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Don't Let Their Future Blow Away: An Integrated Methodology to Inform School Leaders of the Dimensions and Determinants of School Vulnerability Leading to Disaster Learning Loss

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Abstract

School leaders play a key role in the critical functions of emergency response in a school system, including purposefully sustaining safe, secure, and healthy learning environments for all students before and after a disaster. Despite these values, school leaders remain underprepared and often unaware of the vulnerabilities associated with weather, climate, and other disaster events and the potential threat that climate change poses to both student achievement and access to education. This study presents school-leaders with a landscape-scale geospatial vulnerability assessment of school districts exposed to, or threatened by, hurricanes in order to improve mitigation efforts in schools. In this study, the researcher utilized Hazus, a nationally recognized, standardized, and integrated multi-hazard loss estimation methodology, run within a full-featured Geographic Information Systems (GIS) technology platform. Hazus was used to estimate the number of school districts containing high densities of damaged schools after hurricane event scenarios. Schools were identified and mapped based on loss of use days as quantified by a function of the damage caused by wind produced by a specified hurricane scenario, a school's susceptibility to climate change based on location, and proximity to sources of impairment. As a result of this work, a new term was conceptualized: Disaster Learning Loss (DLL). The quantifiable rate of Disaster Learning Loss will provide a tool that school leaders can use to understand dimensions and determinants of school vulnerability to hazards while considering the potential academic impact that climate change will have on student achievement.

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CHAPTER I: INTRODUCTION

"Anticipating, educating, and informing are the keys to reducing the deadly effects of natural disasters." Koïchiro Matsuura, UNESCO Director-General (2005)

Across the globe and in all aspects of society, the tangible effects of climate change are overwhelmingly evident. Growing in frequency and intensity, events like hurricanes are reshaping the way school leaders operate to ensure effective and safe learning systems for our youth. Under pressure from a changing climate, school leaders are finding themselves underprepared and under-resourced. This issue is a growing challenge for school leaders to manage in the existing multifaceted and complex educational system. These pressures are particularly acute for school leaders in coastal regions with less developed contexts lacking the social or infrastructural capacity to implement preventative measures. School leaders are left unsure how to effectively engage surrounding communities and partners in the climate change conversation, leverage and allocate resources, receive effective preparation training, and manage political undercurrents. The complex interactions that exist between our schools and ecosystem dynamics, requires multidisciplinary partnership and research which ultimately improves action toward safer schools. This is not easily accomplished for a multitude of reasons. As a result, the nexus of environmental justice and social justice continues to be overlooked in the field of educational leadership.

Climate change caused many people to endure extreme weather events in 2018, but the United States was particularly hard hit. With an estimated 411 parts per million (ppm) of carbon in the atmosphere, the planet is getting hotter, glaciers are melting, and ocean waters are warming and rising (Environmental Protection Agency [EPA], 2018; IPCC, 2018; National Oceanic and Atmospheric Association [NOAA], 2018; Rignot et al., 2018). The average temperature for the United States was 53.5 degrees F (1.5 degrees above average), making 2018 the 14th warmest year on record and the 22nd consecutive warmer-than-average year (NOAA, 2018). More states suffered record high-temperature events ([USGCRP], 2017) and nine states in the eastern United States had their wettest years on record: Delaware, Maryland, Massachusetts, New Jersey, North Carolina, Pennsylvania, Tennessee, Virginia, and West Virginia (NOAA, 2018; National Weather Service, 2018). Across the rest of the United States, the average precipitation was 34.63 inches (4.69 inches above average), making 2018 the third wettest year in the 124-year record (NOAA, 2018). Coastal seas have been on average nine inches higher since 1900 (Kulp & Strauss, 2017; Strauss, 2013; Wuebbles et al., 2017), and according to the National Aeronautics and Space Administration (2018), climate change may cause global sea levels to increase anywhere between 0.66 to 6.6 feet (0.2 meters to 2 meters) by the end of this century, threatening many of the world’s highly populated coastal cities. This statistic is particularly concerning since eight of the ten largest cities in the world are near coasts, and 44% of the planet's population lives in coastal areas vulnerable to rising seas (United Nations Atlas of the Oceans, 2018).

If the gradual impacts of climate change are not concerning enough, in 2018 alone, a total of 14 separate disasters cost U.S. tax payers $91 billion, of which $73 billion derived from three major events: Hurricane Michael ($25 billion), Hurricane Florence ($24 billion), and the Carr and Camp wildfires in California ($24 billion) (NOAA, 2018). These fundamental climate changes impact millions of Americans, due to displacement caused by sea level rise, storm surge, flooding, damaging strong winds, drought, worsening food shortages, more frequent and intense heat waves, powerful forest fires, crop failures, and crumbling infrastructure from an increase in hurricane intensity (IPCC, 2018; NOAA, 2018). While hurricanes are a natural phenomenon in our climate system, recent research indicates that in the North Atlantic region hurricanes destructive power and intensity has been increasing (Keller & DeVecchio, 2015; Kitchen, 2014; IPCC, 2018; NOAA, 2018). Without drastic course correction, research suggests the impact will be catastrophic to humans as soon as 2040 (IPCC, 2018). There are concerns humanity may have already passed the point of no return when it comes to combating climate change; the only logical thing left to do is adapt the social fabric of society by learning a new way of living.

This dissertation aims to understand the effects of one growing climatic event, hurricanes, and their effect on school systems particularly school leaders. Due to the lack of coherence in the nation’s system of education governance, including some states with centralization and others with decentralization (Fowler, 2013), this study will use the term school leader(s) to identify any and all stakeholders in positions of power overseeing educational policy, finance and leadership. This can include but is not limited to federal and state governmental organizations overseeing education, state boards of education, policy makers, regional school board members, district level leaders, charter school coalitions, independent school districts, school-based leaders within public, private, or charter schools, principals, and/or teachers. The full definition of school leader, as well as other terms used within this dissertation, can be found in Appendix A.

Practitioner Summary

Our nation's educators, including principals and district leaders, are deeply committed professionals who work tirelessly to address the safety, social, emotional and cognitive needs of students. In today's schools, leaders perform many significant duties on a daily basis. Regardless of the size of the school, the number of students, or the school's location (rural to urban), a leader's first responsibility is to foster an environment that is safe, orderly, healthy, and inviting. School leaders are now facing unprecedented challenges in meeting this requirement due to the increase of disasters caused by climate change. Here, I investigate how the field of educational leadership might be impacted by the essential problem of school closures caused by climate change and climate disasters. I evaluate the practical challenges confronting the field should Disaster Learning Loss rates increase and consider ways to purposefully improve the preparation and professional development of educational leaders in sustaining safe, secure, and healthy learning environments in the face of our changing climate. I further theorize that increasing the capacity and knowledge of school leaders around the impact of climate change will lead to a reduction in lost instruction time for students, increasing social equity and environmental justice for future generations.

Background to the Problem

Despite emerging work that articulates standards in the context of school safety (e.g. Armenta & Stader, 2011; FEMA P-1000, 2017), natural hazard disaster leadership practices in schools, as well as appropriate education policy following disasters more broadly, remain loosely theorized and provide only limited practical guidance for school leaders. Over the last decade, extreme weather events have exposed school leaders' limited capacity to manage the effects of climate change in their schools and districts. School leaders are expected to be the front-line specialists and authorities for educating and protecting our children while managing potential health and safety risks from different environmental hazards, including but not limited to community exposure to pandemic, adverse weather events like hurricanes, volcanic eruptions, and earthquakes (Stuart, Patterson, Johnston, & Peace, 2013). However, as the consequences of climate change combine and interact with educational systems, a new context for education leadership presents itself.

Senge (1990) discussed broader philosophical tools that arise when leaders integrate systems thinking, such as mental-model flexibility and visioning, into their daily practice, especially in the face of extreme leadership challenges. Rising sea levels and growing populations along coastal communities, coupled with greater frequency and intensity of natural disasters, are a prime example of the complex systems shaping and changing the dynamics of our world and affecting school systems. In recent decades, the number of natural disasters has increased, and scientists warn that the warming climate is likely to further exacerbate extreme weather with the potential for greater destruction

(IPCC, 2018; NOAA, 2018; United Nations Children's Fund [UNICEF], 2018). Without whole system change, the increased likelihood of extreme weather events has the potential to further reduce children's access to a quality education.

A UNICEF (2018) report shows that 33% of all children living in countries affected by natural disasters and conflict are not able to attend school, with 25% not entering any school and 40% not having completed primary school, due in part to the consequences of natural disasters. Lower academic performance, higher rates of absenteeism, and overall reduction in educational attainment have already been noted among children who have experienced natural disasters (Bruner, Discher, & Chang, 2011; FEMA P-1000, 2017; Kousky, 2016; UNICEF, 2018). An NPR Ed analysis compiled missed days from individual public-school districts affected by natural disasters based on estimates given by education departments from nine U.S. states plus the Virgin Islands and Puerto Rico. According to this report, at least nine million students missed school in the fall of 2017 due to natural disasters (Samsel & Nadworny, 2017).

Despite these staggering statistics, widespread global support to ensure access to education after a disaster is insufficient, as less than four percent of global humanitarian appeals are dedicated to supporting education (UNICEF, 2018). School leaders are hindered by a lack of funding, policy support, and school emergency management and mitigation training. Consequently, school leaders are unsure how to implement operational policies and practices to improve the physical protection of the school facility to resist the conditions of climate change and to improve overall school safety from a wide range of growing hazards and threats (FEMA P-1000, 2017). However, research suggests that school leaders' actions in advance of a natural disaster can be the most critical component to the success of emergency management and ensure student safety (FEMA P-1000, 2017; United States Department of Education, 2007). School leaders, who are well-prepared, trained, and informed, are better equipped to build community resilience during both large-scale (generalized) hazard events and smaller-scale (localized) hazard events (FEMA P-1000, 2017; Stuart, Patterson, Johnston, & Peace, 2013; United States Department of Education, 2007). School leaders who have taken preemptive steps to reduce their risk have been shown to respond more effectively to emergencies, recover more quickly, and better support the entire community in the recovery process after a disaster (FEMA P-1000, 2017). This work is no small task. Depending on the scope of the natural disaster, school leaders can be called upon to do the following: share responsibility in decision making with local responders; open their schools to emergency services; house displaced families; store supplies; and/or manage the collaboration among a broad spectrum of professionals and agencies before, during, and after the disaster event (FEMA P-1000, 2017; United States Department of Education, 2007).

School leaders play a critical role in emergency management, yet they are increasingly finding themselves in unfamiliar territory, lacking the skills, plans, research and support necessary to make decisions in an environment of uncertainty (FEMA P-1000, 2017; Grissom & Loeb, 2011; Stuart, Patterson, Johnston, & Peace, 2013). A 2007 study exploring school emergency preparedness revealed that 25 percent of the 248 respondents (school administrators, certificated personnel, and classified personnel) believed that their school was not prepared for a natural disaster despite having previously experienced the devastating consequences of hurricanes impacting the United States such as Katrina, Ivan, Dennis, Allison, Frances and others (Kano et al., 2007). An underprepared school leader could be left to struggle with questions like when to close and reopen schools, how to find new schools for displaced students, how to help students and teachers cope with the trauma of loss, or how to ensure that everyone returns to a new classroom away from the damaged (often dangerous infrastructure that remains) (FEMA P-1000, 2017; UNICEF, 2018; United States Department of Education, 2007).

With all the other demands placed on school and district leaders, the multifaceted concept of educational leadership is already overwhelming. School leaders find it difficult to effectively navigate operational and safety decisions in a way that remains centered on the students (Kensler & Uline, 2017; Noddings, 2012; Northouse, 2016; Senge, 1990; Senge, 2006; Shields, 2017). Northouse (2001) broadly defined transformational leadership as a process that changes and transforms individuals. Shields (2017) introduced the fundamental and critical approach to leadership as the idea of transformative leadership with a key focus on social transformation as the basis for both individual and collective achievement. In linking these theories, an ideal leadership learning environment is established with preparation and practice for educational leaders focused on the benefit of all children, educators, and school communities ("UCEA NELPS Standards", 2017; "UCEA Vision, Goals, & Values", 2018). An ideal leadership education environment relies on knowledge and skill development anchored in the realities of a changing climate and focuses on social transformation as the basis for both individual and collective achievement (Shields, 2017). Preparation programs, which include information about school vulnerability and climate change, significantly enhance the quality, scope, and reach of a school leader. If provided with the opportunity to understand the potential impact of climate change on a school facility and students, school leaders will be capable of reaching their full leadership potential. It is a movement that will require collective action within the education system broadly and the educational leadership field specifically.

Thus far, many obstacles exist in the preparation and development of school leaders throughout the nation to maintain a common vision for emergency management. Moreover, long-term commitment to implement, practice, sustain, and update emergency management plans has yet to come to fruition (FEMA P-1000, 2017; Kensler & Uline, 2017; Northouse, 2013; United States Department of Education, 2007). These challenges include a lack of inclusionary measures in the National Educational Leadership Preparation (NELP) Standards (2017). These standards do not specify what building- or district-level school leaders should know and be able to do in the face of climate change events, competing public school needs and demands, and scarce resources in an increasingly difficult economic and political environment. There is a general lack of understanding and research informing school leaders of the risk of natural hazards and climate change in the field of educational leadership and educational policy (FEMA P-1000, 2017; UCEA NELP Standards, 2017). To prepare for, respond to, recover from, and mitigate against natural disasters (FEMA P-1000, 2017), school leaders need to have access to the data they need. This data should inform school leaders of the school's vulnerabilities and students' likelihood of risk—based on location as well as the impact and implications of climate change—and provide adequate strategies, including policies and procedures, to assess building performance during a disaster (FEMA P-1000, 2017).

Without additional research informing school leaders of the conditions of climate change and the subsequent learning disruptions caused by natural disasters, school leaders will be inadequately prepared. There must be a new paradigm shift for how school leaders need to be trained. Scientists and politicians around the globe are calling for *all* leaders to develop practical, far-reaching solutions (IPCC, 2018). There is no better place for more practical solutions to be seeded than the field of educational leadership.

Children deserve the opportunity to learn and to be protected from harm (Save the Children, 2018; UNICEF, 2018). However, neither the importance of this task nor the nature of the challenge appears to be fully understood in the field of educational leadership. School leaders—particularly their role in mitigating the effects of or responding to national disasters—continue to be overlooked in educational research. It is true that "transformative leadership, focusing on attitudes and relationships, can offset poor facilities, and limited resources" (Shields, 2017, p. 127), but what happens when school facilities are destroyed? What happens when educational leaders do not have the skills to cope with their school being devastated by a natural disaster?

There is an increasing need for a critical and pragmatic approach to develop the competencies and processes to deal with climate change. It is important to realize the inherent benefits of linking climate science, disaster prevention and management, and school leadership together (James & Paton, 2015; Kensler & Uline, 2017). One way of preparing for such situations is to understand the determinants and dimensions of school vulnerability while providing school leaders with cross-disciplinary research that quantifies the number of days each student could possibly miss due to a natural disaster. Leadership preparation programs must make efforts to support school leaders in identifying accessible resources in advance of, during, or after a natural disaster to mitigate the challenges they will inevitably face due to climate change.

Statement of the Problem

With 56.6 million students attending approximately 133,000 public and private elementary and secondary schools (NCES, 2018), safe school facilities play a crucial role in supporting the educational development of our nation's children (Wagner, 2010). Climate change results in higher temperatures, rampant wildfires, storm surges, rising sea levels, food insecurity, water shortages, intense heat waves, violent storms, flooding, and stronger, more devastating hurricanes. These events create extraordinarily difficult conditions for school leaders to provide quality, essential services and safe educational facilities (Guin, 2015; James & Paton, 2015; Kousky, 2016; NOAA, 2018; Zubenko, 2000).

Over the past three years, there have been 45 major disaster events that have overwhelmed the United States, including several billion-dollar disasters (NOAA, 2018). For coastal communities, the social, economic, and physical scars left behind by major climate disasters are devastating. In many parts of our country, school buildings were vulnerable to the severe damage caused by these natural hazard events. Further, school leaders were not prepared or trained to manage such scenarios, which increased the likelihood of physical and psychological trauma to students, staff, and the surrounding community (Kano et al., 2007). In such scenarios, a school leader's decision making is contextualized by several factors. Such factors include legal requirements, the school leader's knowledge and understanding of the school community and the nature of the event itself, and the leader's preparedness in terms of emergency management planning, training, and previous experience of similar events (Kano et al., 2007; Stuart, Patterson, Johnston, & Peace, 2013).

Research illustrates the importance of school leaders setting a clear direction, establishing high expectations, and developing talent in their schools to fully support teaching and learning (Hesbol, 2013; Leithwood et al., 2004; Shields, 2017), regardless of outside forces and challenges. Existing research shows the demonstrated effects of successful leadership are considerably greater in schools with more difficult circumstances (Leithwood et al., 2004). That does not mean, however, that we should be putting school leaders in unnecessarily difficult situations. School leaders face a dynamic and complex constellation of contextually-bound practices (Hesbol, 2013), which continue to evolve as the extreme circumstances triggered by climate change produce new challenges not previously faced by school leaders. In the case of understanding risk associated with climate change, the more a school leader knows and prepares, the more likely a school leader is to ensure the security of their school facility (FEMA P-1000, 2017).

School leaders will need additional training on how to anticipate the adverse effects of lost instructional time while taking appropriate action to prevent or minimize the damage extreme weather can cause to students and school facilities. It has been shown that well-planned, early adaptation action saves both lives and money (NOAA, 2018). During an emergency, including natural disasters like hurricanes, school leaders must make effective choices quickly. When accompanied by appropriate adaptations, properly prepared school leaders can reduce the vulnerabilities present within their system to minimize lost instructional time, thereby improving long-term academic outcomes for students.

Our current educational goals require a more holistic view of the complex interconnected systems, both ecological and human, influencing the future of educational leadership (Kensler & Uline, 2017; Rippner, 2016). Policymakers and practitioners in all sectors need to be able to peer over the ledges of their silos and see how our changing climate will affect future students and policy (NOAA, 2018; Rippner, 2016; UNICEF, 2018). Beyond the need for greater cross-sector understanding, there is a need for broader collaboration between the sectors. This collaboration allows for more cross-disciplinary studies examining the intersection between climate change and schools, specifically addressing the diminution and determinants of school vulnerabilities as well as adaptation and mitigation efforts school-level leaders can implement.

Purpose of the Study

It is important for school leaders to gain knowledge and awareness from research helping to identify the factors, determinants, and dimensions of school vulnerability in the event of an environmental hazard. While hurricanes are a natural phenomenon a wealth of recent research suggests that there has been an increase in intense hurricane activity (Keller & DeVecchio, 2015; Kitchen, 2014; IPCC, 2018; NOAA, 2018). Although impossible to completely predict as a result of climate change, in the future, there will likely be more intense hurricanes that carry higher wind speeds and more precipitation (IPCC, 2018; NOAA, 2018). The impacts of this trend are likely to be exacerbated by continual sea level rise and a growing population and construction along coastlines (IPCC, 2018; NOAA, 2018; UN Atlas of the Oceans, 2018). The growing frequency of such events means school leaders need access to more information and opportunities to learn about the risks associated with climate change to their schools. This landscape-scale geospatial vulnerability assessment will investigate the influence of the growing frequency and intensity of hurricane events on school districts along the Eastern and Gulf Coast regions of the United States to consider what the real-world distribution and impact of the phenomenon might look like. This study will do the following:

1. Explore the relationship between instructional time lost and hurricane events working to conceptualize a new term known as Disaster Learning Loss;
2. Utilize a transdisciplinary and interdisciplinary perspectives by incorporating definitions and methodology from disciplines traditionally outside of education and educational leadership including geography, atmospheric science, climatology, hazard

and emergency management, and geographic information science (GIS);

3. Use a multiple methodological perspective (Lubienski & Lee, 2017) to explore the complexity of the current education system and its connection to Earth's physical environment and atmosphere;
4. Provide an evidence-based, comprehensive, quantitative estimation of observed and projected climate change-related risks to inform school leaders, decision and policy makers, and other stakeholders within and outside of government who are interested in better understanding the risks presented by climate change to our education system;
5. Build upon the integrated knowledge base of school leaders and policymakers needed to understand, predict, and respond to natural disasters with respect to school systems and buildings, while helping to inform decisions and other strategies in the public education arena, including building adaptive capacity and resilience strategies in schools; and
6. Improve the way school leaders understand mitigation, response, and recovery while developing effective plans to ensure students have reliable, safe, and equitable access to education in the face of an uncertain future.

The general lessons provided by this research project (such as the necessity of preparedness and awareness of the determinants and dimensions of vulnerability) apply more generally to disaster management. However, this project's core focus is on the actions, policy implications, and opportunities specifically for the field of educational leadership.

Research Questions

The study is guided by the following research questions:

1. What counties along the Eastern and Gulf Coast regions of the United States have K-12 schools that are most vulnerable to hurricane events?
2. What is the relationship between hurricane events and school instruction days lost?

A Conceptual Framework for Disaster Learning Loss

A primary objective for school leaders is to purposefully sustain safe, secure, and healthy learning environments for all students. Thus, school leaders need to understand and identify the vulnerabilities facing their school or districts, have access to assessment tools to properly prepare and mitigate hazardous situations, and know how and when to act to ensure equitable access to education regardless of a hazard. Historically, school districts and regions across the United States were identified as vulnerable to disasters based narrowly on traditionally conceived geographical characteristics such as proximity to coastal areas (Keller & DeVecchio, 2015). However, more recent research has found several additional factors that impact vulnerability including proper preparation, knowledge, and economic conditions, which can lead to increased resiliency and adaptive capacity in the aftermath of a disaster or, alternatively, exacerbate its impacts (Coffman & Noy, 2010). These factors also impact the vulnerability assessment of schools, although they are less often the focus of disaster preparation research. As such, a conceptual framework has been created to generate insights regarding how school leaders address and/or prepare for disaster.

This framework leverages the work of multiple disciplines including educational leadership, education safety and management policy, equity research, federal state and local policy, climate science, and vulnerability and risk assessments. The conceptual framework provides the reader with an understanding of how a new theorized concept, Disaster Learning Loss (DLL), will be developed and assessed within the field of educational leadership. The intention of the framework is to support school officials, including educational stakeholders, in their continuous pursuit to provide a safe, hazard-free learning environment while reducing the amount of lost instruction time caused by hazardous events.

Understanding the vulnerability of any given school, student, or district in relation to climate change can be a very complex task for any school leader. To achieve a proper understanding, it is necessary to comprehend the function of a school's "sensitivity to climate change related risks, its exposure to those risks, and its capacity for responding to or coping with climate variability and change" (USGCRP, 2016, p. 249). Assessing the determinants of vulnerability will be an ongoing process through which school leaders identify and evaluate potential risks based on their unique geographic location, coupled with identifying areas of weakness capable of adversely impacting their specific school system (United States Department of Education, 2008). Due to varying characteristics of every school throughout the United States, assessments must be customized by the school leader to fit their unique physical environment, geographic location, school culture and climate, and necessary resources of each educational facility. This process starts with a school leader being capable of identifying the risk factors facing their school and students as outlined in *Figure (1.1).*

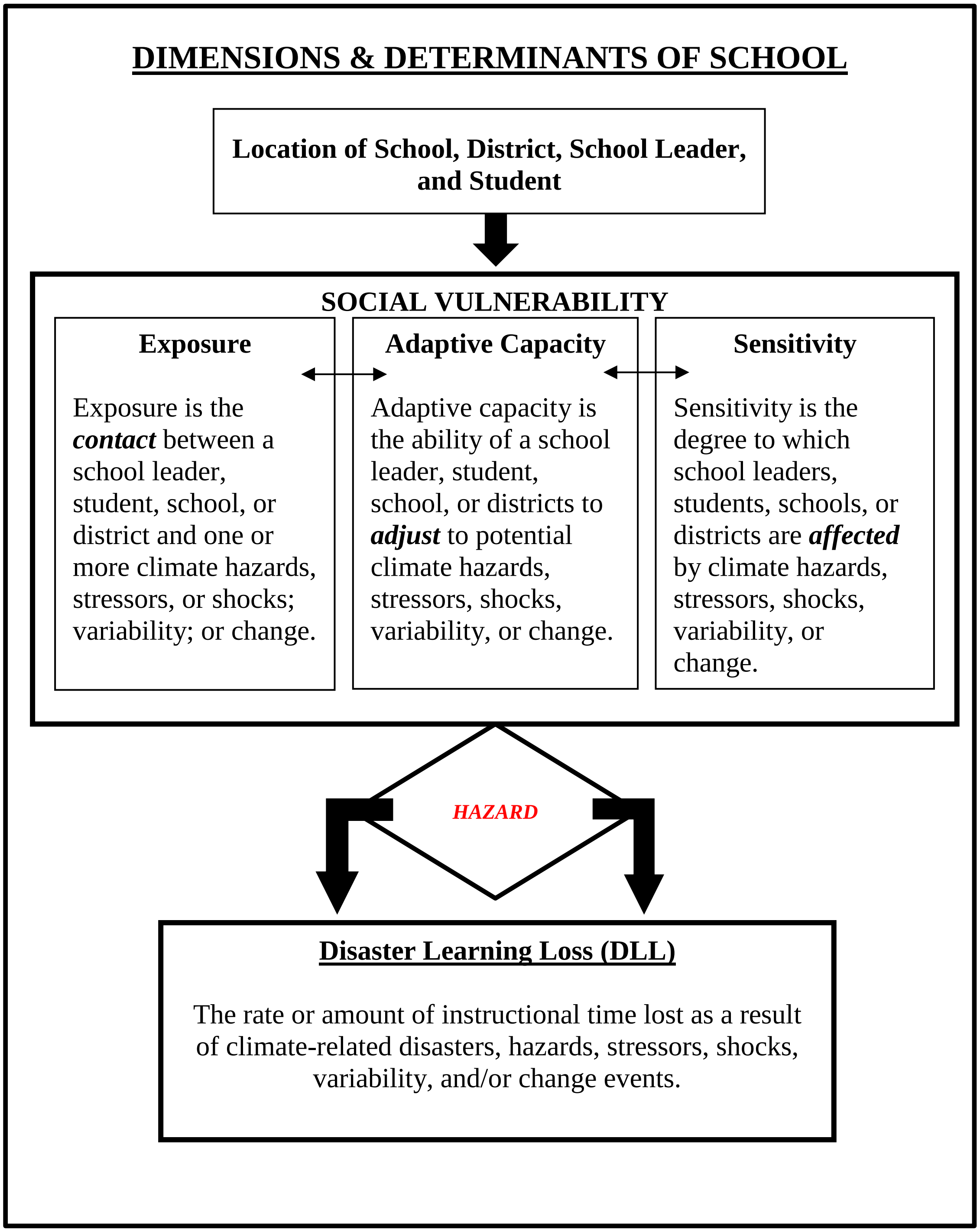

Figure (1.1). A conceptual framework for understanding and defining Disaster Learning Loss (DLL) associated with climate change, shocks, stressors, and variability, including exposure, sensitivity, and adaptive capacity. This framework is an adaption of frameworks created by the U.S. Global Change Research Program (USGCRP) Climate and

Health Assessment, Intergovernmental Panel on Climate Change (IPCC), the National Research Council, and the Federal Emergency Management Agency (FEMA). (Figure source adapted from Crimmins et al., 2016; Turner et al., 2003).

Once school leaders can understand a school's geographic location in relation to regional climate changes, they can begin to conduct a social vulnerability assessment. A social vulnerability assessment explores the exposure, adaptive capacity, and sensitivity of the school and students to extreme weather, posing hazardous risks within and surrounding the facilities, to truly examine what the relationship between weather events and disaster risk (Lubienski, Gulosino, & Weitzel, 2009; USGCRP, 2016;).

Exposure, adaptive capacity, and sensitivity are the factors that make up overall social vulnerability. Social vulnerability incorporates the larger social fabric and socio-economic factors present within the larger school community, including external funding sources and donations and proximity to restoration resources. Social vulnerabilities are exacerbated by natural disasters; therefore, some schools, districts, groups, communities, and students are more vulnerable to events and their aftermath than others (Stuart, Patterson, Johnston, & Peace, 2013). The social vulnerability of any location is then broken down into three categories: exposure, sensitivity, and adaptive capacity.

In this study, **exposure** is defined as the contact between an individual student, school, or district to the physical stressors, including damage or destruction, resulting from climate change-related events (e.g. how many times has a student, school, or district been exposed to a hurricane and how much damage do hurricanes cause in an average season). This exposure “may occur in a single instance or repeatedly over time and may occur in one location or over a wider geographic area” (USGCRP, 2016, p. 250).

Often intertwined with exposure is **sensitivity**, the degree to which a school or a student is affected, either adversely or beneficially, by climate variability (USGCRP, 2018). Sensitivity can be described by an exposure-response relationship, indicating the responsiveness of systems to a given amount of climate change (O’Neill et al., 2013). Sensitivity can also be measured by historical inequalities that have led to vulnerable populations in the United States being disproportionately exposed to environmental risks (Azadegan, 2018; Bullard, 2000; Mohai et al., 2009; Mohai & Bryant 1992; Peterson & Maldonado, 2016). Research has shown historical minority exclusion and institutionalized economic disadvantages have led to a higher risk of socioeconomic insecurity (sensitivity) for Latinx populations after a natural disaster (Azadegan, 2018). Undocumented status further aggravates the level of sensitivity by limiting access to formal services and reducing access to benefits such as health insurance and other social services. This lack of access can have harmful effects on the economic, physical, and emotional well-being of Latinx families after a disaster (Azadegan, 2018).

Adaptive capacity is the ability of the school leader, school, or community in which they are located to adjust to potential hazards, to take advantage of opportunities, or to respond to consequences (USGCRP, 2018). School systems can establish different types of adaptation approaches, some of which are closely related to coping mechanisms that individuals and communities have developed to deal with other stressors. The U.S. Global Change Research Program (2018), the Intergovernmental Panel on Climate

Change (2018), the National Research Council (2018), and the Federal Emergency Management Agency (2018) state that people and communities with strong adaptive capacity tend to have greater resilience. The IPCC (2018) report defines adaptation as "adjustments in ecological, social or economic systems in response to actual or expected climatic change and their impacts" (p. 388), referring to changes a school can make in processes, practices, and structures to mediate potential damages or to benefit from opportunities associated with climate change.

Factors that influence adaptive capacity within school systems include the availability of knowledge and human and financial resources, including their distribution across the population (Klein et al. 2007; O'Neill et al., 2013). Such resources include input from various school personnel (e.g., building-level leaders, district-level leaders, state-level leaders, teachers, campus officials, and facility managers), in partnership with community members, parents, students, and local emergency services, leading to community-wide expertise in working to overcome potential challenges. An example of adaptation within a well-functioning school system would be school leader who is well informed of the risks associated with the location of his/her school to climate-weather-events. Based on their knowledge of the risks, school leaders work to increase the adaptive capacity within and outside the community by collecting items and resources before a disaster occurs; creating a protocol to mobilize the group, regardless of the severity of the event; increasing communication during a disaster event; and distributing the previously collected resources to those in need. School leaders who are not well informed and struggle with limited resources before a hazard are likely to encounter a greater degree of difficulty after a disaster when resources become even more scarce (O'Neill et. al, 2013).

It is important to consider that, as part of a comprehensive assessment of vulnerability, many types of cumulative, compounding, or secondary impacts can occur (USGCRP, 2018), climate change and the resulting impacts to systems of education do not occur in isolation (Meadows, 2015), and an individual student or community could face multiple threats at the same time, at different stages in one's education, or accumulating over the course of one's life (Chaudhuri, 2003; Ligon & Schechter 2003; USGCRP, 2018; Zhang & Wang 2009). As an example, factors that contribute to the degree of exposure or sensitivity can also influence the ability of both individual students and schools to adapt (adaptive capacity) to climate variability and change. These factors can include (a) the socioeconomic status of the student population; (b) certain demographic characteristics (e.g., some communities of color, immigrant students, students with limited English proficiency, Indigenous peoples, students with disabilities, or other populations that may find it difficult to migrate to a new school location after a disaster); (c) existing condition and accessibility of the school's infrastructure; (d) the knowledge and expertise of the school leader in mitigating the effects of natural disasters; (e) family and social capital, meaning the collective skills, knowledge, experience, and social cohesion of a community; (f) interruption of education due to displacement and/or other shocks that lead to irreversible lost instruction time; and (g) other institutional resources (Chaudhuri, 2003; Jacoby & Skoufias, 1997; Ligon & Schechter 2003; USGCRP, 2018; Zhang & Wang 2009). It is also important to consider how some student populations are already experiencing disproportionate access to high-performing quality schools. Existing academic performance, a school's structural state, and availability to capital resources varies drastically across regions, states, and the nation. This disparity will only compound the effects of climate change, further reducing one's capacity to respond to climate change and resulting weather disruptions.

After a climatic event occurs, schools that are highly vulnerable or significantly damaged may have no other choice than to close their doors until sufficient repairs can be made. The rate or amount of instructional time lost resulting from a school closure becomes the new conceptualized term **Disaster Learning Loss** (DLL), as identified in the final stage of this framework. Disaster Learning Loss is defined as the amount of instruction time lost resulting from climate-related disasters, hazards, stressors, shocks, variability, and/or climate change. The interaction between risk (hazard frequency and geographic location) and social vulnerability (social indicators and socio-economic factors) combine to create the most accurate representation of Disaster Learning Loss. Previous research has shown that instructional time lost, including summer learning lag (Cooper et al., 1996), has implications for vulnerable populations, whereas Disaster Learning Loss provides a clear description and identification of the risks specific to school instructional time lost resulting from weather-climate-disaster events.

It is important to equip school leaders with the conceptual framework to establish the determinants of school system vulnerability leading to Disaster Learning Loss, as well as defining the risks and implications of Disaster Learning Loss. School leaders should then conduct a thorough assessment of hazards within school buildings, identify the areas in need of improvement, including additional funding requirements to ensure student safety, and prioritize the most imminent hazards posing the greatest risk to the school or district, potentially reducing the time students are out of classrooms after a disaster occurs. The determinants of vulnerability leading to the Disaster Learning Loss framework, and the action plan predicated on this study's assessment results, will provide school officials with a framework for understanding individualized facility vulnerability and the implications for student achievement.

The identification of a school or district's potential Disaster Learning Loss is an integral element of the continuous improvement process that each school leader—with support from inside and outside their community, including their preparation program—must address to actively promote a safety-oriented learning environment. Furthermore, school leaders must work to reduce the factors that exacerbate the determinants of school vulnerability and ensure equitable access to education after a disaster. Through risk realization at all levels of educational leadership, along with the development and forthcoming conversation around the term Disaster Learning Loss (DLL), the rate of lost instruction time can be reduced by increasing capacity and driving policy decisions to fund disaster mitigation and disaster planning programs in and for schools.

This framework provides the foundation in the exploratory process of this study and helps to identify the determinants and dimensions of vulnerability of school districts at the greatest risk, based on current climate change models.

Limitations, Delimitations, and Assumptions

Limitations. This study has conditions or influences that cannot be controlled by the researcher, placing possible restrictions on the methodology and conclusions of this study. This study will assess vulnerability but will not be able to uncover *all* the underlying mechanisms at work. One issue arising from the use of GIS and spatial analysis is the use of arbitrary or artificial units of spatial reporting on continuous geographical phenomena (Ballas, Clarke, Franklin, & Newing, 2018). Within this study, modification of the area units study boundaries might result in different geographical patterns. An example of this would include moving from county boundaries to school district boundaries. This process introduces statistical bias "when the summary of values are used in statistical analysis to explore geographical association between the different variables" (Ballas, Clarke, Franklin & Newing, 2018, p. 33). Therefore, the Hazus default of county level aggregation will be used to ensure consistence of data while reducing research bias.

