BUILDING CAPACITY FOR CLIMATE ADAPTATION

Assessing the Vulnerability of Transportation Infrastructure to Sea Level Rise for Safety Enhancement in RITI Communities

FINAL PROJECT REPORT

by

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16. Abstract

Sea level rise (SLR) and more frequent extreme weather events are an emerging concern for transportation infrastructures in coastal areas. In particular, the livelihoods and transportation safety of vulnerable populations such as indigenous rural communities may be at higher risk to sea-level rise and exacerbated coastal flooding due to their heavy dependence on natural resources, settlements in relatively isolated fringe land, limited accessibility to services, and alternative economic activities, as well as lack of resources and tools for adaptation. Despite existing studies on sea-level rise's impacts, there is a lack of understanding of how the impacts of tidal flooding and sea-level rise may be unevenly distributed both spatially and socially, and how vulnerable (e.g. rural, relatively isolated) communities have experienced such impacts and perceive future risks. Using survey data, this project helps to better understand the current experience and risk perception of different communities when facing sea-level rise and more frequent coastal flooding. It helps to understand different communities' perceived travel challenges with coastal flooding, the social sensitivity to different types of challenges, and the priorities and concerns to access various types of resources with the projected sea-level rise. The findings could be used to develop adaptation strategies that improve communities' safe access to highly valued resources and activities.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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EXECUTIVE SUMMARY

Sea level rise (SLR) and more frequent, extreme weather events are a concern for transportation infrastructure. According to the National Research Council, Committee on Climate Change et al. (2008), approximately 60,000 miles of coastal roads in the United States are already exposed to flooding from coastal storms and high waves. In particular, the livelihoods and transportation safety of indigenous rural communities may be at higher risk to sea-level rise and exacerbated coastal flooding due to their heavy dependence on natural resources, settlements in relatively isolated fringe land, limited accessibility to services, alternative economic activities, and lack of resources and tools for adaptation (Green, Jackson et al., 2009). Despite existing studies on sea-level rise's impacts, there is a lack of understanding of how the impacts of tidal flooding and sea-level rise may be unevenly distributed both spatially and socially, and how vulnerable (e.g. rural, relatively isolated) communities may have experienced such impacts and perceive future risks. It is also unclear what types of travel means, purposes, and resources the at-risk communities would highly value and prioritize, not to mention whether these concerns and perceptions are consistent with the climate vulnerability assessment findings and adaptation priorities. Through community surveys, this project helps to better understand the experiences and risk perception of different communities when facing sea-level rise and more frequent coastal flooding. It aims to understand different communities' perceived travel challenges with coastal flooding, the social sensitivity to different types of challenges, and the priorities and concerns regarding the access to various types of resources, to support decision making that improves communities' safe access to highly valued resources and activities.

The findings show that currently, coastal communities in the study area, the City and County of Honolulu, Hawai'i, are most frequently affected by the indirect effects of rising sea levels such as storm surge, coastal erosion, and construction/maintenance on coastal roads as compared to direct coastal flooding, emphasizing the importance of taking ripple effects into consideration in transportation vulnerability studies. It also reveals that the most vulnerable residents such as the elderly, households with children, rural residents, and Native Hawaiian and other Pacific Islanders, who currently are experiencing more frequent and severe impacts, are more concerned about future sea-level rise, regardless of their income or car ownership in general. The findings highlight the importance of integrating the planning of vulnerable populations' residences, workspaces, schools, health care, and emergency facilities into consideration in future transportation adaptation to sea-level rise. By comparing the study's findings with the literature, it also found that the coastal communities are highly valued and are concerned about the park, recreational access, and culture and cultural activities access with sea-level rise. More attention should be devoted to how these types of transportation accessibilities will be affected and how to adapt in the future. The findings and lessons learned not only have practical significance in understanding the distribution of transportation impacts and priorities in sea level rise adaptation in Hawai'i but also have the potential to be generalized to vulnerable communities in similar coastal regions.

CHAPTER 1. INTRODUCTION

Climate change is increasingly a focus of research as scientific evidence indicates that climate conditions are changing at a rapid pace. As one of the most widespread climate change impacts, sea level rise has become a pressing threat to infrastructure (National Research Council, Committee on Climate Change et al., 2008). The conservative IPCC Fifth Assessment Report (Pachauri, Allen et al., 2014) projects that the earth is expected to experience an additional sea level rise of 0.26 to 0.82 meters by the end of this century. Semiempirical models show that a higher rate of sea level rise (i.e., 1 to 1.5 meters) is more likely to be reached by 2100 (Grinsted, Moore et al., 2010, Parris, Bromirski et al., 2012, Rahmstorf, 2007). Bloetscher, Romah et al. (2012) noted that coastal populations are at higher risk of sea level rise due to erosion, inundation, and storm surge. Coastal zones tend to have higher groundwater levels which cause a shortage of aquifer storage. This shortage can lead to a low capacity of soil to absorb precipitation which can increase the risk of groundwater flooding (Bloetscher and Romah, 2015, Romah, 2012). Due to this loss of soil storage capacity in coastal areas, rising sea levels can affect energy systems, transportation infrastructure, water infrastructure, and agricultural lands (Karl, Melillo et al., 2009, Zhang, 2011), making coastal zones vulnerable both economically and ecologically (Hoozemans, Marchand et al., 1993).

Hawaiʻi is especially vulnerable to coastal inundation hazards caused by rising sea levels, tsunami, hurricanes, and storm surf due to extensive exposure and the geographic and topographic situation of the islands (Keener, Marra et al., 2012). In Hawaiʻi, a 0.15-meter increase in sea level has been observed in the past century with an expected increase of 0.9 meters by 2100 (Vermeer and Rahmstorf, 2009). In addition to more frequent coastal flooding, sea level rise could also accelerate coastal erosion and shoreline retreat rates (Romine, Fletcher et al., 2013). Sea level rise may also cause substantial groundwater inundation. Rotzoll and Fletcher (2013) estimate that 0.6 m of potential sea-level rise will cause substantial flooding, and a 1 m sea-level rise will inundate 10% of a 1-km wide heavily urbanized coastal zone.

Sea level rise is expected to produce more frequent and widespread coastal flooding that will significantly affect transportation safety (Becken, 2005). Studies found sea level rise and climate change have negatively affected various transportation sectors, such as roads, airports, railways, and ports (Savonis, Burkett et al., 2008). Road networks are especially vulnerable to sea level rise impacts such as erosion and subsidence of road bases, flooding of underground tunnels and low-lying infrastructure, inundation of roadways, traffic congestion, and structure damage due to increased storm intensity (Azevedo de Almeida and Mostafavi, 2016). National Research Council, Committee on Climate Change et al. (2008) reported that there were already 60,000 miles of coastal highways exposed to periodic coastal flooding. Even with small portions of the network affected, sea level rise may lead to large disruptions and delays at the network level, causing loss of accessibility to crucial facilities such as hospitals (Koetse and Rietveld, 2009). In extremes, sea level rise may cause vulnerable communities to lose access to essential resources and services (Bronen, 2010). In particular, the livelihoods and transportation safety of indigenous rural communities are especially susceptible to such challenges due to their heavy dependence on natural resources, settlements in relatively isolated fringe land, limited accessibility to services and alternative economic activities, and lack of resources and tools for adaptation (Green, Jackson et al., 2009).

Although many studies have been conducted to assess the vulnerability of transportation to sea level rise, there are limited studies focusing on transportation vulnerability from the community's perspective. There is a lack of empirical data that assesses the impacts of sea level rise on transportation based on community experience and perceptions. As a result, it remains unclear how sea level rise and tidal flooding may actually impact people's travel and access to resources, whether such impacts are unevenly distributed, and how people would like to adapt to them.

1.1. Study Objectives

With the intent to better understand the impacts of sea level rise and coastal flooding based on empirical evidence, and to identify concerns from a practical point of view, and support transportation adaptation in a local context, this project conducted a transportation vulnerability assessment using data collected from a community survey. It attempts to better understand the impacts of sea level rise and coastal flooding on daily travel, especially the impacts on vulnerable populations in Hawaiʻi Rural, Isolated, Tribal, or Indigenous (RITI) communities, to better understand their current experience and future risk perception as well concerns and priorities for adaptation.

1.2. Report Layout

This report is divided into the following chapters. Chapter 2 summaries sea level rise and coastal flooding's impact on transportation and the associated social and equity concerns in the literature. Chapter 3 presents the data collection method, survey design, and analysis methods. The results of the analysis are shared in Chapter 4. The findings present an evaluation of the current impacts and future risks of sea level rise on daily travel based on people's empirical experience and risk perceptions. The differences in such experience and perceptions are also compared on the basis of socio-demographic characteristics such as residence location, age, ethnicity, household structure, and vehicle ownership. Chapter 5 highlights the key findings, compares the findings with existing studies, and discusses the limitation of the study and directions for future research.

CHAPTER 2. LITERATURE REVIEW

2.1. Sea Level Rise and Coastal Flooding's Impact on Transportation

Sea level has been rising since the late 19th century or early 20th century when global temperatures began to increase and NOAA researchers announced that it will continuously rise at a higher rate during the 21st century (Lindsey, 2019). The Intergovernmental Panel on Climate Change (2007) estimated that the global sea level has risen an average of 1.7 ± 0.5 mm per year over the 20th century. Global sea-level rise (SLR) is caused by the warmer climate melting glaciers, ice caps, and ice sheets accounts for about 40 percent of the observed SLR for 1961-2003 (National Research Council Ocean Studies Board, 2012). How much and how fast it will rise depends on future global warming and the rate of melting. Rising seas increase the risk of coastal flooding, storm surge, and coastal erosion (National Research Council Ocean Studies Board, 2012). In 2017, the global mean sea level was 3 inches above the 1993 average (Lindsey, 2019). NOAA scientists believe that the global mean sea level will rise at least 8 inches by 2100 (Parris, Bromirski et al., 2012).

In recent years, risk assessment and prediction of coastal flooding have become major concerns of governmental agencies and private sectors (New York City Panel on Climate Change, 2009). Many community members along the coastlines of the Tri-State region (New York, New Jersey, and Connecticut) are at risk for loss of property and life due to the rising potential for coastal flooding (New York City Panel on Climate Change, 2009). The factors that affect regional scale sea-level projections are different from global projections because sea level is often affected by ocean currents and wind patterns at local levels (Wuebbles, Fahey et al., 2017). According to Romine, Fletcher et al. (2013) in Hawai'i, the relative rate of sea-level rise around Kauai and Oahu (1 to 2 mm/yr) is almost at the same pace as the global-average rate of sea level rise over the past century.

Sea level rise and coastal flooding could result in more frequent and intense coastal flooding, storm surges, coastal erosions, and other extreme events. These adverse conditions could severely affect infrastructure such as roadways (Asadabadi and Miller-Hooks, 2017). The increased risk of severe flooding can affect transportation infrastructure along the coastline. Roads can be inundated due to the elevated water table levels and such flooding could become more and more frequent (Bloetscher and Romah, 2015, Titus, 2002). Most roads have some type of drainage system, but as the sea level rises, these drainage systems could become less effective (Titus, 2002). If the flooding occurs on a critical road or facility, it can cause traffic delays, congested conditions, trip cancelations, detours, and reduced accessibility and emergency services.

The more frequent and intense flooding from SLR and storm surges has increased the risk of delays, disruptions, and damage across the transportation systems (Savonis, Burkett et al., 2008). Studies have shown that recurrent flooding and inundation already significantly burden major roads in low-lying areas in Washington D.C, Maryland, Virginia, and New Jersey (Ayyub, Braileanu et al., 2012, Heim, 2017, Mitchell, Hershner et al., 2013, Tompkins and DeConcini, 2014). Low-lying road networks in San Francisco Bay and South Florida also experienced inundation, flooding, erosion, and structural damage. Non-motorized transportation modes such as bicycle lanes and pedestrian walkways are prone to the effects of SLR as well (Barry, 2016, Upton, 2014). The impacts have resulted in route closures, detours, and/or complete impassability (Barry, 2016, Upton, 2014). In Jacksonville, Florida, nuisance flooding has occurred a few times a year during full moon tides (Barry, 2016). The high water level has made it difficult for the residents to move around and caused disruption in access to daily activities and services, for instance going to mailboxes, to parks, around the inundated neighborhood, and to other locations (Barry, 2016). The impacts of lack of transportation access caused by flooding are not only physical but also emotional because of frustration due to lack of mobility (Barry, 2016).

