some conditions)?
- Which of the 4 stressors will have the most/least significant impact in your state or region?

Relationship to HGAC

1. In an open-ended format, and without prompting, ask R about their relationship with HGAC, the local MPO.
2. How much contact have you had with HGAC regarding climate change in general? Specifically, were adaptation methods discussed?
3. Are you aware of HGAC's "Report of the Foresight Panel on Environmental Effects"?
4. If so, what is your general reaction to it? Do you have any plans to implement their recommendations?
5. Are there any other agencies or organizations you are working with on issues relating to climate change?

Adaptation to Climate Change

In an open ended format and without prompting, ask R about adaptation to climate change as an alternative solution and policy approach to climate change stressors.

Considering these definitions direct the R to the following questions:

1. How do you describe your public infrastructure? What control do you have over the design and maintenance of these areas?
2. What are your vulnerable public assets?
3. Have you done a hazard vulnerability assessment? What scientific information on climate change are you using for these activities?
4. If so, what was accomplished? How? Has it or will it been implemented?
5. Are there specific thresholds or tipping points that are important to the decision and planning process in regard to adapting to climate change impacts? If so, can you briefly describe these?
6. Were you affected by Hurricanes Rita or Ike?
7. Did you incorporate any resilience methods into your planning after Rita? Were they effective?
8. Do you plan to incorporate any resilience methods into your planning after Ike?
9. Would you consider your city/etc. sustainable [need to define], and has this opinion changed since Ike?
10. Would you consider implementing adaptation efforts if funding was not an issue?
11. Would you be receptive to HGAC providing resiliency services, including research and planning?
12. How would you feel about HGAC hypothetically having authority to mandate climate change resiliency planning?
13. Are you aware of any private sector initiatives regarding climate change adaptation? Are there any public/private initiatives to work together on this issue?