Additionally, the research clearly shows that the impact of disasters varies along many dimensions (Keller & DeVecchio, 2015; IPCC, 2018). Some will be identified within this study, but it's likely that there are more that cannot be observed given the scope and time constraints of this study. The relationships between variables will also vary depending on local context (Hogrebe, 2012). The data used in this study will be the embedded inventories and parameters built into the Hazus Hurricane Model. Therefore, the data will not include information regarding recent building or development of a school, district boundaries, district boundary changes, or recent school closures or openings. The study should be considered based on the identified risk of a general geographic area within a county or state.

The following specific limitations of the Hazus model and data should also be noted:

1. While the Hazus Hurricane Model can be used to estimate losses for an individual school building, the results must be considered as average for a group of similar buildings. It is frequently noted that nominally similar buildings have experienced vastly different damage and loss during a hurricane;
2. The Hazus Hurricane Model contains definitions and assumptions regarding building strengths that represent a norm for construction in hurricane zones. Where construction quality is known to be different from the defined norms, larger uncertainties in loss projections may be realized (FEMA, 2018a).

Geospatial datasets representing the built environment, incorporating social vulnerability, critical infrastructure, and natural hazard risk are the cornerstone to any assessment, including the development of Disaster Learning Loss. However, the quality of the datasets can be inconsistent from community to community. In addition, this study is exploring a localized disaster, raising questions about whether the findings can be extended to other places and other types of disasters.

There are also factors outside the control of the researcher that could impact student, school, and district vulnerability, as referenced in the conceptual framework, including unique demographic, cultural, political, financial, physical, and other educational factors (Holme, Diem & Welton, 2014). This study will not produce a climate change scenario or determine if an extreme weather event will occur in the study region, nor will it be able to determine if a school will be damaged in an extreme weather event. Finally, ecological fallacy may occur as inferences about the relations between individual characteristics will be made based on data about geographical area (Jargowsky, 2005). This issue will be of particular importance in the analysis of areas with high levels of socio-economic and demographic diversity (Ballas, Clarke, Franklin, & Newing, 2018). This issue would be better addressed with more sophisticated small-area estimation methods and more recent data packages, which are not possible in this study given time, resource constraints, and software updates to Hazus.

Delimitations. This study also has delimitations. To keep the data consistent, this study will not deviate from the standard data packages available for use within Hazus. These include the Hurricane Model, which will only include terrain (surface roughness) data derived from National Land Cover Data (NLCD) compiled in 2013 by the Multi-Resolution Land Characteristics (MRLC) Consortium. The only deviation is for the state of Florida, where the land use data is derived from the Florida Water Management District Land Use Land Cover compiled in 1995. The historic storm and a probabilistic storm set in the Hurricane Model uses the Atlantic basin hurricane database, which encompasses the period 1886-2001. The probabilistic storm data sets available within Hazus currently goes through 1995.

The key General Building Stock (GBS) databases in Hazus, including non-residential structures such as schools, are derived from Dun & Bradstreet (D&B). Three reports from the Department of Energy (DOE) are used in defining regional variations in characteristics such as number and size of garages, type of foundation, and number of stories. Schools have been identified as essential facilities in Hazus and will be classified by building structure type and occupancy class. The school data set made available within Hazus was developed from the 2000 Public Elementary/Secondary School Universe Survey Data and the Private School Universe Survey Data, maintained by the National Center for Education Statistics (2018) and the U.S. Department of Education (. The only exception is that of South Carolina's data from 2004, which was provided by the South Carolina Emergency Division (SCEMD). Many charter schools within the entirety of the study's sample have opened since the 2000 survey and will not be included in this study, and the sample population will consist of disproportionately more traditional public and private schools.

This study will use the proprietary geocoding application used to assign geographical coordinates to each school based on its address built within Hazus. Therefore, there may be school location errors outside of the researcher's control. The schools participating in this study must also enroll students in any subset of grades K-12. Schools that only educate early childhood students and daycare centers will not be included in the sample, since they were not included in the Public Elementary/Secondary School Universe Survey Data and the Private School Universe Survey Data.

Assumptions. As Leedy and Ormrod (2010) stated, "Assumptions are so basic that, without them, the research problem itself could not exist" (p. 62). There are seven key assumptions that have helped to shape this study based on decades of scientific observation and analysis:

1. It generally agreed that scientists have high confidence that climate change is happening, and global land and sea temperatures will continue to rise, and that this rise is largely due to greenhouse gases produced by human activities known as anthropogenic climate change (IPCC, 2018; USGCRP, 2018; Kitchen, 2014);
2. Schools operate within extremely complex and multifaceted systems where important non-climate stressors affect academic outcomes (Meadows, 2008; Rippner, 2016; Shields, 2017);
3. Many of the risks associated with climate change and described in this report do not occur in isolation but may be cumulative, compounding, or secondary and some are an will continue to be unknown without additional research (USGCRP, 2018);
4. The impacts, implications, and outcomes of hurricane events can either be amplified or reduced by individual school leaders, community members, and/or societal decisions (USGCRP, 2018);
5. The extent of climate change effects on individual schools will vary over time and geographic location (IPCC, 2018);

6. Climate change presents both opportunity and risk to different districts and schools based on several variables, the most important being location (IPCC, 2018; USGCRP, 2018); and

7. As a global system, the related impacts, risk, vulnerabilities, and opportunities are linked to the changes and impacts happening outside of the United States and vice versa (IPCC, 2018).

Significance of the Study

This research is designed and conducted in response to the call from the Sendai Framework for Disaster Risk Reduction 2015-2030, endorsed by the United Nations General Assembly following the 2015 Third UN World Conference on Disaster Risk Reduction (United Nations Office for Disaster Risk Reduction, 2018). The results of this study were outlined using the four Sendai Framework priorities, with adaptations. These adaptations and modifications include changes to the published language to meet the needs of school district stakeholders, school leaders, and educational policy makers (as seen in *Figure (1.2)*.

Sendai Framework for Disaster Risk Reduction 2015-2030 The Four Priorities adapted for School Districts in Action	
Significance 1. School districts and leaders need to understand disaster risk	Disaster risk management should be based on an understanding of disaster risk in all its dimensions of school and school leader vulnerability, and capacity; exposure of the school leader, student, school, or district and other assets; hazard characteristics and the environment. Such knowledge can be used for risk assessment, prevention, mitigation, preparedness, response, and a reduction in Disaster Learning Loss.
Significance 2. School districts and leaders need to	Disaster risk governance outlined for schools at the national, regional, district, and school level is

strengthen disaster risk governance to manage disaster risk	very important for prevention, mitigation, preparedness, response, recovery, and rehabilitation. It encourages collaboration and partnership while fostering equitable access to education.
Significance 3. School districts need to invest in disaster risk reduction for resilience	Public and private investment in disaster risk prevention and reduction through structural and non-structural measures are essential to enhance the economic, social, health, and cultural resilience of persons, communities, countries and their assets, and the environment.
Significance 4. School districts and leaders need to enhance disaster preparedness for effective response, recovery, rehabilitation and reconstruction	The growth of disaster risk means there is a need to strengthen disaster preparedness for response, act in anticipation of events, and ensure capacities are in place for effective response and recovery at all levels. The recovery, rehabilitation and reconstruction phase is a critical opportunity to build back better, including through integrating disaster risk reduction into development measures.

Figure (1.2). The four priorities for action, developed by the United Nations Office for Disaster Risk Reduction (UNISDR) for the Sendai Framework for Disaster Risk Reduction 2015-2030, with modifications to meet the needs of the field of educational leadership and policy studies. (Figure source: UNISDR, 2018).

Additionally, this study responds to the call to action by the Intergovernmental Panel on Climate Change (2018), asserting that the world has until 2030 to implement rapid and far-reaching changes. This research is intended to provide specific action steps that can be used in the field of education and educational leadership as outlined.

This study provides district-level leaders with a simple school reform effort aimed to improve the safety of school buildings. This approach ensures whole system (district) safety, rather than an individual school-based approach supporting communication and collaboration across sectors. The Sendai Framework for School Leaders (UNISDR, 2018), used in conjunction with the conceptual framework for Disaster Learning Loss, may allow educational leaders to make the individual modifications necessary to reduce the unique rate of Disaster Learning Loss associated with their school and student body. As unique as these approaches can be to any one school, they all depend on the motivations and capacities of local leadership for their success. The chance of any reform reducing Disaster Learning Loss is remote unless district and school leaders agree with its purposes and understand what is required to make it work. This necessitates not only understanding but also partnership between district and school level leaders and the surrounding community to ensure proper implementation of policies and allocation of resources. For example, district leaders must be able to help their school-based leaders and colleagues understand how the externally-initiated reform might be integrated into local emergency management efforts.

Effective leadership working to reduce Disaster Learning Loss results in safer schools, effective mitigation plans, and procedures that ensure that students quickly return to school after a disaster. *Figure (1.3)* illustrates the “additive” effect of global sustainability initiatives, district- and school-level leadership, and community partners working together to reduce Disaster Learning Loss.

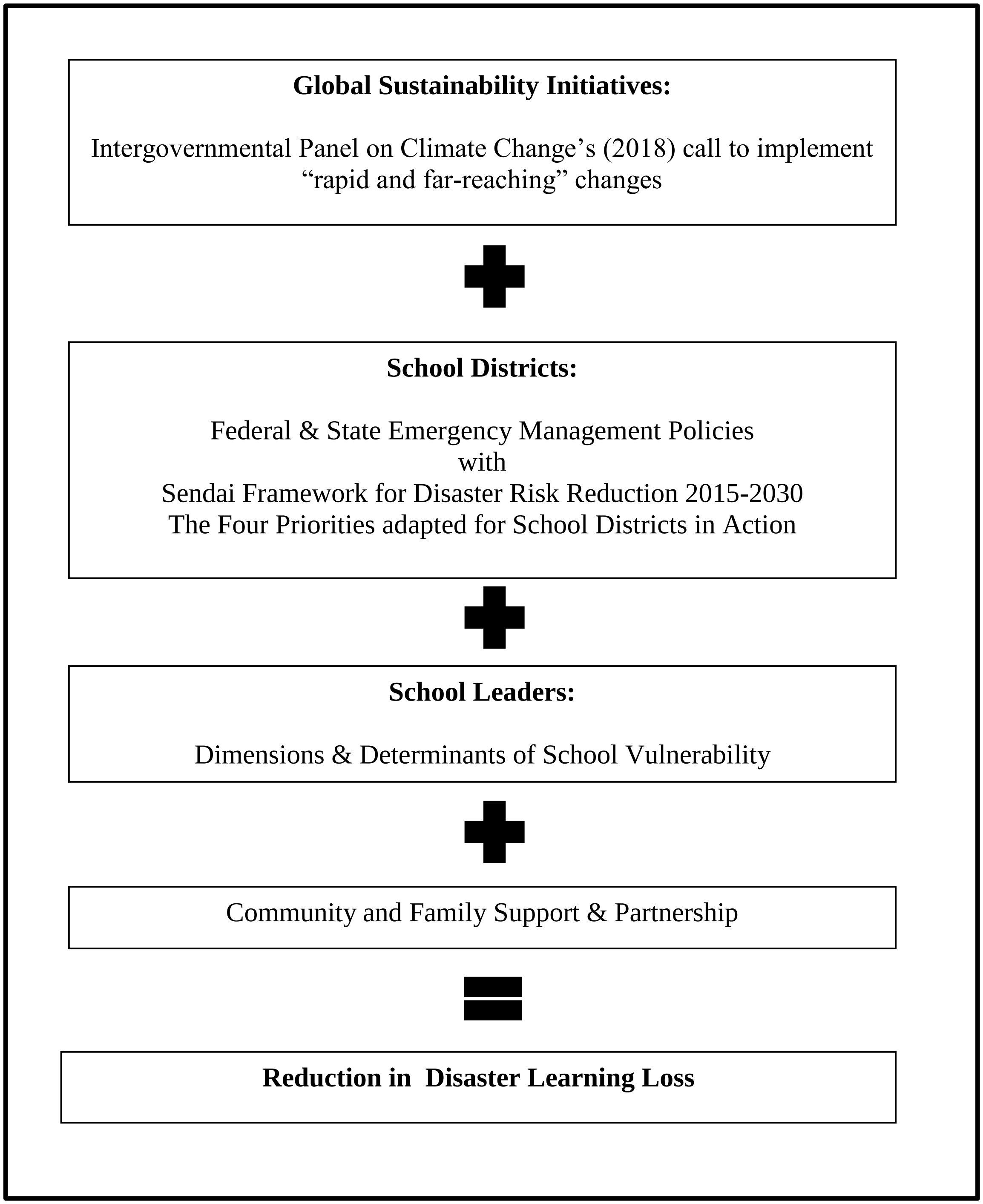

Figure (1.3). The "additive" effect of global sustainability initiatives, district and school level leadership, and community partners working together to reduce Disaster Learning Loss.

Moreover, this study incorporates geospatial analysis, risk analysis, and the FEMA database tool of Hazus. Geospatial analysis is a methodological perspective that has been frequently overlooked in education research (Hogrebe, 2012; Lubienski & Lee, 2016; Morrison & Garlick, 2017). This use of geospatial analysis with Hazus will add to the literature base through the integration of traditional quantitative methodology and spatial data (Hogrebe, 2012; Lubienski & Lee, 2017; Vélez & Solórzano, 2017). Such a combination of methods creates a transdisciplinary approach (Vélez & Solórzano, 2017), using traditional quantitative methodology already found in education research and combines it with a methodological approach used primarily in climate science, economics, sociology, geology, and marketing (Lubienski & Lee, 2016; Vélez & Solórzano, 2017). The integration of climate science with education research creates a transdisciplinary approach working to transform and strengthen the resilience of communities and individuals in hopes of creating a healthier, safer, and more inclusive future while advancing sustainable organizational and instructional practices (Kensler & Uline, 2017).

The approach used within this study will allow for an examination of the relationship between a school’s determinants of vulnerability and climate events. This methodological approach has the potential to help education researchers and practitioners gain a better understanding of how location relates to educational issues (Vélez & Solórzano, 2017), while enabling policy makers to determine patterns across context (Lubienski, Gulosino, & Weitzel, 2009).

Organization of the Study & Chapter Conclusion

Five chapters were used to organize this study. A list of the definition of key terms used in Chapter I, as well as throughout this study, was provided in Appendix A. Chapter I of this study provided background information on observations and projections of climate change in the United States and the ways in which climate change, acting in combination with other factors and stressors, influence our current education system and impact the work of school leaders. The chapter then presents information on the importance of the approaches and methods used in the quantitative projections of schools at risk from climate change. Chapter I introduces the conceptual framework that will be used to think through the study on specific climate-related impacts and exposures within the education system. Additionally, Chapter I provides context regarding how to classify factors that create or exacerbate the vulnerability of certain schools and student groups to the impacts of climate change, while identifying specific schools in the United States that may face greater risks associated with climate change due to their location. Chapter I concludes with the significance of this study for contributions to scholarly literature, the field of education, and climate and education policy.

Chapter II provides a review of the research-related climate and weather, the history of the climate change debate, the science of hurricanes, and an overview of the impact climate change has had on children, schools, and school leadership. Additionally, the chapter provides an overview of the use of GIS and Hazus in research, specifically education research. This information may help inform the quantitative methodology explained in Chapter III. Chapter IV assesses and analyzes the data and results of the study. Chapter V concludes the dissertation by answering the research questions, providing a synthesis of the findings, and introducing recommendations for policy and practice.

CHAPTER II: REVIEW OF THE LITERATURE

"The self is not something ready-made, but something in continuous formation through choice of action." John Dewey (1859-1952)

This literature review compiles and assesses current research on the United States education system and the impacts of climate change and summarizes the current state of vulnerable K-12 schools. Within this chapter, a review of the inclusion, exclusion, bounding criteria, and specific search strategies will be provided. Additionally, background information on observations and projections of climate change in the United States and the ways in which climate change, in combination with other factors and stressors, influences systems of education will be described. The review of the literature will discuss the natural hazard (hurricanes) selected for the study scenario and the benefits and use of geographic information systems (GIS) and Hazus. Additionally, this section will explain how these systems and tools are or are not used in educational research. The review of literature will also review summer learning loss as a basis for the development of the theorized term, Disaster Learning Loss (DLL). This chapter will summarize the extant literature available on the impact of climate change on school systems, current mitigation and adaptation strategies, and the vulnerability of schools. Finally, gaps and limitations in the extant literature will be presented along with, the popular yet unscientific counternarratives, and the critique of the methodology in the literature.

Inclusion, Exclusion, and Bounding Criteria

This literature review drew from a large body of scientific, peer-reviewed research and other publicly available sources. As such, the review used inclusion and exclusion criteria. The inclusion criteria dictate that the study:

a) Must be written in English;

b) Must have been published by a research journal or scientific organization within the last 15 years;

c) Must publish political affiliation (if any);

d) Must address climate change, mitigation, adaptation, vulnerability, GIS, Hazus, or policy in the field of education; and

e) Must represent research that quantifies either observed or future educational impacts associated with climate change, identifies risk factors for students, and recognizes populations that are at greater risk, and if so, must have been published between 2007 and 2018.

The geographic focus of this study is the United States. However, studies, analyses, reports, and/or observations in other countries where the findings have implications for potential U.S. impact and studies of global linkages and implications were also considered.

Exclusion criteria for the study included:

1. Politically-motivated or industry-sponsored research;

2. Studies conducted before 2007, except for seminal studies cited in multiple current studies on the impact of climate change, students' psychological or physical health in schools, or educational outcomes; and
3. Non-scholarly, non-peer reviewed, or non-scientific websites, blogs, bylines, social media postings, publications, studies, and/or news articles.

Following the recommendation of Card (2016), conference presentations and other unpublished works are included in the comprehensive literature review to better address bias, assuming they met the inclusion/exclusion criteria listed above. Additionally, several guiding questions were used in the development of this review of the literature, including:

1. How does current education literature understand and report the impact of climate change and extreme weather events;
2. How are district, school, and policy leaders responding to, mitigating, or adapting to climate change;
3. Are the political shifts around climate change impacting schools and/or students;
4. What are the benefits of GIS and/or Hazus, and how are they used in educational research; and
5. What is the impact of climate change and climate disruptions on school instruction and operation?

A variety of search strategies were used to identify potential studies for inclusion in this literature review, including:

1. Compass, the University of Denver's library search engine;
2. SAGE Premier, as a primary search database;
3. GEOBASE, a database of indexed research literature covering international geoscience literature;
4. Peer-reviewed journals that publish education, climate science, geography, and GIS-related articles; and
5. Google Scholar to identify articles not previously found in the other databases or journals.

Due to the interdisciplinary nature of this study, a large amount of relevant research was available for use. As such, both back-searching and forward-searching were used to identify the most applicable sources (Card, 2016). For each article deemed appropriate, a review of the article's references was conducted to identify additional articles on the topic. Additionally, forward-searching was used to find sources that have cited the article more recently. Much of the scientific research used was published in 2018, resulting in limited success with forward-searching.

It is important to note that this literature review includes a brief overview of observed and projected climate change impacts and the epidemiology of disasters in the United States. However, a detailed assessment of climate science is outside the scope of this report and study. Rather, this study relied on seminal, government-sponsored, and/or peer-reviewed scientific assessments of climate change and climate scenarios as the basis for describing the possible educational impacts.

Climate and Weather

To begin, it is important to understand one of the greatest misconceptions in the climate change debate today: the difference between weather and climate. Simply put, the difference between weather and climate is a measure of time. Climate is how the atmosphere ‘behaves’ over relatively long periods of time related to the statistical probability that any day during the year will be similar to the same day in previous or following years (Kitchen, 2014; NASA, 2018). Understanding climate requires recorded average weather for a particular region and time period, usually over a 30-year or longer period (Kitchen, 2014). Climate is what people expect to happen, like a hot summer in Arizona or winter snow in the Rocky Mountains. Moreover, when scientists and researchers talk about climate change, they are talking in averages of precipitation, temperature, humidity, sunshine, wind velocity, phenomena such as fog, frost, and hail storms, and other measures of the weather that occur over a long period in a specific location or region (Kitchen, 2014; NASA, 2018). Shorter-term climate variations, known as climate variability, exist (Kitchen, 2014) and are represented by periodic or intermittent changes in the Earth system, like volcanic eruptions (NASA, 2018).

On the other hand, weather is experienced day to day. It is what the conditions of the atmosphere are over a short period of time (minutes to months). The was the atmosphere is behaving is described as weather, mainly with respect to its effects upon life and human activities (NASA, 2018). Weather can be conceptualized in terms of today's temperature and humidity: if precipitation will occur, how cloudy it is, and how windy it might be (NASA, 2018).

The Climate Change Debate

The research and science behind climate change is complicated and continually evolving. There is a vast amount of literature, information, scientific studies, and research journals covering the long history and evolution of the scientific topics and concepts related to climate change, climate projections, global warming, and the climate change debate. The intention of this study is to provide school leaders with the necessary highlights and basic content knowledge, or pedagogical know-how, to make an informed decision about the intersection of climate change, local weather variations, and school safety. Therefore, the next section will not provide a comprehensive analysis of the vast scientific information available; rather, it will provide general highlights in language easily accessible to school leaders and emphasizes human interactions with the environment.

Historical context. The climate change debate is not new. In fact, we are in the middle of the second great global warming debate. The first debate began with Thomas Jefferson studying climate back in the late 1700s. On July 1, 1776, he began a twice-daily temperature record—just as he was finishing his work on the Declaration of Independence (Kendall, 2011). His recordings span 50 years. In his published 1787 book, *Notes on the State of Virginia,* Jefferson presented his findings:

> A change in our climate…is taking place very sensibly. Both heats and colds are becoming much more moderate within the memory of the middle-aged. Snows are less frequent and less deep…. The elderly inform me the earth used to be covered

> with snow about three months in every year. The rivers, which then seldom failed to freeze over in the course of the winter, scarcely ever do so now. This change has produced an unfortunate fluctuation between heat and cold, in the spring of the year, which is very fatal to fruits. (p. 88)

By 1794, Samuel Williams authored *The Natural and Civil History of Vermont,* arguing,

> [Climate] change … is so rapid and constant, that it is the subject of common observation and experience. It has been observed in every part of the United States; but is most of all sensible and apparent in a new country, which is suddenly changing from a state of vast uncultivated wilderness, to that of numerous settlements. (p. 70)

Despite being the accepted truth of the time, Noah Webster (1810), the author of Webster's Dictionary as well as a journalist, legislator, and academic, disputed the "popular opinion that the temperature of the winter season, in northern latitudes, has suffered a material change (p.119)," in his *Collection of Papers on Political Literary and Moral Subjects*. Webster asserted that Jefferson and Williams lacked the hard data and authority to draw their conclusions. Williams died a few years after Webster's publication, and despite Jefferson's continued collection of data, he never again made a case for his concerns about global warming or climate change (Kendall, 2011).

Until the second half of the 20th century, the matter was not widely discussed again (Kendall, 2011)—that is, until scientists started to link and understand the impact that greenhouse gases had on the environment (Kendall, 2011; Kitchen 2014; Kitchner, 2010). A groundbreaking paper, published in 1998 by climate scientist Michael Mann and colleagues, plotted proxy data from several sources resulting in a spatial pattern of an upturned hockey stick showing prolonged and gradual global cooling over the past 1,000 years followed by a pronounced and rapid warming in the 20th century (Kitchen, 2010). The "hockey stick" was strongly promoted as proof of human interference in the climate and was cited in many scientific papers and reports, including its prominent feature in the IPCC Third Assessment Report of 2001 (IPCC, 2001). In the years following, the hockey stick came under intense scrutiny (Holland, 2007; Kutzbach et al., 2011; Mann, 2012; Singer, 2010). Nevertheless, the science seems consistently supports the idea that anthropogenic (human-caused) climate change is happening and we are experiencing a rise in temperature on a global scale.

Scientific concepts, projections, and debates. As evidence of anthropogenic climate change continues to mount (Mitchell et al., 2006; Nissan et al., 2018), so too does concern over the impacts of associated changes in location weather and climate (Munoz, Yang, Vecchi, Robertson, & Cook, 2017; Nissan & Conway, 2018). For almost four decades, prominent climate scientists and researchers have been warning of the dangerous effects of the continual emission of greenhouse gases into Earth's atmosphere (Archer, 2016; EPA, 2018; IPCC, 2013; Melillo, Richmond, & Yohe, 2014; Mitchell et al., 2006; U.S. Environmental Protection Agency, 2016). This confounding threat, once viewed as an independent, long-into-the-future problem, is beginning to take the main stage while limited financial and human resources have been applied to tackle the developmental challenges we are seeing emerge (Nissan et al., 2018).

Current climate change predictions tend to focus on what is expected to happen this century; most climate projections extend only through the year 2100 (Archer, 2016; Nissan et al., 2018). Unfortunately, these models often neglect the even larger changes expected to take place over many centuries. It is a widely held scientific belief that generations beyond our grandchildren's grandchildren will inherit atmospheric changes and an altered climate as a result of our current decisions about fossil-fuel burning (Archer, 2016). Most decisions in both the public and private sectors involve responding to the immediate consequences and challenges or planning for the short-term future (Baethgen & Goddard, 2013; Nissan et al., 2018; Vincent et al., 2014). Based on available studies, the debates on climate change can be broadly classified into two domains: the causes and the consequences of climate change.

Seminal studies, publications, and movies have worked to combat the public's skepticism including *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming* by Naomi Oreskes and Erik M. Conway (2010); *Why We Disagree About Climate Change: Understanding Controversy, Inaction and Opportunity* by Mike Hulme (2009); *Storms of My Grandchildren: The Truth About the Coming Climate Catastrophe and Our Last Chance* by James Hansen (2009); *Science as a Contact Sport: Inside the Battle to Save Earth's Climate* by Stephen H. Schneider (2009); *The Lomborg Deception: Setting the Record Straight About Global Warming* by Howard Friel (2010); *The Climate Solutions Consensus* by David E. Blockstein and Leo Wiegman (2010); *Climate Change Science and Policy* by Stephen H. Schneider, Armin Rosencranz, Michael D. Mastrandrea, and Kristin Kuntz-Duriseti, Eds. (2010); and *The Politics of Climate Change* by Anthony Giddens (2009), to name a few. Industry campaigns and media pundits posing as experts expressing an "alternative view" have been successful in casting doubt on the consensus view arrived at by scientists within multiple relevant disciplines. This deliberate obfuscation (Oreskes & Conway, 2010) has established a network of industrial and political alliances by creating a variety of "institutes" and "think tanks" that are based on conjecture and devoted to challenging various forms of expert scientific consensus. With short-term economic gains as the primary goal, aging scientists, conservative politicians, and corporate executives (particularly those involved in fossil fuels) have worked to build broad public skepticism about climate change by denying the atmospheric impacts of carbon emissions (Oreskes & Conway, 2010).

In 2010, Philip Kitcher argued in an essay review titled *The Climate Change Debates* that,

> The major transitions in the history of the sciences, from the 16th and 17th centuries to the present, have involved intricate debates among competing research programs, among well-informed scientists who gave different weight to particular sorts of evidence. It is an absurd fantasy to believe that citizens who have scant backgrounds in the pertinent field can make responsible decisions about complex technical matters, on the basis of a few five-minute exchanges among more-or-less articulate speakers or a small number of articles outlining alternative points of view. Democratic ideals have their place in the conduct of inquiry, for it is arguable that there should be more communication between scientists and outsiders in the construction of research agendas, in the discussion of standards of acceptable risk, and in the articulation of policies based on scientific consensus. Genuine democracy, however, requires a division of labor, in which particular groups are charged with the responsibility of resolving questions that bear on the interests of individuals and societies. (pg. 10)

Political debates, concepts, approaches, and gaps. The problem Kitcher referenced above in 2010 continues today as one of the greatest challenges to communicating scientific findings about climate change: the cognitive disconnect between local and global events (Kaufmann et. al, 2017). Local weather conditions likely play a role in what people think about the broader climate (Kaufmann et al., 2017). It has been further suggested that the continued dissonance may be because early "global warming" terminology oversimplified that the climate is changing in innumerable ways (Kaufmann et al., 2017). The variability of the climate means that some places are still experiencing record-breaking cold, as in the Midwest in February 2018. Individuals living in a place where there has been more record cold weather than record heat lately may doubt reports of climate change (Kaufmann et al., 2017). Anecdotal evidence in social media and political debates indicate that denial and doubt continues. It has been informally suggested that scientists' warnings about the impact of global temperature increase are exaggerated (Kitcher, 2010). Nevertheless, climatologists including James Hansen (NASA Goddard Institute for Space Studies) and Stephen Schneider (Stanford University), have worked tirelessly to alert policy makers, politicians, and the public to the dangers of continued warming.

Just this past year, in November of 2018, the sitting President Donald Trump publicly denounced and dismissed the warnings of the potentially catastrophic impact of climate change from his own administration, comprised of 13 federal agencies and more than 300 leading climate scientists (Cillizza, 2018). The National Oceanic and Atmospheric Administration (NOAA) warned Americans to prepare for devastating impacts to the economy, health, and environment with projected climate impacts of $141 billion from heat-related deaths, $118 billion from sea level rise, and $32 billion from infrastructure damage by the end of the century, among others (NOAA, 2018). The report's very blunt conclusions and findings are directly at odds with President Trump's agenda of environmental deregulation (Davenport & Pierre-Louis, 2018), despite the report being the second volume of the National Climate Assessment mandated by Congress and made public by the White House. President Trump's comments on the report were as simple as "I don't believe it" (Cillizza, 2018). Despite his own admission that he had only read "some" of the report. In February of 2018, President Trump showed his own cognitive disconnect between local and global events when he tweeted:

Regardless of public opinion and political conjecture, multiple organizations around the globe, including more than 1,300 scientists with the Intergovernmental Panel on Climate Change (IPCC), continue to publish reports describing a world of worsening food shortages and wildfires, intensified storms including hurricanes, and a mass die-off of coral reefs as soon as 2040. According to a recent study, which looked at details of ice and snow from the entire continent of Antarctica since 1979, Antarctica's crucial ice sheet has been melting for the entire 39-year period (Rignot et. al, 2018). This recent finding challenges the traditional scientific view that the East Antarctic ice sheet is relatively stable and resistant to changes, and this finding is critically important when estimating how much seas will rise around the globe as a result of global warming. Research shows the continent holds a majority of the planet's ice and, if melted, would cause the average sea level to rise 188 feet (Rignot et. al, 2018). This suggests that current elevated carbon dioxide rates, which have risen to highs never seen by humans due to carbon pollution, are creating major changes in our natural ecosystems, which will have subsequent impacts on our social systems. As Jefferson initially noted, “an unfortunate fluctuation between heat and cold” in the spring has been “very fatal to fruits” (Kendall, 2011). Today, the fluctuations in temperature are putting more than fruit in jeopardy. To better understand the impact this reality will have on schools and children, it is important to understand the impact of climate change on hurricanes, specifically what hurricanes are, how they form, the impact hurricanes have had in recent years, and what current research indicates might happen with a continued warming climate.

Understanding Hurricanes

Hurricanes are an atmospheric phenomenon that the National Weather Service (2018) defines as a "tropical cyclone with maximum sustained winds of 74 mph (64 knots) or higher.” Be it a typhoon, cyclone, or hurricane, each of these names refer to the same type of storm system in different locations around the globe (Keller & DeVecchio, 2015). Storms in the western Pacific Ocean are called typhoons; storms in the South Pacific and Indian Ocean are called cyclones; and storms in the Atlantic and Eastern Pacific are called hurricanes (Keller & DeVecchio, 2015). Scientists often refer to all three as simply “tropical cyclones.” Due to the focused geographic location of this study being in the Atlantic and Gulf Coast region, this dissertation uses the term "hurricane." Meteorologists, researchers, and scientists will often refer to all three of these (typhoon, cyclone, or hurricane) as "tropical cyclones" (Kitchen, 2014; Keller & DeVecchio, 2015; NWS, 2018).

Hurricanes are the most intense tropical cyclones resulting from rising warm air causing clouds to spiral (Keller & DeVecchio, 2015). These massive storm systems form over warm ocean water and move toward a land mass (Keller & DeVecchio, 2015). Hazards from hurricanes can include, "high winds, heavy rainfall, storm surge, coastal and inland flooding, rip currents, and tornadoes" (NOAA, 2018). The frequency and intensity of hurricane activity is determined by many factors that involve complex interactions between the ocean and atmosphere (Kitchen, 2014; Keller & DeVecchio, 2015; NOAA, 2018).

Categories. Hurricanes are classified by their wind speed on a damage-potential scale developed by Robert Simpson, a National Weather Service meteorologist in 1973 (Encyclopedia of Natural Hazards, 2013; Pfos, & Santos, 2013). The Saffir-Simpson Hurricane Wind Scale (1973) is divided into five categories, shown in *Figure (2.1)*, based on the storm's highest 1-minute-average wind speed and estimated property damage (Keller & DeVecchio, 2015). Today, a Category 3 or higher is considered a major hurricane (National Hurricane Center, 2018). However, some researchers, meteorologists, and atmospheric and climate scientists warn that the Saffir-Simpson scale might not be the best indication of how dangerous a hurricane could be to the communities and residents living in its path (Kantha, 2006). In other words, the scale might no longer be the most useful measure to help the public understand how to make effective decisions about when to evacuate, how to properly prepare, and how to formulate relief operations in the aftermath of hurricanes (Kantha, 2006). The scale is described in *Figure (2.1)*.

Category	**Sustained Winds**	**Types of Damage Due to Hurricane Winds**
1	74-95 mph	Very dangerous winds will produce some damage: Well-constructed frame homes could have damage to roof, shingles, vinyl siding, and gutters. Large branches of trees will snap, and shallow-rooted trees may be toppled. Extensive damage to power lines and poles will likely result in power outages that could last a few to several days.
2	96-110 mph	Extremely dangerous winds will cause extensive damage: Well-constructed frame homes could sustain major roof and siding damage. Many shallow-rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks.
3 (major)	11-129 mph	Devastating damage will occur: Well-built framed homes may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes.
4 (major)	130-156 mph	Catastrophic damage will occur: Well-built framed homes can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months.
5 (major)	157 mph or higher	Catastrophic damage will occur: A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

Figure (2.1). Saffir-Simpson Hurricane Wind Scale (1973).

Recurrence intervals and probabilities of occurrences. Hurricane events are expressed through the concept of return period, which is a statistical estimator for extreme phenomena reoccurrence based on data of shorter range (Elsner, Jagger, & Tsonis, 2006; Patlakas et al., 2016; Woo, 2011). Table 1 shows some representative recurrence intervals and the associated probability of occurrence in any given year. The probability of occurrence in any given year is independent of all other events that may occur during the same interval. For example, if a hurricane event had a calculated return period of 500 years**,** this does not mean that the region will not experience a similar event for another 500**-**years, nor does it mean that the region could not experience two 500-year hurricanes in consecutive years.

Table 1

Recurrence Intervals Based on Probability of Occurrence

Recurrence Interval (Years)	Probability of occurrence in any given year	Probability of occurrence in any given year (%)
1,000	1 in 1,000	.1
500	1 in 500	.2
100	1 in 100	1

Predicting the occurrence of future extreme events from a range of meteorological phenomena is a complex task. Extreme events are, by their nature, rare. Three dimensions are often considered to help predict extreme events: event magnitude, return period, and spatial scale (Elsner, Jagger, & Tsonis, 2006; Lane, 2008; Ralph et al., 2014). Event magnitude is discussed above (with reference to *Figure (2.1)*).