Many studies have been conducted to evaluate the potential impacts of sea level rise or coastal flooding on transportation infrastructure (Bloetscher, Romah et al., 2012, Burkett, 2002, Han, Zegras et al., 2017, Jacob, 2007, Lu and Peng, 2011, Lu, Peng et al., 2015, Peterson, McGuirk et al., 2008, Savonis, Burkett et al., 2008, Suarez, Anderson et al., 2005, Titus, 2002, Wang, Chan et al., 2015, Wu, Hayat et al., 2013). For example, Bloetscher, Romah et al. (2012) used the Florida Department of Transportation (FDOT) information system, satellite imagery, local roadway, and hydrologic data to identify vulnerable parts of Florida's state transportation infrastructure in Dania Beach and Punta Gorda under local sea level rise scenarios. Wu, Hayat et al. (2013) used geographic information system (GIS) to investigate the transportation infrastructures at risk due to the effects of sea level rise and storm surge in Hampton Roads, Virginia. Suarez, Anderson et al. (2005) estimated the potential impact of global warming induced riverine and coastal flooding on system vehicle miles traveled (VMT) and vehicle hours traveled (VHT) in the Boston Metro Area. Han, Zegras et al. (2017) utilized a land use-transport model to forecast the impacts of 4-ft sea level rise on travel distances, travel speeds, and transit usage in the greater Boston region by 2030.

However, while there are many studies based on scientific projections and transportation modeling, there are few studies based on empirical experience and people's risk perception. In addition, there is a lack of discussion of such impacts and vulnerability from the environmental equity lens. Especially, whether the most socially vulnerable groups would be at higher risk to such impacts and in what ways they are at risk, needs to be explored.

2.2. Social Vulnerability and Equity Concerns

Most sea level rise impact studies focused on assessing the physical impacts such as damaged infrastructure and loss of property, and less on the social vulnerability of affected communities (Felsenstein and Lichter, 2014). The vulnerability of coastal communities exposed to such environmental hazards could be greater for particular communities due to their sociodemographic characteristics (Hardy and Hauer, 2018). In the hazard research literature, since O'Keefe et al. published "Taking the Naturalness out of Natural Disasters" in 1976 (Phil O'Keefe, 1976), many researchers tried to examine social vulnerability, as a consequence of socioeconomic factors, to natural hazards. In 1994, Blaikie, Cannon et al. (1994) came up with the "pressure and release model" of social vulnerability. In this model, "pressure" means the causes that drive vulnerability to create unsafe conditions, and "release" means the way to reduce the fundamental vulnerability of the community. According to Blaikie, Cannon et al. (1994)'s definition, social vulnerability is the "characteristics of an individual or group that influences their capacity to anticipate, cope with, resist and recover from a physical hazard". The most vulnerable social groups are usually the ones with a higher level of sensitivity and lower adaptive capacity when facing coastal hazards.

Measuring accurate impacts of natural hazards in terms of social vulnerability can be challenging since the vulnerability depends on a variety of ways many interrelated factors interact with different types of hazards (Felsenstein and Lichter, 2014). The social vulnerability index has been created as a measure to describe the social conditions within a community that impact its residents' ability to respond to hazards. One of the most widely adopted approaches is the one created by Cutter, Boruff et al. (2003), which is identified as the Social Vulnerability Index (SoVI) for the United States based on the 1990 county-level socioeconomic and demographic data from census using factor analysis. The index helps to visualize the geographic variation in social vulnerability and identify priorities for preparedness and resource allocation at the county level. A similar approach has been adopted by the Centers for Disease Control and Prevention (CDC) (Flanagan, Gregory et al., 2011), Federal Emergency Management Agency (Zuzak, 2020), and the National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management (2021) to measure the uneven capacity of preparedness and response at the census tract and block group levels. However, these nationally applicable social vulnerability indicators need to be customized to fit the local context and tailored to specific climate stressors to better inform local policy decisions.

Usually, characteristics such as income, gender, race, age, education levels, language isolation, and physical conditions are the commonly identified factors influencing social vulnerability (Ekstrom, 2012). Among these factors, income is usually considered as a key factor that links to other vulnerability factors Low-income residents tend to have fewer assets available for preparation, protection, or recovery from a possible disaster (Flanagan, Gregory et al., 2011). Moreover, residents' income levels are significantly associated with other factors such as residential locations and car ownership, which may further increase vulnerability, especially when their access to income-generating activities and livelihood are affected. Climate change also has a serious impact on public health, a threat that can affect human health outcomes and disease patterns both directly and indirectly (Haines, Kovats et al., 2006). People who are in need of health care or emergency services could become more vulnerable if their access to health care and emergency resources are affected by sea level rise and coastal flooding (Portier, Tart et al., 2013). Given the most vulnerable might be affected more by such impacts, it demonstrates the importance of considering socially vulnerable groups when assessing transportation vulnerability to the projected changes.

In Hawai'i, according to the University of Hawai'i Sea Grant's report, a 3.2 ft of sea level rise would cost $19 billion in loss of land and structures and 116 miles of flooded major roads and coastal highways (Hawaiʻi Climate Change Mitigation and Adaptation Commission, 2017). According to the U.S. National Tidal Datum Epoch (NTDE), due to the high mean sea levels and seasonal high tides, Honolulu already experienced several minor flooding events in 2017 (1983-2001). During the summer of 2017, Honolulu Harbor experienced the highest hourly water level, and 35cm above the mean higher high water (MHHW). Sea level rise is especially challenging in the state of Hawai'i since there are high concentrations of population, properties, and transportation infrastructure along the coastline (Hawaiʻi Climate Change Mitigation and Adaptation Commission, 2017). To improve community resilience and better adapt to the projected sea level rise, it is crucial to understand how the communities are being affected now and what their concerns are with the projected risk, particularly for the socially vulnerable groups. In Hawai'i, the most vulnerable groups could be low income residents, the elderly and children, certain ethnic groups such as Native Hawaiian and Pacific Islanders, especially residents without a car. To better understand the needs and challenges of the community, we conducted a community survey to determine coastal residents' current experience with coastal flooding, how their travel and access to various resources are affected, and their concerns with the projected sea level rise. The next chapter describes the data and methodology we employed to explore these questions.

CHAPTER 3. DATA AND METHODOLOGY

To raise people's attention to sea level rise and increase the participation rate, we tried to engage the community through facilitated community workshops with surveys, ranking exercises, and impact mapping. To help the participants better understand the projected climate changes and overcome the barriers in communicating scientific findings such as massive uncertainty and scientific abstraction in sea level rise projection, we designed the survey with explicit impact description and explanation, different geographical scales of maps, and separation of today's impacts and future concerns. To boost survey participation and obtain diverse opinions from different communities especially the most vulnerable ones, we went to different coastal neighborhood board meetings throughout the island of Oahu to introduce the project and recruit survey participants, e.g. Hawai'i Kai, Waimanalo, Ewa beach, Kahuku, and Waianae (Table 3.1). We conducted the outreach during different times of the day and different days of the week and created an online version of the survey with the intent to make it easier for coastal residents' who couldn't attend the workshop to participate. If there was no response to any of the workshop or community events due to either time limitation or lack of interest, we tried to follow up with the participants through email and conduct another community outreach in the same neighborhood. Using the printed survey as well as online platforms (Appendix A), we asked the community members to identify where they experienced coastal hazard impacts on transportation and how their travels have been affected. We also asked questions to understand their perceptions of sea level rise, and their current concerns for future adaptation.

Table 3.1 Community Outreach for Data Collection

Event	Location	Date and Time	Number of Participants	Number of Responses
Kahuku Point Restoration	Kahuku point near Turtle Bay	11/10/2018, 9:00am	18	0
Keehi Small Boat Harbor	Kalihi	11/12/2018, 5:00pm	6	0
Kahuku Public Library	Kahuku Intermediate/High School	11/13/2018, 4:30pm	35	0
Kahaluu Neighborhood Board Meeting	Key Project	11/14/2018, 7:00pm	42	0
Sunset Beach	Haleiwa near Ke'iki Beach Road	11/18/2018, 9:00am	35	25
Waiahole Bridge Meeting	Key Project	11/19/2018, 5:00pm	34	0
La Ohana Loko I'a Workday	Paepae o He'eia Fish Ponds	11/24/2018, 6:00am	40	23
Keehi Small Boat Harbor Regatta	Kalihi	11/28/2018, 5:00pm	30	0
Hawai'i Kai Neighborhood Board Meeting	Haha'ione Elementary School	1/29/2019, 7:00pm	37	17

Event	Location	Date and Time	Number of Participants	Number of Responses
Waimanalo Neighborhood Board Meeting	Army National Guard at Bellows	2/11/2019, 7:00pm	30	16
Ewa Neighborhood Board Meeting	Ewa Beach Public Library	2/14/2019, 7:00pm	32	16
Waianae Coast Neighborhood Board Meeting	Waianae District Park	3/5/2019, 6:30pm	14	3
Koolauloa Neighborhood Board Meeting	Hauula Community Center	3/14/2019, 6:00pm	28	11
Department of Urban and Regional Planning Students	University of Hawai'i at Manoa	Spring 2019	62	62
Online Survey	Zoho Survey	Spring and Fall 2019	55	55
Total			498	228

There were a total of 228 responses collected from all community workshops and online surveys, with an average response rate of 45%. The respondents surveyed varied in age, ethnicity, income, and home ownership (Table 3.2). While the survey respondents may not be a representation of the Oahu population as a whole, the data collection plan was designed to ensure a wide representation of the vulnerable community in coastal regions throughout the study area (Figure 3.1).

Table 3.2 Demographics of Survey Respondents

Demographic characteristics	Respondents
Gender	
female	58%
male	39%
Ethnicity	
Asian	37%
Caucasian or White	32%
Native Hawaiian	15%
Hispanic or Latino	6%
African American	3%
Other Pacific Islanders	3%
Age	
18-24	22%
25-34	19%
35-44	18%
45-54	12%
55-64	11%
65-74	8%
Property ownership	
Owners	50%
Renters	43%
Car ownership	79%
Household income	
0-30,000	17%
30,000-60,000	14%
60,000-90,000	14%
90,000-120,000	12%
> 120,000	13%

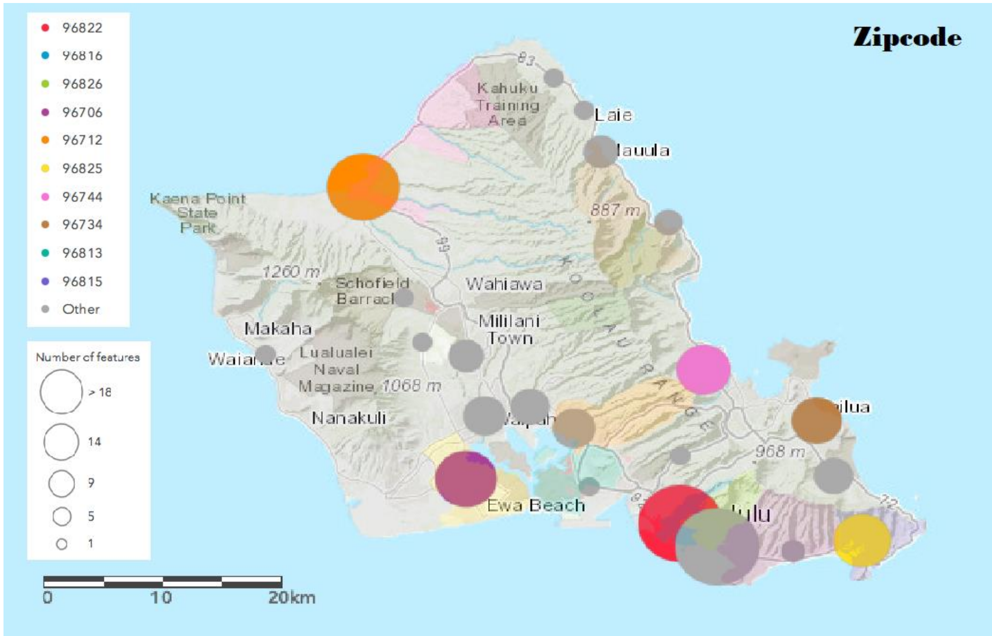


Figure 3.1 Survey respondents by zipcode

The survey collected responses to 30 questions to understand people's experience and perception of sea level rise and coastal flooding, and to examine possible relationships between the current and expected distribution of sea level rise's impacts, risk perception, opinion of adaptation, and demographic characteristics such as age, race, car ownership, household structure, and residence location at rural, urban or suburban location on the island of Oahu. The survey questions are provided in Appendix A. Statistical tests were deployed to determine whether the data collected from the survey support or contradict the equity propositions. Six demographic characteristics were analyzed to explore whether any group experiences extraordinary impacts. These demographic characteristics are the location of residence, age, ethnicity, income, household structure, and car ownership as shown in Table 3.3. Using a map (Figure 3.2) from the City and County of Honolulu General Plan (1992 edition, amended in 2002), we classified the residence zipcode into three categories: urban, suburban, and rural (Table 3.4). The analysis was conducted by using SPSS Statistics software by IBM. The next chapter presents the results of the analysis.

Table 3.3 Demographic Classification for Analysis

Demographics	Survey Classification		Analysis Classification
Age	18-24	45-54	Young: Under 34
	25-34	55-64	Middle Age: 35-64
	35-44	65 or older	Elderly: 65+
Ethnicity	Native Hawaiian	Caucasian or White	Native Hawaiian and Other Pacific Islander
	Other Pacific Islander	Asian	All others
	Hispanic or Latino	Other	
	African American		
Income	0-$30,000	$90,000-$120,000	Low income: <$60000
	$30,000-$60,000	>$120,000	All others

Demographics	Survey Classification	Analysis Classification
	$60,000-$90,000	
Household Structure	Household with children	Household with children
	Household without children	Household without children
Car Ownership	Does your household own a car?	Household with car
		Household without car
Location of Residence	What is your home address zip code?	Urban:
		Rural
		Suburban

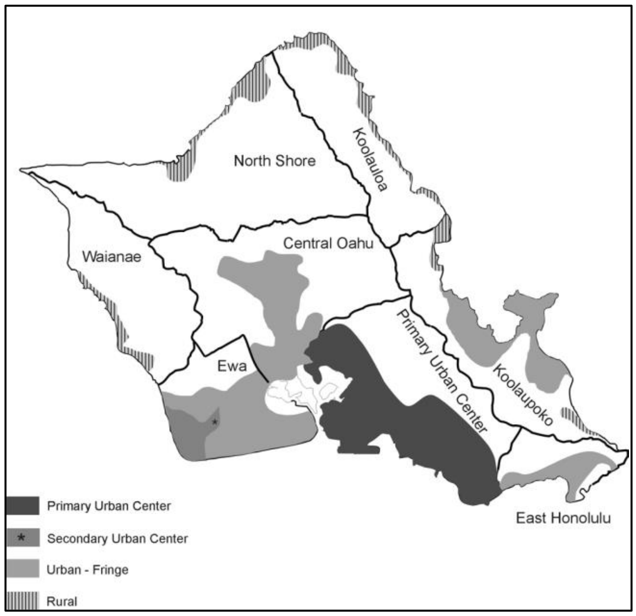


Figure 3.2 City and County of Honolulu General Plan Development Pattern
(Department of General Planning City and County of Honolulu, 2002, pp. 11)

Table 3.4 Zipcode Classification

Classification	Zipcode					
Urban	96813	96816	96819	96848	96859	
	96814	96817	96822	96850	96860	
	96815	96818	96826	96853		
Suburban	96701	96707	96744	96795	96821	96857
	96706	96734	96782	96797	96825	96863
Rural	96712	96730	96759	96786	96791	
	96717	96731	96762	96789	96792	

CHAPTER 4. FINDINGS

This chapter analyzes analyzed how the respondents have experienced the impacts of coastal flooding on travel and how they perceive future risks with the projected sea level rise from an equity lens. We asked respondents a series of questions regarding their perceived impacts of any coastal hazards such as king tides, storm surge, inland ground water inundation, coastal erosion, construction/maintenance on coastal roads, and other coastal flooding. Respondents were instructed to answer based on their memories of the current and past situations as well as their expectations for future projected changes.

4.1. Current Experience of Coastal Flooding

First, we asked the respondents about the types of adverse conditions they have experienced on the coastal roads. The majority of the respondents (83%) have experienced adverse conditions on coastal roads. Fifty percent of respondents have experienced construction and maintenance on coastal roads, followed by storm surge experienced by 39 percent of respondents, and coastal erosion with 35 percent respondents (see Figure 4.1). When describing how travel is affected by these conditions, respondents mentioned that construction and maintenance on coastal roads are mostly caused by coastal erosion, storm events, and flooding. The types of impacts associated with the adverse conditions vary, but the most prevalent impacts are detours due to road closure, flooded routes, flooded trip origin/destination, and reduced service (Figure 4.2). The survey results also show that construction/maintenance on coastal roads not only has the most occurrences, but also the most frequent negative impacts.

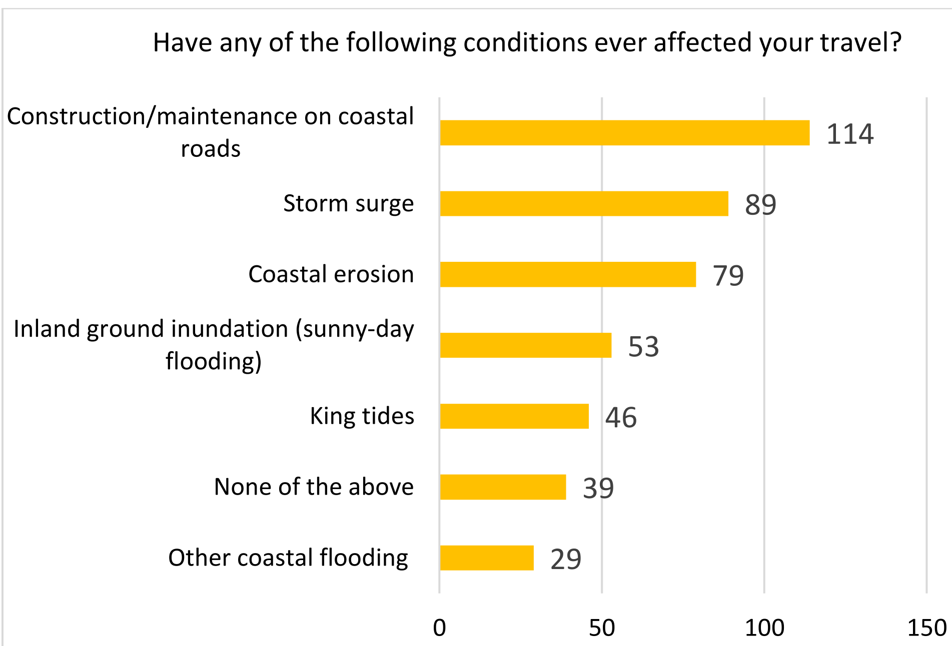


Figure 4.1 Experience of adverse conditions on coastal roads

To test whether the experience of various types of adverse conditions on travel is associated with the respondent's residential location (i.e. urban, rural, and suburban) or demographic characteristics, a One-way Analysis of Variance (ANOVA) test was performed. The results in Table 4.1 show that there is no significant difference among respondents regarding their experience of king tides, groundwater inundation, and construction and maintenance on coastal roads. There are significant differences among groups with different residential locations (i.e. urban, suburban, and rural) with regards to the experience of storm surge ($F(2,188) = 4.102$, $p = .018$), coastal erosion ($F(2,188) = 9.042$, $p < .001$) and other types of coastal flooding ($F(2,188) = 3.756$, $p = .025$), with rural residents having significant higher percentage of respondents experiencing negative impacts on travel than urban and suburban respondents (Figure 4.3). There are significant differences among different age groups in terms of their experience with coastal erosion ($F(2,209)= 4.035$, $p=0.019$), with the elderly having a much higher percentage of respondents experiencing coastal erosion compare with other groups (Figure 4.3). There are also significant differences between Native Hawaiian & Pacific Islander and other ethnic groups regarding the experience of coastal erosion on travel ($F(1,207) = 4.042$, $p = .046$), with a higher percentage of Native Hawaiian and other Pacific Islanders experiencing such impacts than other groups (Figure 4.3). Finally, there is a statistically significant difference between households with children and without children with regards to their experience of the impacts of coastal erosion ($F(1,215) =6.985$, $p = .009$) and other types of coastal flooding ($F(1,215) =11.216$, $p = .001$), with more household with children experiencing negative travel impacts on travel compared with household without children (Figure 4.3). Income and having a car or not, in general, are not statistically associated with the experience of any adverse coastal conditions. The findings indicate that the current adverse impacts of coastal flooding on travel may affect more households in need of child care, k-12 and college access, elderly population, rural resident, and also Native Hawaiian and other Pacific Islanders regardless of their income or car ownership. This finding could be associated with the spatial distribution of the residence location of the vulnerable population, as well as the spatial distribution of k-12 schools and health care facilities. Such vulnerability could be caused by the location of their residence or facilities are in vulnerable coastal areas, or the roads accessing these locations are in vulnerable coastal regions.