The recurrence interval terminology is widely used by policymakers, risk management teams, researchers, and scientists to assess the risks associated with extreme events. Management strategies are also developed based on recurrence interval estimations. One major complication when calculating the frequency of hurricane events is that, in order to accurately assess changes in the return period of any extreme event, scientists use long-term monitoring programs (IPCC, 2017; IPCC 2013; Lane, 2008). The observation of enough of these events to form any statistically viable conclusions within research is going to take many years. With observed changes to the hydrological cycle and behavior of air masses across the globe, it is now widely expected that the magnitude of extreme events will increase based on the observed and continued predicted increase in global air and sea temperature rise (Mitchell et al., 2006; IPCC, 2018; IPCC, 2013). Many leading scientific organizations (e.g., IPCC and NOAA) have concluded in recent years that we may continue to expect more intense and frequent devastating events without drastic human-led efforts to decrease greenhouse gases and the burning of fossil fuels.

The growing devastation. According to the NOAA report (2017), a total of 16 natural disasters devastated the United States in 2017, causing an estimated $306 billion in damage. Hurricane Harvey was one of the more impactful storms that year, flooding Houston and other parts of Texas and causing more than $125 billion in damage (U.S. National Oceanic and Atmospheric Administration, 2017). The National Weather Service (2018) added two more shades of purple to its rainfall maps to effectively map Hurricane Harvey's rainfall amounts. In 2018, 22 major hurricanes smashed into land around the

Northern Hemisphere, making it the most active hurricane season on record (National Oceanic and Atmospheric Administration, 2018) and the third most active year in a consecutive series of above-average and damaging Atlantic hurricane seasons (The National Weather Service, 2018). In total, the 2018 Atlantic hurricane season featured 15 named storms, eight hurricanes, and two major hurricanes totaling $33.3 billion in damages (The National Weather Service, 2018). The season started earlier, continued later, and was less predictable than ever (National Oceanic and Atmospheric Administration, 2018).

Hurricane Lane in 2018 brought high surf, high winds, and a massive amount of rain to densely populated areas of Hawaii in late August as a Category 5 storm (The National Weather Service, 2018). Hawaii is frequently grazed by dangerous tropical storms, but it's rare for the state to be directly hit by a hurricane (Belles, 2018; Lam, 2018). However, Lane became the wettest tropical cyclone on record in Hawaii with rainfall accumulations of 52.02 inches (Lam, 2018). On Hawaii's Big Island, some regions saw rainfall totals as high as 40 inches (Lam, 2018), and damage is estimated to surpass $10 million (The National Weather Service, 2018).

Hurricane Florence developed in mid-September 2018 and made landfall over the Carolinas on September 14, becoming one of the wettest storms on record (NOAA, 2018). Despite slowing to a Category 1 before hitting land, Florence brought a devastating amount of rainfall with more than 30 inches of rain in some regions. As a result of the storm's lingering impact, more than a million people were left without power, 48 people died, and damages topped $60 billion (The National Weather Service, 2018). The mechanisms for how each hurricane develop comes from a complex string of atmospheric events, yet scientists say they are all occurring in a warmer and wetter environment (NOAA, 2018). Preliminary research has shown that Florence was especially devastating because the storm traveled across offshore waters that were several degrees warmer than the historical trend, enabling the system to become somewhat larger and deposit more rain (The National Weather Service, 2018).

A few weeks later, Hurricane Michael walloped the Florida panhandle as a deadly Category 4 storm. Michael was one of the strongest storms to hit Florida in a century and the third strongest storm on record to hit the U.S (The National Weather Service, 2018). Heading west over the Caribbean, Michael initially slowed, but the warmer-than-average ocean water temperatures in the Gulf of Mexico made it stronger. With recorded wind speeds as high as 155 miles per hour in Florida and Georgia, 34 people died, and damages were estimated to total $30 billion (The National Weather Service, 2018).

A disaster is not an event but instead a process with a temporal dimension and spatial dimension (Guan & Chen, 2014). Therefore, in the assessment of the impact from natural disasters, climate change, and extreme weather, a life-cycle and systems perspective must be taken. Using the pre-impact phase as the reference point for comparison to the during- and post-impact phases allows for a more holistic understanding (Guan & Chen, 2014; Meadow, 2008).

Climate change is not only exacerbating extreme weather events but also causing them. The research shows that the oceans have absorbed nearly all of the excess energy created by anthropogenic climate change (Mitchell et al., 2006), estimated to be 93 percent of the increase in the planet's energy inventory from 1971-2010 (Wuebbles et al., 2017). The implications are disturbing, with large impacts across all aspects of society, including education. The Intergovernmental Panel on Climate Change (IPCC, 2018) stated

> warming of the climate system is unequivocal and impacts on natural and human systems from global warming have already been observed. Evidence from attributed changes in some climate and weather extremes for a global warming of about 0.5°C supports the assessment that an additional 0.5°C of warming compared to present is associated with further detectable changes in these extremes. Several regional changes in climate are assessed to occur with global warming up to 1.5°C compared to pre-industrial levels, including warming of extreme temperatures in many regions, increases in frequency, intensity, and/or amount of heavy precipitation in several regions, and an increase in intensity or frequency of droughts in some regions. Many land and ocean ecosystems and some of the services they provide have already changed due to global warming (IPCC, 2018, Executive Summary).

Although additional research on how global warming will affect hurricanes in the long term is still needed, it has been suggested that, as ocean temperatures increase, Atlantic hurricanes may increase by 2.7–5.3% when compared to the last two decades of the 20th and 21st century (Balaguru & Judi, 2018; Wuebbles et al., 2017). As ocean waters warm and ice sheets melt, storms increase in power and move more slowly (Kossin, 2018). One of the most treacherous things a hurricane can do is slow down. As seen with Hurricane Florence and Hurricane Lane in 2018, slow-moving hurricanes can stall over land, ushering in devastating flooding that can last for days. James Kossin (2018) of NOAA published a study that found hurricanes on average have slowed by 10 percent since 1949. It is thought that a warmer atmosphere weakens tropical circulation, meaning hurricanes could continue to slow and generate more rain in the future as the world continues to warm (Kossin, 2018).

Understanding the Impact.

The problem compounds with rising seas and growing populations along the coastal regions. Higher sea levels give coastal storm surges a higher starting point when major storms approach and pile water up along the shore (Wuebbles et al., 2017). The resulting storm surge reaches higher land areas and penetrates further inland in low-lying areas. The risk is even greater if storms make landfall during high tides (Kossin, 2018; UN Atlas of the Oceans, 2018; Wuebbles et al., 2017). Growing population density on coastlines also increases the destructive and often deadly potential of hurricanes. According to a study on global population, "there is an 80% probability that world population, now 7.2 billion people, will increase to between 9.6 billion and 12.3 billion in 2100" (Gerland et al., 2014, p. 234). As the rate of population increases, so too does the demand for increased infrastructure and urbanization. To cope with the growth of new urban centers, reclamation takes place in nearby low-lying areas (Schultz, 2006). According to a NOAA (2013) report, which analyzed data from the 2010 census, 39 percent of the U.S. population is concentrated in counties directly on the shoreline or low-lying land. These high-density counties contribute an estimated $6.6 trillion to the U.S. economy each year (NOAA, 2018) but are the areas at the highest risk for the loss of human lives when an extreme weather event occurs.

Hurricane Katrina is an illuminating example. Hitting the Gulf Coast of the United States in 2005, Katrina displaced more than one million Gulf Coast residents, caused around $110 billion in damages, and resulted in the deaths of more than 1,800 people (Barbier, 2015). As is often the case in natural disasters, poor people were the most vulnerable to the destruction caused by the storm. Rescued from flooded homes, many people were sent to neighboring states where they had no family, little understanding of how to navigate systems and resources, no jobs, and no idea of how long they would be displaced. The problems though are not just the inconvenience, trauma, PTSD, stress, and uncertainty that come with displacement from natural disasters; they are also an economic toll (Kousky, 2016). For some, the cost of paying rent while displaced in addition to paying the mortgage on an uninhabitable property is inconceivable. Then, there is the additional burden of paying out of pocket for essentials—like food, water, a bed, clothing, or a car—while waiting for reimbursement from aid funds or insurance.

Tragedies like Hurricane Katrina often receive lots of attention in the moment, but interest and aid are often short lived, leaving those with less access or means in difficult situations long term. Katrina became a clear example that people who are poor and marginalized often suffer disproportionately from the effects of climate events, in part because they tend to live on low-lying land and their houses are weakly constructed (Kousky, 2016; Schultz, 2006). Individuals in these areas are also less likely to own their homes, which means that it is less likely they are eligible for assistance to rebuild.

Katrina was at one time an atypical version of a disaster, but today, similar problems are no longer affecting only a small percentage of the population (Elsner, Jagger, & Tsonis, 2006). Rather, a new report from the Internal Displacement Monitoring

Centre (2018) finds that, in 2017, more than 18.8 million people around the world were displaced from their homes due to natural disasters. Weather-related hazards triggered the majority of the displacements, with floods accounting for 8.6 million and tropical cyclones accounting for 7.5 million (Grid, 2018). Unfortunately, general awareness around the impact climate change has on communities is still relatively limited.

In 2006, *An Inconvenient Truth* hit the big screen. This American documentary film, directed by Davis Guggenheim about former United States Vice President Al Gore's campaign to educate people about global warming, sparked controversy among skeptics. The film suggested that Katrina was a consequence of global warming (Guggenheim, 2006). Since the release of the film, there has been heightened awareness of the potential risk associated with increased hurricane intensity (IPCC, 2018; NASA, 2018; USGCRP, 2018). However, research in both the social and natural sciences has been mostly devoted to increasing the ability to predict disasters and prepare for them. Curiously, there are few analyses to prepare for the aftermath of disasters. Specifically, there are even fewer analyses dedicated to preparing educational systems, and school leaders in particular, to manage the multifaceted, complex recovery and restoration process. The next section of this literature review provides an educational systems perspective of the impacts of hurricanes and natural disasters.

Disaster Learning Loss. It is true that great teaching is critical to student success, but educators have long known that the secret to a great education hinges on more than great classrooms alone (Shields, 2013). For students to succeed, they must feel a sense of security and safety, both physically and emotionally (Senge et al., 2012). Absent that foundation it is hard for students to focus, yet finding an effective balance is a complex task often falling squarely on school leaders' shoulders. School leaders must be good managers (Grissom & Loeb, 2011), while working to open communication lines within and among stakeholders, including teachers, parents, and colleagues (Hesbol, 2013). The role of the school leader is filled with conflict and ambiguity as school leaders are constantly pulled in multiple directions attempting to meet the multifaceted needs of children today (Shields, 2017; Hesbol, 2013). Leadership can be both complex and simple. Regardless of the methodological approach employed by a school leader, the essential objective is to help the organization establish a defensible set of directions while influencing members to move in those directions (Leithwood et al., 2004). Influencing members of a community to increase sustainability and mitigation efforts intended to reduce the impact of climate change is an exceptionally difficult practice that changes from school to school and district to district. To lead students, parents, staff, administrators, and the larger community in a defensible set of directions with a shared sense of belonging while developing mutual respect across diverse backgrounds (Hesbol, 2013) requires a shift in the way school leaders are currently trained. This shift starts with preparation programs that train school leaders to be prepared to manage any emergency event -- in order to prevent or minimize physical and psychological trauma to their students, staff, and surrounding community (Kano et al., 2007). This shift in training for school leaders continues with district leaders understanding the unique local impact climate change will have on their schools and how to effectively support school leaders to manage emergency situations.

Multifaceted, complex, and overwhelming to begin with, the job of a school leader only becomes even more difficult in the face of an emergency. As stated by Northouse (2013), “To be an effective leader, one needs to respond with the action that is required of the situation” (p. 296). However, few school principals cite being prepared for natural disaster emergencies. In a 2007 study exploring the preparedness of school sites in the event of an emergency, 25 percent of the 248 respondents (school administrators, certificated personnel, and classified personnel) noted that their school was not prepared for a natural disaster (Kano et al., 2007).

The fact that many schools are not prepared for the devastation of natural disasters has become increasingly evident after Hurricane Katrina. Before the 2005 hurricane, New Orleans’ School District faced extreme difficulty with governance and management problems, which were only exacerbated by Hurricane Katrina. Wracked by ineffective administration and led by numerous permanent and interim superintendents, school board meetings were often said to be contentious. Budget deficits, scandal, and corruption were just some of the concerns regularly discussed within the community (Sims & Rossmeier, 2015). When Hurricane Katrina made landfall in New Orleans on August 29, 2005, it was the beginning of a new school year. All public-school students, as well as the entire school system’s staff, were forced to evacuate the city. Wind and flooding from the hurricane further battered the city’s already dilapidated school facilities. As flood waters receded, school and district leaders were unprepared for how to manage the devastation as uncertainty surrounded the future of the school system. Few school leaders were equipped to understand the process forward, let alone know when, or even if, schools would reopen (Sims & Rossmeier, 2015).

The majority of schools were significantly damaged or destroyed, making them unusable for future operations. Months before Hurricane Katrina, the school system was on the brink of becoming bankrupt. After the storm, the Louisiana Legislature voted for a state-run Recovery School District (RSD) to assume responsibility for most public schools in New Orleans (Sims & Rossmeier, 2015). That decision led to New Orleans having the most decentralized public-school system in the country, with 93 percent of public-school students attending charter schools by fewer than 10 years after the storm, the highest rate of any city in the country (Beckett, Mohr, Verma, & Hesla, 2019; Sims & Rossmeier, 2015). The recovery efforts and policy reforms that were undertaken in the wake of Hurricane Katrina reshaped the entire educational environment including greater access to district-owned facilities, lower facilities costs for charters, new governance structures, access to new, renovated, or refurbished facilities for every student in the New Orleans Parish, and the implementation of school improvement plans for schools throughout Louisiana (Beckett, Mohr, Verma, & Hesla, 2019).

The School Facilities Master Plan was one of the largest school disaster recovery programs in the United States, with nearly $2 billion dedicated to facility repairs and construction funded by FEMA (Louisiana Department of Education, 2018). Since the early days after Hurricane Katrina, New Orleans has experienced numerous changes to its governance structures in order to maximize school effectiveness and student success and to mitigate the inherent challenges (Beckett et al., 2019; Sims & Rossmeier, 2015).

However, the lessons learned, and policy changes implemented in New Orleans Parish have yet to extend to nationwide reform efforts working to ensure a reduction in Disaster Learning Loss.

Whereas hierarchical command and control is not easily achieved in the calmest of times, early establishment of mitigation plans, district networks of support, and an understanding of the impact climate change has on schools can provide a plausible path for productively organizing the diverse expertise needed to solve the complex educational problems faced in a school emergency (Bryk, Gomez, & Grunow, 2010). District and school leaders effectively working together to arrange human and technical resources so that the entire school community is capable of getting better at getting better (Bryk, Gomez, & Grunow, 2010; Englebart, 2003) can lead to effective mitigation plans that prioritize student safety while reducing Disaster Learning Loss.

There are significant constraints or hurdles to be addressed at many levels to ensure student safety, yet the fact remains that the group most often overlooked in disaster research and management is school leaders. In Leadership for Green Schools (2017), Drs. Lisa Kensler and Cynthia Uline highlight the need for school leaders to consider sustainability within their daily practice by saying,

> the urgent need for sustainability science to find answers and influence practice results from a long list of ecological, social, and economic challenges confronting humanity today. These challenges include climate change, natural disasters, biodiversity loss, population growth, social inequities and economic crises, all of which have become common features in our daily news. Such challenges relate to individual behaviors as well as regional and global patterns of behavior, the results of which often transcend state, national and even cultural borders. Addressing these profound challenges requires we shift our fundamental worldview from one that sees humankind as separate from and conquerors of

> nature, to one that sees humankind as integral with and dependent upon nature. (p. 6)

Kensler and Uline (2017) argue that schools are deeply interrelated, interdependent, and nested within our ecological, social, and economic systems. Schools and economics cannot, and will not, exist without healthy environments and ecosystems—they are integral to our collective future. In spite of this, we've overexploited our environments while underutilizing them, subsequently putting our schools and future generations at risk. It can be argued that most school leaders are deeply invested in the long-term success of all their students (Rippner, 2016; Shields, 2017; Wagner, 2010). They just lack the understanding and instruction of the connection between ecosystems services and student achievement. For principals to be effective, they must receive proper training, support, and resources from their district partners (Anderson & Reynolds, 2015) and display self-confidence when managing the difficult and multi-faceted conditions that lead to Disaster Learning Loss. Effective leaders appear to display self-confidence in a multitude of situations (Northouse, 2013). With self-confidence comes appropriate decision making. By providing school leaders with the necessary information about the associated risks to their school based on location, extreme weather, climate change, and sustainability practices, school leaders will be better able to act with self-confidence in an emergency and to challenge the status quo, while increasing capacity and knowledge and mitigating risks.

Leadership preparation is part of an ongoing process of developing successful principals (Anderson & Reynolds, 2015). Integrating the necessary information about sustainability, the power of community networks, and climate change into high-quality preparation programs may result in principals who are better trained and prepared to lead more successful schools. Education leaders are well suited to be at the forefront of leading community restoration after a natural disaster by modeling new ways of living in the world through the hidden and written curriculum (Kensler & Uline, 2017). A leader's basic competencies are explained by effective problem solving and performance, and these competencies are in turn affected by the leader's attributes, experience, and external environment (Northouse, 2013). As noted by Senge (2006), "There is something in all of us that loves to put together a puzzle, that loves to see the image of the whole emerge" (p. 68). Without the inclusion of sustainability, climate change, and the associated risks of extreme weather, principals will continue to lack the whole image.

The barriers to more widespread adoption of such practices include different priorities, lack of funding, and lack of political will, (IPCC, 2018) as well as lack of systems thinking (Senge, 1990; Senge, 2006; Meadows, 2008) and information about climate change integrated into leadership preparation programs. Today, systems thinking is needed more than ever because we are becoming overwhelmed by complexity (Meadows, 2008). The deep responsivity for cultivating education conditions requires school leaders to heed the scientific warnings and interrelated crises facing our school systems (Kensler & Uline, 2017).

As highlighted earlier in this chapter, anthropogenic climate change is projected to increase global temperature and the frequency of extreme weather events (Kitchen, 2014). In light of this projection, school systems need to explore current and future practices to ensure they are meeting the future needs of schools and students including rebuilding more resiliently and minimizing damage from future storm events. We need to do things differently if we are to implement changes that will rectify inequities not exacerbate them and create a more level and more optimistic playing field (Shields, 2017). This starts with understanding how climate change will impact children and youth in and out of school. It is inevitable that future school leaders will require the necessary skillset to implement precautionary and safety measures against hazard in the classroom, school, home, and community. If given the proper preparation training, school leaders will have the ability to think creatively and laterally, while making ethical judgments about present and looming disaster situations so they can identify and facilitate opportunity within crisis. Much more work and research is needed to improve emergency preparedness and compliance with pertinent laws along with the development of new policies intended to protect all students (Kano et al., 2007).

Impact on children and youth. A large base of scientific research has indicated that climate change is real, and our children are at the greatest risk (IPCC, 2018; Kitchen, 2014; NOAA, 2018; UNICEF, 2018). Natural disasters are increasingly threatening human health, access to resources, and overall well-being in the United States. Many scientific research centers, nonprofit organizations that operate independently of any government, and government-sponsored programs have been established over the last decade to enhance the understanding of how climate change affects children and youth as well as to improve ways of informing decisions about this growing threat. A consistent finding in the research calls for significant changes to be made in all areas of leadership to ensure the safety and prosperity of future generations (IPCC, 2018; UNICEF, 2018; United Nations Office for Disaster Risk Reduction, 2018). This call should be heard loudly in the field of educational leadership, yet current research on the matter is still deficient.

Nevertheless, it is well understood that, when a weather-related disaster occurs, school systems are disrupted, and families are often forced out of their homes for extended periods of time, which threatens a child's fundamental right to education. A growing body of research acknowledges that migration due to climate change is real (IPCC, 2015; UNICEF, 2018). In 2008, The International Organization for Migration developed a working definition of "environmental migrants" for peoples displaced by climate change, but general adoption of the definition is lacking:

> Environmental migrants are persons or groups of persons who, predominantly for reasons of sudden or progressive change in the environment that adversely affects their lives or living conditions, are obliged to leave their habitual homes, or choose to do so, either temporarily or permanently, and who move either within their country or abroad. (IOM, 2008)

When communities become displaced by climate disruption, they become known as climate migrants (UNICEF, 2018), referred to as student migrants in this study. Children within these displaced communities are deprived of their schools and therefore future opportunity. These student migrants are the children who have been pushed out of the areas they grew up in, whose schools have been destroyed, and who have little hope for return. These are the children with limited or no options for quickly reenrolling in a new school. These student migrants are deprived of the necessary skills to complete their education and compete effectively in the market and are subsequently left without equitable opportunity.

It's clear that natural disasters and climate shocks affect children through many interrelated pathways, including interrupting children's education by displacing families, increasing student absenteeism, causing PTSD, destroying schools, and pushing children into the labor force early (Kousky, 2016). Looking across the research, natural disasters harm children's physical and mental health and disrupt their education (IPCC, 2018; Kousky, 2016; UNICEF, 2018) resulting in lower academic outcomes. According to the UNICEF (2012) report on disaster risk reduction in school curricula, "Developmental gains in education are reversed with the damage or destruction of school facilities, the prolonged disruption of education, limited access to schooling, and decreased education quality" (p. 4).

Natural disasters do not discriminate, but hasty recovery strategies resulting from poor preparation and underprepared school leaders will. If schools, school districts, and states are to improve educational achievement and ensure successful student outcomes in the future, they will need to address chronic absenteeism caused by climate disasters (Bruner, Discher, & Chang, 2011; IPCC, 2018; UNICEF, 2018; United Nations Office for Disaster Risk Reduction, 2018). The best way to do this is to provide school leaders with the information they need to understand the risks posed by climate change to their schools. Researchers in the field of educational leadership need to consider the factors, impacts on, implications for, and risks to social justice and equity in schools by adopting a broader understanding of the changes (adaptations) that will come as a result of climate change, including long-term academic performance, student mitigation, and return-to-school strategies.

Although people experience climate change differently, some research suggests there may be positive effects on communities and children by creating shared experience and "galvanizing creative ideas and actions in ways that transform and strengthen the resilience of and creativity of community and individuals" (Fritze, et al., 2008, p. 9). Nevertheless, education comes about through experience, but that should never mean that all passive or active experiences are genuinely or equally educative and some are actually mis-educative (Dewey, 1938). Accordingly, research shows climate disruptions often lead to negative academic outcomes, resulting from negative psychological and mental health outcomes (Fritze, 2008; Swim et al., 2011). Fritze and colleagues (2008) highlighted a number of these negative psychological and mental health outcomes including,

> posttraumatic stress disorder (PTSD); other stress-related problems such as complicated grief, depression, anxiety disorders, somatoform disorders, and drug and alcohol abuse … higher rates of suicide attempts and completions; elevated risk of child abuse; and increased vulnerability of those with pre-existing severe mental health issues. (p. 10)

Research also suggests that children often exhibit more severe distress after climate disruptions and disasters than adults do (Crimmins, 2016; Fann, 2015; Fritze, 2008; Swim et al., 2011).

The root causes of weak educational attainment at the upper secondary level are usually attributed to limited initial access to education resulting from conflict and climate disruptions (UNICEF, 2018). An abundance of scientific reports highlights the devastating impact extreme weather is having on our communities across the country (IPCC 2018; NOAA, 2018; UNICEF, 2018). Hurricanes are devastating because of the extreme damage to property, destruction of infrastructure, and toll of human lives. Hurricanes can devastate a school building by tearing off roofs, flooding gymnasiums, destroying classrooms, breaking windows, and leaving behind mold, mud, and debris. Many children have no idea what the future holds in the aftermath of a hurricane. Loss and displacement after a climate shock can affect children for years after (Crimmins et al., 2011).

The inherent characteristics of children, families, schools, principals, communities, countries, and the disaster itself, influence the overall impact and response (Crimmins et al., 2011; IPCC, 2018). However, across the research, the greatest impacts on children vary due to socioeconomic conditions, local institutions, and political realities that influence disaster response and recovery (Kousky, 2016). This variation makes it difficult to clearly identify causal linkages. Regardless of the variations that exist, it is critical that high risk areas are identified (including communities, schools, districts, and students) to ensure mitigation plans are in place for acquiring the essentials necessary for returning to normalcy as soon as possible after a disaster (UNICEF, 2018).

In 2018, Hurricane Michael led to devastating floods in Florida that destroyed hundreds of schools (FEMA, 2018). It was estimated that at least 539 schools were in the direct path of Hurricane Michael in 2018 (FEMA, 2018). Schools in 21 Virginia counties and eight in Florida closed due to flooding and power outages related to the storm (Balingit, 2018). School buildings were transitioned and used as shelters, as children and their parents slept in school hallways, taking shelter from the hurricane, which rendered classrooms inoperable (Balingit, 2018). In Panama City, Florida, an official posted to the school system's Facebook (2018), "We do not yet have a timeline for returning to school because we have not been able to complete a damage assessment on our buildings let alone make plans for repairs. Much of the county is still without power and there is little to no cell service in town." These school closings come just a year after hurricanes forced the cancellation of classes in Houston and Puerto Rico, where dozens of schools were closed permanently because of damage or flagging enrollment (Balingit, 2018).

A growing body of evidence continues to show an overall reduction in student academic performance and educational attainment along with higher rates of absenteeism among children who have experienced climate shocks (Crimmins et al., 2011; IPCC, 2018). Research examined children's mental health after Hurricane Katrina in 2005 and found that those who had experienced the climate shock reported higher rates of PTSD symptoms as well as other negative mental health impacts and behaviors, such as aggression in adolescents (Marsee, 2008).

It is estimated that only about 26 percent of adolescents from countries affected by natural disasters reach upper secondary school (UNICEF, 2018). Climate events disproportionately affect high-risk, low-income, and vulnerable students (IPCC, 2018). This pattern is particularly alarming as year-over-year data recordings and future climate models suggest that climate-related disruptions are increasing in frequency and intensity (IPCC, 2018; Kitchen, 2014; NOAA, 2018) subsequently putting more schools and students at risk. At the same time, research has suggested the phenomenon of high school dropouts may have roots in a school's ecological health (Kensler & Uline, 2017). Kensler and Uline said, "The quality and state of the school facility communicates the degree to which communities value and care for their next generation. Students notice these messages as they relate to themselves and their peers across town" (p. 32). After a disaster, only some schools are able to reopen, due to disproportionate access to capital or disproportionate awareness of risk. Subsequently, school leaders' ability to prepare or adapt before the disaster can communicate significant messages to students that have already been historically and systematically marginalized by the education system. Such facts, as well as current climate predictions, are why climate activists have long linked their cause to wider concerns around social justice and equity. This is also why school leaders need to take note of climate change risks and additional research needs to be conducted to equitably prepare all school leaders.

The potential consequences of climate events on education will require researchers and policymakers to focus their attention on the links between climate change and student achievement and the potentially devastating implications (IPCC, 2018). Inaction has already cost billions of dollars in cleanup efforts, displaced thousands of people, and caused even more extensive trauma. Policy makers and school leaders need to heed the early warnings and create systematic change at every level to mitigate the devastating consequences of climate change while ensuring our country's most important assets, our children and young people, are able to continue their educational pursuits. Sadly, but also optimistically, many natural disaster impacts are preventable in the sense that we can change policy and increase the ways school leaders understand how to lessen the harm climate events and disasters do to children. Sound policies for protecting students and school facility assets require good information about vulnerability to hurricane events.

Impact on education policy. Over the last 25 years, states have taken back much of their constitutional authority over education policy (Fowler, 2013). Within the broad policy guidance of the separate states, state policy actors are considerably more important than federal or local ones as individual school districts are tasked to make the crucial decisions that dictate a school's resiliency and safety standards (Fowler, 2013; Rippner, 2016; Young & Diem, 2016). However, a variety of speculation around climate change has made it difficult to enact widespread policy change or to connect education policy with climate change in an effort to ensure student safety from increased extreme weather and climate events. Nevertheless, education policy is intended to guarantee the systems and structures established promote student safety and high academic standards (Rippner, 2016; Young & Diem, 2016).

Climate change is observed and measured on long-term time scales of 30 years or more (Kitchen, 2016), while decision frameworks for school officials, districts, and regional planners are often based on much shorter time scales (Fowler, 2013; Rippner, 2016). Often, school policy is in response to epidemiological, local, regional, or state political shifts or budgeting factors (Rippner, 2016); many policies are a result of, or in response to, a specific situation or individual legislators acting as the most important actors in the education policy process (Fowler, 2013; Rippner, 2016). Usually the most influential individual legislators are members of an education committee as every state legislature has at least one education committee. These committees are tasked to develop education laws, review existing legislation, and hold hearings on education policy issues (Folwer, 2013). Because education is a major budget item in all states, the members of the finance committee are highly influential throughout the policy making process (Fowler, 2013; Rippner, 2016).

Subsequently, and in response to the increased price tag associated with extreme weather events, recent policies have focused on enhancing the safety of rural and urban communities by retrofitting and reconstructing vulnerable school buildings (FEMA, 2018). However, limited resources make this difficult to enact on the scale needed to ensure every school building is properly fortified, and access to adequate school facilities is a continued barrier. The U.S. school system is built on the reliance of local tax and spending policies that follow distinct jurisdictional lines and delegates the responsibility for running schools to local school districts (Hanushek, 2014; Rippner, 2016; Young & Diem, 2016). This organization of school funding creates significant shortfalls in available support after a large-scale natural disaster event, as evidenced by the impact on the facilities in the New Orleans Parish from Hurricane Katrina in 2005 (Beckett, Mohr, Verma, & Hesla, 2019; Sims & Rossmeier, 2015). Hurricane Katrina significantly damaged or destroyed most school buildings, rendering many of them unusable, and created emergency policy shifts that have transformed—and will continue to transform—the educational policy landscape in the area (Beckett, Mohr, Verma, & Hesla, 2019; Sims & Rossmeier, 2015). Even with the $1.8 billion dedicated to facility repairs and construction funded by FEMA (Louisiana Department of Education, 2018), many are concerned there are not enough preventative measures and policies to ensure that similar situations do not happen in the future, since less than four percent of global humanitarian pleas are dedicated to education (UNICEF, 2018).

These shortfalls in preventative funding for education in emergencies have a devastating impact on children's hope for a better future. Current research suggests policy actions needed to mitigate and adapt to human caused climate change have been framed by continual observations of the past 150 years, as well as alarming climate and sea-level projections for the twenty-first century (Clark et al., 2016). This extensive research points to clear evidence that greater attention should be given primarily to near-term impacts, as well as establishment of policies that ensure student safety from future impacts (IPCC, 2018). Funding of education system recovery in emergencies lacks prioritization, which potentially leaves a generation of children affected by disaster without the skills they need to contribute to their communities and economies, exacerbating what is already a desperate situation for millions of children and their families (UNICEF, 2018).

Schools are far more than a place for teaching children: They serve as community strongholds, design centers, and community builders, and they are often seen as the steward or center of the community (Hesbol, 2013; Murphy, 2002; Senge et al., 2012; Shields, 2013; Skrla, McKenzie, & Scheurich, 2009). They are the places working toward the development of an inclusive learning community, and they often serve as a focal point for a community's social and cultural life (Hesbol, 2013). Serving many critical functions within the communities where they are located, the complete loss or temporary closure of a school building can severely disrupt the social fabric of a community. For example, school buildings often serve as designated shelters for displaced families after a natural disaster (FEMA, 2018). Even when they may not be a designated shelter, school policy across the country is that if children cannot be returned home safely, they must be sheltered in place in the school until parents can pick them up (FEMA, 2018). So even if a school is not officially designated as a shelter, school policies have made them into de facto shelters.

As climate change places more schools at risk from extreme weather events, there is a call for education research to reconceptualize its idea of school safety and mitigation efforts (FEMA, 2018). Researchers should adopt a broader understanding of the impact climate change will have on educational leadership and policy, and they should design research studies that examine the role school leaders play in natural disaster response, recovery, and mitigation. Additional research is also needed that supports school leaders in receiving the information and training necessary to understand the risks, impacts, and implications to students missing school for extended periods of time after a disaster.

Research on Learning Loss

Cooper et al. (1996) conducted a research synthesis of 39 studies examining the effects of summer vacation on standardized achievement test scores. The statistical integration included 13 of the 39 studies. The resulting meta-analysis indicated that summer learning loss equaled at least one month of lost instructional knowledge, meaning children's tests scores were at least one month lower when they returned to school in fall than scores were when students left in spring. The authors speculated that, without practice, facts and procedural skills are most susceptible to being forgotten. Moreover, the meta-analysis revealed that all students, regardless of the resources in their home, lost roughly equal amounts of math skills over summer. However, substantial economic differences were found for reading. On some measures, middle-class children showed gains in reading achievement over summer, but disadvantaged children—defined by substantial economic differences, including some students of color and students with disabilities—showed losses. Reading comprehension scores of both income groups declined, but the scores of disadvantaged students declined more. The authors believed that income differences could be related to differences in opportunities to practice and learn reading skills over summer, with more books and reading opportunities available for middle-class children.

It is theorized that the same principles would be true for student migrants displaced by natural disasters and unable to attend classes. The development of Disaster Learning Loss (DLL) would quantify the amount of time student migrants would be unable to practice, including retaining the facts and procedural skills most susceptible to forgetting. This initial study would provide the framework needed to identify the determinants of vulnerability that schools, students, and school leaders face, which exacerbate or lessen the amount of instructional time lost from natural disasters. Moreover, the study can help establish whether natural disasters disproportionately impact the time certain populations of students are out of school.

The next section of the review of the literature will discuss prior studies on the geospatial perspective, geographic information system (GIS), and Hazus concepts and will also introduce the foundations of the literature for Disaster Learning Loss (DLL).

Geospatial Perspective & GIS

Extreme weather resulting from climate change and subsequent school closures can take on varied spatial signatures. Kousky (2016) explains, “Spatial variation is important for estimating disasters’ effects because damage from a disaster is a function not only of the event itself but also of where and how societies build—and the resources available to recover and respond” (p. 75). Although an understanding of the individual-level factors associated with vulnerability is essential to assessing student and school risk (as outlined in the conceptual framework in chapter I), an understanding of how potential exposures and data overlap with the geographic location is critical for designing and implementing appropriate adaptations strategies (Hogrebe, 2012; Lubienski & Lee, 2016; USGCRP, 2016). After all, what occurs at a school or district will vary according to differences in community and neighborhood context (Hogrebe, 2012).

Despite its importance, geospatial analysis and understanding the role of neighborhood context in education remains understudied as a methodological perspective in education research (Hogrebe, 2012; Lubienski & Lee, 2016; Morrison & Garlick, 2017; Wei et al., 2018). In turn, this leaves out a large portion of relevant data on educational outcomes and the factors that influence these outcomes, resulting in a lack of holistic understanding of the variation that exists within the data (Hanushek, 2014). However, location and opportunity are so thoroughly intertwined that spatial analysis must be considered when properly assessing children and education (Hanushek, 2014). The best way to incorporate a geospatial perspective and analysis is through the use of geographic information system (GIS) technology, which can identify and find patterns in data across different geographic contexts through the production of cartographic maps (Lubienski, Gulosino, & Weitzel, 2009).