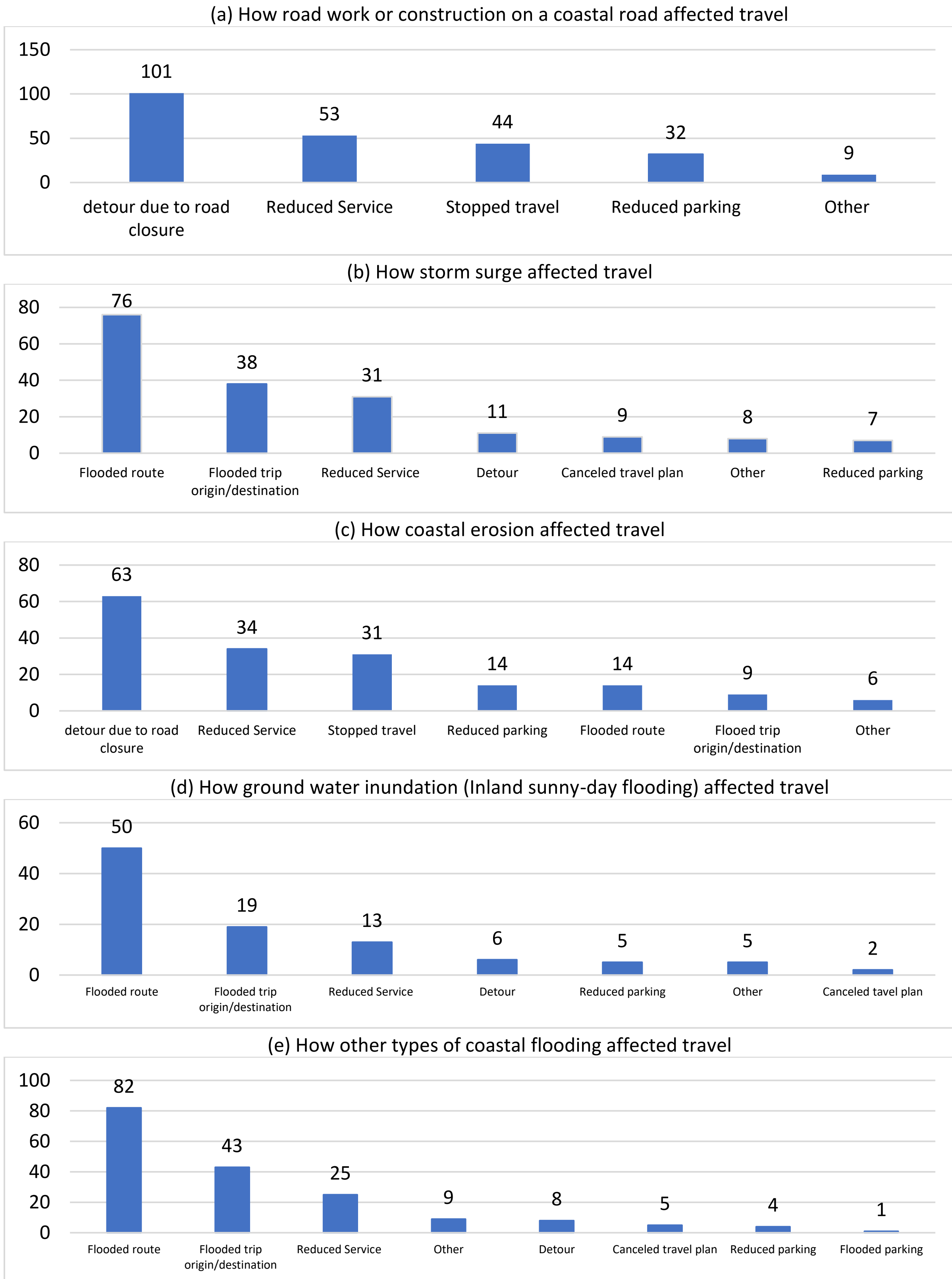


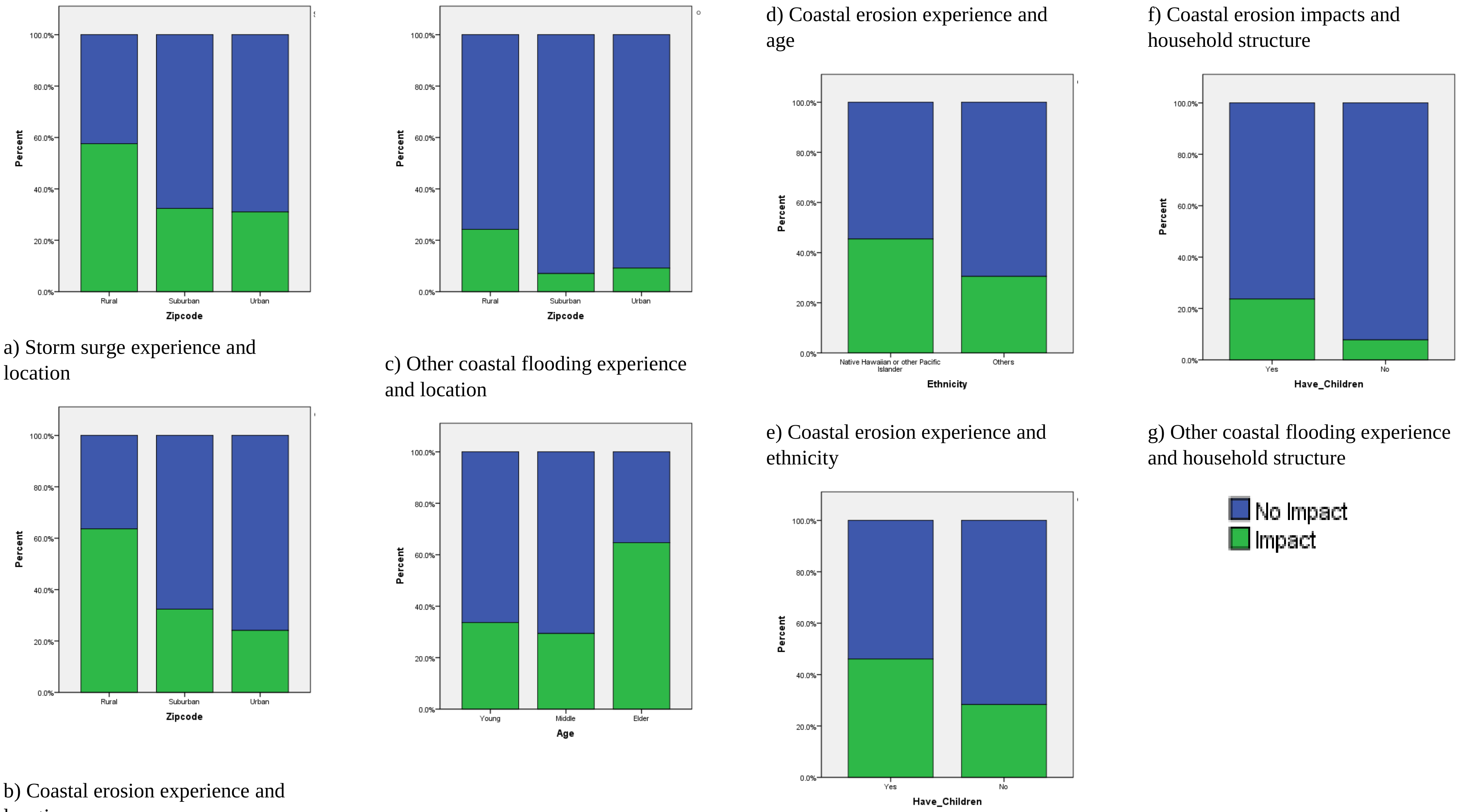
Figure 4.2 Types of travel impacts of adverse conditions on coastal roads

Table 4.1 Experience of Hazard Equity Test Statistics

Q2 Have any of the following conditions ever affected your travel? Please check all that apply.

Hazards Type	Statistics	Location	Age	Ethnicity	Income	Household with/without Children	Car Ownership
King tides	F (ANOVA)	1.925	.581	1.923	.348	2.647	2.518
	df (between groups)	2	2	1	1	1	1
	df (within groups)	188	209	207	188	215	190
	Sig.	.149	.56	.167	.556	.105	.114
Storm surge	F (ANOVA)	4.102	1.589	1.624	.011	1.270	3.564
	df (between groups)	2	2	1	1	1	1
	df (within groups)	188	209	207	188	215	190
	Sig.	**.018***	.207	.204	.915	.261	.061
Groundwater inundation	F (ANOVA)	.568	2.383	.976	.711	.068	1.111
	df (between groups)	2	2	1	1	1	1
	df (within groups)	188	209	207	188	215	190
	Sig.	.567	.095	.324	.400	.794	.293
Coastal erosion	F (ANOVA)	9.042	4.035	4.042	.064	6.985	.677
	df (between groups)	2	2	1	1	1	1
	df (within groups)	188	209	207	188	215	190
	Sig.	**.000***	**0.019 ***	**.046***	.800	**.009***	.412
Construction maintenance on coastal roads	F (ANOVA)	1.545	.258	.550	.068	.973	.057
	df (between groups)	2	2	1	1	1	1
	df (within groups)	188	209	207	188	215	190
	Sig.	.216	.773	.459	.795	.325	.812
Other types of coastal flooding	F (ANOVA)	3.756	1.693	.783	2.457	11.216	.749
	df (between groups)	2	2	1	1	1	1
	df (within groups)	188	209	207	188	215	190
	Sig.	**.025***	.186	.377	.119	**.001***	.388

*** significant at the 0.05 level**



a) Storm surge experience and location

b) Coastal erosion experience and location

c) Other coastal flooding experience and location

d) Coastal erosion experience and age

e) Coastal erosion experience and ethnicity

f) Coastal erosion impacts and household structure

g) Other coastal flooding experience and household structure

Figure 4.3 Experience of Hazard by different groups

In terms of the level of severity, we also asked the respondents to rate the level of impact on a scale of 1 to 5, with 5 being the most severe, and 1 as not at all. It shows that construction/maintenance on coastal roads and coastal erosion has the highest average impact rating, while gradual coastal flooding such as king tides and ground inundation has relatively less perceived severity (Figure 4.4). ANOVA test was performed to compare the level of impacts of various hazard conditions among groups with different demographic characteristics such as age, race, car ownership, household structure, and residence location (i.e. rural, urban or suburban). The results in Table 4.2 show that there is no significant difference among different groups' perceptions regarding the level of impacts king tides, gradual coastal flooding, or inland ground water inundation. There are significant differences between Native Hawaiian & other Pacific Islander and other ethnicity groups in terms of storm surge level of impacts ($F(1,21) = .001$, $p = .047$), coastal construction and maintenance impacts ($F(1,27) = 3.486$, $p = .005$), and coastal erosion impacts ($F(1,21) = .131$, $p = .043$), with Native Hawaiian and other Pacific Islander rating the severity of impacts higher than others (Figure 4.5). There are also significant differences among groups with different residential locations (i.e. urban, suburban, and rural) regarding coastal erosion ($F(2,18) = 9.391$, $p = .002$) and coastal construction and maintenance impacts ($F(2,22) = 3.754$, $p = .040$), with rural residents rate the impacts much higher than urban and suburban residents (Figure 4.5). Finally, there is also a statistical significance difference between a household with children and without children with regards to their perception of the impacts of coastal erosion ($F(1,25) = .342$, $p = .025$), with a household with children having much higher ratings than a household without children (Figure 4.5). Age, income, and having a car or not, in general, are not statistically associated with the different perceptions of the levels of impacts. The findings imply that the current impacts of coastal flooding may be experienced more greatly by households with concerns about school access, and by rural residents, Native Hawaiians, and other Pacific Islanders concerned about access to various resources through coastal roads.

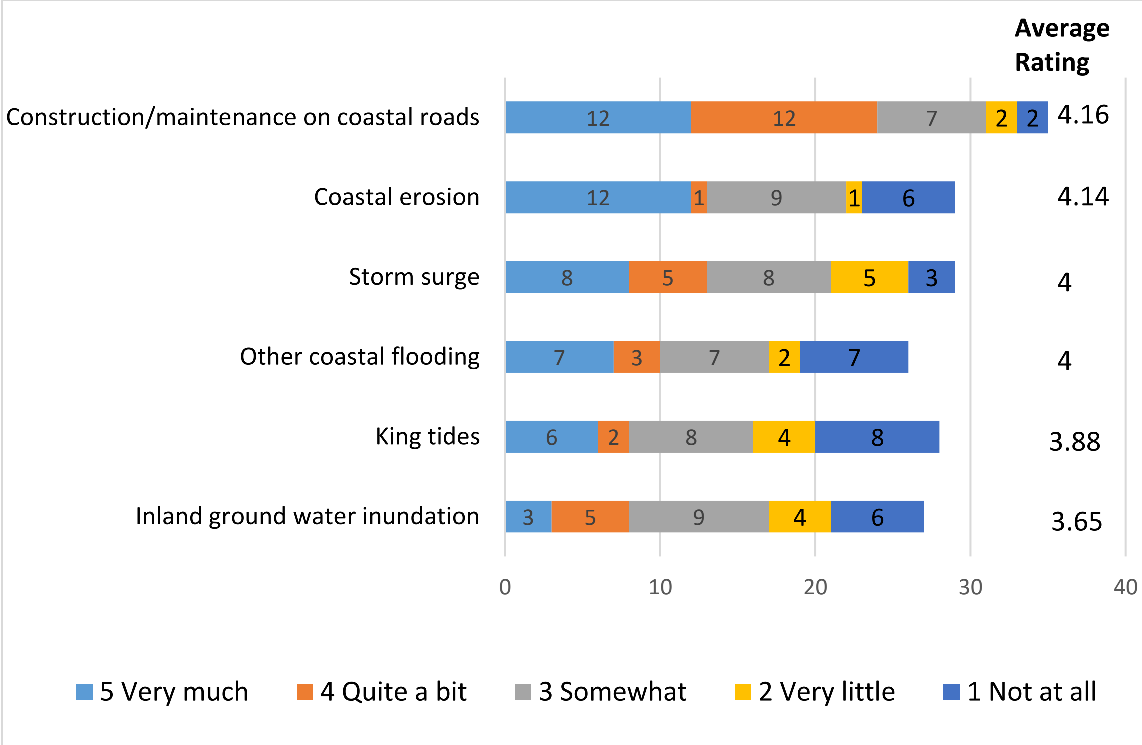


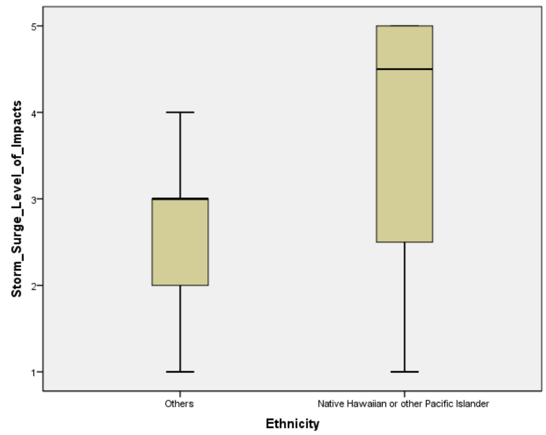
Figure 4.4 Level of impacts by hazard conditions

Table 4.2 Level of Impacts (1-5) Equity Test Statistics

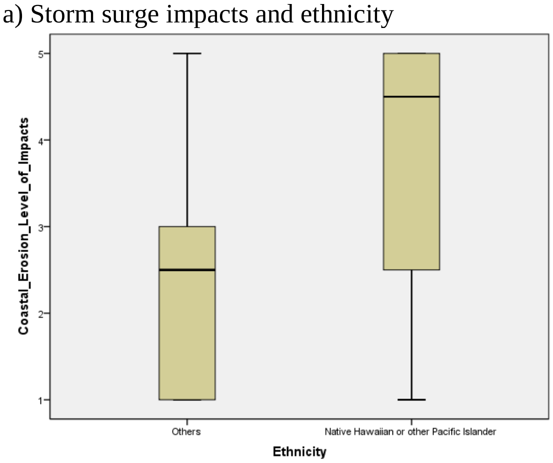
Q28 Rate how various conditions affect your travel on a scale of 1 to 5, 1 as the minimal impacts and 5 as the most severe

Hazards Type	**Statistics**	**Location**	**Age**	**Ethnicity**	**Income**	**Household with/without Children**	**Car Ownership**
King tides	F (ANOVA)	1.153	1.686	.440	4.750	.032	3.982
	df (between groups)	2	2	1	1	1	1
	df (within groups)	17	22	21	16	24	23
	Sig.	.339	.208	.228	.406	.199	.094
Storm surge	F (ANOVA)	7.450	.182	.001	1.344	.732	.034
	df (between groups)	2	2	1	1	1	1
	df (within groups)	17	22	21	15	25	23
	Sig.	.064	.835	**.047***	.214	.170	.797
Groundwater inundation	F (ANOVA)	1.950	.508	3.011	.054	.738	.720
	df (between groups)	2	2	1	1	1	1
	df (within groups)	17	21	20	15	23	22
	Sig.	1.950	.609	.238	1.000	.198	.129
Coastal erosion	F (ANOVA)	9.391	.588	.131	.689	.342	.598
	df (between groups)	2	2	1	1	1	1
	df (within groups)	18	22	21	14	25	23
	Sig.	**.002***	.564	**.043***	.828	**.025***	.239
Construction maintenance on coastal roads	F (ANOVA)	3.754	.536	3.486	.499	.017	2.313
	df (between groups)	2	2	1	1	1	1
	df (within groups)	22	28	27	20	31	29
	Sig.	**.040***	.820	**.005***	.123	.184	.083
Other types of coastal flooding	F (ANOVA)	2.859	1.161	2.651	8.988	.616	5.709
	df (between groups)	2	2	1	1	1	1
	df (within groups)	14	20	19	14	22	21
	Sig.	.091	.333	.177	.774	.120	.059

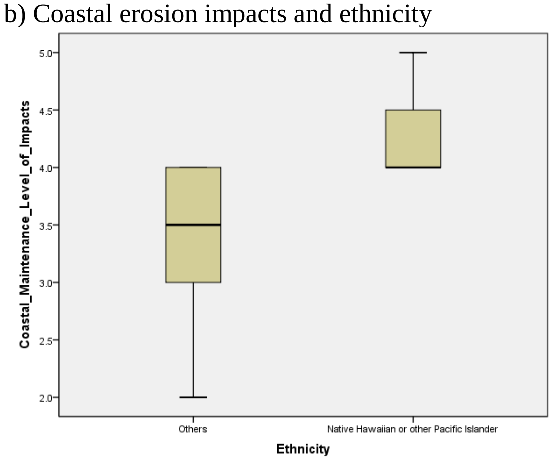
*** significant at the 0.05 level**



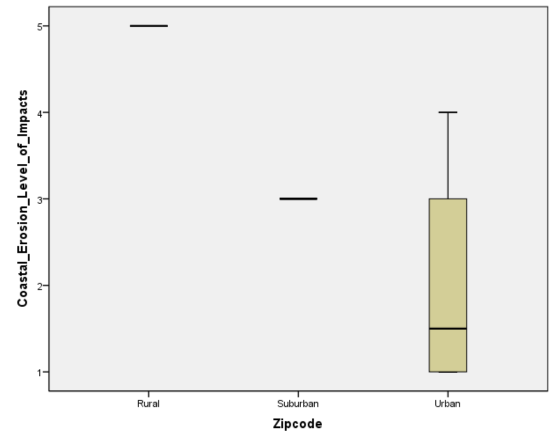
a) Storm surge impacts and ethnicity



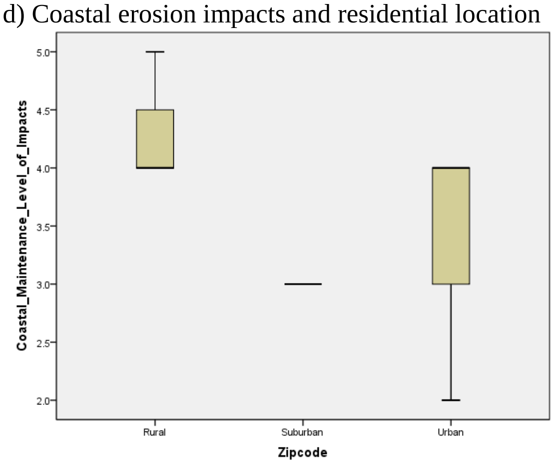
b) Coastal erosion impacts and ethnicity



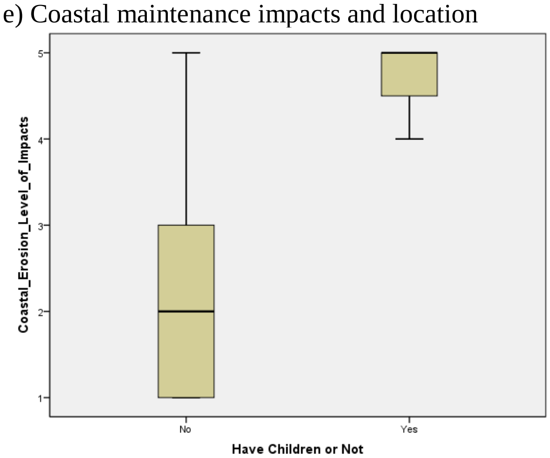
c) Coastal maintenance impacts and ethnicity



d) Coastal erosion impacts and residential location



e) Coastal maintenance impacts and location



f) Coastal erosion impacts and household structure

Figure 4.5 Level of impacts rating by different groups

4.2. Current Coastal Flooding's Impacts on Transportation

Due to dominant automobile travel on Oahu, 65 percent of respondents answered that their travel was affected by these coastal hazard conditions while they were driving, followed by walking (36%), cycling (19%), and transit (15%) (Figure 4.6). Figure 4.7 presents the experience of adverse conditions by affected transportation mode. It shows that construction and maintenance on coastal roads, storm surge, and coastal erosion are the three dominant adverse conditions among all travel modes. In particular, it is also worth noting that construction and maintenance are the most experienced transportation disruptions by people who drive, followed by transit riders. It is consistent with respondents' descriptions about how road closures and rerouting due to construction/maintenance have slowed down traffic or increase detour time. Transit commuters have experienced more storm surge and king tide flooding, which might indicate the exposure of transit stops and routes in low-lying coastal areas. Residents who travel by motorcycle have experienced more coastal erosion and other types of coastal flooding (e.g. adverse travel conditions caused by storms or rainfall as described by the respondents). Motorcycle commuters experience the most coastal erosion and weather-related closures possibly due to their preference to drive along scenic coastal roads as compared to car or transit commuters. Finally, it is interesting to find that people cycling experience much more groundwater inundation compared to other modes, which indicates that bike routes and facilities further inland are also at risk.

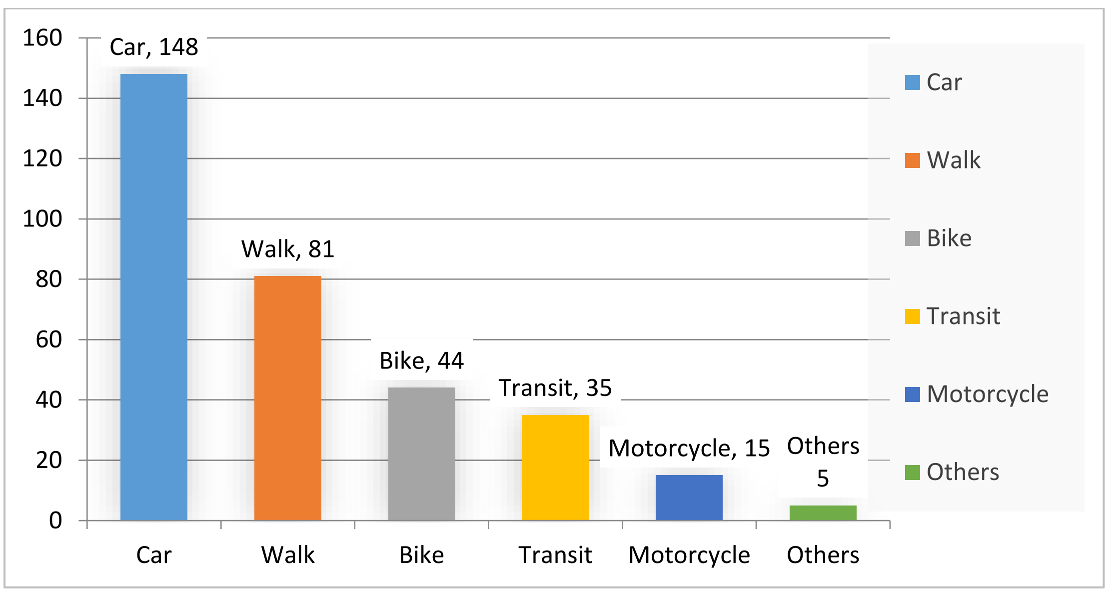


Figure 4.6 Affected transportation modes

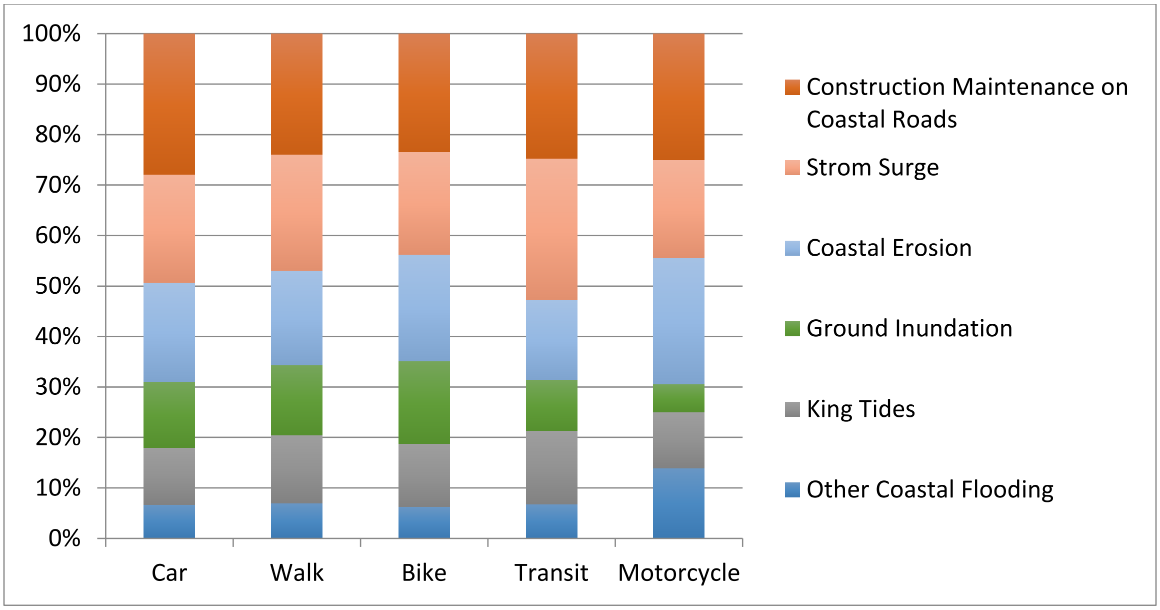


Figure 4.7 Experience of Adverse Conditions by transportation mode

Out of the 228 responses, over one-third (36% each) of the respondents indicated that they were affected by the adverse conditions when they commuted to work or returned home (Figure 4.8). Trips to go grocery shopping and family/ social events were are not as affected (22 percent each); the trips for recreation/leisure and other shopping purposes counted 16 percent each, and school trips counted for 14 percent of the respondents. Travel accessibility to work and home is critical to households, especially for those households whose family income depends on daily economic activity.