Cartography, the study and practice of making maps, and the production of cartographic maps (McMaster, Kessler, & Howard, 2009) has become digitalized, and the creation of computer software (GIS) has enabled geographers and researchers to more accurately study issues of space and place (Vélez & Solórzano, 2017). GIS is a framework for gathering, managing, and analyzing data. By integrating many types of data, it analyzes spatial location and constructs layers of information into visualizations using maps and 3D scenes (ESRI, 2018; Vélez & Solórzano, 2017). Once the data has been transformed into visualizations, it is easier to determine if there are spatial relationships in the data than simply observing an abstract frequency distribution curve (Hogrebe, 2012; Morrison & Garlick, 2017). This inductive approach to research reveals deeper insights into data, such as patterns, relationships, and situations (Goodchild & Janelle, 2004).

GIS has created several simultaneous revolutionary changes in the way that data can be managed (Clarke, 2011). It has been widely adopted by hundreds of thousands of organizations in virtually every field to make maps that communicate, perform analysis, share information, and solve complex problems (Lubienski & Lee, 2016; Morrison & Garlick, 2017; Vélez & Solórzano, 2017).

GIS has been used in education research to examine the role of space and place in education outcomes, gain actionable intelligence from all types of data, and uncover trends related to the social, cultural, political, and historic aspects of children and schools (Vélez & Solórzano, 2017). Regrettably, in the field of scientific research, it is believed that humanities scholars lack the technical and managerial expertise to apply GIS technologies effectively (Clarke, 2011; Hogrebe, 2012; Lubienski & Lee, 2017). As such, it has not been widely adopted by the field to date (Lubienski, Gulosino, & Weitzel, 2009). However, the development of GIS continues to provide a multitude of opportunities for research and teaching across a wide variety of academic disciplines including education and educational leadership. It is proven to be a tool that effectively complements multiple types of research methodologies (quantitative and qualitative approaches).

Geographic Information System mapping technology. GIS technology integrates geographic science with tools for understanding and collaboration. Maps developed within GIS are the geographic containers for the data layers and analytics within a study. The technology integrates different kinds of data layers using spatial location including imagery, features, and base maps linked to spreadsheets and tables. The system then performs spatial analysis allowing for research evaluation, suitability and capability analysis, estimations and predictions, and interpretation. Due to the complexity of incorporating multiple factors and their complicated interactions, the geospatial context of location may serve as a proxy variable to better represent effects (Hogrebe, 2012). This process allows researchers to ask additional questions about their data, refine their understanding, and further investigate why relationships are occurring (Morrison & Garlick, 2017). GIS then uses an inductive approach to research through the visualizations using maps and 3D scenes based on findings (Goodchild & Janelle, 2004). The visualization rarely requires a specialized or advanced statistical background, helping to ensure that the findings from a study are more accessible and engaging to the public than traditional data displays (Fombuena, 2016; Vélez & Solórzano, 2017). Once the data has been transformed into visualizations through maps, it is easier to determine if there are spatial relationships in the data than simply observing an abstract frequency distribution curve (Hogrebe, 2012; Morrison & Garlick, 2017). Moreover, the creation of maps produces a comprehensive understanding of how space impacts individual lives in education (Vélez & Solórzano, 2017). Finally, the technology incorporates apps and plug-ins, including Hazus, to provide focused user experiences.

Even though the use of GIS in education is still in its infancy, there are several studies that have successfully used GIS as a methodological approach to answer some of the most difficult questions facing education today including:

- an examination of school choice opportunities and equitable access for students in the Detroit, Washington, D.C., and New Orleans areas by Lubienski, Gulosino, & Weitzel (2009);
- a dissertation studying educational leaders' perception of spatial thinking by Branch (2009);

- an examination of school competition as part of the school choice process for schools in Missouri by Misra, Grimes, & Rogers (2012);
- a mixed methods study examining the school choice patterns of urban families by Yoon and Lubienski (2017);
- an analysis of the opportunity and access to advanced mathematics courses in school districts across Missouri by Hogrebe and Tate (2017);
- a dissertation exploring principal turnover in the Denver Metropolitan area by Beckett (2017);
- a study using qualitative methods and GIS to visualize representations of undocumented Latinx people's experiences in South Phoenix by Hidalgo (2017);
- a study using crowdsourced GIS data to georeference child well-being by Dalyot & Dalyot, (2018); and
- an analysis exploring the intersection between neighborhoods, race and educational inequity using ordinary least squares (OLS) regression, spatial filtering regression, and geographically weighted regression (GWR) to explore determinants of student performance in Salt Lake County by Wei et al. (2018).

GIS can highlight how geographic or spatial features can limit access to educational opportunities (Vélez & Solórzano, 2017) especially in disaster management scenarios. The integration of traditional quantitative methodology and spatial data—used primarily in climate science, economics, sociology, geology, and marketing—in combination with educational data creates a transdisciplinary approach, strengthening education research (Hogrebe, 2012; Lubienski & Lee, 2017; Vélez & Solórzano, 2017).

One way to improve planning, policy, and mitigation and to understand resource allocation is accomplished by way of assessing exposure, vulnerability, and risk. In other words, a current status quo with some measurable landscape of people, students, and schools currently exists, allowing a "what-if" analysis to be conducted. In the case of this study, the question is, what is the impact on school instruction days if a hazard occurs? The best way to answer this question in studying the spatial variation of the phenomenon is through a geographic information system (GIS). Within this study, improved GIS capabilities combine different elements of vulnerability, providing school leaders with ways to visually consider the risks associated with their individual school (Ballas, Clarke, Franklin, & Newing, 2018).

In the case of this study, a GIS-based decision-support tool, Hazus, helps to integrate both the physical and social components of school and district risk while leveraging interdisciplinary data and information to quantify potential outcomes. This GIS-based loss estimation methodology will compute the associated impacts on school buildings, infrastructure, and vulnerable student populations resulting from hurricane scenarios. Additionally, Hazus will explore the relationship between the spatial phenomenon of hurricanes and the determinants of vulnerability leading to Disaster Learning Loss (DLL).

***Hazus Hurricane Model*.** Hazus is an industry-recognized and standardized methodology for assessment of potential losses from floods, earthquakes, and hurricanes (Nastev & Todorov, 2013). The Hazus software application is provided by FEMA free of charge to Geographic Information Systems (GIS) professionals, mitigation planners, emergency managers, risk analysts, and others engaged in disaster loss estimation (FEMA, 2018a, 2018b). The purpose of the software is to enable users to “anticipate the consequences of hurricanes, develop strategies for reducing risk, and mitigate the effects of hurricane winds” (FEMA, 2018a, p. 1). The software built for GIS combines science, engineering, and mathematical modeling with GIS technology (Nastev & Todorov, 2013) and can be applied to small and large geographic areas with the ability to select from a wide range of population characteristics (FEMA, 2018a, 2018b).

The Hazus hurricane model represents significant advancement over other hurricane loss prediction models in that it estimates a number of factors, including wind-induced loads, building response and damage, and loss. Other systems simply use historical loss data to model loss as a function of wind speed (Vickery et al., 2006). This model has provided practitioners and policymakers alike with a tool to reduce damage and improve the allocation of the nation’s emergency management resources (FEMA, 2018a, 2018b), while providing a visual depiction that promotes the necessary communication and interaction among end-users (Nastev & Todorov, 2013). Hazus has been used in the assessment step in the mitigation planning process, which is the foundation for a community's long-term strategy to reduce disaster losses and break the cycle of disaster damage, reconstruction, and repeated damage.

The software uses a peer reviewed model and simulates the entire disaster (Ding, et al., 2008; Neighbors et al., 2013; Vickery et al., 2000a, 2000b; Vickery et al., 2006). Hazus uses a hazard-load-resistance-damage-loss methodology (FEMA, 2018a), which "provides the framework needed to reliably examine the effect of mitigation in a quantitative manner by modeling building components with increased resistances" (Vickery et al., 2006, p. 82). Potential loss estimates available to be analyzed within Hazus include:

- Physical damage to schools, critical facilities, and infrastructure;
- Economic loss, including school closure days, business interruptions, repair, and reconstruction costs;
- Social impacts, including estimates of shelter requirements, displaced households, and population exposed to scenario hurricanes (FEMA, 2018a).

Inventories available for selection within Hazus include population, demographic, and infrastructure data (FEMA, 2018a, 2018b; Remo, Pinter & Mahgoub, 2015). In previous studies, Hazus has been shown to be capable of producing reasonable risk assessments using the default data inventory (Ding et al., 2008; Neighbors et al., 2013; Pei et al., 2017; Remo, Pinter & Mahgoub, 2015; Vickery et al., 2006; Vickery et al., 2000a, 2000b). FEMA has run the Hazus program for more than two decades (Hazus Website, 2018; Nastev & Todorov, 2013) and has been used and validated by academics, industry professionals, and researchers alike. The overall conceptual approach taken in the development of the Hazus model is illustrated in *Figure (2.2)*. This model shows how the

Hazus Inventory is incorporated with the hazard under consideration leading to the Natural Hazards Impact Assessment and Risk Evaluation and Engineering Assessment, allowing for mitigation plans to be developed.

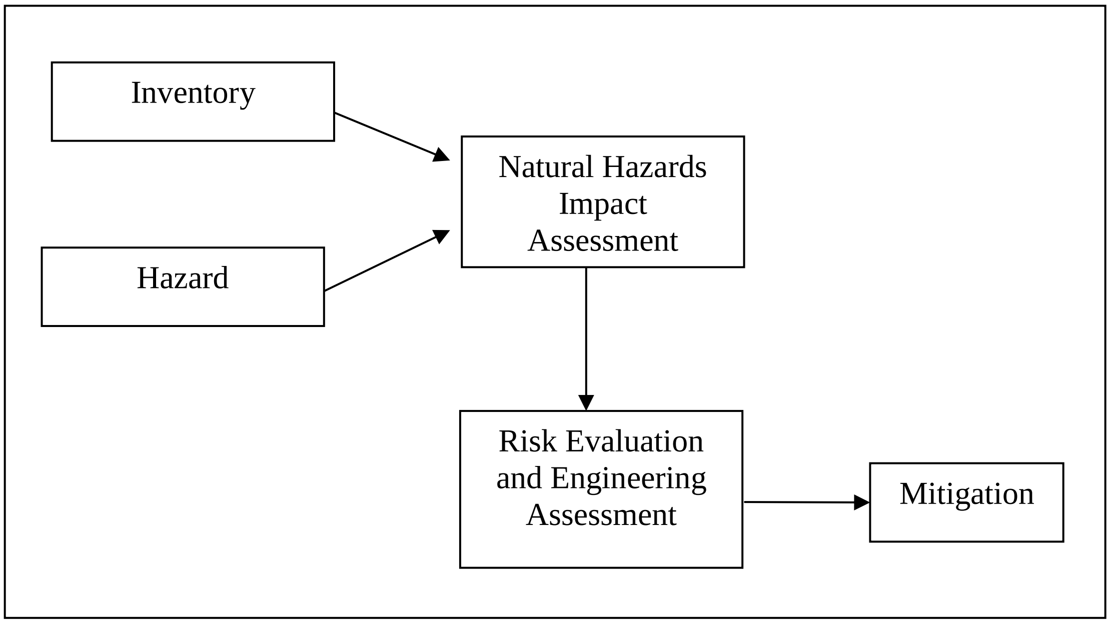

Figure (2.2). Conceptual Steps in Assessing and Mitigating Losses due to Natural Hazards in Hazus. (Figure source: FEMA, 2018b).

Since the development of the first Hazus model in 1997, Hazus has been used extensively in the U.S. for natural hazard loss estimations, research studies, and industry reports in support of all phases of emergency management including mitigation, preparedness, response, and recovery (FEMA, 2018a, 2018b).

After running Hazus models, the data can be further explored using the spatial statistics tools available within GIS to examine the distribution of values, center of a group of features, or the directional trend for a particular attribute—in the case of this study, school—or to spot outliers (extreme high or low values). Having this ability is useful when summarizing data, defining classes and ranges within the study region, reclassifying data, or looking for data errors.

Summary and Gaps in the Literature

Drawing on the research literature, many studies highlight the need for change in every industry to improve practice and policy in the face of a climate-disrupted future. However, little research was available on addressing the needs of school leaders and their capacity to mitigate risks, improve disaster recovery efforts, strengthen partnerships, and/or implement resilience in relation to climate change. It is clear that more work and research is needed to improve emergency preparedness and compliance among school leaders, along with the development of new policies intended to protect all students (Kano et al., 2007). Climate change is an emerging area of interest in educational research but one where research is limited, and key research questions remain. Understanding the relationship between climate change and education will help to ensure sustainable and safe schools where inspired and informed leaders have the knowledge necessary to effectively mitigate risk and damage from our changing climate. It was clear from the research that certain factors impact the vulnerability of children (IPCC, 2018; NOAA, 2018; UNICEF, 2018), but it is still unclear how these factors translate into academic outcomes, which needs additional study.

The extant literature also indicates that few studies have integrated geospatial analysis into educational research (Hogrebe, 2012; Lubienski & Lee, 2017), and even fewer have integrated Hazus with educational leadership. To address some of the gaps in literature and methodologies, the use of geospatial analysis, GIS, and Hazus can help determine the geographic variations of determinants of vulnerability while quantifying the rate of lost instruction time resulting from natural disasters. The visualizations produced in GIS can create powerful displays of the spatial data (Vélez & Solórzano, 2017) produced in Hazus, which can lead to a new dimension of understanding a phenomenon (Morrison & Garlick, 2017). Spatial data integration and spatial analysis have become standard tools in climate change vulnerability assessments and research (Ballas, Clarke, Franklin, & Newing, 2018). Measuring and mapping vulnerability supports adaptation decision-making, yet little research has been conducted to combine climate change vulnerability mapping with the location of schools across the country. Educational research is well positioned to incorporate multiple methodologies and disciplines to address many of the current gaps in literature and problems facing education today.

Social research has the power to improve access to education while increasing equity within education (Ballas, Clarke, Franklin, & Newing, 2018; Creswell; 2014). By researching and better understanding the complexity of community systems and their connection to the physical environment, we can provide the public powerful and influential information to better mitigate the devastating impacts of our climate-disrupted future.

On April 22, 2016, a total of 175 world leaders ratified the Paris Agreement at the United Nations Headquarters in New York (United Nations Climate Change Website, 2018), becoming the largest number of countries ever to sign an international agreement on a single day. Since then, a total of 184 countries have joined the Paris Agreement as growing concern mounts (United Nations Climate Change Website, 2018). In September of 2019, Secretary-General António Guterres will convene a Climate Summit to "bring world leaders of governments, the private sector, and civil society together to support the multilateral process and to increase and accelerate climate action and ambition" (United Nations Climate Change Website, 2018). The topic of educating children in the face of climate change needs to be a topic of discussion and more research needs to be conducted to ensure every child has access to high quality education regardless of our changing climate.

Finally, it's important to note that climate change and the resulting impacts on systems of education do not occur in isolation (Meadows, 2015), and an individual student or community could face multiple threats at the same time, at different stages in one's education, or accumulating over the course of one's life (USGCRP, 2018). Though important to consider as part of a comprehensive assessment of changes in risks, many types of cumulative, compounding, or secondary impacts are beyond the scope of this study and therefore not included. However, brief insights gained on educational research needs while conducting this assessment will be provided at the end of chapter four to help inform future research decisions.

The research shows there is an increasing need for new methods and tools that support cross-disciplinary knowledge construction from complex geospatial datasets related to the field of education. This study will address some of the gaps in the literature and methodologies to help determine the geographic variations of the impact of climate change on school districts, while estimating the rate of potential Disaster Learning Loss to students in highly affected areas. Educational research is well positioned to incorporate multiple methodologies that would address many of the current gaps in literature on school leadership and the impact of climate change, but educational research is often characterized by disciplinary divides that prevent it from consulting methodological approaches used outside of educational research (Lubienski & Lee, 2016). GIS and Hazus can leverage modeling expertise with information visualization and data source integration to create powerful displays of spatial data for diverse audiences (Vélez & Solórzano, 2017), which help school leaders with critical decision making before, during, and after major hurricanes make landfall. This helps optimize limited resources and reduce potential duplication, while enhancing data quality and increasing overall capabilities of school leaders to reduce risk and save lives, which adds a new dimension of understanding phenomena (Morrison & Garlick, 2017).

Chapter Conclusion

The literature reviewed in this chapter covered the impact of climate change, weather, and hurricanes on the education system; a history of GIS; and the benefits of this approach, all of which provides context for the methodology used in this study. Chapter 3 will review the research methodology and further explain the research design, data sources, the use of Hazus, and ethical considerations.

CHAPTER III: METHODOLOGY

"How we treat our land, how we build upon it, how we act toward our air and water, will in the long run tell what kind of people we really are." (Laurance S. Rockefeller, 1965)

This chapter will outline the research design used to answer the three research questions for this study, followed by the data sources selected for implementation. This chapter will discuss the estimation strategy used, including a description of GIS, and Hazus to produce maps of the study area and visualizations of the results. Finally, this chapter will review the limitations and ethical considerations of this study.

Research Questions

The study is guided by the following research questions:

1. What counties along the Eastern and Gulf Coast regions of the United States have K-12 schools that are most vulnerable to hurricane events?
2. What is the relationship between hurricane events and school instruction days lost?

Research Design

To address the needs of the ever-broadening weather-climate-disaster impacts on and implications for school districts, as well as answer the research questions outlined above, this dissertation's research design will be organized into the following steps:

1. Identify hazard, study region, and data.
2. Run Hazus Model(s).
3. Initial Analysis: Interpret outputs and results.
    a. Develop maps from the Hazus outputs.
4. Secondary Analysis: Interpret outputs and results to determine estimated rate of Disaster Learning Loss (DLL) in districts most impacted by storm scenario.
    a. Develop maps from results.
5. Consider mitigation options and recommendations specific to support school leaders.
    a. A graphical organizer has been developed to further explain and simplify the complexity of the research methodology and design (*Figure (2.3)*).

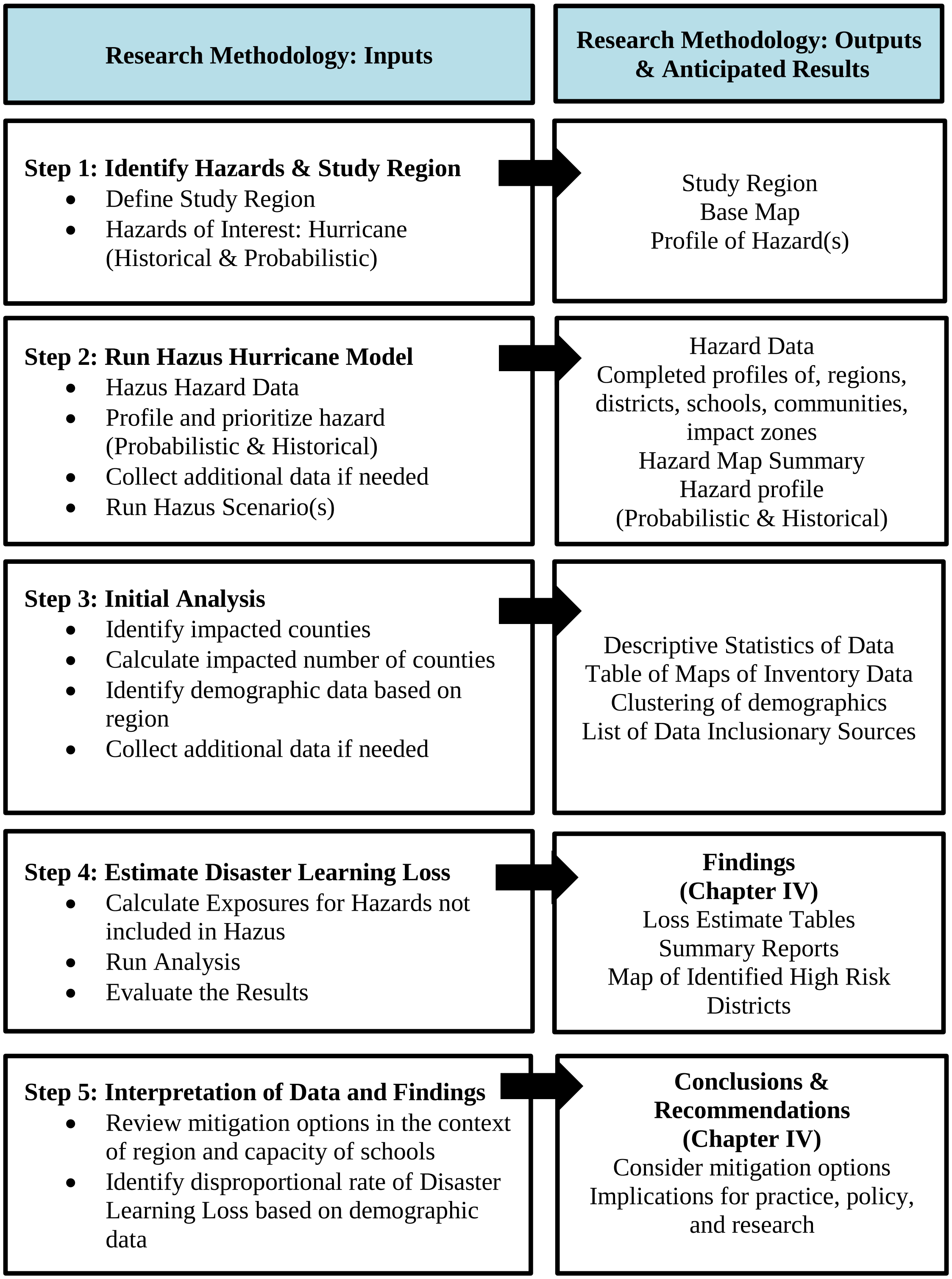

Figure (2.3). Graphic Organizer of the research design used in this study.

Using formulas embedded in Hazus, Hazus computes damage probabilities, expected building losses, expected contents losses, and expected loss-of-use for different classes of buildings. Hazus also computes estimates of direct economic loss and short-term shelter needs (Hazus User Manual, 2018). To calculate Disaster Learning Loss (DLL), resulting from a hurricane causing a school's closure, a quantitative approach will be used to estimate potential school closures in conjunction with the Hazus Hurricane Model. Hazus uses Geographic Information Systems (GIS) technology to estimate physical, economic, and social impacts of disasters. The Hurricane Model embedded within Hazus estimates the economic and social losses from hurricane winds –it does not consider damage caused by flooding, storm surge, rainfall, etc. The model provides practitioners and policymakers with a tool to help reduce wind damage, reduce disaster payments, and make wise use of the nation's emergency management resources. The system will graphically illustrate the limits of identified high-risk counties and schools located within those counties due to a hurricane scenario. Spatial relationships between populations, schools, counties, districts, and the specified hurricane model(s) will be explored to identify the determinants of vulnerability, a crucial function in the pre-disaster planning process, which aligns with this study's conceptual framework and addresses the existing gaps in the literature. Perhaps more importantly, it responds to the Sendai Framework for Disaster Risk Reduction 2015-2030, endorsed by the UN General Assembly following the 2015 Third UN World Conference on Disaster Risk Reduction (United Nations Office for Disaster Risk Reduction, 2018), as the results from this study will be outlined using the four priorities addressed within the Sendai Framework.

Data Sources

Because school recovery and reopening after a natural disaster are multifaceted (involving not only advance preparation but also response and recovery) and the nature of mitigation and risk is multi-layered (requiring data and information about the hazard, exposure, and vulnerability), the range of data required for a study such as this is vast. As such, this study will use and explore Level 1 data sources built into the Hazus framework and model for comparison and analysis. These data sources include both probabilistic and deterministic historical models. Table 2 outlines and identifies the parameter data and leveling indication used within Hazus.

Table 2

Summary of Hurricane Model Capabilities & Data available for use within Hazus.

Parameter/Data	Level 1 (Default Data)	Level 2 (User-Supplied Data)
Wind Model	Default Probabilistic	User-Defined Scenario
Coastal Surge Model	Default Historic	User-Defined Scenario
School Building Inventory	Default	User-Supplied
Faculties and Building Classes	Residential Commercial and Industrial Essential Facilities	
Terrain	Default	
Loss Functions	Default	
Damage Functions	Default	
Shelter Requirements	Default	
Debris	Default	

Note. Adapted from: FEMA, 2018a.

Identified as "Essential Facilities" in Hazus, the school building inventory (Appendix B) is classified by building structure type and occupancy class and held under the key General Building Stock (GBS) databases in Hazus. This data includes square footage by occupancy and building type, building count by occupancy and building type, valuation by occupancy and building type, and general occupancy mapping. For these databases, residential structures are derived from Census 2010 and non-residential structures are derived from Dun & Bradstreet. Additionally, three reports from the Department of Energy (DOE) were used in defining regional variations in characteristics such as number and size of garages, type of foundation, and number of stories (FEMA, 2018a, 2018b). The inventory's baseline floor area is based on a distribution contained in the DOE's Energy Consumption Report (FEMA, 2018a, 2018b).

The school data set was developed from the 2000 Public Elementary/Secondary School Universe Survey Data and the Private School Universe Survey Data maintained by the National Center for Education Statistics (2018) and the U.S. Department of Education (FEMA, 2018a). As a result, many charter schools that have opened since the 2000 survey will not be included in this study, and the sample population will consist of disproportionately more traditional public schools. This study will use the proprietary geocoding application used to assign geographical coordinates to each school based on its address built within Hazus. Therefore, there may be school location errors outside of the researcher’s control. The schools participating in this study must also enroll students in any subset of grades K-12. Schools that only educate early childhood students and daycare centers will not be included in the sample, since they were not included in the Public Elementary/Secondary School Universe Survey Data and the Private School Universe Survey Data.

The Hurricane Model derived from the National Land Cover Data (NLCD) was compiled in 2013 by the Multi-Resolution Land Characteristics (MRLC) Consortium to ascertain surface roughness. The historic storm and a probabilistic storm set—both of which will be used for analysis—in the hurricane model use the Atlantic basin hurricane database from the Hurricane Research Division in the NOAA/National Weather Service, National Centers for Environmental Prediction, National Hurricane Center, and Tropical Prediction Center (HURDAT). HURDAT is the official record of tropical storms and hurricanes for the Atlantic Ocean, Gulf of Mexico. This data encompasses the period 1886-2001. The probabilistic storm set, however, only goes through 1995.

Geographic Sample Region

The geographic scope of the Hazus Hurricane Model is limited to the Atlantic and Gulf coasts of the United States and Hawaii. In this study, specific states and specific hurricanes were isolated for analysis to provide both a historical and future-looking analysis. The sample was selected based on the region dominated by the effects of hurricanes as seen in *Figure (3.1).*

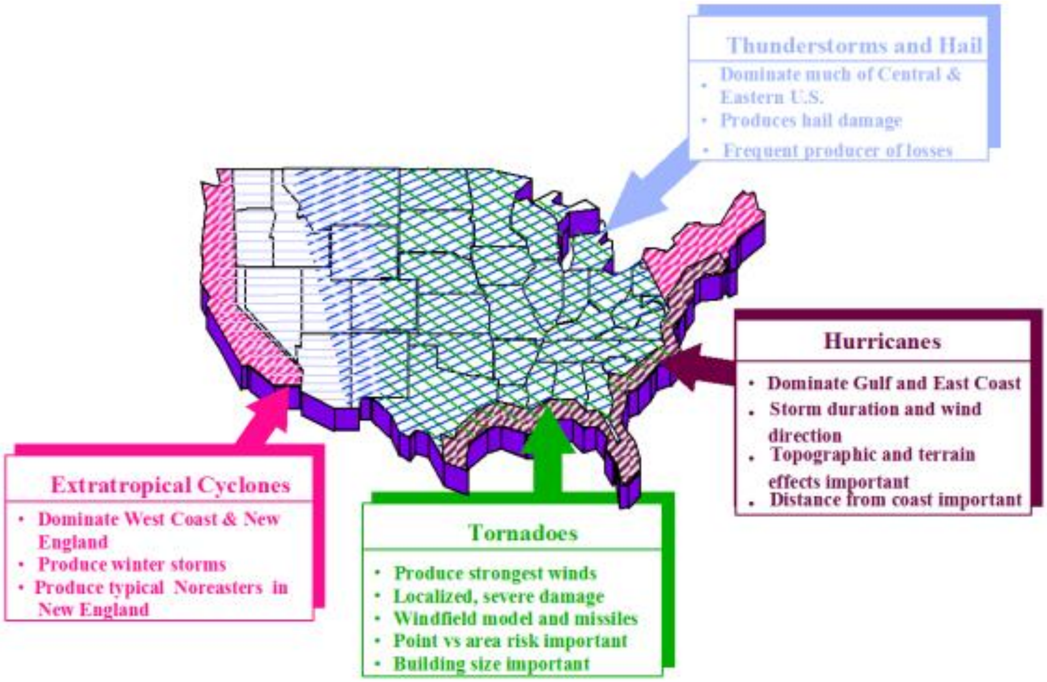

Figure (3.1). Meteorological Events Contributing to the Wind Hazard in Different Regions of the Continental United States. (Figure source: FEMA, 2018a).

To narrow the findings, allowing for analysis, the states selected for inclusion in this study are (a) Texas, (b) Louisiana, (c) Alabama, (d) Mississippi, and (e) Florida, as seen in *Figure (3.2).*

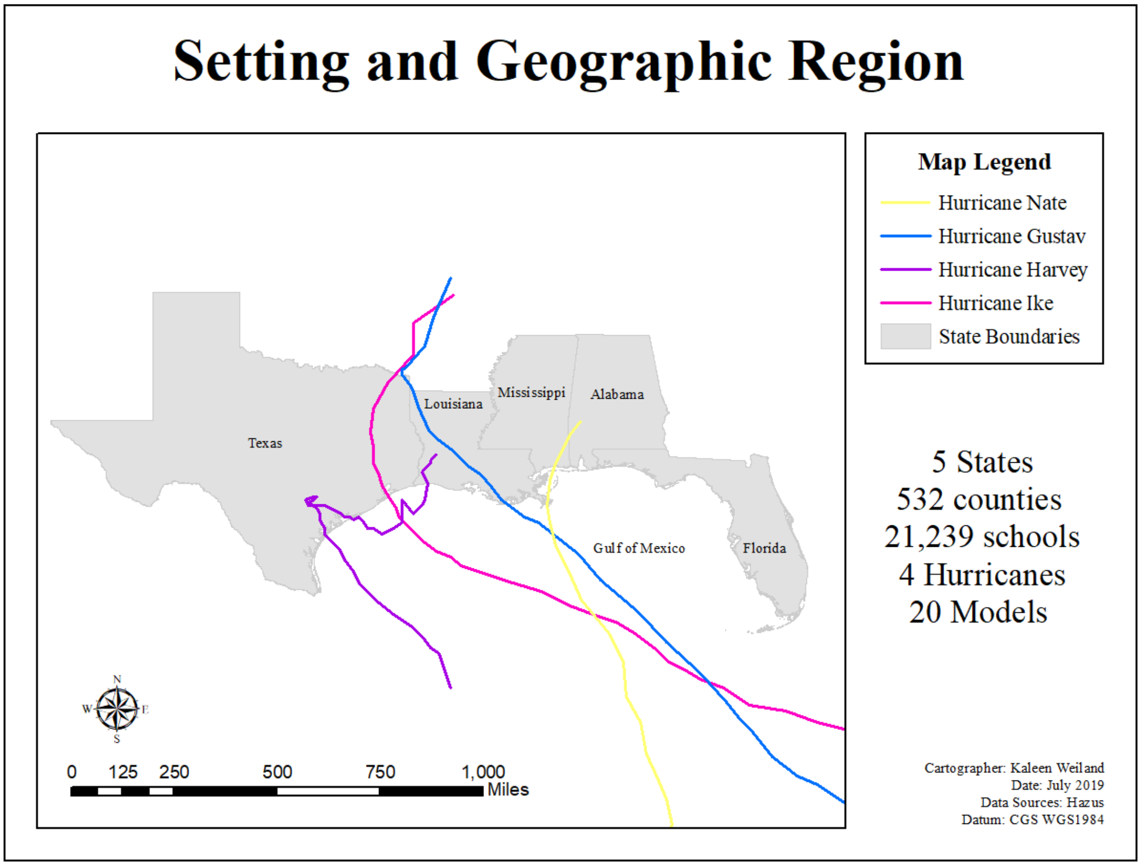

Figure (3.2). Sample States used within this study including storm tracks.

These states were purposefully selected based on hurricane scenarios available within the Hazus software program. A list of all the counties used within the Hazus models has been provided in Appendix E.

Hazus contains GIS boundary maps for the U.S. and the Territories with five GIS map layers: states (or territories), territory grids, counties, census tracts, and census blocks (FEMA, 2018a). This data set was developed from the 2010 version of Census TIGER/Line files. Census Tract and County boundaries were clipped to take account of the coastal configuration. The study was aggregated on the County level (Appendix D).

The territory grids were developed by the Pacific Disaster Center (PDC). The positional accuracy varies with the scale of the source map used (such as 1:20,000, 1:24,000, 1:30,000, 1:63,000 and 1:100,000). Additional GIS layer(s) will be imported showing current district boundaries in each state included in the study.

The hurricanes selected for analysis include 2008 Hurricane Ike making landfall in Texas, 2008 Hurricane Gustav making landfall in Louisiana, 2017 Hurricane Harvey making landfall in Texas, and 2017 Hurricane Nate making landfall in Louisiana.

Estimation Strategies and Procedures

Identifying potential exposure alone is not sufficient for understanding trends in disaster losses. The extant literature shows that social and economic vulnerability are critical ingredients in properly assessing risk (Mechler & Bouwer, 2014; Cutter et al., 2003). Therefore, this study has developed three research questions to explore the determinants of vulnerabilities facing schools today in an effort to better inform and prepare school leaders. In an effort to answer these questions, the following data will be collected from the models: the number of schools in each state; the number of people in the region; the number of census tracks in the state; capital stock losses including damage to buildings and cost contents; income loss from relocation losses; total income losses from relocation, capital, wages, and rentals; and school building stock exposure by general occupancy.

Hazus risk identification model

To answer the first research question, this study will use the Hazus technology to run a series of Level 1 (default) Hurricane Models. The literature shows hurricanes are a complex atmospheric system comprising of multiscale systems interacting in a nonlinear and varying degree of intensity (Keller & DeVecchio, 2015). However, there are known environmental features including

> vertical wind shear, trough interactions, warm eddy core interactions, outflow patterns, eddy angular flow convergence, upper level cooling, dry air intrusions, eye wall cycles, low-level temperature advection, rain band downdrafts, and ocean currents. (FEMA, 2018a, p. 2-47).

It is these variables that are used to develop the Hazus Hurricane Model. One of the more difficult variables to model within an atmospheric system is the rainfall. As indicated in the literature review, this is also a factor that causes hurricanes to be extremely dangerous. Even the most comprehensive modeling systems available have limited success estimating the rainfall intensity and location associated with the hurricane (Elsberry, 1998). As such and given the limited experience and knowledge of the researcher in the science of atmospheric studies, the default scenarios will be run through the Hazus model.

Hazus calculates and estimates potential damage to school buildings, a key factor used to determine Disaster Learning Loss. Damage will be described by one of four discrete damage states: Slight, Moderate, Extensive or Complete. It should be assumed, actual building damage varies as a continuous function of hurricane demand. Ranges of damage are used to describe building damage, since it is not practical to have a continuous scale, and damage states will allow school leaders, policymakers, and stakeholders with a clear understanding of the building's expected physical condition. Additionally, loss functions will be used as they relate the physical condition of the building to various loss parameters (i.e., direct economic loss, casualties, and loss of function). For this study, loss of function will be the key factor when establishing the rate of Disaster Learning Loss. For example, direct loss of function due to moderate damage is assumed to correspond to 10% replacement value of structural and nonstructural components of the school building, on the average. The four damage states of the Hazus model methodology descriptions vary for each model building type based on the type of structural system and material used within the school. Table 3 provides structural damage states for light frame wood buildings typical of the conventional construction used for single-family homes and some schools.