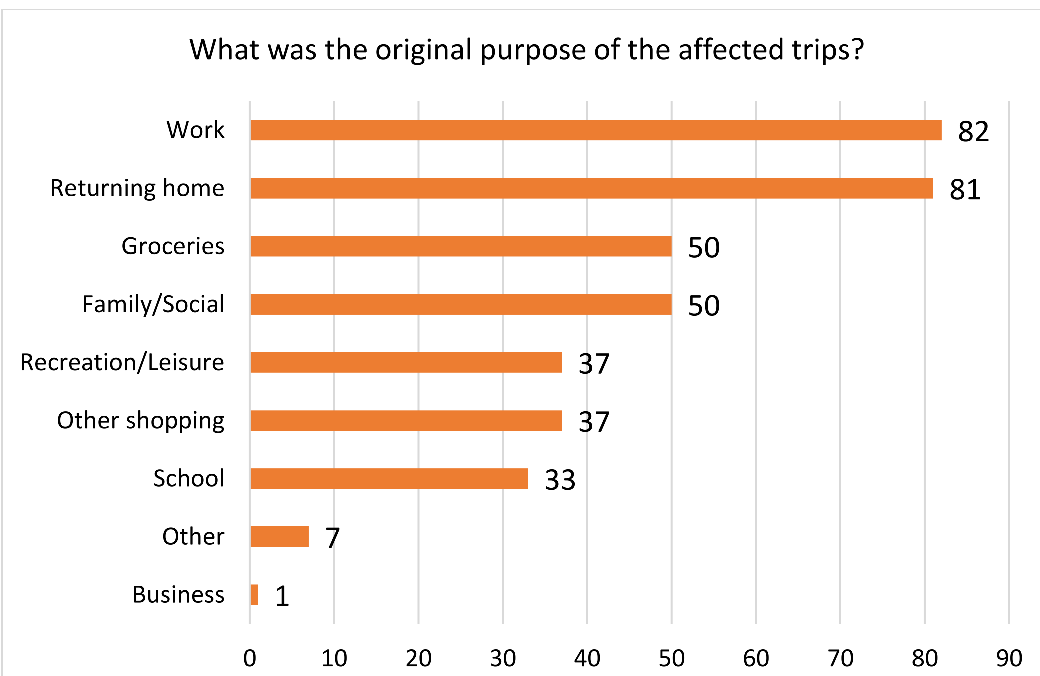


Figure 4.8 Trip purpose of affected trips

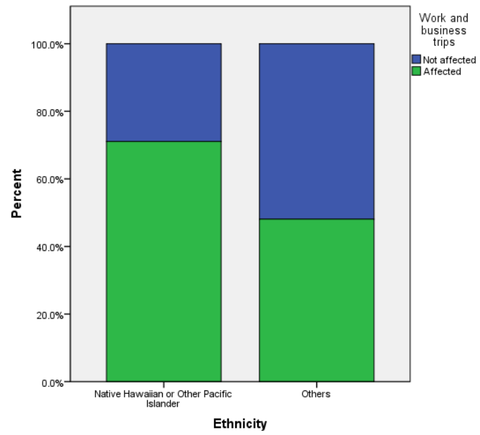
A Chi-square test of dependence was performed to explore whether the types of affected trip purposes are associated with the respondent's demographic characteristics. Table 4.3 summarizes the test results. It indicates no significant relationship between types of affected trip purpose and car ownership. There is also no association between recreational/leisure trips and any demographics tested. There are significant associations between ethnicity, age, income, household structure, and affected trip purposes. In particular, there are higher percentages of affected trips in almost all trip purposes reported by Native Hawaiian & other Pacific Islanders compared to other groups except recreational/leisure trips (Figure 4.9). This may be in part because some Native Hawaiian & Pacific Islanders live in rural areas, and residents in rural areas reported a higher percentage of grocery trips being affected compared to urban and suburban residents(Figure 4.10)), but this explanation does not draw the whole picture. School location, grocery access, as well as social networking might all have an influence. Also, it is not surprising to find that young residents had more school trip affected compared with middle-aged and elderly residents (Figure 4.10). However, it is interesting to find that there is no significant association between school trips affected and household with children or not. This could imply that for young and middle-aged residents whose school trips are affected, the trip purpose is more about access to adult education such as college. Finally, it is also interesting to find that income, in general, is not associated with the various types of affected trips except shopping other than grocery. Future research is needed to better understand what kinds of shopping trips are most affected by households in general.

Table 4.3 Affected Trip Purpose and Demographics Relationship

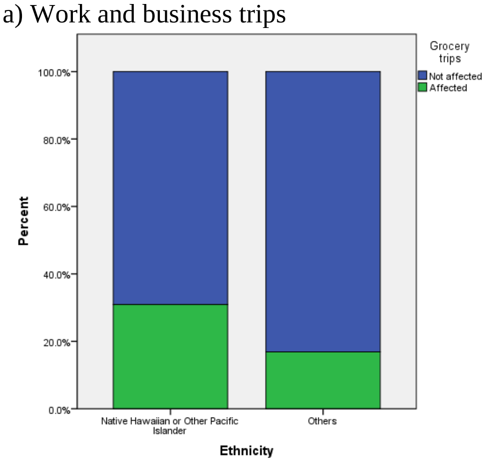
Trip Purpose		**Location**	**Age**	**Ethnicity**	**Income**	**Household with/without Children**	**Car Ownership**
Work/ Business	Pearson Chi-square	4.191	.968	5.919	1.658	.044	.401
	df	2	2	1	1	1	1
	N	124	144	142	123	145	122
	Asymp. Sig. (Chi)	.123	.616	**.015***	.198	.833	.526
Recreation/Leisure	Pearson Chi-square	.968	1.272	1.812	1.116	.000	1.619
	df	2	2	1	1	1	1
	N	191	212	209	190	217	192
	Asymp. Sig. (Chi)	.616	.529	.178	.291	.994	.203
Grocery	Pearson Chi-square	11.966	1.077	4.849	.045	2.214	2.191
	df	2	2	1	1	1	1
	N	191	212	209	190	217	192
	Asymp. Sig. (Chi)	**.003***	.584	**.027***	.831	.137	.139
Other Shopping	Pearson Chi-square	4.731	.995	6.636	4.068	5.979	.121
	df	2	2	1	1	1	1
	N	191	212	209	190	217	192

Trip Purpose		Location	Age	Ethnicity	Income	Household with/without Children	Car Ownership
	Asymp. Sig. (Chi)	.094	.608	**.010***	**.044***	**.014***	.728
School	Pearson Chi-square	3.015	6.370	5.923	.235	.303	.926
	df	2	2	1	1	1	1
	N	191	211	209	190	216	191
	Asymp. Sig. (Chi)	.221	**.041***	**.015***	.628	.582	.336
Family/ Social	Pearson Chi-square	1.197	2.284	8.960	.754	1.195	.374
	df	2	2	1	1	1	1
	N	191	212	209	190	217	192
	Asymp. Sig. (Chi)	.550	.319	**.003***	.385	.274	.541

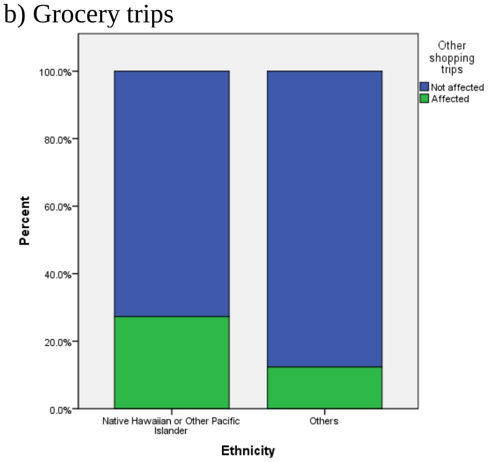
*** significant at the 0.05 level**



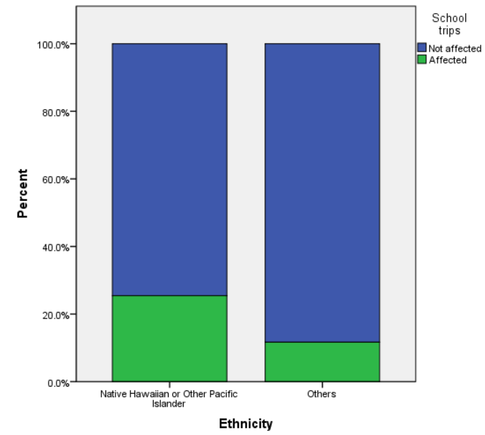
a) Work and business trips



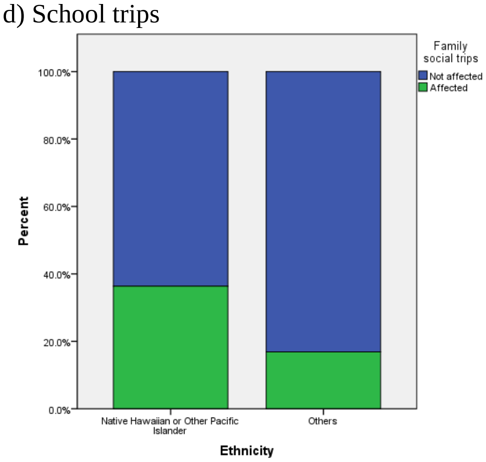
b) Grocery trips



c) Other shopping trips



d) School trips



e) Family and social trips

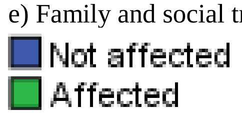
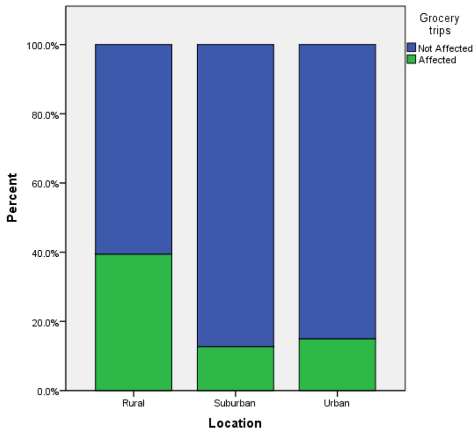
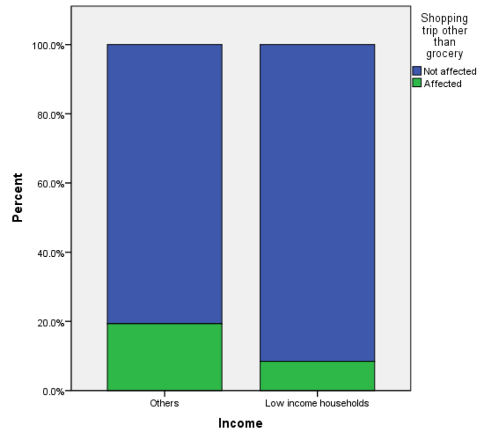


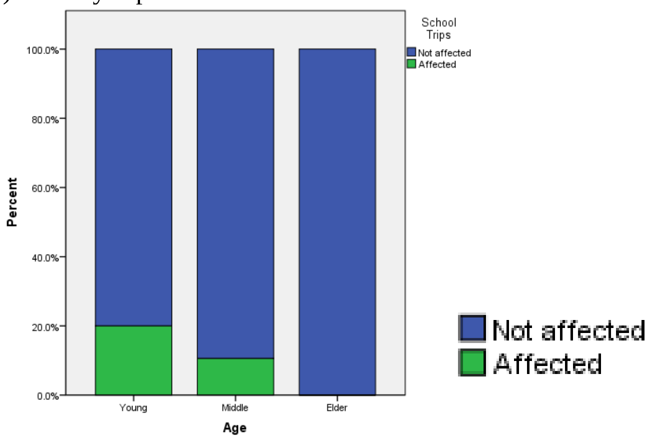
Figure 4.9 Affected trip purpose and ethnicity



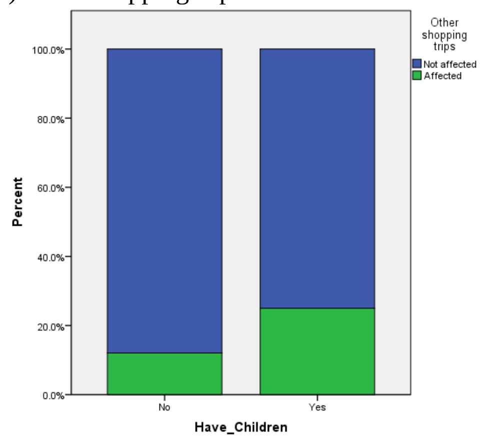
a) Grocery trips and Location



c) Other shopping trips and income



b) School trips and Age



d) Other shopping trips and household structure

Figure 4.10 Affected trip purpose and demographic

To understand the degree of impacts on various types of trips, we asked respondents to rate how coastal flooding and erosion have affected their access to various types of resources and opportunities on a scale of 1 to 5 (Question 26), with 1 as not affected at all and 5 as the most severely affected. Figure 4.11 shows the rating for the impacts on various types of accessibility by the number of responses being affected from somewhat to very much, excluding not at all (1) and very little (2) categories. The results show that park and recreation activity has been rated as the most affected by most people, followed by grocery and livelihood activities, and traditions and cultural activities. Access to university and college, although experienced by fewer people, also has the second-highest average rating in terms of severity, which is consistent with findings in Table 4.3.

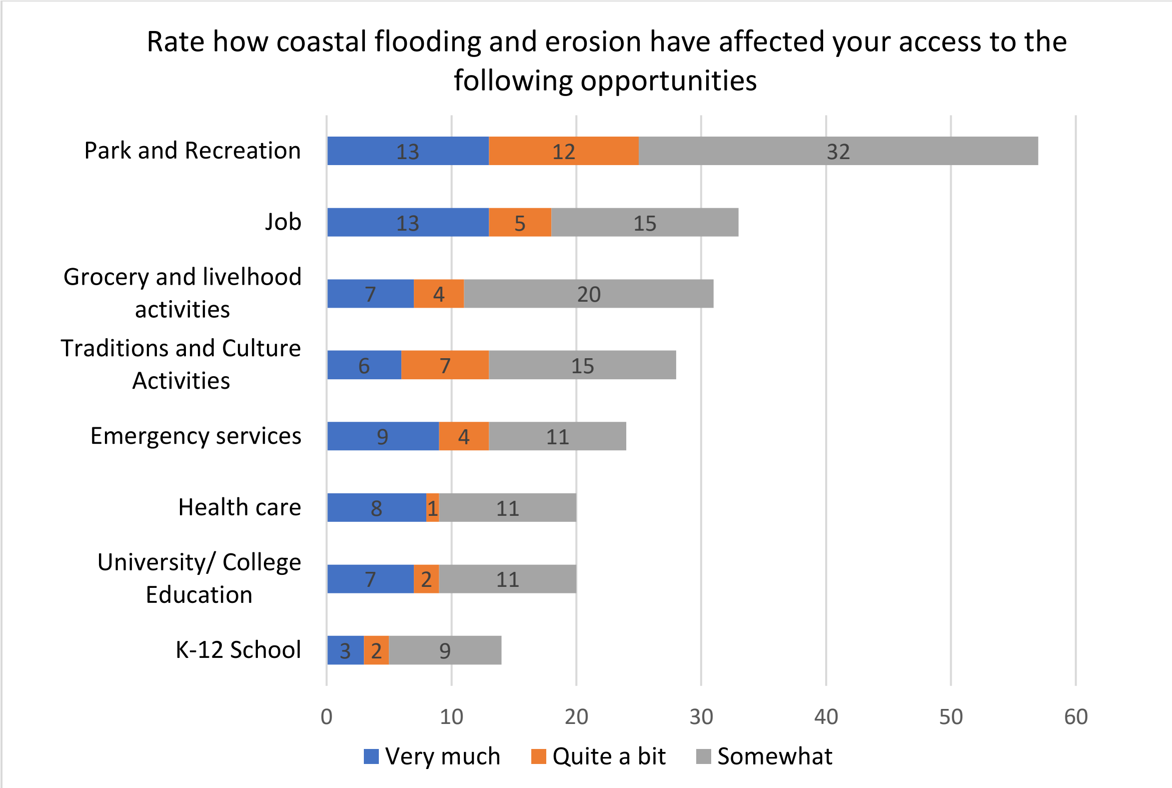


Figure 4.11 The Impact of coastal flooding and erosion on accessibility

Table 4.4 summarizes the results of the ANOVA tests which compare the level of impacts on various accessibilities among groups with different demographic characteristics. Again, it echoes that ethnicity is related to the degree of reductions in accessibility to jobs, grocery and livelihood activities, K-12 school access, and traditions and cultural activities. In addition, it shows that Native Hawaiian and other Pacific Islanders perceived more reduction on access to health care and emergency services compared with other groups (Figure 4.12). Regarding the location impact, besides the accessibility to groceries, it indicates that rural residents perceived more reduction on job access and k-12 access as well. There are no differences among different income groups' perceived impacts on various types of accessibilities. It is also interesting to find that households with children perceive more reduction in accessibility to cultural and traditional activities compared to the ones without children. Finally, there is an interesting finding that turns out to be surprising and deserves further research. That is, households with at least one car do rate the impacts on current access to emergency services as higher than the ones without a car, which is a finding we currently can't explain.

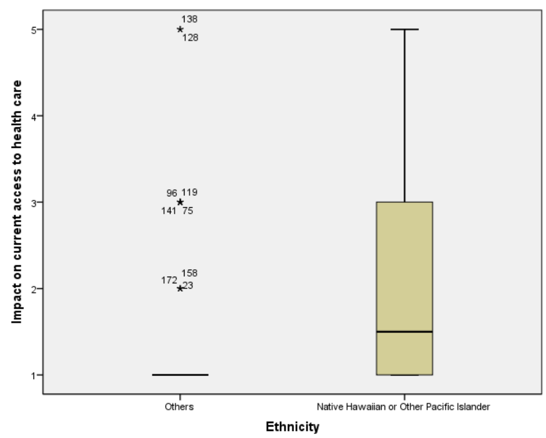
Table 4.4 Current impacts on Accessibility (1-5) Equity Test Statistics

Q26 Please rate how coastal flooding and erosion have affected your access to the following opportunities on a scale of 1 to 5, 1 as the minimal impacts and 5 as the most severe

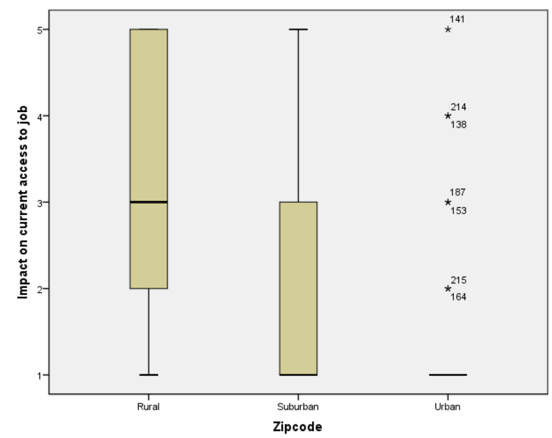
Accessibility Type	**Statistics**	**Location**	**Age**	**Ethnicity**	**Income**	**Household with/without Children**	**Car Ownership**
Job	F (ANOVA)	18.368	2.002	9.913	.022	1.410	2.240
	df (between groups)	2	2	1	1	1	1
	df (within groups)	94	101	100	94	104	104
	Sig.	**.000***	.140	**.001***	.695	.409	.319
Grocery and livelihood activities	F (ANOVA)	10.395	.219	3.169	.179	.004	1.820
	df (between groups)	2	2	1	1	1	1
	df (within groups)	94	99	99	92	101	102
	Sig.	**.000***	.804	**.010***	.357	.707	.248
University/ College Education	F (ANOVA)	1,243	.620	.664	2.070	6.943	.270
	df (between groups)	2	2	1	1	1	1
	df (within groups)	87	92	92	85	95	95
	Sig.	.294	.540	.812	.456	.123	.736
K-12 School	F (ANOVA)	10.909	.196	48.853	.825	.331	5.761
	df (between groups)	2	2	1	1	1	1
	df (within groups)	83	89	88	82	92	91
	Sig.	**.000***	.822	**.000***	.891	.632	.288
Park and Recreation	F (ANOVA)	.349	2.104	.392	.739	.383	2.312
	df (between groups)	3	2	1	1	1	1
	df (within groups)	89	95	94	89	100	98
	Sig.	.706	.128	.069	.248	.190	.218
Traditions and Culture Activities	F (ANOVA)	1.752	1.265	2.607	1.545	6.831	.347
	df (between groups)	2	2	1	1	1	1
	df (within groups)	86	92	91	84	95	94
	Sig.	.179	.287	**.026***	.600	**.019***	.638
Health Care	F (ANOVA)	13.558	1.973	17.917	2.073	.229	4.159
	df (between groups)	2	2	1	1	1	1
	df (within groups)	88	93	92	87	95	96
	Sig.	.000	.145	**.000***	.438	.481	.339

Accessibility Type	Statistics	Location	Age	Ethnicity	Income	Household with/without Children	Car Ownership
Emergency Services	F (ANOVA)	14.926	1.558	26.203	1.391	.155	11.631
	df (between groups)	2	2	1	1	1	1
	df (within groups)	86	91	90	87	93	94
	Sig.	,000	.216	**.005***	.470	.742	**.001***

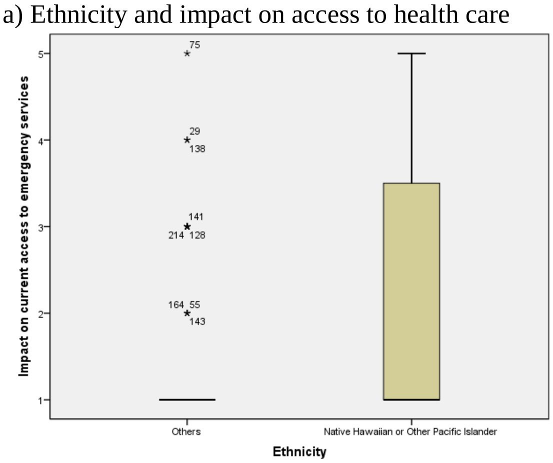
*** significant at the 0.05 level**



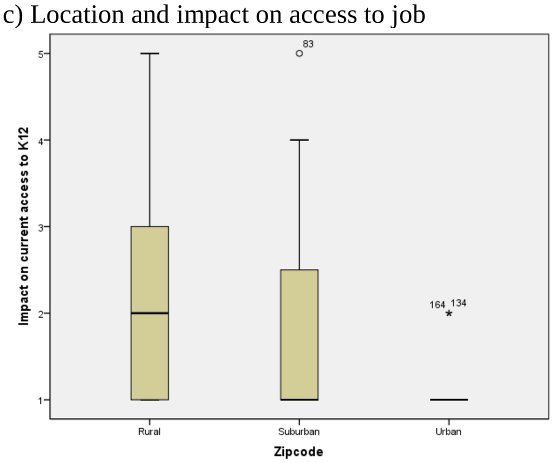
a) Ethnicity and impact on access to health care



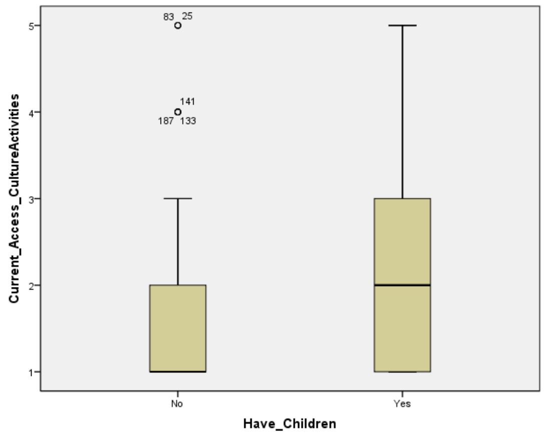
c) Location and impact on access to job



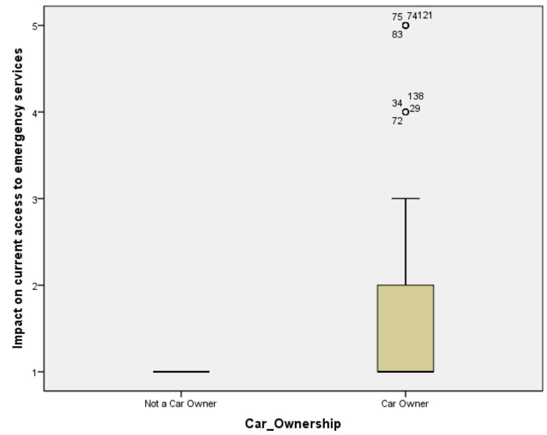
b) Ethnicity and impact on access to ES



d) Location and impact on access to K12 school



e) Household structure and impact on access to culture activities



f) Car ownership and impact on access to ES

Figure 4.12 Impacts on various accessibility and demographics

4.3. Expected Sea Level Rise's Impact on Transportation

Finally, we asked participants to rate how they expect future sea level rise will affect their access to the same types of resources and opportunities on a scale of 1 to 5 (Question 27), with 1 as little impact and 5 as the most severely affected. Figure 4.13 displays the rating for sea level rise's impact on various types of accessibilities. It shows that most people are concerned with the potential impacts on access to park and recreation facilities, followed by emergency services, grocery and livelihood activities, and tradition and culture activities.