Table 3

Example of Damage States for School Buildings and Single-Family Homes

Damage State	Description
Minor	Small plaster cracks at corners of door and window openings and wall ceiling intersections; small cracks in masonry chimneys and masonry veneers; minor water damage to the interior of the building. Small cracks are assumed to be visible with a maximum width of less than 1/8 inch (cracks wider than 1/8 inch are referred to as “large” cracks).
Moderate	Large plaster or gypsum-board cracks at corners of door and window openings; small diagonal cracks across shear wall panels exhibited by small cracks in stucco and gypsum wall panels; large cracks in brick chimneys; toppling of tall masonry chimneys. Water damage resulting in partial replacement of drywall, flooring and/or building fixtures and other materials.

Extensive	Large diagonal cracks across shear wall panels or large cracks at plywood joints; permanent lateral movement of floors and roof; toppling of most brick chimneys; cracks in foundations; splitting of wood sill plates and/or slippage of structure over foundations; significant water damage resulting in full replacement of drywall, flooring and/or building fixtures and other materials.
Complete	Structure may have large permanent lateral displacement or be in imminent danger of collapse due to cripple wall failure or failure of the lateral load resisting system; some structures may slip and fall off the foundation; large foundation cracks, and extensive water damage resulting in full drywall, foundation, and structure replacement. Three percent of the total area of buildings with Complete damage is expected to be collapsed, on average.

Note. Descriptions have been modified from the Hazus Hurricane Manual (2018) to align with, and meet the specific needs of, the field of educational leadership.

After the models have been run, the results of the scenarios will be compared to determine the extent of the variation and the significant variables that impact the rate of Disaster Learning Loss. The results of the Hazus models will be used as the data for the subsequent geospatial analysis with GIS.

Geospatial Analysis

To answer the second research question, a map rendering will be developed within GIS to represent the quantitative values for the severely damaged schools in the study region. This will produce a quantitative approach to examine the relationship and impact of Disaster Learning Loss and climate events (hurricanes) across school districts over the course of 10 years (2008 -2017), as well as probabilistic scenarios into the future. ArcGIS ArcMap 10.5.1 software will be used to create a spatial map of the study areas. Supplemental material including line graphs and charts may also be developed to fully illustrate the study and its findings.

Validity and Reliability

This study relies on the validity and reliability of the *2018 Climate Change Impacts in the United States: The Fourth National Climate Assessment (NCA*) and other peer-reviewed scientific assessments of climate change and climate scenarios as the basis for describing climate change and the resulting impacts on educational systems around the United States.

The hurricane loss estimation methodology used within this study is based on sound scientific and engineering principals and experimental and experience data (FEMA, 2018a). The Hazus methodology has been tested against the judgment of experts and, to the extent possible, against records from several past hurricanes (FEMA, 2018a). Nevertheless, uncertainties are inherent in any loss estimation methodology. These uncertainties arise from incomplete or inaccurate inventories of the built environment and the ever-changing demographics and economic parameters that exist in the real world. To keep the estimates of loss within a factor of two, data used in the study tracked closely with inventories and parameters assumed, embedded, and built into the basic methodology of Hazus. Furthermore, the Hazus Hurricane Model only estimates the economic and social losses from hurricane winds. It does not consider other damages caused by hurricanes like flooding, storm surge, rainfall, etc. Due to the natural variation of hurricanes, limited and incomplete data about actual hurricane damage precludes complete calibration of the methodology (FEMA, 2018a). Nevertheless, the Hazus Hurricane Model has provided a credible estimate of such aggregated losses (FEMA, 2018a). If a Hazus All-Wind Model is developed, future research would be able to explore Disaster Learning Loss to include the wind hazard and the effects associated with all of the meteorological phenomena that produce damaging winds. This research could improve loss estimates and help guide school leaders working to improve the allocation of resources to stimulate risk mitigation efforts and plan for hurricane response.

Ethical Considerations

Social research has the power to improve access to education while increasing equity within education (Creswell, 2014). By researching and better understanding the complexity of educational systems and their connection to the physical environment, we can provide the public with powerful and possibly influential information to better mitigate the devastating impacts of our climate-disrupted future. Nevertheless, it is important to note that the methods outlined in this chapter may present some ethical considerations that need to be noted. While collecting data, analyzing the data, and reporting the data, I will avoid collecting harmful information about the participants, schools, or districts included within the study (Creswell, 2014). I will respect the privacy and anonymity of those working within my study region. Specifically, I will not collect any personal information about the individual students, leadership teams, or employees working within or for the counties and/or districts included in the study. I will clearly state who owns the raw data from the study (Creswell, 2014). While analyzing the data, I will avoid disclosing only results that may be perceived as positive or siding with any political or popular opinion (Creswell, 2014). The master raw data, shapefiles, and program scenarios run through Hazus will be stored in a secured, password-protected location. I will include and report multiple perspectives and contrary findings (Creswell, 2014). Finally, when reporting the data, I will not disclose any individual school, student, or leadership names when identifying the rate of Disaster Learning Loss.

Chapter Conclusion

This chapter reviewed the quantitative research design for and approach to this study, as well as data sources, input and anticipated output variables, estimation strategy, and ethical considerations. This study used a multi-step research design process to judge the potential societal, social, and educational impacts from hurricanes using computer programs, including Hazus, available in ArcGIS. In combining these layers of information and data, while using the conceptual framework identifying the determinants of vulnerability, in combination with Hazus technology, a series of maps were produced to answer the study's research questions. When visualized, the results provide a sense of potential areal, economic, educational, and demographic impact from the scenario while quantifying the key concept of this study: Disaster Learning Loss.

The subsequent chapter will provide the findings from the multi-step study explained in the methodology. The results from the Hazus model will be presented, followed by the geospatial analysis.

CHAPTER IV: FINDINGS

"Each of us as human beings has a responsibility to reach out to help our brother and sisters affected by disasters. One day it may be us or our loved ones needing someone to reach out and help." (Michael Hawkins, 2017)

This section contains the findings from the collected quantitative and qualitative data, as well as the geospatial analysis that addresses this study's research questions. The research questions are:

1. What counties along the Eastern and Gulf Coast regions of the United States have K-12 schools that are most vulnerable to hurricane events?
2. What is the relationship between hurricane events and school instruction days lost?

This study was designed to investigate the influence of the growing frequency and intensity of hurricane events on counties along the Eastern and Gulf Coast regions of the United States and to explore the relationship between hurricane events and school instruction days lost to consider what the real-world distribution and impact of the phenomenon might look like. These results are intended to support school leaders in their efforts to ensure safe learning environments while informing policymakers, state and district level leadership of the potential adverse impacts a changing climate may have on schools and students.

These findings are organized into two main sections, each expected to answer the key research questions. The first section of this chapter will address the first research question with quantitative data exploring the historical models from four hurricanes impacting the study region. The next section will answer the second research question describing the relationship between hurricane events and school instruction days lost with the probabilistic models and geospatial analysis.

The findings were obtained using the Hazus modeling outputs. The objective of the Hazus models was to identify K-12 schools located within counties (see Appendix E for a full list) along the Eastern and Gulf Coast regions of the United States which are most vulnerable to hurricane events, as well as explore the relationship between school instruction days lost and hurricane events. In line with this objective, the analysis focused on comparing the hurricane models: 2008 hurricane events (Gustav and Ike) and 2017 hurricane events (Harvey and Nate). This data was used to estimate the damage (and resulting loss of functionality) associated with school facilities for each of the given (probabilistic) hurricane scenarios. By evaluating this information, a determination may be made whether the school response capabilities and the continual operational functionality of the schools within the region are likely to be overwhelmed by the growing intensity and frequency of impacting hurricane events. For each hurricane event, deterministic (historical) models were run and compared to establish a baseline for evaluation. Then, probabilistic scenarios were modeled and compared to explore the relationship between lost instruction time and more intense and frequent hurricanes. This comparison resulted in the ability to consider what the real-world distribution and impact of the phenomenon might look like.

The next section provides the analysis and overview of the findings from the deterministic hurricane models.

Question 1: Model Analysis of Deterministic Hurricane Events

Hurricane Gustav, 2008. Hurricane Gustav steadily moved in a northwest direction over the Gulf of Mexico until it made its final landfall near Cocodrie, Louisiana, on September 1, 2008, as a Category 2 hurricane with peak wind speeds of 155 mph. Coastal Louisiana experienced a 9-13 feet storm surge with the highest waves along the Mississippi River Delta. New Orleans Mayor, Ray Nagin, issued a mandatory evacuation of the entire city on August 30. Some 1.9 million people evacuated southern Louisiana in advance of the hurricane—the largest evacuation in the state's history (National Weather Service, 2008).

The hurricane loss estimates provided in the next section are based on a region that includes 400 counties from the following states Louisiana, Mississippi, and Texas. Table 4 presents the relative distribution of the aggregate total replacement value of educational facility losses based on general occupancies in each region impacted by Hurricane Gustav.

Table 4

Education Building Exposure by Occupancy Type for Hurricane Gustav, 2008

State	Education Building Exposure	Total Exposure in the Study Region	Percent of Total
Louisiana	$5,074,415	$447,066,415	1.14%
Mississippi	$4,635,901	$263,908,159	1.76%
Texas	$33,853,649	$2,483,458,804	1.36%
Total	$43,563,965	$3,194,433,378	1.36%

Louisiana. The Hazus deterministic (historical) model estimated population of 4,533,372, over 46,011 square miles, and 1,138 census tracks (Census Bureau, 2010). There were an estimated 1,823,390 buildings in the Louisiana region which had an aggregate total replacement value of $447,066,000 (in 2014 dollars). For essential facilities, there were 257 hospitals in the region with a total capacity of 17,009 beds. In 2008, there were 1,963 schools, 1,321 fire stations, 413 police stations and 76 emergency operation facilities.

Peak gusts in the Louisiana study region reached 101 mph. Hazus estimated that 4,450 buildings would be at least moderately damaged, and 126 buildings would be completely destroyed. The model estimated 700 displaced households. Additionally, 0 schools in the region were estimated to experience damage, or destruction. Based on the Hazus model, it is estimated that 19 schools in the region would experience more than 1 day of Disaster Learning Loss.

Mississippi. With an estimated population of 2,967,297, the geographical size of the region was 47,663.89 square miles and contains 661 census tracts. There were over 1,115,000 households in the region (Census Bureau, 2010). There were an estimated 1,241,000 buildings in the region with a total building replacement value (excluding contents) of $263,908,000 (in 2014 dollars). Approximately 92% of the buildings (and 73% of the building value) were associated with residential housing. For essential facilities, there were 134 hospitals in the region with a total capacity of 14,549 beds. There were 1,410 schools, 1,010 fire stations, 416 police stations and 86 emergency operation facilities.

Peak gusts in the Mississippi deterministic study region reached 74 mph. Hazus estimated that about 4 buildings were at least moderately damaged, and 0 buildings will be completely destroyed. The model estimated 0 displaced households. Additionally, an estimated 0 schools in the region experienced minor damage, 1 school experienced moderate damage, 0 schools experienced severe damage and 0.00 had complete destruction. Based on the Hazus model, it is estimated that 0 schools in the region would experience more than 1 day of Disaster Learning Loss.

Texas. The geographical size of the Texas study region was 264,719.18 square miles and contains 5,253 census tracts. There were over 8,922,000 households in the region and a total population of 25,145,561 people (Census Bureau, 2010). There were an estimated 8,556,000 buildings in the region with a total building replacement value (excluding contents) of $2,483,459 (in 2014 dollars). Approximately 92% of the buildings (and 80% of the building value) were associated with residential housing. For essential facilities, there were 815 hospitals in the region with a total capacity of 87,929 beds. There were 11,765 schools, 2,714 fire stations, 2,424 police stations, and 427 emergency operation facilities.

Peak gusts in the Texas study region reached 51 mph. Hazus estimated that 0 buildings were at least moderately damaged, and 0 buildings will be completely destroyed. The model estimated 0 displaced households and 0.00 minor, moderate, or severe damage to school buildings. Based on the Hazus model, it was estimated that 0 schools in the region would experience more than 1 day of Disaster Learning Loss.

Exploring the educational impact Hurricane Gustav had on the entire study region, Table 5 provides a list of each region, the estimated number of schools in the region and the estimated number of Disaster Learning Loss days.

Table 5

Expected Disaster Learning Loss for Hurricane Gustav, 2008

State	Number of Schools	Probability of at least Moderate Damage > 50%	Probability of Complete Damage > 50%	Expected DLL Days
Louisiana	1,963	0	0	19
Mississippi	1,410	0	0	0
Texas	11,765	0	0	0
Total	15,138	0	0	19

When compared to the other modeled hurricane events, this modeled provided an example of the variability of hurricane events on schools. As well as the isolated impact hurricanes can have on communities. The model report 19 Disaster Learning Loss days across the region. According to multiple news agencies (Carrier & Jeff, 2008; Complete INC, 2008), the community of Houma, Louisiana and the surrounding area in south-central Louisiana sustained extensive wind damage causing many roofs to blow off, windows blown out of houses and trees throughout the region to be knocked down. The region was left without power. One school, Ellender High in Houma, sustained water damage causing their new gym floor to buckle and a rear wall to collapse.

Hurricane Ike, 2008. Hurricane Ike became known as the most intense storm of the 2008 Atlantic Hurricane Season having begun as a tropical disturbance near Africa at the end of August 2008. By September 3, 2018, Ike strengthened to hurricane status and then explosively intensified as it was upgraded to a major hurricane with winds of 115 mph only three hours after being upgraded to a hurricane. Ike continued to intensify and was further upgraded to a Category 4 hurricane on the Saffir-Simpson Hurricane Wind Scale (see *Figure (2.1))* three hours later with winds of 135 mph. Hurricane Ike made its final continental landfall near Galveston, TX, on September 13, 2018 as a strong Category 2 hurricane with a Category 5 equivalent storm surge (National Weather Service, 2008).The hurricane loss estimates provided in the next section are based on a region that includes 385 counties from the following states: Florida, Louisiana, and Texas. Table 6 presents the relative distribution of the aggregate total replacement value of educational losses based on general occupancies in each region impacted by Hurricane Ike.

Table 6

Education Building Exposure by Occupancy Type for Hurricane Ike, 2008

State	Education Building Exposure	Total Exposure in the Study Region	Percent of Total
Florida	$23,218,278	$2,081,609,514	1.12%
Louisiana	$5,074,415	$447,066,415	1.14%
Texas	$33,853,649	$2,483,458,804	1.36%
Total	$62,146,342	$5,012,134,733	1.24%

Florida. The Hazus deterministic (historical) model estimated population of 18,801,310 people over 56,622.89 square miles, containing 4,207 census tracks (Census Bureau, 2010). There are an estimated 7,262,000 buildings in the region with a total building replacement value (excluding contents) of $2,081,610 (in 2014 dollars). Approximately 91% of the buildings (and 78% of the building value) are associated with residential housing. For essential facilities, there are 349 hospitals in the region with a total capacity of 69,280 beds. There are 3,904 schools, 1,856 fire stations, 818 police stations, and 129 emergency operation facilities.

Peak gusts in the Florida study region reached 53 mph. Hazus estimated that next to 0 buildings were damaged or destroyed. The model estimated 0 displaced households. Additionally, 0 schools in the region were estimated to experience damage or destruction.

Based on the Hazus model, it is estimated that 0 schools in the region would experience more than 1 day of Disaster Learning Loss.

Louisiana. The geographical size of the region is 46,011.03 square miles and contains 1,138 census tracts. There are over 1,728,000 households in the region and a total population of 4,533,372 people (Census Bureau, 2010). There are an estimated 1,823,000 buildings in the region with a total building replacement value (excluding contents) of $447,066,000 (in 2014 dollars). Approximately 92% of the buildings (and 78% of the building value) are associated with residential housing. For essential facilities, there are 257 hospitals in the region with a total capacity of 17,009 beds. There are 1,963 schools, 1,321 fire stations, 413 police stations, and 76 emergency operation facilities.

Peak gusts in the Louisiana study region reached 84 mph. Hazus estimated that about 19 buildings were at least moderately damaged. There were an estimated 0 buildings that will be completely destroyed and 0 displaced households. Additionally, an estimated 0 schools in the region experienced minor damage, 0 schools experienced moderate damage, 0 schools experienced severe damage and 0.00 were completely destroyed. Based on the Hazus model, it was estimated that 0 schools in the region would experience more than 1 day of Disaster Learning Loss.

Texas. The Hazus deterministic (historical) model estimated the geographical size of the region at 264,719.18 square miles and containing 5,253 census tracts. There are over 8,922,000 households in the region and a total population of 25,145,561 people (Census Bureau, 2010). There are an estimated 8,556,000 buildings in the region with a total building replacement value (excluding contents) of $2,483,459 (in 2014 dollars).

Approximately 92% of the buildings (and 80% of the building value) are associated with residential housing. For essential facilities, there are 815 hospitals in the region with a total capacity of 87,929 beds. There are 11,765 schools, 2,714 fire stations, 2,424 police stations, and 427 emergency operation facilities.

Peak gusts in the Texas study region reached 110 mph. Hazus estimated that 42,733 buildings were at least moderately damaged, and 1,181 buildings will be completely destroyed. The model estimated 9,037 displaced households. Additionally, the expected school building damage by occupancy estimated 348.62 schools in the region experienced minor damage, 72.57 schools experienced moderate damage, 5.58 schools experienced severe damage, and 0.00 were completely destroyed. Based on the Hazus model, it is estimated that 19 schools in the region would experience more than 372 days of Disaster Learning Loss.

Exploring the educational impact Hurricane Ike had on the entire study region, Table 7 provides a list of each region, the estimated number of schools in the region and the estimated number of Disaster Learning Loss days.

Table 7

Expected Disaster Learning Loss for Hurricane Ike, 2008

State	Total Number of Schools	Probability of at least Moderate Damage > 50%	Probability of Complete Damage > 50%	Expected DLL Days
Florida	3,904	0	0	0
Louisiana	1,963	0	0	0
Texas	11,765	4	0	372
Total	17,632	4	0	372

This model demonstrated the overlap that may exist between Disaster Learning Loss and housing displacement. With an estimated 9,037 displaced households, more than 348 schools with minor damage, more than 72 schools with moderate damage, and more than 5 schools with severe damage, the impact in Texas alone is substantial. It could be assumed that many of the students experiencing Disaster Learning Loss, as a result of their school being damaged by the hurricane, are simultaneously experiencing housing displacement. A report prepared for the Galveston Housing Authority, organized by Georgia State University (2010), found that Hurricane Ike destroyed almost 60 percent (569 units) of the Island's public housing. Despite subsidized private-market housing being made available for the displaced public housing residents, the demand for housing assistance continued to outstrip the supply leaving many of the communities most vulnerable citizens without a home. Since 1970, socioeconomic trends in the region indicate the city has doubled the poverty rate of the county leading up to 2010, and both the city and the county experienced increases over the last four decades. To put this in perspective, the city's poverty rate is similar to that of Houston and post-Katrina New Orleans, but less than that Atlanta (Oakley and Ruel, 2010). The combination of socioeconomic stressors and public housing shortages coupled with the estimated Disaster Learning Loss reveal a potential precarious situation for students working toward their future goals.

Hurricane Harvey, 2017. Hurricane Harvey was an extremely destructive hurricane, which would later be classified as a 500-year flooding event (Trenberth, Cheng, Jacobs, Zhang, & Fasullo, 2018). Harvey was the first major hurricane to make landfall in the United States since Hurricane Wilma in 2005, making landfall along the Texas coast near Port Aransas on August 25, 2017, as a category 4 hurricane with peak winds at 130 mph. As Harvey made landfall, its forward motion slowed to nearly 5 mph. As the center of Harvey slowly moved east-southeast and back offshore, heavy rainfall continued to spread through much of the region. The intense rainfall caused catastrophic drainage issues and made rivers rise greatly. Approximately 46 percent of the rivers reached new record levels. Harvey maintained tropical storm intensity the entire time while inland over the Texas coastal bend and southeast Texas (National Weather Service, 2017).

The hurricane loss estimates provided in the next section are based on a region that includes 254 counties from the state of Texas. Table 8 presents the relative distribution of the aggregate total replacement value of educational losses in each region impacted by Hurricane Harvey.

Table 8

Education Building Exposure by Occupancy Type for Hurricane Harvey, 2017

State	Education Building Exposure	Total Exposure in the Study Region	Percent of Total
Texas	$33,853,649	$2,483,458,804	1.36%
Total	$33,853,649	$2,483,458,804	1.36%

Texas. The Hazus deterministic (historical) model estimated a geographical size of the region of 264,719.18 square miles, containing 5,253 census tracts. There are over 8,922,000 households in the region and a total population of 25,145,561 people (Census Bureau, 2010). There are an estimated 8,556,000 buildings in the region with a total building replacement value (excluding contents) of $2,483,459 (in 2014 dollars). Approximately 92% of the buildings (and 80% of the building value) are associated with residential housing. For essential facilities, there are 815 hospitals in the region with a total capacity of 87,929 beds. There are 11,765 schools, 2,714 fire stations, 2,424 police stations and 427 emergency operation facilities.

Peak gusts in the Texas study region reached 134 mph. Hazus estimated that about 14,919 buildings were at least moderately damaged and 2,169 buildings that will be completely destroyed. The model estimated 3,420 displaced households due to the hurricane. Of these, 2,093 people (out of a total population of 25,145,561) will seek temporary shelter in public shelters. The total economic loss estimated for the hurricane is $2,326.7 million dollars, which represents 0.09% of the total replacement value of the region's buildings.

Additionally, the expected school building damage is estimated to have 19.77 schools in the region experienced minor damage, 15.01 schools experienced moderate damage, 11.22 schools experienced severe damage and 0.00 were had complete destruction. Based on the Hazus model, it is estimated that 24 schools in the region would experience more than 37 days of Disaster Learning Loss. Exploring the educational impact Hurricane Ike had on the entire study region, Table 9 provides the estimated number of schools in the region and the projected number of Disaster Learning Loss days.

Table 9

Expected Disaster Learning Loss for Hurricane Harvey, 2017

State	Total Number of Schools	Probability of at least Moderate Damage > 50%	Probability of Complete Damage > 50%	Expected DLL Days
Texas	11,765	24	0	37
Total	11,765	24	0	37

Of all the models developed, this one proved to be the most confounding with 24 schools estimated to experience moderate damage and an estimated Disaster Learning Loss of only 37 days across the region. Considering that Hurricane Harvey was later classified as a 500-year flooding event it was expected that the damage reported in the model would have been substantially higher. The Hazus models and findings however, only demonstrate and mitigate the effects of hurricane winds. Flooding damage was not considered for this model or any others within this study. This finding once again demonstrates the variability that can occur with hurricane events as well as the damage that can be observed by the differing destructive elements hurricanes cause (e.g. wind, flooding, storm surge, etc.).

Additionally, these results may also illustrate resilience factors within communities leading to a reduced Disaster Learning Loss. The State of Texas spans a substantial landmass at an estimated a geographical size of 264,719.18 square miles. With 11,765 schools, this model may demonstrate what happens when students are bussed to neighboring schools after a hurricane event, or a coalition of community support coming in after a hurricane to rebuild and reconstruct. Additional research and exploration on a regional, county or community level would be recommended to explore the trends, impacts and resulting Disaster Learning Loss resulting from this model.

Hurricane Nate, 2017. Hurricane Nate was the 14th named storm, 9th hurricane and the last to make landfall of the 2017 Atlantic Hurricane Season. Nate was an extremely fast-moving hurricane making landfall near the mouth of the Mississippi River on October 7, 2017, with winds peak winds of 90 mph (Category 1). It was the strongest hurricane to make landfall in Mississippi since 2005. The storm's forward motion slowed as the anticipated northward turn began. A second landfall occurred just west of Biloxi, MS on 8 October 2017. Nate quickly took on a north-northeasterly motion after landfall as the circulation came under the influence of the mid-latitude westerlies. Nate was the first hurricane in October to make landfall along the northern Gulf Coast since the 2002 Atlantic Hurricane Season (National Weather Service, 2017).

The hurricane loss estimates provided in the next section are based on a region that includes 213 counties from the following states: Alabama, Louisiana, and Mississippi. Table 10 presents the relative distribution of the aggregate total replacement value of educational losses based on general occupancies in each region impacted by Hurricane Nate.

Table 10

Education Building Exposure by Occupancy Type for Hurricane Nate, 2017

State	Education Building Exposure	Total Exposure in the Study Region	Percent of Total
Alabama	$7,184,150	$490,323,690	1.47%
Louisiana	$5,074,415	$447,066,415	1.14%
Mississippi	$4,635,901	$263,908,159	1.76%
Total	$16,894,466	$1,201,298,264	1.41%

Alabama. The Hazus deterministic (historical) model estimated the geographical size of the region being 51,626.57 square miles and containing 1,180 census tracts. There are over 1,883,000 households in the region and a total population of 4,779,736 people (Census Bureau, 2010). Hazus estimated that there were 2,057,412 buildings in the region with a total building replacement value (excluding contents) of $490,324 (in 2014 dollars). For essential facilities, there are 145 hospitals in the region with a total capacity of 18,903 beds. There are **2,197 schools,** 1,541 fire stations, 572 police stations, and 92 emergency operation facilities.

Peak gusts in the Alabama study region reached 67 mph. Hazus estimated that 4 buildings were at least moderately damaged and 0 buildings that will be completely destroyed. The model estimated 0 displaced households. Additionally, an estimated 0 schools in the region experienced minor damage, 0 schools experienced moderate damage, 0 schools experienced severe damage and 0.00 were had complete destruction. Based on the Hazus model, it is estimated that 0 schools in the region would experience more than 1 day of Disaster Learning Loss.

Louisiana. The Hazus deterministic (historical) model estimated a population of 4,533,372 people over 46,011.03 square miles, and 1,138 census tracks. There are an estimated 1,823,390 buildings in the Louisiana region which have an aggregate total replacement value of $447,066,000 (in 2014 dollars). For essential facilities, there are 257 hospitals in the region with a total capacity of 17,009 beds. There are 1,963 schools**,** 1,321 fire stations, 413 police stations, and 76 emergency operation facilities.

Peak gusts in the Louisiana study region reached 53 mph. Hazus estimated that about 0 buildings were at least moderately damaged. The model estimated 0 displaced households. An estimated 0 schools in the region experienced minor damage, 0 schools experienced moderate damage, 0 schools experienced severe damage and 0.00 were had complete destruction. Based on the Hazus model, it is estimated that 0 schools in the region would experience more than 1 day of Disaster Learning Loss.

Mississippi. The Hazus deterministic (historical) model ran with a geographical size of the region at 47,663.89 square miles and containing 661 census tracts. There are over 1,115,000 households in the region and a total population of 2,967,297 people (Census Bureau, 2010). There are an estimated 1,241 buildings in the region with a total building replacement value (excluding contents) of $263,908,000 dollars (in 2014 dollars). Approximately 92% of the buildings (and 73% of the building value) are associated with residential housing. For essential facilities, there are 134 hospitals in the region with a total capacity of 14,549 beds. There are **1,410 schools,** 1,010 fire stations, 416 police stations, and 86 emergency operation facilities.

Peak gusts in the Mississippi study region reached 71 mph. Hazus estimated that about 4 buildings were at least moderately damaged. The model estimated 0 displaced households. An estimated 0 schools in the region experienced minor damage, 0 schools experienced moderate damage, 0 schools experienced severe damage, and 0.00 were completely destroyed. Based on the Hazus model, it is estimated that 0 schools in the region would experience more than 1 day of Disaster Learning Loss.

Exploring the educational impact Hurricane Nate had on the entire study region, Table 11 provides a list of each region, the estimated number of schools in the region and the projected number of Disaster Learning Loss days.

Table 11

Expected Disaster Learning Loss for Hurricane Nate, 2017

State	Total Number of Schools	Probability of at least Moderate Damage > 50%	Probability of Complete Damage > 50%	Expected DLL Days
Alabama	2,197	0	0	0
Louisiana	1,963	0	0	0
Mississippi	1,410	0	0	0
Total	5,570	0	0	0

Once again, these results show the variability of hurricane events. In this three-state region model, there was no estimated Disaster Learning Loss. Considering the peak gust wind speed of 71 mph, this is not surprising when we compare this storm to the other three historical models.

Summary of Deterministic Models. The results of the deterministic (historical) model outputs and findings from the study sample showed a total of 44,535 schools with 28% having an observed probability of at least **moderate damage > 50%** to a school building as a result from a hurricane event and the probability of **complete damage** > 50% being 0%. The study sample model output shows the combined storms resulting in 482 days of lost instruction across the study regions as summarized in Table 12.

Table 12

Expected Disaster Learning Loss for Study Sample Deterministic Scenarios

Hurricane Event & Date	Total Number of Schools	Probability of at least Moderate Damage > 50%	Probability of Complete Damage > 50%	Expected DLL
Hurricane Gustav, 2008	15,138	0	0	19
Hurricane Ike, 2008	17,632	4	0	372
Hurricane Harvey, 2017	11,765	24	0	37
Hurricane Nate, 2017	5,570	0	0	0
Total	44,535	28	0	428

The next section will explore the probabilistic models of the same sample regions with increased conditions at 100-year, 500-year, and 1,000-year event returns.

Question 2: Model Analysis of Probabilistic Hurricane Events

Once the historical (deterministic) models were run to establish a comparable baseline, the probabilistic scenarios were modeled and compared to explore the relationship between Disaster Learning Loss and the possibility of more intense and frequent hurricanes. This comparison considers what the real-world distribution and impact of the phenomenon might look like. Probabilistic models were estimated and run at the state level and aggregated at the county level, approximating the damage for 100-year, 500-year, and 1,000-year return hurricane events (see Table 1 for explanation of return events). The results are listed by state and organized in alphabetical order for each model (100-, 500-, and 1,000-year returns).

Alabama 100-Year. Hazus estimates that about 89,749 buildings will be at least moderately damaged. This is over 4% of the total number of buildings in the region. There are an estimated 11,432 buildings that will be completely destroyed. The model estimates 27,274 households to be displaced due to the hurricane. Of these, 19,333 people (out of a total population of 4,779,736) will seek temporary shelter in public shelters. Of the 2,197 schools in the study region, 194 will have a probability of at least moderate damage > 50%, and 0 will have the probability of complete damage > 50%, resulting in 248 expected Disaster Learning Loss days.

Alabama 500-Year. Hazus estimates that about 160,235 buildings will be at least moderately damaged. This is over 8% of the total number of buildings in the region. There are an estimated 43,748 buildings that will be completely destroyed. The model estimates 94,885 households to be displaced due to the hurricane. Of these, 65,644 people (out of a total population of 4,779,736) will seek temporary shelter in public shelters. Of the 2,197 schools in the study region, 221 will have a probability of at least moderate damage > 50%, and 0 will have the probability of complete damage > 50%, resulting in a total of **250 expected Disaster Learning Loss days** across the region.

Alabama 1,000-Year. Hazus estimates that about 180,531 buildings will be at least moderately damaged. This is over 9% of the total number of buildings in the region. There are an estimated 64,575 buildings that will be completely destroyed. The model estimates 124,945 households to be displaced due to the hurricane. Of these, 86,917 people (out of a total population of 4,779,736) will seek temporary shelter in public shelters. Of the 2,197 schools in the study region, 221 will have a probability of at least moderate damage > 50%, and 3 will have the probability of complete damage > 50%, resulting in a total of **253 expected Disaster Learning Loss days** across the region**.**

Florida 100-Year. Hazus estimates that about 760,431 buildings will be at least moderately damaged. This is over 10% of the total number of buildings in the region. There are an estimated 156,021 buildings that will be completely destroyed. The model estimates 444,461 households to be displaced due to the hurricane. Of these, 257,503 people (out of a total population of 18,801,310) will seek temporary shelter in public shelters. Of the 3,904 schools in the study region, 541 will have a probability of at least moderate damage > 50%, and 0 will have the probability of complete damage > 50%, resulting in a total of **654 expected Disaster Learning Loss days** across the region**.**

Florida 500-Year. Hazus estimates that about 999,325 buildings will be at least moderately damaged. This is over 14% of the total number of buildings in the region. There are an estimated 154,025 buildings that will be completely destroyed. The model estimates 825,900 households to be displaced due to the hurricane. Of these, 568,157 people (out of a total population of 18,801,310) will seek temporary shelter in public shelters. Of the 3,904 schools in the study region, 917 will have a probability of at least moderate damage > 50%, and 15 will have the probability of complete damage > 50%, resulting in a total of **1,006 expected Disaster Learning Loss days** across the region**.**

Florida 1,000-Year. Hazus estimates that about 1,503,865 buildings will be at least moderately damaged. This is over 21% of the total number of buildings in the region. There are an estimated 220,668 buildings that will be completely destroyed. The model estimates 892,961 households to be displaced due to the hurricane. Of these, 642,976 people (out of a total population of 18,801,310) will seek temporary shelter in public shelters. Of the 3,904 schools in the study region, 1,331 will have a probability of at least moderate damage > 50%, and 19 will have the probability of complete damage > 50%, resulting in a total of **1,739 expected Disaster Learning Loss** days across the region.

Louisiana 100-Year. Hazus estimates that about 101,723 buildings will be at least moderately damaged. This is over 6% of the total number of buildings in the region. There are an estimated 9,449 buildings that will be completely destroyed. The model estimates 24,705 households to be displaced due to the hurricane. Of these, 17,355 people (out of a total population of 4,533,372) will seek temporary shelter in public shelters. Of the 1,963 schools, 247 will have a probability of at least moderate damage > 50% resulting in a total of **421 expected Disaster Learning Loss days** across the region.

Louisiana 500-Year. Hazus estimates that about 208,585 buildings will be at least moderately damaged. This is over 11% of the total number of buildings in the region. There are an estimated 30,215 buildings that will be completely destroyed. The model estimates 82,449 households to be displaced due to the hurricane. Of these, 56,738 people (out of a total population of 4,533,372) will seek temporary shelter in public shelters. Of the 1,963 schools in the study region, 351 will have a probability of at least moderate damage > 50% and 1 will have a probability of complete damage > 50%, resulting in a total of **491 expected Disaster Learning Loss days** across the region**.**

Louisiana 1,000-Year. Hazus estimates that about 317,900 buildings will be at least moderately damaged. This is over 17% of the total number of buildings in the region. There are an estimated 42,486 buildings that will be completely destroyed. The model estimates 108,014 households to be displaced due to the hurricane. Of these, 73,335 people (out of a total population of 4,533,372) will seek temporary shelter in public shelters. Of the 1,963 schools in the study region, 564 will have a probability of at least moderate damage > 50%, resulting in a total of **1,098 expected Disaster Learning Loss days** across the region**.**

Mississippi 100-Year. Hazus estimates that about 68,397 buildings will be at least moderately damaged. This is over 6% of the total number of buildings in the region. There are an estimated 7,760 buildings that will be completely destroyed. The model estimates 17,930 households to be displaced due to the hurricane. Of these, 12,195 people (out of a total population of 2,967,297) will seek temporary shelter in public shelters. Of the 1,410 schools in the study region, 137 will have a probability of at least moderate damage > 50%, resulting in a total of **253 expected Disaster Learning Loss days** across the region**.**

Mississippi 500-Year. Hazus estimates that about 98,828 buildings will be at least moderately damaged. This is over 8% of the total number of buildings in the region. There are an estimated 35,271 buildings that will be completely destroyed. The model estimates 66,928 households to be displaced due to the hurricane. Of these, 43,421 people (out of a total population of 2,967,297) will seek temporary shelter in public shelters. Of the 1,410 schools in the study region, 112 will have a probability of at least moderate damage > 50%, and 1 will have the probability of complete damage > 50%, resulting in a total of **151 expected Disaster Learning Loss days** across the region**.**

Mississippi 1,000-Year. Hazus estimates that there are 1,241,810 buildings in the region which have an aggregate total replacement value of $263,908,000 (in 2014 dollars). The model estimates 81,595 households to be displaced due to the hurricane. Of these, 53,267 people (out of a total population of 2,967,297) will seek temporary shelter in public shelters. Of the 1,410 schools in the study region, 132 will have a probability of at least moderate damage > 50%, and 8 will have the probability of complete damage > 50%, resulting in a total of **187 expected Disaster Learning Loss days** across the region**.**

Texas 100-Year. Hazus estimates that about 205,013 buildings will be at least moderately damaged. This is over 2% of the total number of buildings in the region. There are an estimated 12,497 buildings that will be completely destroyed. The model estimates 47,623 households to be displaced due to the hurricane. Of these, 33,861 people (out of a total population of 25,145,561) will seek temporary shelter in public shelters. Of the 11,765 schools in the study region, 370 will have a probability of at least moderate damage > 50%, and 0 will have the probability of complete damage > 50%, resulting in a total of **1,758 expected Disaster Learning Loss days** across the region**.**

Texas 500-Year. Hazus estimates that about 532,957 buildings will be at least moderately damaged. This is over 6% of the total number of buildings in the region. There are an estimated 46,161 buildings that will be completely destroyed. The model estimates 159,361 households to be displaced due to the hurricane. Of these, 118,302 people (out of a total population of 25,145,561) will seek temporary shelter in public shelters. Of the 11,765 schools in the study region, 1,673 will have a probability of at least moderate damage > 50%, and 0 will have the probability of complete damage > 50%, resulting in a total of **2,320 expected Disaster Learning Loss days** across the region**.**

Texas 1,000-Year. Hazus estimates that about 683,505 buildings will be at least moderately damaged. This is over 8% of the total number of buildings in the region. There are an estimated 68,211 buildings that will be completely destroyed. The model estimates 226,205 households to be displaced due to the hurricane. Of these, 166,184 people (out of a total population of 25,145,561) will seek temporary shelter in public shelters. Of the 11,765 schools in the study region, 2,068 will have a probability of at least moderate damage > 50%, and 0 will have the probability of complete damage > 50%, resulting in a total of **2,563 expected Disaster Learning Loss days** across the region**.**

Hurricane Model Comparison: Deterministic vs. Probabilistic

Once the probabilistic data by state was collected, the data was then compiled and analyzed for the four hurricane events (historical, 100-year, 500-year and 1,000-year).

Hurricane Gustav, 2008: Comparing Deterministic and Probabilistic Data. Exploring the impact Hurricane Gustav had on educational outcomes in the entire study region when compared to the possibility of 100-, 500-, and 1,000-year events, Table 13 provides a list of each region, the estimated number of schools in the region and the projected number of Disaster Learning Loss days with a 100-, 500-, or 1,000-year return.

Table 13

Expected Disaster Learning Loss for Study Sample Probabilistic Scenarios

Hurricane Region	Total Number of Schools	100-Year Probability DLL (in days)	500-Year Probability DLL (in days)	1,000-Year Probability DLL (in days)
Louisiana	1,963	421	491	1,098
Mississippi	1,410	253	151	187
Texas	11,765	1,758	2,320	2,068
Total	15,138	2,432	2,962	3,353

Hurricane Ike, 2008: Comparing deterministic and probabilistic data.

Exploring the impact Hurricane Ike had on educational outcomes in the entire study region when compared to the possibility of 100-, 500-, and 1,000-year events, Table 14 provides a list of each region, the estimated number of schools in the region and the projected number of Disaster Learning Loss days with a 100-, 500-, or 1,000-year return.

Table 14

Expected Disaster Learning Loss for Study Sample Probabilistic Scenarios

Hurricane Region	Total Number of Schools	100-Year Probability DLL (in days)	500-Year Probability DLL (in days)	1,000-Year Probability DLL (in days)
Florida	3,904	654	1,006	1,739
Louisiana	1,936	421	491	1,098
Texas	11,765	1,758	2,320	2,563
Total	17,605	2,833	3,817	5,400

Hurricane Harvey, 2017: Comparing deterministic and probabilistic Data. Exploring the educational impact Hurricane Harvey had on the entire study region, Table 15 provides the estimated number of schools in the region and the projected number of Disaster Learning Loss days with a 100-, 500-, or 1,000-year return.

Table 15

Expected Disaster Learning Loss for Study Sample Probabilistic Scenarios

Hurricane Region	Total Number of Schools	100-Year Probability DLL (in days)	500-Year Probability DLL (in days)	1,000-Year Probability DLL (in days)
Texas	11,765	1,758	2,320	2,563
Total	11,765	1,758	2,320	2,563

This single state hurricane model reveals that gradual Disaster Learning Loss would pointedly increase should more intense hurricanes continue to occur. At a 100-year return, the study region was estimated to experience 1,758 days across the state of DLL. Should conditions worsen to a 1,000-year return the region is estimated to experience 805 more DLL days across the state.

Hurricane Nate, 2017: Comparing deterministic and probabilistic Data. Exploring the educational impact Hurricane Nate had on the entire study region, Table 16 provides a list of each region, the estimated number of schools in the region and the projected number of Disaster Learning Loss days with a 100-, 500-, or 1,000-year return.

Table 16

Expected Disaster Learning Loss for Study Sample Deterministic Scenarios

Hurricane Region	Total Number of Schools	100-Year Probability DLL (in days)	500-Year Probability DLL (in days)	1,000-Year Probability DLL (in days)
Alabama	2,197	248	250	253
Louisiana	1,936	421	491	1,098
Mississippi	17,632	253	151	187
Total	21,765	922	892	1,538

Table 16 display concerning findings of the potential estimated impact of Disaster Learning Loss should current climate projections come to fruition. A 1,000-year return of a hurricane that followed the same path as Hurricane Nate would result in an estimated 1,538 Disaster Learning Loss days across the study's modeled regions. The number of students impacted may cause extreme hardship on school leadership as they would need to navigate the multitude of issues that would arise with that many schools experiencing damage and needing to be closed.

Summary of Probabilistic Models

This section will provide a summary of the probabilistic models. Table 17 provides data on the number of school days within each region estimated to be impacted.

Table 17

Total operational schools expected to experience Disaster Learning Loss for the Probabilistic Scenarios Compared to the Deterministic Models

Hurricane	State	Total Schools	Determ. Model DLL	Estimated DLL for 100-Year Event	Estimated DLL for 500-Year Event	Estimated DLL for 1,000-Year Event
Ike, 2008						
	Florida	3,904	0	654	1,006	1,739
	Louisiana	1,936	0	421	491	1,098
	Texas	11,765	372	1,758	2,320	2,563
	Region	**17,605**	**372**	2,833	3,817	5,400
Harvey, 2017						
	Texas	11,765	37	1,758	2,320	2,563
	Region	11,765	**37**	1,758	2,320	2,563
Gustav, 2008						
	Louisiana	1,963	19	421	491	1,098
	Mississippi	1,410	0	253	151	187
	Texas	11,765	0	1,758	2,320	2,068
	Region	15,138	**19**	2,432	2,962	3,353
Nate, 2017						
	Alabama	2,197	0	248	250	253
	Louisiana	1,936	0	421	491	1,098
	Mississippi	1,410	0	253	151	187
	Region	5,543	**0**	922	892	1,538

When all 16 models are combined, the data provided insight into the potential implications and consequences of increased hurricane events on school systems throughout all the samples study regions. Based on the lack of literature surrounding school leader's ability to manage hurricane events compounded with these findings additional consideration into this phenomenon is merited.

Geospatial Analysis

Identifying potential exposure alone is not sufficient for understanding trends in disaster losses. The extant literature shows that social and economic vulnerability are critical ingredients in properly assessing risk (Mechler & Bouwer 2014, Cutter et al., 2003). Simply put, where someone lives makes a big difference in the quality of their lives and the opportunities open to them (Dreier, Mollenkopf, & Swanstrom, 2014). As such, demographic data along with a geospatial analysis was conducted on two counties of the 534 counties within the five-state sample. A full list of all the counties, as well as the number of schools within each county, used within the models is provided in Appendix E. These counties were selected from the five sample states by purposeful random sampling using confirming cases (Creswell, 2014; Palinkas, Horwitz, Green, Wisdom, Duan, & Hoagwood, 2015) to help answer the research questions and explore the determinants of vulnerabilities facing schools today in an effort to better inform and prepare school leaders of the potential implication of current projections of increasing hurricane intensity and frequency. The regions were selected based on their geographic location in relation to one of the four sample historical hurricane events modeled, coupled with the size of their population and the number of reported schools within the county. One large county (more than 100 schools) and one small county (less than 100 schools) was selected to explore similarities and/or differences between rural and urban contexts impacted by a hurricane event.

Sampling was consistent with the aims and assumptions inherent in the use of this studies method and intended to maximize efficiency and validity while achieving a breadth of understanding (Palinkas et al., 2015). The intended purpose of the regional models was to confirm the importance and meaning of possible patterns within the state data from the historical and probabilistic models while checking the viability of emergent findings with new data and additional cases at the regional level (Palinkas et al., 2015). As recommended by Palinkas et al. (2015), this form of purposeful random sampling using confirming cases is usually employed to provided potential additional examples that fit already emergent patterns to add richness, depth and credibility. This strategy provided the ability to compare and contrast the regional context to the state models while to identifying similarities and differences in the phenomenon of hurricane impact on Disaster Learning Loss.

A model was run for each county based on a historical storm that impacted the region. A second model was run exploring the impact of a 500-year return event. The two counties selected include:

- St. James Parish, Louisiana
- Nueces County, Texas

St. James Parish, LA. A historical model of Hurricane Gustav was run on the St. James Parish area. The geographical size of the St. James Parish region was estimated at 257.96 square miles and contained 7 census tracts. There were over 7,000 households in the region and a total population of 22,102 people (Census Bureau, 2010). There were an estimated 8,000 buildings in the region with a total building replacement value (excluding contents) of $2,022,000 (in 2014 dollars). Approximately 94% of the buildings (and 82% of the building value) were associated with residential housing. Hazus estimated that about 176 buildings were at least moderately damaged. This is over 2% of the total number of buildings in the region. There were an estimated 10 buildings that will be completely destroyed. The model estimated 17 households to be displaced due to the hurricane. Of these, 14 people (out of a total population of 22,102) will seek temporary shelter in public shelters.

Of the 9 schools in the study region, 0 will have a probability of at least moderate damage > 50%, and 0 will have the probability of complete damage > 50%, resulting in **5 expected Disaster Learning Loss days** across the Parish**.** *Figure (4.1)* displays the distribution of schools in the Parish along with the estimated Disaster Learning Loss days for each school based on its geographical location and the recorded windspeed in the area. Estimated peak wind gusts in the St. James Parish reached 97 mph.

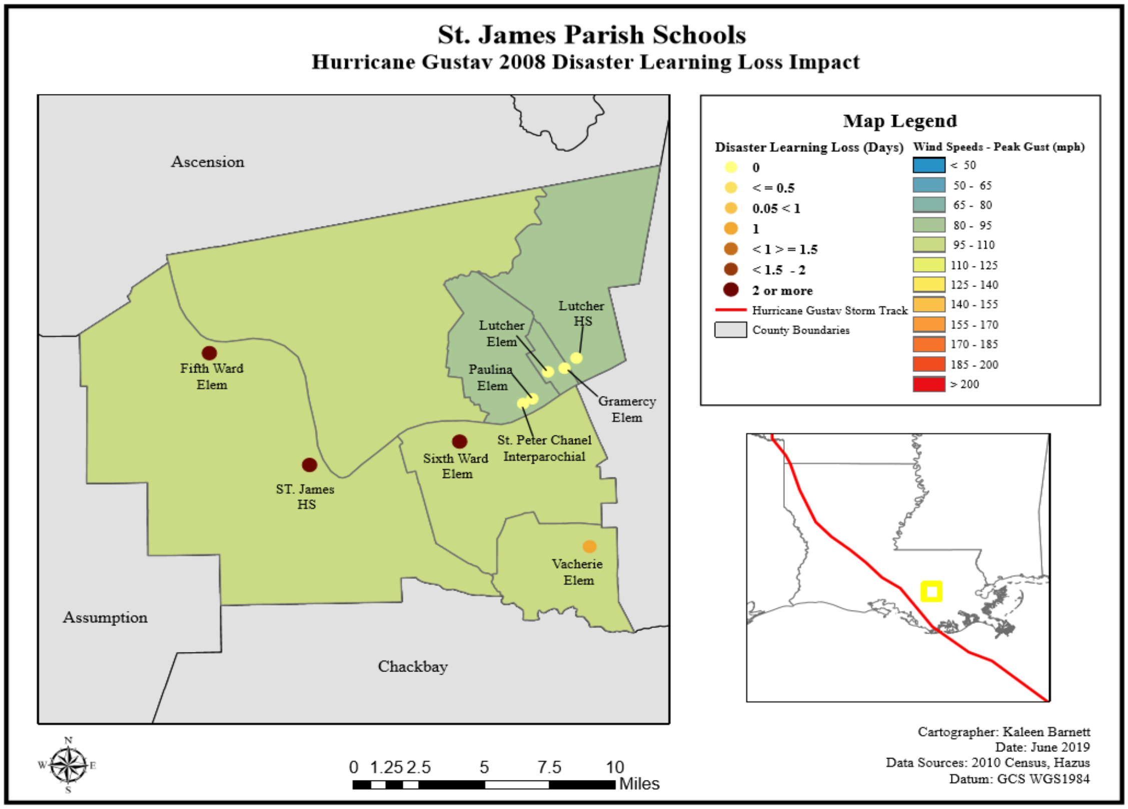

Figure (4.1). Geographical Map of the St. James Parish exploring Disaster Learning Loss for Hurricane Gustav.

A second probabilistic model was run in the St. James Parish estimating the Disaster Learning Loss rate if a 500-year event, with the same hurricane storm track as Gustav, hit the region. Hazus estimates that about 3,133 buildings will be at least moderately damaged. This is over 36% of the total number of buildings in the region. There are an estimated 507 buildings that will be completely destroyed. The model estimates 922 households to be displaced due to the hurricane. Of these, 725 people (out of a total population of 22,102) will seek temporary shelter in public shelters.

Of the 9 schools in the study region, 8 will have a probability of at least moderate damage > 50%, and 0 will have the probability of complete damage > 50%, resulting in **more than 2-days expected Disaster Learning Loss** across the Parish**.** *Figure (4.2)* displays the distribution of schools in the Parish along with the estimated Disaster Learning Loss days for each school based on its geographical location and the estimated windspeed in the area for a 500-year return event (estimated to be between 100 – 140 mph).

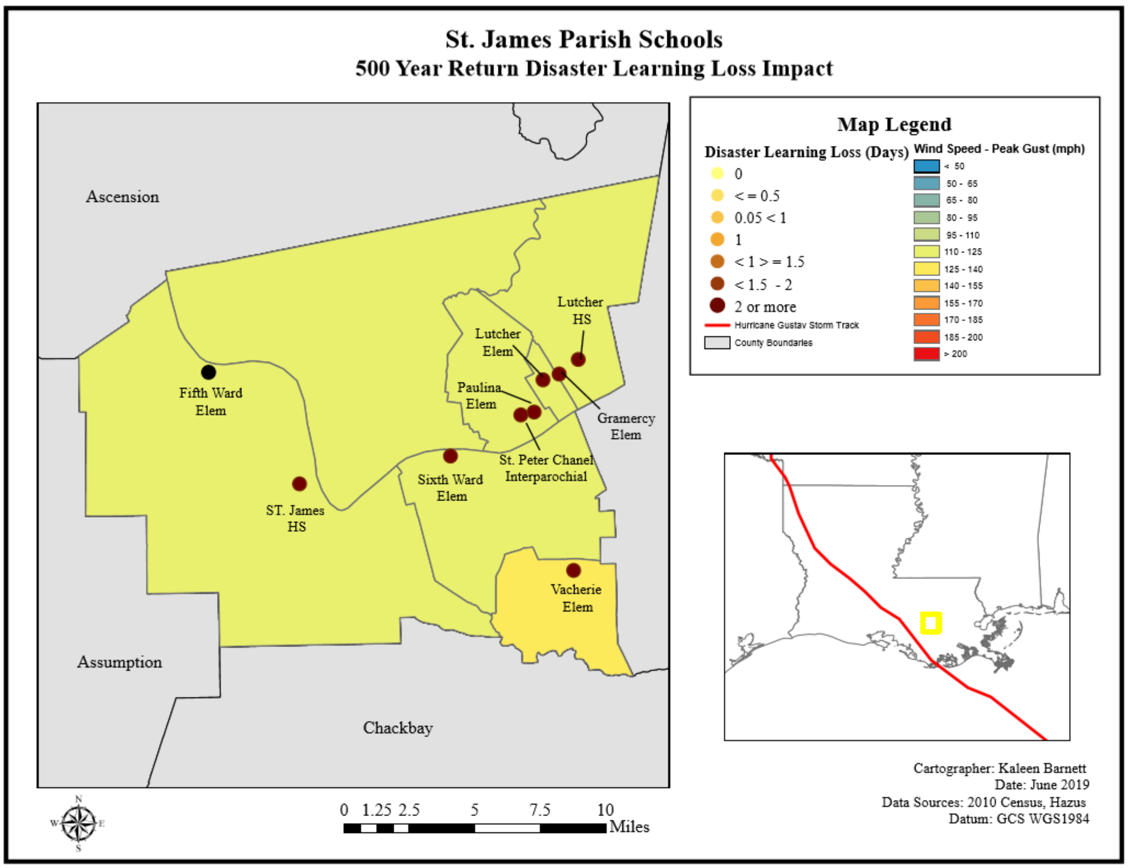

Figure (4.2). Geographical Map of the St. James Parish exploring Disaster Learning Loss for a 500-year return.

***Social vulnerability factors for St. James Parish*.** The National Center for Education Statistics (2018) estimated St. James Parish to have 8 operational schools, serving 3,762 students, for the 2017-2018 school year. Of those students, 21 were designated English Language Learners (ELL), and 485 had Individualized Educational Plans (IEPs). The Parish community demographics are listed to be 50% Black, 48% White, 2% Hispanic or Latino (of any race), and 1% two or more races. The region currently is 76.9% houses and 23.2% apartments/other housing structure with 39.2% being built before 1970, 45.5% being built between 1970-1999, and 15.1% being built 2000 and after. The median household income is estimated to be $62,534 with 82.3% of the population in the labor force and 17.6% unemployed or disabled (NCES, 2018). In the past 12 months NCES (2019) estimates 21.7% of families in the Parish with an income below the poverty level and 26.1% of families with Food Stamp/SNAP benefits.

In order to increase standards, rigor, and validity within these research findings, confirmability was attempted within the St. James Parish model (Guba & Lincoln, 1981). Multiple calls into district personal and an email to the Education Board was sent to attempt to discover publicly available data confirming or contradicting the findings from the Hazus model estimating Disaster Learning Loss days. The audit trail (Guba & Lincoln, 1981), did not result in the collection or confirmation of the data within the model for two reasons. First, it was conveyed that data from 2008 was no longer available. Second, district representatives were not aware of centralized, publicly available data reporting on school closure days and/or operational days. Future studies are therefore recommended to confirm credibility, dependability and confirmability (Guba & Lincoln, 1981) of the Hazus models.

Nueces County, Texas. A historical model of Hurricane Harvey was run on the Nueces, Texas region. The geographical size of the region is 850.03 square miles and contains 81 census tracts. There are over 124,000 households in the region and a total population of 340,223 people (Census Bureau, 2010). There are an estimated 118,000 buildings in the region with a total building replacement value (excluding contents) of $33,596,000 (in 2014 dollars). Approximately 92% of the buildings (and 78% of the building value) are associated with residential housing. Hazus estimates that about 2,534 buildings will be at least moderately damaged. This is over 2% of the total number of buildings in the region. There are an estimated 221 buildings that will be completely destroyed. The model estimated 657 households to be displaced due to the hurricane. Of these, 332 people (out of a total population of 340,223) will seek temporary shelter in public shelters.

Nueces County, listed as county number 178, is in Region 2 of the State of Texas. The region spans the following cities and/or towns: Agua Dulce, Banquete, Bishop, Corpus Christi, Driscoll, Port Aransas, and Robstown. There are 15 independent school districts within the county (Texas Education Agency, 2019). Of the 164 schools in the study region, 5 will have a probability of at least moderate damage > 50%, and 0 will have the probability of complete damage > 50%, resulting in **157 expected Disaster Learning Loss days** across the county**.** *Figure (4.3)* displays the distribution of schools in the county along with the estimated Disaster Learning Loss days for each school based on its geographical location and the recorded wind speed in the area. Estimated peak wind gusts in the Nueces, Texas region reached 131 mph.

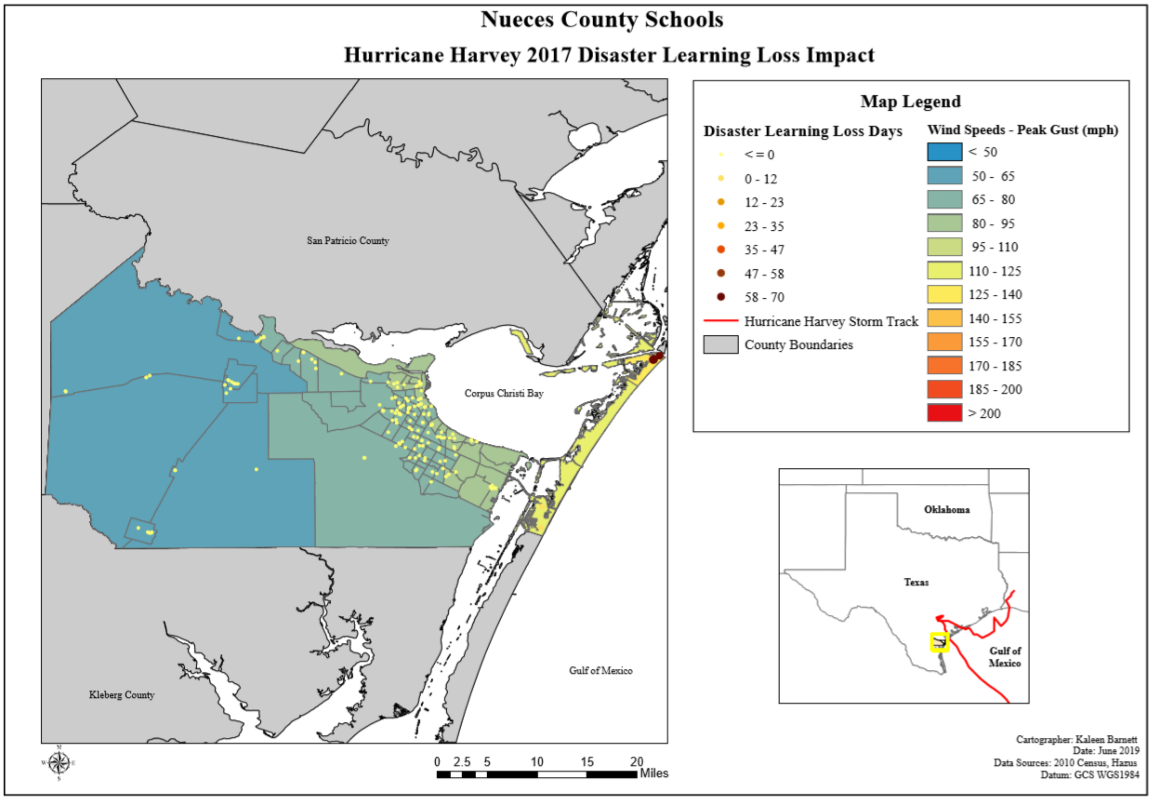

Figure (4.3). Geographical Map of Nueces County exploring Disaster Learning Loss for Hurricane Harvey.

A second probabilistic model was run in the Nueces County region estimating the Disaster Learning Loss rate if a 500-year event, with the same hurricane storm track as Harvey, hit the region. Hazus estimated that about 57,439 buildings will be at least moderately damaged. This is over 48% of the total number of buildings in the region. There are an estimated 10,307 buildings that will be completely destroyed. The model estimated 29,967 households to be displaced due to the hurricane. Of these, 21,142 people (out of a total population of 340,223) will seek temporary shelter in public shelters. Of the 164 schools in the study region, 129 will have a probability of at least moderate damage > 50%, and 0 will have the probability of complete damage > 50%, resulting in **a Disaster Learning Loss throughout the region for an estimated range of 58-70 days for most schools** across the county. *Figure (4.4)* displays the distribution of the increased wind speed in the county for a 500-year return event resulting in the 100% Disaster Learning Loss (estimated to be between 110 – 170 mph).

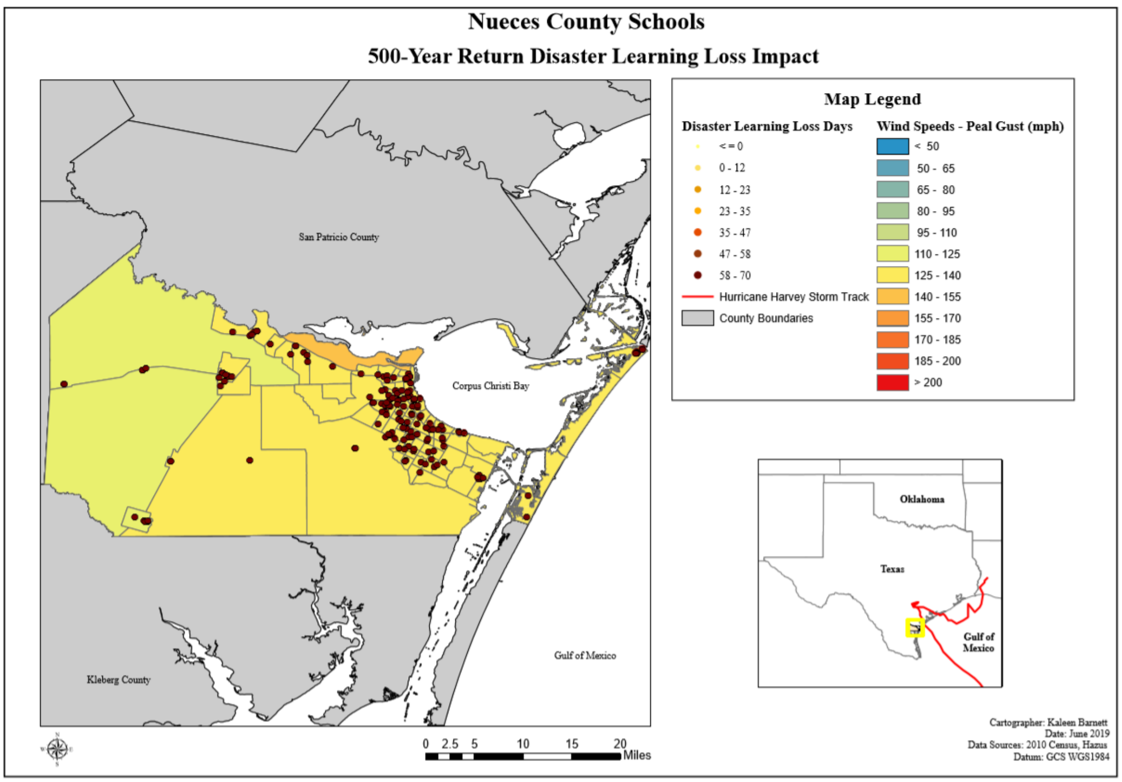

Figure (4.4). Geographical Map of Nueces County exploring Disaster Learning Loss for a 500-year event return.

***Social vulnerability factors for Nueces County, Texas*.** The Nueces County Profile estimated a population of 362,265 people in 2018. It is estimated that 93.55% of the population identified as urban residents and 6.45% rural residents (Census Bureau, 2010). The Nueces community demographics are listed to be 64.2% Hispanic (Ethnicity), with a Racial demographic of 4.3% Black, 90.9% White, and 4.8% two or more races or other (Census Bureau, 2018). Of the 362,265 residents in 2018, 24.6% are under the age of 17. The median household income is estimated to be $51,910 with 16.1% of the population below the poverty line (Census Bureau, 2017).

Chapter Conclusion

Data from the 20 Hazus models (deterministic and probabilistic) as well as the comparative analysis provided insight into how school systems are already being impacted by the essential problem of Disaster Learning Loss. The topics of growing hurricane intensity and its relation to increased Disaster Learning Loss emerged, as did the potential impact of the dimensions and determinants of social vulnerability leading to the likelihood of increased or decreased Disaster Learning Loss. This data was unexpected based on the lack of literature available to effectively prepare school leaders for the consequences of hurricane events. If a school is forced to close as a result of a hurricane event, school leaders are often left to manage the multitude of organizational and potential safety tasks before, during, and after the event. This can include but is not limited to communication action planning, establishment of a temporary shelter within their building for displaced community members, environmental and health clean-up of water or structural damage to the facility, organization of a return to school plan, establishment of a plan to make up the lost instruction days, weeks or months, emergency budget reallocation, among others. The next and final chapter will analyze potential themes and meanings behind the data, and provide recommendations for policy, practice and research.

CHAPTER V: DISCUSSION, CONCLUSIONS AND RECOMEMENDTIONS

"Being a leader brings with it a responsibility to do something of significance that makes families, communities, work, organizations, nations, the environment, and the world better places than they are today. Not all these things can be quantified" (Kouzes & Posner, 2008, p.13).

The objective of this integrated landscape-scale geospatial vulnerability assessment was to understand where and how school systems are exposed to, or threatened by, hurricane events. The secondary question for the study was the following: What is the relationship between hurricane events and school instruction days lost?

This fifth and final chapter will analyze potential themes and meanings behind the data. To do so, the quantitative models and spatial data will be combined, compared and analyzed. The quantitative Hazus models and data will be reviewed, starting with the models from 2008 and then moving to the 2017 models. The analysis focused on possible implications from the comparison of deterministic (historical) models and probabilistic hurricane models. Additionally, the geospatial analysis of the counties was added into the respected year of impact, as it was gathered expressly to help explain a localized impact and explore possible dimensions and determinants of social vulnerability. Following the interpretation of the quantitative and county-level geospatial analysis, additional limitations acknowledged for this study will be provided along with recommendations for educational leadership practice, policy, and areas for future research aligned with the

Sendai Framework for Disaster Risk Reduction 2015-2030, The Four Priorities adapted for School Districts in Action (UNISDR, 2018). Concluding ideas will be provided at the end of the chapter.

Interpretation of Data Findings

The Hazus deterministic (historical) models for the four hurricane events (Gustav, Ike, Nate, and Harvey) were relatively straightforward. The data illustrated that hurricanes, generally regardless of intensity, have some impact on instructional time lost. As stated in Chapter Four, of the summary of deterministic models, 28 schools of the total sample across all states impacted by the four historical hurricanes (44,535 schools) experienced an estimated a probability of at least moderate damage > 50% resulting from the hurricane events under study (see Table 12). The results illustrated that an estimated 482 days of Disaster Learning Loss across the study regions resulted from these four storms. The data demonstrated that, the higher the wind speed in a region, the more likely there will be damage to a school resulting in a higher Disaster Learning Loss. As explained in Chapter 2, meteorologists rank hurricanes on the Saffir-Simpson Hurricane Wind Scale (see *Figure (2.1)),* which assigns strength based on peak wind speeds (Keller & DeVecchio, 2015). As Hurricane Harvey proved, the system can be flawed at times, as wind is just one of a multitude of hazards associated with hurricane events. Storm surge, inland flooding from excessive rainfall and tornadoes all have the potential to cause extreme havoc on a community and schools when accompanying landfalling hurricanes.

Many people, school leaders included, who have endured the fringe of a Category 4 hurricane often underestimate its destructive power. As seen in the models computed for analysis in this study, each and every hurricane event is different. Even school systems well away from a storm's center are subject to collateral damage and subsequent Disaster Learning Loss. The variation of hurricane events provide real world examples of why school leaders need to be prepared regardless of the seasonal forecast or proximity to a hurricane landfall.

In order to explore the implications of historical events and project future implications (the probabilistic models) while also considering current levels of social vulnerability, this study combined deterministic models, probabilistic models, and current demographic data at the county level. The integrated method, as well as the conceptual framework, of this study recognized that quantitative data results must be taken as just one explanation of how communities, school leaders and policymakers perceive the environmental and social justice issues facing future student learning outcomes and Disaster Learning Loss. The combined analysis may be useful to those charged with implementing crucial pre-disaster planning processes in schools and districts, but it should never be taken as uninvestigated fact, as the conceptual framework shows there are a number of other factors that need to be considered when assessing for vulnerability. Unfortunately, there is a lack of literature about the impact hurricane events have on school systems and lost instructional time. Not studying learning loss perhaps mistakenly suggests to school leaders that historical hurricane events have not meaningfully impacted students' classroom instruction time, and therefore, future threats are unlikely to keep students out of school for any significant period of time. Consequently, the implications suggest that appropriate mitigation efforts do not warrant current consideration, evaluation, or a school leader's time and attention. However, collective results from the individual deterministic models combined with the probabilistic models (as shown by the Table 17 results) indicate that these perceptions are inaccurate. Closer examination of the individual deterministic models combined with the probabilistic forecast illustrates that if current predictions of more intense and more frequent hurricane events are likely to happen (Archer, 2009; IPCC, 2018; NOAA, 2018), the potential Disaster Learning Loss in the study regions will be exponentially higher than previously (historically) experienced. These gaps in perception between what has happened historically and what may happen in the near future deserve closer examination by school leaders and researchers alike.

The addition of the county-level geospatial analysis with current demographic data worked to enrich this study's findings and begin to explain regional and local variation by allowing for articulation of what the determinants and dimensions of social vulnerability maybe leading to Disaster Learning Loss. For a school leader to understanding the vulnerability associated with their location in relation to climate change it is required to comprehend the function of a school's sensitivity to climate change, its exposure to those risks, and its capacity for responding to or coping with climate variability and change (USGCRP, 2016). As described in Chapter I, assessing the determinants of vulnerability is an ongoing process through which school districts and leaders identify and evaluate potential risks, and areas of weakness capable of adversely impacting the school system (The United States Department of Education, 2008). Once a school leader can understand the school's geographic location in relation to potential regional hurricane events, they can begin to conduct a social vulnerability assessment using the conceptual framework available within this study to explore the exposure, adaptive capacity, and sensitivity of the school and students to truly examine what the relationship of the phenomenon (Lubienski, Gulosino, & Weitzel, 2009; USGCRP, 2016;).

Exposure, adaptive capacity, and sensitivity are the factors that make up overall social vulnerability. Exposure, the contact between any component of a school system, and one or more climate hazards, stressors, shocks, variability or change can be determined through the Hazus models. To determine adaptive capacity and sensitivity, a school leader needs to explore additional variables within and surrounding their system. This can include but is not limited to factors like housing displacement after a hurricane event, mean family income levels, employment rates before the hurricane event, the distribution of renters versus homeowners in the community, the percent of the population receiving food and/or housing assistance, etc. These factors among others are the cumulative measure of a school systems sensitivity and adaptive capacity leading to a deeper understanding of the systems resilience and a potential increase or decrease in Disaster Learning Loss.

Combining regional and local context, demographic data, probabilistic models and evidence of future vulnerability, may result in the beginning of an exploration into the hidden or underlining educational equity issues that could arise from climate change and increased hurricane intensity and frequency. This research has important implications for researchers and policy advocates trying to address inequities in schools and communities. Every year, natural disasters like hurricanes, disrupt normal activities due to evacuations, displacement, loss of life, and extensive damage to property. Schools located in affected areas may be unable to operate normally, or at all. Students may also experience difficulty with access to food, housing and other resources. The distribution of damage and difficulty maybe disproportionate across an impacted region therefore needing additional exploration and study into the factors that contribute to or limit Disaster Learning Loss.

In this light, and the best way to begin to tackle an understanding of Disaster Learning Loss, was to start at the state level and move inward toward a more localized context. As such, the findings were organized to provide summary tables and graphs for all the larger regional states impacted by each hurricane event from historic to probabilistic, then a review into the micro-implications of two modeled hurricane events from historical to probabilistic with demographic data at the county level was conducted. The next section will provide the analysis of the larger regional areas impacted by each hurricane event from historic to probabilistic with additional analysis from the regional findings incorporated with the corresponding hurricane:

Hurricane Gustav, 2008. With respect to Hurricane Gustav, many would not be alarmed by the approximate 19 historical Disaster Learning Loss days, as calculated by the Hazus model, across the entire three state region. However, when the introduction of the probabilistic models calculates an increase with a 100-year return Disaster Learning Loss days to 2,432, alarms are warranted. With an increased 1,000-year return, the Disaster Learning Loss almost doubles that of a 100-year return. The regions could expect devastating consequences to their school's infrastructure and systems of operation with a 100-year, 500-year and 1,000-year return. Table 17 illustrates this example showing the total estimated Disaster Learning Loss for a 1,000-year return at 3,353 Disaster Learning Loss days across the region. It's difficult to conceptualize what that actually means for students being out of classrooms, teachers having the increased pressure of trying to fast track learning, and school leaders being responsible for managing the strained budgets of renovation costs coupled with the possibility of an extended school year to make up for the lost days. To try and put this number into perspective, in the United States, students are required to spend 175 to 180 instructional days of a year in school.

The Disaster Learning Loss comparison between the 2008 historical event and the probabilistic models at the state level can be better illustrated with the regional probabilistic model of St. James Parish. A smaller community, relatively inland and away from the dangers of storm surge, the school system experienced minimal impacts, as modeled by Hazus, during 2008 Hurricane Gustav, but the 500-year probabilistic model tells a different story. The nine schools would be subject to wind speeds between 100–140 mph, up from 97 mph. The resulting damage is estimated to cause *all* of the nine schools in the region to lose functionality and close for a minimum of 2 days until sufficient repairs could be made. Importantly, the rest of the state of Louisiana would be experiencing a calculated average of 491 Disaster Learning Loss days at a 500-year return. In other words, even if the St. James Parish were able to resume functionality quickly after the event, it can be assumed that the school leaders in the area would experience a different kind of stress than rebuilding, namely the unanticipated and unplanned pressure of accommodating students from around the state whose schools will not be able to return to operational status due to the extensive damage estimated by the model.

Hurricane Ike, 2008. As a strong Category 2 hurricane with a Category 5 equivalent storm surge (National Weather Service, 2008), Hurricane Ike allows for a comparison of conditions in 2008 with Hurricane Gustav, showing that every hurricane and the resulting Disaster Learning Loss is unique. Within the regions examined, Hurricane Ike produced an estimated historical Disaster Learning Loss of 372 days as modeled by Hazus, resulting in a higher Disaster Learning Loss than Hurricane Gustav throughout the region. In terms of general familiarity with historical hurricane events compared to the anticipated increased intensity of hurricanes, this second model reinforced the point that a 100-, 500- and 1,000-year return of Hurricane Ike would likely cause devastating damage to the school systems in the study region—similar to what we saw with the probabilistic models of Hurricane Gustav. As seen in Table 17 and Table 13, the anticipated Disaster Learning Loss almost doubles from a 100-year return to a 1,000-year return: 2,833 Disaster Learning Loss days to 5,400 Disaster Learning Loss days.

Even though the differing scales of the regions could make it easy to dismiss the localized impact (see data for the state of Texas within the models), it's important to note that total days increase of Disaster Learning Loss projected across each state in the probabilistic models is relatively consistent. According to the data (see Table 14), the number of schools within each state almost uniformly increases with a 100-, 500-, and/or 1,000-year event return. Related to these concerns, the data demonstrates the growing scale of the impact extending into regions previously unimpacted by hurricane seasons.

The 2017 hurricane season was one of the most hyperactive on record. From August to October 2017, ten consecutive storms reached hurricane status (Franklin to Ophelia), which is the highest number of major hurricanes recorded since 2005 (NOAA, 2017; National Weather Service, 2017). The next section will highlight two of the recorded events (Hurricane Nate and Hurricane Harvey) of the ten storms that made landfall in the United States during the 2017 Atlantic hurricane season and allow for a comparative analysis of the two hurricanes previously described from 2008.

Hurricane Nate, 2017. The mildest of all the hurricane models, Hurricane Nate provided key insight into the regional variation on the impact hurricanes can have. The Hazus historical model showed that zero buildings were estimated to be destroyed at > 50%. The data also noted that schools were least impacted operationally by this hurricane with Hazus estimating that 0 schools in the region would experience > 1 day of Disaster Learning Loss. Similarly, the impact to the population in terms of displacement was estimated to be negligible.

In contrast, the probabilistic models show a very different and impactful outcome. Table 14 displays the significant increase of Disaster Learning Loss across all the regions with 100-, 500-, and 1,000-year event return. In other words, school leaders located in regions that might be considered relatively safe based on historical conditions could become overwhelmed by 100-, 500-, and 1,000-year return. For example, of the 1,936 schools in Louisiana, Hazus estimated 1,098 Disaster Learning Loss days across the region could be expected with a 1,000-year event—a significant increase from the 0 days estimated in the historical model.

Hurricane Harvey, 2017. Related to the concerns seen within the extant literature, Hurricane Harvey demonstrates the growing intensity of storms (see Archer, 2009; IPCC, 2018; NOAA, 2018) and subsequent increased Disaster Learning Loss. Hurricane Harvey brought 500-year rainfall and flood conditions to the Houston area (National Weather Service, 2017). In some parts of Texas, 1,000-year thresholds or more were reached (National Weather Service, 2017). More alarmingly, regions throughout Texas have seen no fewer than three such flooding events (500-year return) since 2014 (NOAA, 2017). These recent catastrophic weather events are consistent with current research that extreme events are becoming much more common.

When considering the consequences of such events happening on school systems, the Hurricane Harvey model would suggest alarming consequences, as seen in Table 12. With 24 school buildings estimated to experience at least Moderate Damage > 50%, the State of Texas alone would expect to experience an average of 37 Disaster Learning Loss days across the impacted region. Although this seems relatively low compared to the modeled Disaster Learning Loss of Hurricane Ike at 372 days, it needs to be put in context with the fact that the model was only estimating the Disaster Learning Loss for one state (Texas) compared to the three states modeled within Hurricane Ike (Florida, Louisiana, and Texas). Additionally, Texas has the highest population of all the sample states in the study with more than 8,922,000 households in the region and a total population of 25,145,561 people (Census Bureau, 2010). This means that even at 37 Disaster Learning Loss days the number of students impacted by the instructional time lost could be greater. It's also important to once again note that the Hazus models only account for estimated wind damage from a hurricane. Hurricane Harvey was recorded as a 500-year flooding event so it can be assumed that the Disaster Learning Loss rate for the event was actually substantially higher as a result of flooding damage to schools.

The increase in storm intensity may compound the rate of Disaster Learning Loss with a growing population. As the data shows in the regional model of the Nueces County, Texas, region, Hazus estimates that about 2,534 buildings were at least moderately damaged from Hurricane Harvey. This is over 2% of the total number of buildings in the region. There were an estimated 221 buildings that would be completely destroyed. The model estimated 657 households to be displaced due to the hurricane. Of these, 332 people (out of a total population of 340,223) would seek temporary shelter in public shelters. Of the 164 schools in the study region, the model estimated 157 expected Disaster Learning Loss days across the county**.** As seen in *Figure (4.4),* the concentration of damaged schools close to shorelines, and schools located further inland are offered greater protection. In contrast, the probabilistic model of an increased calculated 500-year event impacting the region may result in complete devastation as seen in Table 17. The model estimates the schools in the region would be subject to wind speeds between 110-170 mph, up from 50-110 mph as modeled in the historic analysis.

There was ambiguity surrounding the exact amount of Disaster Learning Loss days the region would experience within this model due to new data and calculations of projected 500-year events, but it was estimated that a minimum of 58–70 Disaster Learning Loss days would be expected. More importantly, it’s important to take this data in context with the demographic data in the region. The majority of the community is a minority population at 64.2% Hispanic (Ethnicity) and 16.1% of the population is reported to be below the poverty line (Census Bureau, 2017). Hazus estimated that, at a 500-year event return, 57,439 buildings would be at least moderately damaged. This is over 48% of the total number of buildings in the region. There are an estimated 10,307 buildings that will be completely destroyed, displacing an estimated 29,967 households. Of these, 21,142 people (out of a total population of 340,223) will seek temporary shelter in public shelters. The amount of lost instruction time reported from the modeled Disaster Learning Loss coupled with the social vulnerability factors may have devastating long-term consequences on the school system, the capacity of regional school leaders to meet state and federal educational mandates, overall school and student resilience, and institutional and community resilience.

Summary of Findings

Consistent with the extant literature, the data showed socioeconomic and demographic characteristics are intertwined components when determining the resilience and vulnerability of individuals, households, and regions (Chaudhuri, 2003; Ligon & Schechter 2003; Zhang & Wang 2009). Students who survive a major hurricane might find their education temporarily disrupted or permanently ended, potentially derailing future plans. A concerning factor considering existing research finds education to be one of the key components of resiliency, and any interruption to education has a high probability of permanently reducing human capital while keeping students and families from rising above the poverty line (Chaudhuri, 2003; Jacoby & Skoufias, 1997). Increased Disaster Learning Loss has the potential to deny students access to education; therefore, Disaster Learning Loss increases uncertainty about future student outcomes. That exposure to risk and uncertainty about the future adversely affects wellbeing, increases the likelihood of poverty and school dropout rates, and reduces long-term income generating capacity (Chaudhuri, 2003).

Together, the above findings and examples demonstrate the current informality of disaster awareness and preparedness and the potential student inequality and marginalization taking place as a result of the lack of knowledge and understanding within the field of educational leadership. In summary, these results show that Disaster Learning Loss is currently taking place in our schools and is projected to increase. Moreover, the geographic aspects of vulnerability, including socioeconomic status and demographics of a community, are intertwined with Disaster Learning Loss. This trend in the data signals a call to action in the school social justice movement for a more innovative and transformative orientation towards a stronger focus on prevention and capacity building within the field of educational leadership and policy. More specifically, this data demonstrates that school leaders should be equipped to monitor every facet of a storm or hazard and know how to handle each threat that may come their way.

Limitations of the Present Study

The present study is not without its limitations. In addition to the general limitations described in Chapter 1, a number of additional limitations were found as the study progressed. First, the findings from this study are not generalizable or transferable to all school settings across all regions within and outside the sample used for this study. In addition, no causal claims can be made about the impact or risk of Disaster Learning Loss on student learning based on this initial study and the introduction of Disaster Learning Loss. The geospatial analysis, map, and models were produced by a combination of data from the National Center for Education Statistics (2018), Hazus Software, Census Data from 2010–2017, and data from a variety of sources published by individual school districts. Positions of schools and data shown are based on information available at the time the map data was last updated. They are approximations and are not the product of an on-the-ground survey.

Another important limitation was that this study cannot test every hurricane model available within Hazus to determine potential Disaster Learning Loss at the state or regional level. While the models selected were purposefully broad spanning 2008 to 2017, with inclusion of historical and probabilistic data in order to capture unexpected findings, the regional models were selected to narrow the focus of Disaster Learning Loss and included the dimensions and determinants of social vulnerability as outlined in the conceptual framework. Furthermore, the Hazus models only estimate damage caused or potentially caused by hurricane winds. Additional regional and models which include other components of damage could potentially help demonstrate the variation of social vulnerability across the larger study region as well as more accurately estimate Disaster Learning Loss.

In spite of these limitations and the complex dynamic interlinkages between the environment and Disaster Learning, the strengths of the present study are significant and illuminate important suggestions for future inquiry into the impact and current reality of Disaster Learning Loss. The next section will offer some directions for areas of future research, practice, and policy while helping to construct meaning from the data analysis.

Implications for Leadership Practice and Action

The results and findings of this study suggest practical implications for professional practice. The guiding research question for this study was the following: What counties along the Eastern and Gulf Coast regions of the United States have K-12 schools that are most vulnerable to hurricane events? In brief, it’s almost impossible to identify exactly which schools, counties, or districts are most vulnerable to hurricane events based on the natural variation and impossibility to predict where future hurricane events will happen. However, exploration into Disaster Learning Loss coupled with increased school leadership awareness of the potential consequences of climate change may lower Disaster Learning Loss observed in the probabilistic data models within this study.

The data collected for this study and reviewed in this chapter appear consistent with the literature about the extent of climate change, the effects it will have on individual regions varying over time, and the ability of different societal and environmental systems to mitigate or adapt to change (IPCC, 2017). "Taken as a whole," the IPCC (2017) states, "the range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time." This study's data showed consistent findings specific to the field of education.

The Sendai Framework modified to meet the needs of the field of educational leadership outlined **Significance 1** as: **School districts and leaders need to understand disaster risk.** In an effort to achieve this Significance, school leaders can begin with an exploration of their region's Disaster Learning Loss variation, including their communities' unique dimensions and determinants of social vulnerability. School leaders and leadership training programs should base their understanding of disaster risk in all its dimensions on school and school leader vulnerability and capacity; exposure of the school leader, student, school, or district and other assets; hazard characteristics; and the environment. Such knowledge can be used for risk assessment, prevention, mitigation, preparedness, response, and a reduction in Disaster Learning Loss.

It's true that competing public needs and demands, scarce resources, and lack of understanding of risks from hurricanes make this a challenging task to achieve. However, and from a critical social theory perspective, if this work is not done and awareness of Disaster Learning Loss does not increase, issues of social injustice may be exacerbated without change to educational practice. Simply put, superintendents, district leaders, principals, and school boards must invest as much, if not more, in dedicating time to safety and preparedness planning as they would in response and recovery. School leaders should sustain and maintain a level of interest and activities, especially when there isn't currently a crisis at the forefront of everyone's minds and parents aren't demanding to know what their schools are doing to strengthen safety. These efforts done proactively can strengthen school-community trust and confidence in school leadership.

In terms of increasing awareness and prevention efforts, this may fall to the district to explore how best to handle these efforts, but incorporation of this additional information should aim to reduce social vulnerability and prevent the transmission of Disaster Learning Loss going beyond the proximate causes to address future risks associated with climate change.

Additionally, school leaders need to establish procedures to help displaced students return to school with the supports (both in and out of school) needed to engage successfully. Globally, the number of displaced people is at the highest level since the end of the Second World War. Displaced students tend to come from some of the poorest and least-served parts of communities, and their vulnerability is exacerbated when displacement deprives them of education (Chaudhuri, 2003). Determining the education status of displaced students maybe challenging for school administration and reason enough for additional research into Disaster Learning Loss.

Given that data from this study corroborates the literature about challenges facing education in light of a changing climate, it becomes important to explore both technical and adaptive options for those school leaders that will be tasked with managing the new paradigm facing the future of education. Technical solutions are appropriate to consider in this case, as we enter into a new hurricane season every year; adaptive solutions, though, are preferred for exploring what long-term efforts may make mitigation efforts more likely to develop lasting improvements.

Data from this study indicated there is a high likelihood that the increase of more intense hurricanes will result in higher Disaster Learning Loss. There are multiple technical solutions to address this concern. One way to start the conversation about improving practice and reducing Disaster Learning Loss would be for school leaders, administrators, and/or district personnel to explore which social vulnerability elements would increase or decrease Disaster Learning Loss in their unique context, then establish programs and polices focused on what to do and what not to do before, during, and after a hurricane event. This includes **Significance 3** of the Sendai Framework modified for Educational Leadership, stating **School districts and leaders need to invest in disaster risk reduction for resilience.** Public and private investment in disaster risk prevention and reduction through structural and non-structural measures are essential for enhancing the economic, social, health, and cultural resilience of persons, communities, countries, and their assets, as well as the environment.

School leaders, administrators, and/or district personnel should leverage resources available within their state or through the federal government (see, for example, FEMA's P-1000 guide) to ensure their practices, resource allocation, and policies meet current best practices ensuring student safety. Furthermore, districts and counties need to invest in pre-disaster mitigation designed to not only reduce disaster relief and recovery spending but to also further improve the school's resiliency. Increased collaboration and a shared vision between school-based leaders and district-level leaders needs to be established to better address the concerns surrounding the anticipated impact of climate change. District leaders need to establish clear lines of communication, confer with administrators about potential time constraints, and discuss what district leaders might do to support these administrators in increasing prevention and mitigation efforts within each school.

In terms of the unique concerns facing rural education leaders (balancing efficient resource allocation with the long-term and overall welfare of their, and surrounding, affected communities), a rural community devastated by a hurricane may consider consolidating with a nearby district or school by bussing students long distances to ensure they return to their classroom instruction. In considering school consolidation to increase efficiency and get students back into classrooms, districts must recognize the important social role schools play in communities and the unintended consequences and stress bussing and long-distance travel to school can have on students. Successful consolidation requires consultation with multiple affected stakeholders and consideration of costs. Basic plans, negotiation of costs, and effective communication established before a disaster could reduce extended Disaster Learning Loss, improve communication across all parties, increase resilience, and reduce overall stress for school leaders.

Implications for Policy

The Sendai Framework modified to meet the needs of the field of educational leadership outlined **Significance 2** as follows: **School districts, school-based leaders and policymakers need to strengthen disaster risk governance to manage disaster risk.** It is incumbent upon school and district leadership, as well as policymakers, to find authentic ways to increase disaster risk governance to lower Disaster Learning Loss and promote prevention, mitigation, preparedness, increased response, recovery, and rehabilitation. Clear policies and guidelines that govern natural disaster emergency management may foster collaboration, communication across stakeholders, and partnership, while improving equitable access to education regardless of extreme hurricane events. This process should begin at the federal level with action-focused guideless, similar to FEMA's P-1000 document (2018), and move down through state, region, and district stakeholders to ensure the unique determinants and dimensions of vulnerability are considered and appropriately planned for at the local level. Policies directed at reducing Disaster Learning Loss and overall social vulnerability will be instrumental in keeping students in school and/or returning them to classrooms quickly after a disaster.

Faced with crises and disasters, most governments', districts', and schools' reflexive response is to safeguard student safety by closing a school until sufficient repairs can be made. When faced with extended closure, short-term options like condensing classrooms with neighboring unaffected districts may be hastily established. This decision often does not consider students whose houses have been damaged or destroyed causing displacement. Displacement is often devastating and extremely difficult for a community's most vulnerable families. Temporary, consolidated school systems may lack qualified teachers or overburden experienced teachers, resources, and infrastructure, exacerbating problems within the tattered school system and increasing the distress of students.

Lack of proper mitigation planning may result in funding sources being poorly managed and being cut off at short notice. Additional research should be conducted that explores legislation and policy and that addresses systemwide post-disaster planning and procedure, resource allocation, consolidation measures, and educational displacement. Legislation enshrining the education rights of displaced families increases the likelihood that the right to education will be fulfilled.

An inclusive legal framework does not necessarily prevent regional or local discriminatory practices. Schools may demand birth certificates, prior education credentials, national identification papers, or proof of residency to enroll. This process can be extremely difficult if a family's home and/or the school the student was attending was destroyed and records are not available after a hurricane event. Official clarification of enrollment policy at the state and federal level and conditions for extenuating circumstances after disasters can reassure school gatekeepers that the law does not require complete documentation for student enrollment. A strong national legal framework working to reduce Disaster Learning Loss may provide avenues for individuals to voice complaints while ensuring equitable access to education. Still, undocumented students may face even greater obstacles to access after hurricane events. Additional research should be conducted to explore existing policies and conditions that impact undocumented populations, as well as migrants, refugee students, and other vulnerable populations, experiencing Disaster Learning Loss.

In summary, and as outlined in **Significance 4** of the Sendai Framework Modified for Educational Leadership, **school districts and leaders need to cooperatively enhance disaster preparedness policy while building the capacity of the school system to effectively respond, recover, and reconstruct.** The growth of disaster risk means there is a need to strengthen disaster preparedness within school policy and practice at all levels of response. School leaders need to act in anticipation of events and ensure capacities are in place for effective response and recovery to reduce Disaster Learning Loss. More importantly, policy needs to support the efforts of school leaders. There is a clear need for additional research into ideas for more quickly delivering disaster recovery funds to schools and districts and for enhancing the resilience of schools to mitigate the risk and effects of hurricane events.

As the risk of climate disruptions increases, local and national policymakers, school leaders, and practitioners must integrate information about climate risks and their potential impacts with efforts to promote equitable education and the quick return of students to their education after a hurricane. The ability to identify communities and schools at high risk of disruption by using information from models, such as this study, will help to reduce the damage and long-term negative impacts devastating storms could have on unprepared school systems, while leading resilience-building efforts in families and communities.

Directions for Future Research

This study provides multiple avenues for future studies, many of which have been described in the previous sections. The following section will provide additional recommendations for future studies.

One of the reasons climate change has garnered increased national attention is the growing number of people across the United States impacted by national disasters including hurricanes, floods, storm surge, increased wildfires, heatwaves, and more. This study explored the impact hurricanes can have on educational outcomes and introduced a new conceptualized term, Disaster Learning Loss, but there was no exploration of other disasters and the possible relationship they can have to Disaster Learning Loss. In addition to estimating the impact of hurricane events, Hazus also estimates impacts to the physical, social, and economic vitality of a community from earthquakes, tsunamis, and floods. An exploration of the other disasters available within Hazus and how they are related to Disaster Learning Loss, or the lack thereof, could be a direction for future research.

The data indicated that localized demographic characteristics can play an important role in determining the rate of Disaster Learning Loss. However, the small sample size (two counties) makes it difficult to know if these findings are accurate or anomalous. Additional studies that explore the relationship between socioeconomic status, racial and ethnic demographics, and Disaster Learning Loss, as well as research into district-level student demographics and other measures of social vulnerability and Disaster Learning Loss, could be illuminating.

This study did not explicitly explore the individual role of district- or school-based leaders and personnel, including superintendents and school boards, in the impact of Disaster Learning Loss. Rather, The Sendai Framework was modified to better fit the language of the field of educational leadership, along with the formulation of an integrated methodology to better inform school leaders of the dimensions and determinants of school vulnerability, leading to Disaster Learning Loss as the starting point for the formulation of a method to discover how this process occurs. Case studies exploring the potential impact leaders have on reducing or increasing Disaster Learning Loss could be helpful in understanding the full complexity of Disaster Learning Loss.

As this study's literature review notes, few studies have explored the impact climate change has on school leadership, from both a practice perspective as well as a district and statewide policy perspective. It could be eye-opening to see what ideas teachers and administrators would generate if introduced to the potential impact of Disaster Learning Loss, if a study were conducted with this as the guiding research question. Research should look to foster communication among school leaders, scientists, engineers, and practitioners across disciplines in order to increase understanding of and better ways to deal with hurricane and other future climate change risks.

In summary, as our climate continues to change, so too must our approach to research exploring the nexus of environmental and social/educational justice. This includes research into existing and emerging climate hazards and strategies to mitigate or eliminate them specific to school leaders. Examples of research under this objective can include the following: the prevalence and evaluation of school-based processes and procedures to limit Disaster Learning Loss from climate exposure; rehabilitation of schools after climate disasters; factors inhibiting and effective low-cost methods of increasing, resilience strategies in schools in high-risk states or communities; factors inhibiting, and effective low-cost methods of increasing, availability of certified school leaders and partner organizations in high-risk states or communities; and modeling of the geographic, socioeconomic, and other distributions of factors correlated with high expected climate risk to children.

The relationship between education and hurricanes is complex, but efforts to understand the risks and best practices are growing. This study is a response to the calls for additional research to enhance interpretation of the hurricane risk and climate change. The information provided by the models was intended to support school leaders, practitioners, state and local officials, and policy makers in evaluating, planning for, and mitigating the effects of hurricane damage in advance of stronger storms, in an effort to reduce disaster payments, and make wise use of the school's limited emergency management resources.

Chapter Conclusion

Children have the right to an education in a safe environment. In many parts of the United States, however, school buildings are highly vulnerable to significant damage, collapse, or destruction in a hurricane. According to NOAA's Hurricane Research Division statistics (2018), the U.S. averages one-to-two hurricane landfalls each season. The past two hurricane seasons have been particularly destructive for students, schools, families, and communities in the United States. School leaders play a critical role in the safety and education of future generations. Past disasters, as well as the models developed within this study, have clearly demonstrated the devastating effects of hurricanes and subsequent Disaster Learning Loss.

Despite the critical role that schools play in young people's lives and in broader communities, many obstacles still exist in attempting to reduce or mitigate Disaster Learning Loss. However, district and school leaders are hungry for concrete examples of how to take on the real challenges they are faced with in their local context. As the data from this study illustrates, Disaster Learning Loss has already taken place and is projected to increase in the future. Finding a way to bridge the existing gaps between research, educational leadership practice, and policy at school, district, and state level, could yet prove powerful by forging preventative measures that mitigate risk and lower the rate of Disaster Learning Loss.

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Appendices

Appendix A

Definition of Terms

The following terms are used throughout this dissertation:

Adaptive capacity. Is the ability of students, schools, institutions, or districts to adjust to potential climate hazards, stressors, shocks, variability, or change. A related term, resilience, is used in this study to describe the ability to prepare and plan for, absorb, recover from, and adapt to adverse weather-climate-events (USGCRP, 2018).

Cartography (as a research tool) and visualization. Are terms defined by the balance between visual communication and visual thinking (Taylor & MacEachren, 1994) when seeing the location of hazards, schools, or the extent of the geography of the study region (Ballas, Clarke, Franklin, & Newing, 2018). Cartography is the study and practice of making maps (McMaster, Kessler, & Howard, 2009).

Climate Change. Is the data-informed identification of a change in global or regional climate patterns over more than 30 years (Kitchen, 2014). Climate change has been apparent from the mid to late 20th century onwards and attributed largely to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels (Kitchen, 2014).

Disaster. "Usually a sudden event that causes great damage or loss of life during a limited time and in a limited geographic region" (Keller & DeVecchio, 2015, p. 534). In this study, disaster is an interchangeable term with climate event, climate shock, climate disturbance, and natural disaster, most often referring to a hurricane.

Disaster Learning Loss. A theorized term used to identify the amount of instructional time lost because of climate-related disasters, hazards, stressors, shocks, variability, and/or change.

Environmental Migrants. Persons or groups of persons who, for reasons of sudden or progressive change in the environment that adversely affects their lives or living conditions, are obliged or choose to leave their habitual homes, either temporarily or permanently, and who move either within their country or abroad" (IOM working definition, 2008). In popular media, as well this study, this term is interchangeable with climate migrants and climate refugees. A sub-group specific to this study is student migrants.

Forecast. With respect to this study and to natural disasters, forecast is an announcement that states that a particular event, most notably a hurricane, is likely to occur during a particular time interval and within a specified geographic region, often with some statement of the degree of its probability (Keller & DeVecchio, 2015).

Exposure. Exposure is contact between a school and climate variability or one or more climate hazards, stressors, shocks, or changes.

General Building Stock (GBS). A term used when identifying non-residential structures, such as schools, in the software program Hazus. These buildings are derived from Dun & Bradstreet (D&B) data. Additional specifics are provided in Chapter Three of this dissertation.

Geospatial Analysis. This term is defined as the use of spatial data in research that allows a researcher to consider the influence of geographic context on the issue

(Hogrebe, 2012). Geospatial analysis is conducted using geographic information systems (GIS).

Geographic information systems (GIS). "Computers capable of storing, retrieving, transforming, and displaying spatial information about Earth and of making maps with these data" (Keller & DeVecchio, 2015, p. 537). This digital mapping technology software (Vélez & Solórzano, 2017) is used within this study to run Hazus and to generate spatial maps to examine visual patterns within the data (Hogrebe, 2012).

Global Climate Model. "Computer programs that use environment data in mathematical equations to predict global change, such as increases in mean temperature, changes in precipitation, or some other atmospheric variable" (Keller & DeVecchio, 2015, p. 537). In the case of this study, the imbedded climate and hurricane models available within Hazus technology are used.

Global Warming. "The increase in mean annual temperature of the lower atmosphere and oceans in the past 150 years, primarily as a consequence of burning fossil fuels that emit greenhouse gases into the atmosphere" (Keller & DeVecchio, 2015, p. 537). This increase in the average global temperature can lead to climate change (Kitchen, 2014).

Greenhouse Gases. "Gases such as carbon dioxide, water vapor, methane, and CFCs (any of a class of compounds of carbon, hydrogen, chlorine, and fluorine) that absorb and radiate infrared radiation at different wavelengths and delay the loss of infrared wavelengths to space" (Kitchen, 2014, p. G-7).

Hazus. A FEMA-sponsored software that is industry recognized and considered to be a standardized methodology for assessment of potential loss from floods, earthquakes, and hurricanes (Nastev & Todorov, 2013).

Hurricane. The National Weather Service (2018) defines a hurricane as a "tropical cyclone with maximum sustained winds of 74 mph (64 knots) or higher." Be it a typhoon, cyclone, or hurricane, each of these names refers to the same type of storm system in different locations around the globe (Keller & DeVecchio, 2015). Storms in the western Pacific Ocean are called typhoons, storms in the South Pacific and Indian Ocean are called cyclones, and storms in the Atlantic and Eastern Pacific are called hurricanes (Keller & DeVecchio, 2015). Scientists often refer to all three as simply "tropical cyclones." Due to the focused geographic location of this study being in the Atlantic and Gulf Coast regions, this dissertation uses the term hurricane.

Hurricane Model. A peer-reviewed model available within Hazus that simulates an entire hurricane disaster (Vickery et al., 2000a, 2000b.).

Impact. In this study, impact relates to the results of a hazardous event, notably hurricanes, and the effect or influence of social structures and social action.

Indirect effect. Indirect effect is a change that depends upon intervening factors. In the case of this study, such effects from a natural disaster—notably hurricanes—"could include emotional distress; the donation of money, goods, and services, or the payment of taxes to finance recovery; also called a secondary effect" (Keller & DeVecchio, 2015, p. 538).

Linkage. With respect to this study, and to natural hazards, a relationship between two phenomena (Keller & DeVecchio, 2015), often referred to in this study when discussing climate change, natural disasters, and education or educational leadership.

Mitigate or Mitigation. In this study, mitigate or mitigation refers to diminishing or moderating the impact of more frequent and intense hurricanes caused by climate change (Kitchen, 2014).

Probabilistic. In risk theory, and for the purpose of this study, the likelihood of a hazard occurring over a period of time in a specified geographic region, often referred to when identifying Hazus models.

Risk. In the field of Risk Management and within Risk Theory, "risk is the combination of the nature of the hazard, the exposure of the hazard, the longevity of the event and the probability of the event's occurrence" (Kitchen, 2014, p. G-13).

Risk Theory. The topic of risk gives rise to concrete problems that require empirical investigations, but these empirical investigations need to be structured by theoretical frameworks. The study of Risk Theory intellectualizes how people and societies are confronted with risks, including but not limited to financial markets, nuclear power plants, natural disasters, and privacy leaks in ICT systems (Roeser, Hillerbrand, Sandin, & Peterson, 2012; Wildavsky, 1982).

Resiliency. The antonym of vulnerability, resiliency is described as the capacity of a system, community, or society exposed to hazards to adapt by resisting or changing in order to reach and maintain an acceptable level of functioning and structure (United Nations, 2018).

Scale. In GIS and the development of maps, “the relationship between the distance between features on the map and their actual distance apart on Earth’s surface. Expressed either as a ratio, such as (1:24,000) or as a bar scale, a segmented line on the map” (Keller & DeVecchio, 2015, p. 542). In this study, scale is also referred to as spatial and temporal scales, which are changes in time and space.

School Leadership. In this study, school leadership or school leader is any person, at all levels of leadership, responsible for the process of enlisting and guiding the talents and energies of teachers, principals, administrators, staff, pupils, family members, and community toward achieving common educational aims. In this study, this term is often used synonymously with educational leadership, school leader, district-level leadership, or school-level leadership.

Sensitivity. Sensitivity is the degree to which students, schools, students, or districts are affected by climate hazards, stressors, shocks, variability, or change.

Social Structures. The underlying force that drives social action (Moore, 2005).

Social Systems. The main concept of sociological systems theory (Zafirovski, 2015), which conceptualizes societies as well as groups within them. Also, the broader philosophical tools that arise from and complement systems thinking, such as mental-model flexibility and visioning (Senge, 1990, 2000; Zafirovski, 2015).

Student Migrants. These are the children who have been pushed out of the areas they grew up in or students residing in locations where their schools have been destroyed with little hope for returning. These are the children with limited or no options for quickly reenrolling in a new school. These student migrants may be deprived of the skills necessary to complete their education and compete effectively in society and subsequently left without equitable opportunity. See also environmental migrants.

Uncertainty. Insufficient knowledge of a potential hazard, the factors that influence the hazards, or the outcomes that limit the researcher's ability to project the future outcome with accuracy and/or reliability.

Vulnerability. The tendency or predisposition to be adversely affected by stressors or impacts, including climate-related stressors (USGCRP, 2016). This term is connected and/or related to vulnerable populations and populations at risk throughout this study.

Weather. "Atmospheric conditions, such as air temperature, humidity, and wind speed, at any given time and place" (Keller & DeVecchio, 2015, p. 545).

Appendix B

Essential Facilities School Meta Data

School Facilities Hurricane Specific Attributes

1. Identification_Information:
    1.1 Citation:
        Citation Information:
            Originator: Applied Research Associates, Inc., Raleigh, NC, developed this database under contract to the National Institute of Building Sciences.
            Publication_Date: 20030000
            Title: HAZUS-MH: Essential Facilities: School Facilities Hurricane Specific Attributes Database
            On-line Linkage: http://www.fema.gov/hazus/,
        http://www.nibs.org/hazus/.

1.2 Description:
    Abstract:
        This database contains the Hurricane Specific Attributes related to the Schools features.

1.3 Time_Period_of_Content:
    Time_Period_Information:
        Range_of_Dates/Times:
        Beginning_Date: 20030000
        Ending_Date: 20030000

1.4 Status:
    Progress: Complete
        Maintenance_and_Update_Frequency: As needed

1.5 Spatial_Domain
    Bounding_Coordinates:
        West_Bounding_Coordinate: -170.350 degrees
        East_Bounding_Coordinate: -131.494 degrees
        North_Bounding_Coordinate: 70.462 degrees
        South_Bounding_Coordinate: 54.128 degrees

1.6 Keywords:
    Theme:

Theme_Keyword: HAZUS
Theme_Keyword: Inventory
Theme_Keyword: Essential Facilities
Theme_Keyword: Emergency Response Facilities
Theme_Keyword: Schools

Place:

Place_Keyword: USA
Place_Keyword: Alabama
Place_Keyword: Connecticut
Place_Keyword: Delaware
Place_Keyword: District of Columbia
Place_Keyword: Florida
Place_Keyword: Georgia
Place_Keyword: Louisiana
Place_Keyword: Maine
Place_Keyword: Maryland
Place_Keyword: Massachusetts
Place_Keyword: Mississippi
Place_Keyword: New Hampshire
Place_Keyword: New Jersey
Place_Keyword: New York
Place_Keyword: North Carolina
Place_Keyword: Pennsylvania
Place_Keyword: Rhode Island
Place_Keyword: South Carolina
Place_Keyword: Texas
Place_Keyword: Vermont
Place_Keyword: Virginia
Place_Keyword: West Virginia

1.7 Access_Constraints: None

1.8 Use_Constraints: None

1.9 Point_of_Contact

Contact_Information:
Contact_Person_Primary:
Contact_Person: Eric Berman
Contact_Address:
Address_Type: mailing and physical address
Address:
Federal Emergency Management Agency

500 C Street, S.W.
City: Washington
State: D.C.
Postal Code: 20472
Contact_Voice_Telephone: 202-646-3427
Contact_Electronic_Mail_Address: Eric.Berman@fema.dhs.gov

2. Data_Quality_Information
2.1 Attribute_Accuracy: Unknown
2.2 Logical_Consistency_Report: Unknown
2.3 Completeness_Report: Unknown
2.4 Positional_Accuracy: Unknown
2.5 Lineage: Unknown

3. Spatial_Data_Organization_Information
3.1 Indirect_Spatial_Reference:
3.2 Direct_Spatial_Reference_Method: Point
3.3 Point_and_Vector_Object_Information:

4. Spatial_Reference_Information
4.1 Horizontal_Coordinate_System_Definition:
4.1.1 Geographic:
Geographic Coordinate System (Longitude/Latitude)
Latitude Resolution: Unknown
Longitude Resolution: Unknown
Geographic Coordinate Units: Decimal Degrees
4.1.4 Geodetic_Model:
Horizontal Datum Name: North American Datum of 1983
4.2 Vertical_Coordinate_System_Definition: Not Applicable

5. Entity_and_Attribute_Information:
5.2 Overview_Description
5.2.1 Entity_and_Attribute_Overview:
The school facilities hurricane specific attributes database file and the individual state files contain 3 fields.

Entity_and_Attribute_Detail_Citation: SchoolId	HAZUS-MH Internal ID
Entity_and_Attribute_Detail_Citation: huBldgSchemeName	Wind Building Characteristics Mapping Scheme Name
Entity_and_Attribute_Detail_Citation: sbtName	Wind Specific Building Type

6. Distribution Information

6.1 Distributor

Contact Organization Primary: FEMA Distribution Center
Contact Address:
Address_Type: mailing address
Address: P.O. Box 2012
City: Jessup
State or Province: MD
Postal Code: 20794-2012
Contact Voice Telephone: 800-480-2530
Contact FAX Number: 301-362-5335

6.2 Resource Description: N/A

6.3 Distribution Liability

No warranty expressed or implied is made by FEMA regarding the utility of the data on any other system nor shall the act of distribution constitute any such warranty. FEMA will warrant the delivery of this product in a computer-readable format, and will replace if the product is determined unusable, or when the physical medium is delivered in damaged condition.

6.4 Standard Order Process

The HAZUS order form can be downloaded from the FEMA website (http://www.fema.gov/hazus/hazus6c.htm). Completed order forms should be mailed or faxed to the FEMA distribution center.

6.5 Custom Order Process: N/A

7. Metadata_Reference_Information

7.1 Metadata_Date: 20030313

7.2 Metadata_Contact:

Contact_Information:
Contact_Person_Primary:
Contact_Person: Eric Berman
Contact_Address:
Address_Type: mailing and physical address
Address:
Federal Emergency Management Agency
500 C Street, S.W.
City: Washington
State: D.C.
Postal Code: 20472
Contact_Voice_Telephone: 202-646-3427
Contact_Electronic_Mail_Address: Eric.Berman@fema.dhs.gov

7.3 Metadata_Standard_Name: FGDC Content Standard for Digital Geospatial Metadata

7.4 Metadata_ Standard_Version: FGDC-STD-001-1998

Appendix C

Boundary and Aggregation Levels

U.S. Counties

1. Identification_Information:

 1.1 Citation:

  Citation Information:
  Originator: Atkins, Atlanta, GA, developed this database under contract to the Federal Emergency Management Agency (FEMA).
  Publication_Date: 20140000
  Title: HAZUS-MH: Boundary: U.S. Counties
  On-line Linkage:
  http://www.fema.gov/hazus
  http://www.nibs.org/?page=hazus

 1.2 Description:

  Abstract:
  This data set portrays the 2010 U.S. County polygons of the United States in the fifty states, the District of Columbia, and Puerto Rico. Atkins developed this data set from the 2010 version of TIGER/Line files. The 2010 U.S. Census data was downloaded from the Minnesota Population Center, National Historical Geographic Information System (NHGIS) Version 2.0, Minneapolis, MN: University of Minnesota 2011 (http://www.nhgis.org).

  The contact information for the Census Bureau is: U.S. Department of Commerce, U.S. Census Bureau, Geography Division. 8903 Presidential Parkway, Room 303 WP I, Upper Marlboro, Maryland, 20772. Telephone: (301) 457-1128. E-Mail Address: tiger@census.gov. The U.S. Census Bureau website address is http://www.census.gov/.

Purpose:
This data set is intended for geographic analysis and display using HAZUS. HAZUS is designed to produce loss estimates for use by state, regional and local governments in planning for earthquake, flood, and wind loss mitigation, emergency preparedness and response and recovery.

 1.3 Time_Period_of_Content:

  Time_Period_Information:
  Range_of_Dates/Times:

Beginning_Date: Unknown
Ending_Date: 20100000

1.4 Status:

Progress: Complete
Maintenance_and_Update_Frequency: Because the Census 2010 TIGER/Line(r) was prepared by the U.S. Census Bureau for the decennial census of 2010, no changes or updates will be made until the decennial census.

1.5 Spatial_Domain

Bounding_Coordinates:
West_Bounding_Coordinate: -179.147 degrees
East_Bounding_Coordinate: -179.778 degrees
North_Bounding_Coordinate: 71.389 degrees
South_Bounding_Coordinate: 14.605 degrees

1.6 Keywords:

Theme:
Theme_Keyword: HAZUS
Theme_Keyword: HAZUS-MH
Theme_Keyword: Inventory
Theme_Keyword: County
Theme_Keyword: Boundary
Place:
Place_Keyword: USA
Place_Keyword: Alabama
Place_Keyword: Alaska
Place_Keyword: Arizona
Place_Keyword: Arkansas
Place_Keyword: California
Place_Keyword: Colorado
Place_Keyword: Connecticut
Place_Keyword: Delaware
Place_Keyword: District of Columbia
Place_Keyword: Florida
Place_Keyword: Georgia
Place_Keyword: Hawaii
Place_Keyword: Idaho
Place_Keyword: Illinois
Place_Keyword: Indiana
Place_Keyword: Iowa

Place_Keyword: Kansas
Place_Keyword: Kentucky
Place_Keyword: Louisiana
Place_Keyword: Maine
Place_Keyword: Maryland
Place_Keyword: Massachusetts
Place_Keyword: Michigan
Place_Keyword: Minnesota
Place_Keyword: Mississippi
Place_Keyword: Missouri
Place_Keyword: Montana
Place_Keyword: Nebraska
Place_Keyword: Nevada
Place_Keyword: New Hampshire
Place_Keyword: New Jersey
Place_Keyword: New Mexico
Place_Keyword: New York
Place_Keyword: North Carolina
Place_Keyword: North Dakota
Place_Keyword: Ohio
Place_Keyword: Oklahoma
Place_Keyword: Oregon
Place_Keyword: Pennsylvania
Place_Keyword: Puerto Rico
Place_Keyword: Rhode Island
Place_Keyword: South Carolina
Place_Keyword: South Dakota
Place_Keyword: Tennessee
Place_Keyword: Texas
Place_Keyword: Utah
Place_Keyword: Vermont
Place_Keyword: Virgin Islands
Place_Keyword: Virginia
Place_Keyword: Washington
Place_Keyword: West Virginia
Place_Keyword: Wisconsin
Place_Keyword: Wyoming

1.7 Access_Constraints: None

1.8 Use_Constraints: None

1.9 Point_of_Contact

Contact_Information:
Contact_Person_Primary:
Contact_Person: Eric Berman
Contact_Address:
Address_Type: mailing and physical address
Address:
Federal Emergency Management Agency
500 C Street, S.W.
City: Washington
State: D.C.
Postal Code: 20472
Contact_Voice_Telephone: 202-646-3427
Contact_Electronic_Mail_Address: Eric.Berman@fema.dhs.gov

2. Data_Quality_Information

2.1 Attribute_Accuracy: Unknown
2.2 Logical_Consistency_Report: Unknown
2.3 Completeness_Report: Unknown
2.4 Positional_Accuracy: The digital data source from which the data sets were extracted was the 2010 Version of Census TIGER/LineT files. Because the U.S. Census Bureau's mission is "to count and profile the Nation's people and institutions" it does not require high levels of positional accuracy for its geographic products such as TIGER/Line files. Showing relative position of elements is the major intent in its files and maps.

Census TIGER/Line (r) files are the outcome of a variety of source data (USGS topographic maps, GBF/DIME-files, aerial photography, etc.). The U.S. Census Bureau express that they cannot specify the accuracy of feature updates added by its field staff or of features derived from the GBF/DIME-Files or other map or digital sources. Only the positional accuracy of USGS sources that accomplish with the United States National Map Accuracy Standards can be approximate. The positional accuracy varies with the scale of the source map used (such as 1:100,000, 1:24,000, 1: 63,000, 1:20,000 and 1:30,000).

2.5 Lineage: Unknown

3. Spatial_Data_Organization_Information

3.1 Indirect_Spatial_Reference:
3.2 Direct_Spatial_Reference_Method: Polygons
3.3 Point_and_Vector_Object_Information: 3,221

4. Spatial_Reference_Information

4.1 Horizontal_Coordinate_System_Definition:
4.1.1 Geographic:
Geographic Coordinate System (Longitude/Latitude)
Latitude Resolution: Unknown
Longitude Resolution: Unknown
Geographic Coordinate Units: Decimal Degrees
4.1.4 Geodetic_Model:
Horizontal Datum Name: North American Datum of 1983
4.2 Vertical_Coordinate_System_Definition: Not Applicable

5. Entity_and_Attribute_Information:
5.2 Overview_Description
5.2.1 Entity_and_Attribute_Overview:
County database file and the individual state and territory files contain 6 fields.

Entity_and_Attribute_Detail_Citation: CountyFips	County Fips
Entity_and_Attribute_Detail_Citation: CountyFips3	County Fips 3 digits
Entity_and_Attribute_Detail_Citation: CountyName	County Name
Entity_and_Attribute_Detail_Citation: State	State Abbreviation
Entity_and_Attribute_Detail_Citation: StateFips	State Fips
Entity_and_Attribute_Detail_Citation: NumAggrTracts	Number of Census Tracts

6. Distribution Information
6.1 Distributor
Contact Organization Primary: FEMA Distribution Center
Contact Address:
Address_Type: mailing address
Address: P.O. Box 2012
City: Jessup
State or Province: MD
Postal Code: 20794-2012
Contact Voice Telephone: 800-480-2520
Contact FAX Number: 301-362-5335
6.2 Resource Description: N/A
6.3 Distribution Liability
No warranty expressed or implied is made by FEMA regarding the utility of the data on any other system nor shall the act of distribution constitute any such warranty. FEMA will warrant the delivery of this product in a

computer-readable format, and will replace if the product is determined unusable, or when the physical medium is delivered in damaged condition.

6.4 Standard Order Process

Hazus may be ordered via the Internet from the FEMA Map Service Center (MSC) utilizing the MSC Web store (msc.fema.gov). Hazus is available for online download or may be ordered on DVD.

6.5 Custom Order Process: N/A

7. Metadata_Reference_Information

7.1 Metadata_Date: 20140000

7.2 Metadata_Contact:

Contact_Information:
Contact_Person_Primary:
Contact_Person: Eric Berman
Contact_Address:
Address_Type: mailing and physical address
Address:
Federal Emergency Management Agency
500 C Street, S.W.
City: Washington
State: D.C.
Postal Code: 20472
Contact_Voice_Telephone: 202-646-3427
Contact_Electronic_Mail_Address: Eric.Berman@fema.dhs.gov

7.3 Metadata_Standard_Name: FGDC Content Standard for Digital Geospatial Metadata

7.4 Metadata_ Standard_Version: FGDC-STD-001-1998

Appendix D

Demographics Meta Data

1. Identification_Information:

   1.1 Citation:

      Citation Information:
      Originator: Atkins, Atlanta, GA, for U.S. States and Puerto Rico, and IBM, Fairfax, VA, for American Samoa, Guam, Marianas and Virgin Islands, developed this database under contract to the Federal Emergency Management Agency (FEMA).
      Publication_Date: 20140000, 20170000 for Territories
      Title: Hazus-MH: Inventory: Demographics
      On-line Linkage:
      http://www.fema.gov/hazus
      http://www.nibs.org/?page=hazus

   1.2 Description:

      Abstract: This data set provides distributions of income, population, demographics, occupancies, and housing unit development from the 2010 U.S. Census. The 2010 U.S. Census data was downloaded from the Minnesota Population Center, National Historical Geographic Information System (NHGIS) Version 2.0, Minneapolis, MN: University of Minnesota 2011 (http://www.nhgis.org). All data was developed at the census block level for the United States in the fifty states, the District of Columbia, and Puerto Rico.

      Demographic data and Census Tract Boundaries for American Samoa, Guam, Marianas and Virgin Islands were obtained from: http://www.census.gov/2010census/news/press-kits/island-areas/island-areas.html Census Block boundaries for these territories are unavailable from U.S. Census and are based on a 1km x 1km grid developed and populated with demographic data by the Pacific Disaster Center derived using population data and a grid from Landscan 2014 (http://ghin.pdc.org).

      The contact information for the Census Bureau is: U.S. Department of Commerce, U.S. Census Bureau, Geography Division. 8903 Presidential Parkway, Room 303 WP I, Upper Marlboro, Maryland, 20772. Telephone: (301) 457-1128. E-Mail Address: tiger@census.gov. The U.S. Census Bureau website address is http://www.census.gov/.

      Purpose:

This data set is intended for geographic analysis and display using Hazus. Hazus is designed to produce loss estimates for use by state, regional and local governments in planning for earthquake, flood, and wind loss mitigation, emergency preparedness and response and recovery.

1.3 Time_Period_of_Content:
Time_Period_Information:
Range_of_Dates/Times:
Beginning_Date: Unknown
Ending_Date: 20100000
1.4 Status:
Progress: Complete
Maintenance_and_Update_Frequency: Because the Census 2010 TIGER/Line(s) was prepared by the U.S. Census Bureau for the decennial census of 2010, no changes or updates will be made until the decennial census.
1.5 Spatial_Domain
Bounding_Coordinates:
West_Bounding_Coordinate: -179.147 degrees
East_Bounding_Coordinate: 146.473 degrees
North_Bounding_Coordinate: 71.389 degrees
South_Bounding_Coordinate: 14.382 degrees
1.6 Keywords:
Theme:
Theme_Keyword: HAZUS
Theme_Keyword: HAZUS-MH
Theme_Keyword: Inventory
Theme_Keyword: Block
Theme_Keyword: Boundary
Theme_Keyword: Census Block
Theme_Keyword: Demographics
Place:
Place_Keyword: USA
Place_Keyword: Alabama
Place_Keyword: Alaska
Place_Keyword: American Samoa
Place_Keyword: Arizona
Place_Keyword: Arkansas
Place_Keyword: California
Place_Keyword: Colorado
Place_Keyword: Connecticut
Place_Keyword: Delaware

Place_Keyword: District of Columbia
Place_Keyword: Florida
Place_Keyword: Georgia
Place_Keyword: Guam
Place_Keyword: Hawaii
Place_Keyword: Idaho
Place_Keyword: Illinois
Place_Keyword: Indiana
Place_Keyword: Iowa
Place_Keyword: Kansas
Place_Keyword: Kentucky
Place_Keyword: Louisiana
Place_Keyword: Maine
Place_Keyword: Marianas
Place_Keyword: Maryland
Place_Keyword: Massachusetts
Place_Keyword: Michigan
Place_Keyword: Minnesota
Place_Keyword: Mississippi
Place_Keyword: Missouri
Place_Keyword: Montana
Place_Keyword: Nebraska
Place_Keyword: Nevada
Place_Keyword: New Hampshire
Place_Keyword: New Jersey
Place_Keyword: New Mexico
Place_Keyword: New York
Place_Keyword: North Carolina
Place_Keyword: North Dakota
Place_Keyword: Ohio
Place_Keyword: Oklahoma
Place_Keyword: Oregon
Place_Keyword: Pennsylvania
Place_Keyword: Puerto Rico
Place_Keyword: Rhode Island
Place_Keyword: South Carolina
Place_Keyword: South Dakota
Place_Keyword: Tennessee
Place_Keyword: Texas
Place_Keyword: Utah
Place_Keyword: Vermont
Place_Keyword: Virgin Islands

Place_Keyword: Virginia
Place_Keyword: Washington
Place_Keyword: West Virginia
Place_Keyword: Wisconsin
Place_Keyword: Wyoming

1.7 Access_Constraints: None
1.8 Use_Constraints: None
1.9 Point_of_Contact

Contact_Information:
Contact_Person_Primary:
Contact_Person: Eric Berman
Contact_Address:
Address_Type: mailing and physical address
Address:
Federal Emergency Management Agency
500 C Street, S.W.
City: Washington
State: D.C.
Postal Code: 20472
Contact_Voice_Telephone: 202-646-3427
Contact_Electronic_Mail_Address: Eric.Berman@fema.dhs.gov

2. Data_Quality_Information

2.1 Attribute_Accuracy: Unknown
2.2 Logical_Consistency_Report: Unknown
2.3 Completeness_Report: Unknown
2.4 Positional_Accuracy: The digital data source from which the data sets were extracted was the 2010 Version of Census TIGER/Line files. Because the U.S. Census Bureau's mission is "to count and profile the Nation's people and institutions" it does not require high levels of positional accuracy for its geographic products such as TIGER/Line files. Showing relative position of elements is the major intent in its files and maps.

Census TIGER/Line (r) files are the outcome of a variety of source data (USGS topographic maps, GBF/DIME-files, aerial photography, etc.). The U.S. Census Bureau express that they cannot specify the accuracy of feature updates added by its field staff or of features derived from the GBF/DIME-Files or other map or digital sources. Only the positional accuracy of USGS sources that accomplish with the United States National Map Accuracy Standards can be approximate. The positional accuracy varies with the scale of the source map used (such as 1:100,000, 1:24,000, 1: 63,000, 1:20,000 and 1:30,000).

2.5 Lineage: Unknown

3. Spatial_Data_Organization_Information
   3.1 Indirect_Spatial_Reference:
   3.2 Direct_Spatial_Reference_Method: Polygons
   3.3 Point_and_Vector_Object_Information: 11,098,632

4. Spatial_Reference_Information
   4.1 Horizontal_Coordinate_System_Definition:
   4.1.1 Geographic:
      Geographic Coordinate System (Longitude/Latitude)
      Latitude Resolution: Unknown
      Longitude Resolution: Unknown
      Geographic Coordinate Units: Decimal Degrees
   4.1.4 Geodetic_Model:
      Horizontal Datum Name: North American Datum of 1983
   4.2 Vertical_Coordinate_System_Definition: Not Applicable
5. Entity_and_Attribute_Information:
   5.2 Overview_Description
   5.2.1 Entity_and_Attribute_Overview:
   The Demographics database file and the individual state and territory files contain 60 fields.

Entity_and_Attribute_Detail_Citation: CensusBlock
Entity_and_Attribute_Detail_Citation: Population
Entity_and_Attribute_Detail_Citation: Households
Entity_and_Attribute_Detail_Citation: GroupQuarters
Entity_and_Attribute_Detail_Citation: MaleLess16
Entity_and_Attribute_Detail_Citation: Male16to65
Entity_and_Attribute_Detail_Citation: MaleOver65
Entity_and_Attribute_Detail_Citation: FemaleLess16
Entity_and_Attribute_Detail_Citation: Female16to65
Entity_and_Attribute_Detail_Citation: FemaleOver65
Entity_and_Attribute_Detail_Citation: MalePopulation
Entity_and_Attribute_Detail_Citation: FemalePopulation
Entity_and_Attribute_Detail_Citation: White
Entity_and_Attribute_Detail_Citation: Black

Census Block
Total Census Block Population
Total Census Block Households
Population in Group Quarters
Males less than 16-yrs old
Males between 16 and 65
Males over 65-yrs old
Females less than 16-yrs old
Females between 16 and 65
Females over 65-yrs Old
Total Male Population
Total Female Population
Population Stating White
Population Stating Black
Population Stating Native American
Population Stating Asian
Population Stating Hispanic
Population Stating Pacific Islander
Population Stating Other Race Only

Entity_and_Attribute_Detail_Citation: NativeAmerican
Entity_and_Attribute_Detail_Citation: Asian
Entity_and_Attribute_Detail_Citation: Hispanic
Entity_and_Attribute_Detail_Citation: PacificIslander
Entity_and_Attribute_Detail_Citation: OtherRaceOnly
Entity_and_Attribute_Detail_Citation: IncLess10
Entity_and_Attribute_Detail_Citation: Inc10to20
Entity_and_Attribute_Detail_Citation: Inc20to30
Entity_and_Attribute_Detail_Citation: Inc30to40
Entity_and_Attribute_Detail_Citation: Inc40to50
Entity_and_Attribute_Detail_Citation: Inc50to60
Entity_and_Attribute_Detail_Citation: Inc60to75
Entity_and_Attribute_Detail_Citation: Inc75to100
Entity_and_Attribute_Detail_Citation: IncOver100
Entity_and_Attribute_Detail_Citation: ResidDay
Entity_and_Attribute_Detail_Citation: ResidNight
Entity_and_Attribute_Detail_Citation: Hotel
Entity_and_Attribute_Detail_Citation: Visitor
Entity_and_Attribute_Detail_Citation: WorkingCom
Entity_and_Attribute_Detail_Citation: WorkingInd
Entity_and_Attribute_Detail_Citation: Commuting5Pm
Entity_and_Attribute_Detail_Citation: OwnerSingleUnits
Entity_and_Attribute_Detail_Citation: OwnerMultUnits
Entity_and_Attribute_Detail_Citation: OwnerMultStructs
Entity_and_Attribute_Detail_Citation: OwnerMHs
Entity_and_Attribute_Detail_Citation: RenterSingleUnits
Entity_and_Attribute_Detail_Citation: RenterMultUnits
Entity_and_Attribute_Detail_Citation: RenterMultStructs
Entity_and_Attribute_Detail_Citation: RenterMHs
Entity_and_Attribute_Detail_Citation: VacantSingleUnits

Income Less than 10K
Income between 10K and 20K
Income between 20K and 30K
Income between 30K and 40K
Income between 40K and 50K
Income between 50K and 60K
Income between 60K and 75K
Income between 75K and 100K
Income over 100K
Population Residing by Day
Population Residing by Night
Population in Hotels
Visitor Population
Pop Working in Commercial Occup
Pop Working Industrial Occupancies
Population Commuting at 5pm
Owner Occupied Single Family Units
Owner Occupied Multi-Family Units
Owner Occup Multi-Family Structures
Owner Occupied Manuf Housing
Renter Occupied Single Family Units
Renter Occupied Multi-Family Units
Renter Occup Multi-Family Structures
Renter Occupied Manuf Housing
Vacant Single Family Units
Vacant Multi-Family Units
Vacant Multi-Family Structures
Vacant Manuf Housing
Units Built Before 1940
Units Built Between 1940 and 1949
Units Built Between 1950 and 1959
Units Built Between 1960 and 1969
Units Built Between 1970 and 1979
Units Built Between 1980 and 1989
Units Built Between 1990 and 1998

Entity_and_Attribute_Detail_Citation: VacantMultUnits
Entity_and_Attribute_Detail_Citation: VacantMultStructs
Entity_and_Attribute_Detail_Citation: VacantMHs
Entity_and_Attribute_Detail_Citation: BuiltBefore40
Entity_and_Attribute_Detail_Citation: Built40to49
Entity_and_Attribute_Detail_Citation: Built50to59
Entity_and_Attribute_Detail_Citation: Built60to69
Entity_and_Attribute_Detail_Citation: Built70to79
Entity_and_Attribute_Detail_Citation: Built80to89
Entity_and_Attribute_Detail_Citation: Built90to98
Entity_and_Attribute_Detail_Citation: BuiltAfter98
Entity_and_Attribute_Detail_Citation: MedianYearBuilt
Entity_and_Attribute_Detail_Citation: AvgRent
Entity_and_Attribute_Detail_Citation: AvgValue
Entity_and_Attribute_Detail_Citation: SchoolEnrollmentKto12
Entity_and_Attribute_Detail_Citation: SchoolEnrollmentCollege

Units Built After 1998
Median Year Built (Units)
Average Cash Rent
Average Home Value
School Enrollment up to High School

College and University Enrollment

6. Distribution Information

6.1 Distributor

Contact Organization Primary: FEMA Distribution Center
Contact Address:
Address_Type: mailing address
Address: P.O. Box 2012
City: Jessup
State or Province: MD
Postal Code: 20794-2012
Contact Voice Telephone: 800-480-2520
Contact FAX Number: 301-362-5335

6.2 Resource Description: N/A

6.3 Distribution Liability

No warranty expressed or implied is made by FEMA regarding the utility of the data on any other system nor shall the act of distribution constitute any such warranty. FEMA will warrant the delivery of this product in a computer-readable format, and will replace if the product is determined unusable, or when the physical medium is delivered in damaged condition.

6.4 Standard Order Process

Hazus may be ordered via the Internet from the FEMA Map Service Center (MSC) utilizing the MSC Web store (msc.fema.gov). Hazus is available for online download or may be ordered on DVD.
6.5 Custom Order Process: N/A

7. Metadata_Reference_Information
7.1 Metadata_Date: 20140000
7.2 Metadata_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Scott McAfee
Contact_Address:
Address_Type: mailing and physical address
Address:
Federal Emergency Management Agency
500 C Street, S.W.
City: Washington
State: D.C.
Postal Code: 20472
Contact_Voice_Telephone: 202-646-3427
Contact_Electronic_Mail_Address: Scott.McAfee@fema.dhs.gov
7.3 Metadata_Standard_Name: FGDC Content Standard for Digital Geospatial Metadata
7.4 Metadata_ Standard_Version: FGDC-STD-001-1998

Appendix E

List of counties used within Hazus models by State

Alabama:

County Name	Number of Schools
Autauga	20
Baldwin	68
Barbour	14
Bibb	12
Blount	22
Bullock	6
Butler	12
Calhoun	50
Chambers	20
Cherokee	9
Chilton	14
Choctaw	8
Clarke	16
Clay	10
Cleburne	9
Coffee	23
Colbert	30
Conecuh	9
Coosa	4
Covington	19
Crenshaw	5
Cullman	43
Dale	23
Dallas	39
DeKalb	23

Elmore	27
Escambia	22
Etowah	54
Fayette	7
Franklin	14
Geneva	12
Greene	7
Hale	10
Henry	10
Houston	47
Jackson	30
Jefferson	322
Lamar	5
Lauderdale	29
Lawrence	17
Lee	45
Limestone	27
Lowndes	10
Macon	10
Madison	148
Marengo	16
Marion	15
Marshall	39
Mobile	182
Monroe	12
Montgomery	123
Morgan	51
Perry	8
Pickens	12
Pike	15
Randolph	13

Russell	27
Shelby	77
St. Clair	33
Sumter	12
Talladega	42
Tallapoosa	17
Tuscaloosa	77
Walker	34
Washington	8
Wilcox	9
Winston	14
Total	**2,197**

Florida

County Name	Number of Schools
Alachua	60
Baker	6
Bay	48
Bradford	10
Brevard	114
Broward	332
Calhoun	4
Charlotte	23
Citrus	24
Clay	47
Collier	62
Columbia	17
DeSoto	9
Dixie	5
Duval	211

Escambia	66
Flagler	13
Franklin	2
Gadsden	16
Gilchrist	4
Glades	6
Gulf	5
Hamilton	5
Hardee	9
Hendry	13
Hernando	28
Highlands	19
Hillsborough	293
Holmes	7
Indian River	28
Jackson	17
Jefferson	3
Lafayette	2
Lake	51
Lee	120
Leon	56
Levy	13
Liberty	6
Madison	10
Manatee	70
Marion	61
Martin	27
Miami-Dade	512
Monroe	17
Nassau	15

Okaloosa	45
Okeechobee	10
Orange	251
Osceola	57
Palm Beach	229
Pasco	88
Pinellas	153
Polk	155
Putnam	22
Santa Rosa	34
Sarasota	67
Seminole	75
St. Johns	52
St. Lucie	50
Sumter	10
Suwannee	6
Taylor	7
Union	3
Volusia	90
Wakulla	8
Walton	19
Washington	7
Total	**3,904**

Louisiana

County Name	Number of Schools
Acadia	35
Allen	13
Ascension	36
Assumption	11
Avoyelles	16

Beauregard	12
Bienville	9
Bossier	40
Caddo	102
Calcasieu	82
Caldwell	7
Cameron	4
Catahoula	6
Claiborne	9
Concordia	12
De Soto	10
East Baton Rouge	217
East Carroll	5
East Feliciana	8
Evangeline	15
Franklin	9
Grant	9
Iberia	29
Iberville	12
Jackson	5
Jefferson	155
Jefferson Davis	16
Lafayette	78
Lafourche	39
LaSalle Parish	10
Lincoln	24
Livingston	47
Madison	8
Morehouse	13
Natchitoches	20

Orleans	162
Ouachita	78
Plaquemines	10
Pointe Coupee	10
Rapides	73
Red River	6
Richland	14
Sabine	12
St. Bernard	14
St. Charles	21
St. Helena	3
St. James	9
St. John the Baptist	18
St. Landry	47
St. Martin	22
St. Mary	31
St. Tammany	84
Tangipahoa	46
Tensas	4
Terrebonne	50
Union	9
Vermilion	27
Vernon	21
Washington	20
Webster	18
West Baton Rouge	13
West Carroll	5
West Feliciana	5
Winn	8
Total	**1,963**

Mississippi

County Name	Number of Schools
Adams	17
Alcorn	19
Amite	5
Attala	14
Benton	5
Bolivar	39
Calhoun	10
Carroll	4
Chickasaw	9
Choctaw	6
Claiborne	7
Clarke	9
Clay	11
Coahoma	21
Copiah	10
Covington	12
DeSoto	53
Forrest	31
Franklin	5
George	8
Greene	6
Grenada	10
Hancock	14
Harrison	75
Hinds	133
Holmes	16
Humphreys	6
Itawamba	9
Jackson	56

Jasper	9
Jefferson	6
Jefferson Davis	6
Jones	25
Kemper	5
Lafayette	17
Lamar	25
Lauderdale	34
Lawrence	6
Leake	10
Lee	43
Leflore	19
Lincoln	15
Lowndes	25
Madison	43
Marion	11
Marshall	20
Monroe	15
Montgomery	6
Neshoba	12
Newton	14
Noxubee	8
Oktibbeha	14
Panola	14
Pearl River	27
Perry	8
Pike	22
Pontotoc	13
Prentiss	15
Quitman	5

Rankin	52
Scott	13
Sharkey	5
Simpson	12
Smith	6
Stone	6
Sunflower	34
Tallahatchie	8
Tate	12
Tippah	13
Tishomingo	9
Tunica	9
Union	11
Walthall	7
Warren	23
Washington	32
Wayne	9
Webster	5
Wilkinson	5
Winston	9
Yalobusha	5
Yazoo	13
Total	**1,410**

Texas:

County Name	Number of Schools
Anderson	33
Andrews	7
Angelina	49
Aransas	6

Archer	8
Armstrong	2
Atascosa	33
Austin	17
Bailey	5
Bandera	7
Bastrop	31
Baylor	4
Bee	17
Bell	143
Bexar	721
Blanco	6
Borden	1
Bosque	13
Bowie	65
Brazoria	123
Brazos	63
Brewster	10
Briscoe	2
Brooks	4
Brown	27
Burleson	13
Burnet	20
Caldwell	18
Calhoun	9
Callahan	12
Cameron	214
Camp	8
Carson	7
Cass	21

Castro	6
Chambers	19
Cherokee	32
Childress	3
Clay	7
Cochran	6
Coke	4
Coleman	6
Collin	369
Collingsworth	3
Colorado	15
Comal	61
Comanche	9
Concho	10
Cooke	24
Coryell	31
Cottle	1
Crane	3
Crockett	3
Crosby	11
Culberson	2
Dallam	5
Dallas	998
Dawson	10
Deaf Smith	15
Delta	4
Denton	294
DeWitt	29
Dickens	2
Dimmit	6

Donley	5
Duval	9
Eastland	18
Ector	55
Edwards	2
El Paso	362
Ellis	72
Erath	22
Falls	17
Fannin	24
Fayette	16
Fisher	5
Floyd	9
Foard	2
Fort Bend	225
Franklin	4
Freestone	17
Frio	10
Gaines	8
Galveston	131
Garza	6
Gillespie	18
Glasscock	2
Goliad	5
Gonzales	14
Gray	12
Grayson	70
Gregg	64
Grimes	13
Guadalupe	47

Hale	29
Hall	4
Hamilton	6
Hansford	7
Hardeman	5
Hardin	29
Harris	1,566
Harrison	40
Hartley	6
Haskell	6
Hays	69
Hemphill	4
Henderson	37
Hidalgo	403
Hill	41
Hockley	21
Hood	21
Hopkins	19
Houston	18
Howard	16
Hudspeth	5
Hunt	51
Hutchinson	14
Irion	2
Jack	6
Jackson	11
Jasper	20
Jeff Davis	4
Jefferson	110
Jim Hogg	3

Jim Wells	25
Johnson	83
Jones	14
Karnes	17
Kaufman	58
Kendall	18
Kenedy	1
Kent	1
Kerr	31
Kimble	4
King	1
Kinney	3
Kleberg	23
Knox	5
La Salle	4
Lamar	28
Lamb	14
Lampasas	10
Lavaca	13
Lee	11
Leon	13
Liberty	47
Limestone	14
Lipscomb	5
Live Oak	6
Llano	5
Lubbock	134
Lynn	7
Madison	5
Marion	6

Martin	4
Mason	3
Matagorda	21
Maverick	29
McCulloch	6
McLennan	147
McMullen	1
Medina	25
Menard	3
Midland	61
Milam	19
Mills	8
Mitchell	12
Montague	16
Montgomery	166
Moore	12
Morris	8
Motley	1
Nacogdoches	41
Navarro	30
Newton	8
Nolan	10
Nueces	164
Ochiltree	8
Oldham	8
Orange	29
Palo Pinto	15
Panola	12
Parker	54
Parmer	11

Pecos	10
Polk	19
Potter	63
Presidio	4
Rains	4
Randall	45
Reagan	3
Real	3
Red River	11
Reeves	7
Refugio	7
Roberts	1
Robertson	12
Rockwall	30
Runnels	15
Rusk	30
Sabine	9
San Augustine	5
San Jacinto	8
San Patricio	33
San Saba	6
Schleicher	3
Scurry	12
Shackelford	3
Shelby	16
Sherman	3
Smith	94
Somervell	6
Starr	31
Stephens	5

Sterling	3
Stonewall	2
Sutton	4
Swisher	8
Tarrant	725
Taylor	70
Terrell	1
Terry	8
Throckmorton	2
Titus	20
Tom Green	105
Travis	447
Trinity	11
Tyler	16
Upshur	28
Upton	4
Uvalde	20
Val Verde	21
Van Zandt	35
Victoria	49
Walker	25
Waller	18
Ward	7
Washington	14
Webb	100
Wharton	22
Wheeler	6
Wichita	62
Wilbarger	11
Willacy	17

Williamson	202
Wilson	32
Winkler	5
Wise	31
Wood	20
Yoakum	7
Young	11
Zapata	7
Zavala	9
Total	**11,765**