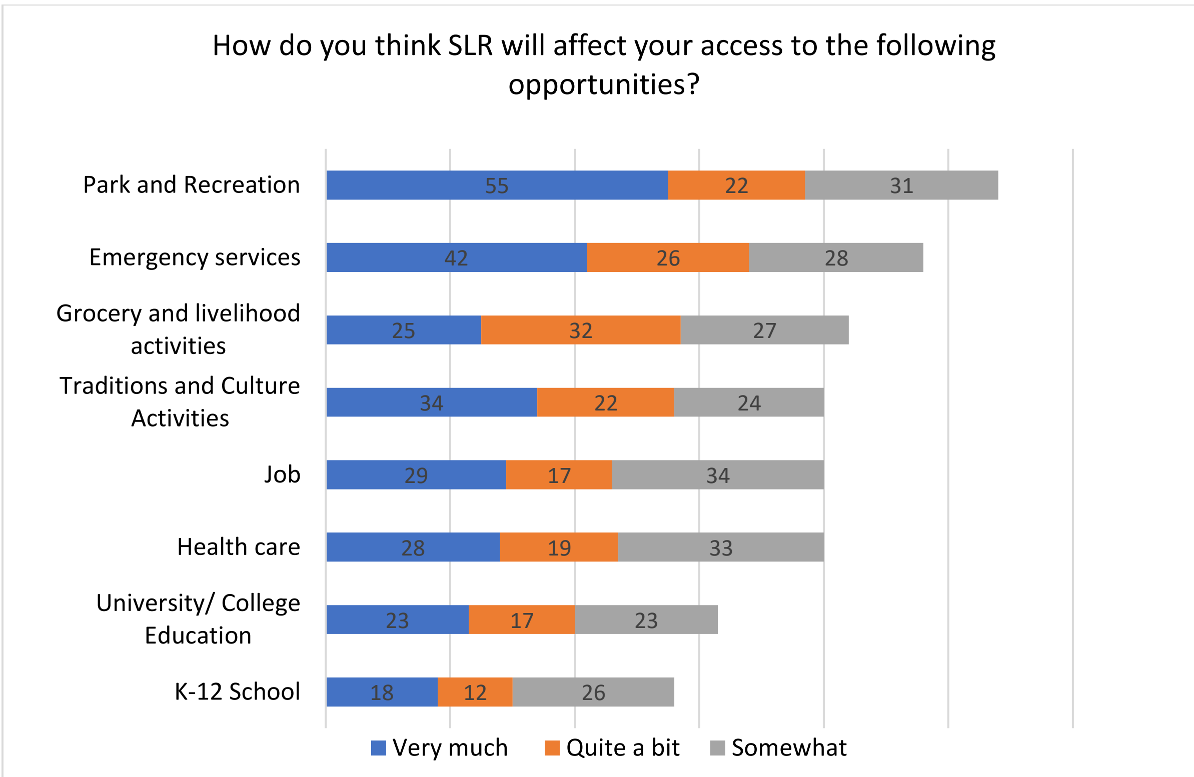


Figure 4.13 The concern of sea level rise's impact on accessibility

ANOVA tests were performed to compare the expected level of impacts of sea level rise on various accessibilities among groups with different demographic characteristics (Table 4.5). The table indicates that the expected level of impacts of sea level rise on accessibility is mostly associated with residential location, ethnicity, with children or not, and having a car or not. In particular, rural residents, in general, think sea level rise will have more severe impacts on their access to job, grocery and livelihood resources, health care services, and emergency services compared with urban and suburban residents (Figure 4.14). For suburban residents, their concern of sea level rise's impacts on emergency services access is also significantly higher than urban residents' (Figure 4.14). Native and other Pacific Islanders also do think sea level rise will have a higher level of impacts on almost all types of accessibilities except park and recreation and emergency services. It is worth noting the biggest difference between Native Hawaiian/other Pacific Islanders' expected impacts and other ethnicity groups' is regarding culture and traditional activities access reduction (Figure 4.15). Low income, in general, is not related to the expected level of impacts of sea level rise on accessibility except park and recreational access, where low-income residents reported a slightly higher level of concerns ((M = 4.04, SD = 1.228) compared with the middle and high-income residents (M = 3.5, SD = 1.384) (Figure 4.16). With children or not significantly affect people's perception of how sea level rise will impact their access to university/college education, K-12 school, park and recreational facilities, and culture and traditional activities. Households with children, in general, consider sea level rise will have higher levels of impact in all these aspects, which are not surprising (Figure 4.16). Finally, respondents without a car generally have higher levels of concern for sea level rise's impact on job access, grocery and livelihood activities, K-12 school access, health care, and emergency services access compared to the ones with at least one car (Figure 4.17). This is not surprising given the ones without cars usually have lower accessibility at present too.

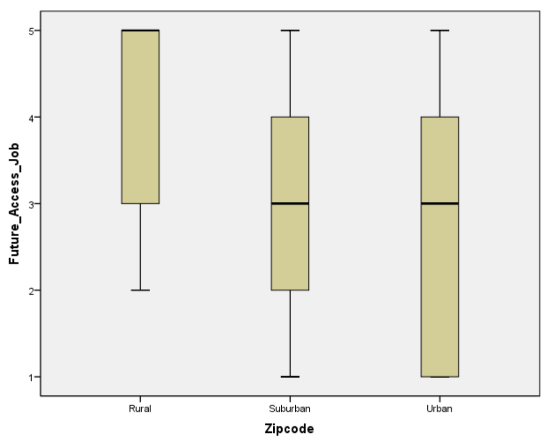
Table 4.5 Sea Level Rise's Impacts on Accessibility (1-5) Equity Test Statistics

Q26 Please rate how do you think SLR will affect your access to the following opportunities on a scale of 1 to 5, 1 as the minimal impacts and 5 as the most severe

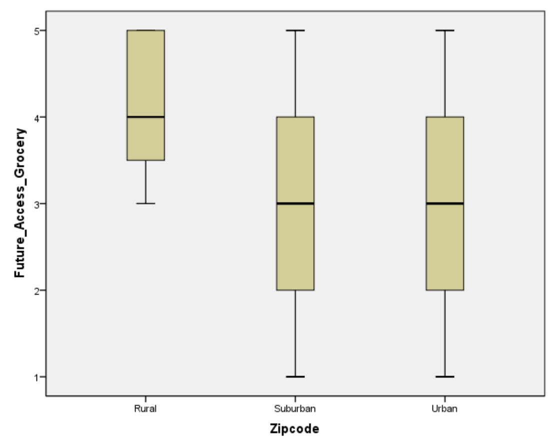
Accessibility Type	Statistics	Location	Age	Ethnicity	Income	Household w/o Children	Car Ownership
Job	F (ANOVA)	4.787	1.307	.367	1.530	.015	.673
	df (between groups)	2	2	1	1	1	1
	df (within groups)	114	123	122	112	127	127
	Sig.	**.010***	,274	**.006***	.490	.491	**.019***
Grocery and livelihood activities	F (ANOVA)	4.528	1.4582	.001	.000	.061	.097
	df (between groups)	2	2	1	1	1	1
	df (within groups)	110	119	119	108	125	123
	Sig.	**.013***	.237	**.016***	.415	.263	**.026***
University/ College Education	F (ANOVA)	1.656	1.314	2.064	.016	1.054	1.041
	df (between groups)	2	2	1	1	1	1
	df (within groups)	100	110	109	98	116	113
	Sig.	.196	.273	**.012***	.200	**.028***	.101
K-12 School	F (ANOVA)	2.449	4.004	3.491	1.592	.077	10.541
	df (between groups)	2	2	1	1	1	1
	df (within groups)	95	105	105	94	112	108
	Sig.	.092	.411	**.000***	.130	**.002***	**.036***
Park and Recreation	F (ANOVA)	3.441	8.367	.911	2.752	5.310	.890
	df (between groups)	2	2	1	1	1	1
	df (within groups)	112	121	120	110	127	125
	Sig.	.389	.091	.376	**.035***	**.008***	.638

Accessibility Type	Statistics	Location	Age	Ethnicity	Income	Household w/o Children	Car Ownership
Traditions and Culture Activities	F (ANOVA)	.026	2.055	2.854	.089	.018	1.698
	df (between groups)	2	2	1	1	1	1
	df (within groups)	108	117	117	106	124	121
	Sig.	.974	.133	**.007***	.539	**.008***	.384
Health Care	F (ANOVA)	4.999	2.716	4.684	3.655	.634	1.590
	df (between groups)	2	2	1	1	1	1
	df (within groups)	108	116	116	106	123	120
	Sig.	**.008***	.070	**.018***	.753	.097	**.012***
Emergency Services	F (ANOVA)	4.293	6.740	2.000	.078	1.140	.267
	df (between groups)	2	2	1	1	1	1
	df (within groups)	109	118	117	107	124	122
	Sig.	**.016***	.204	.053	.444	.089	**.035***

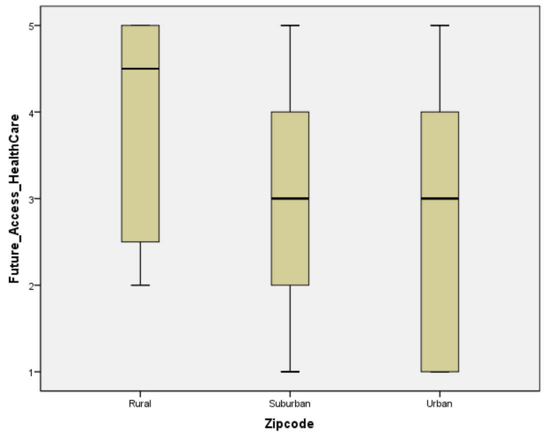
*** significant at the 0.05 level**



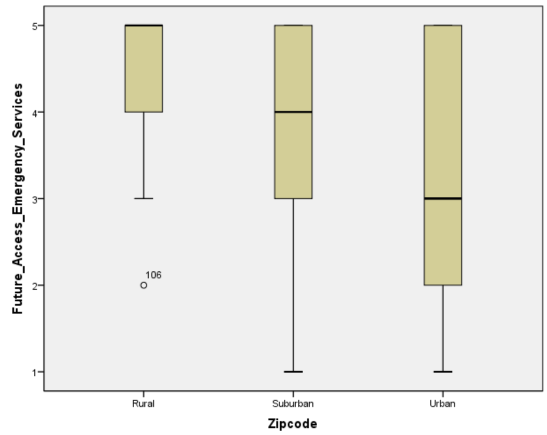
a) SLR impact on job access



b) SLR impact on grocery and livelihood access

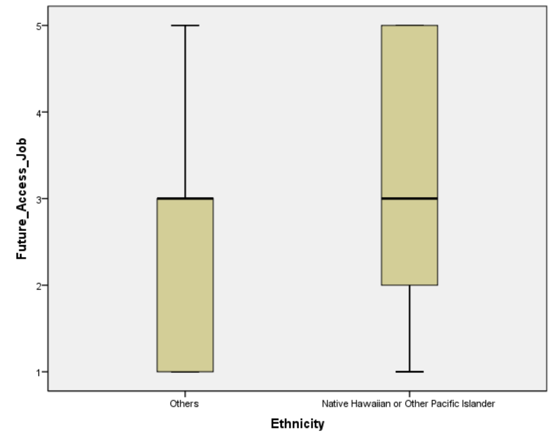


c) SLR impact on health care access

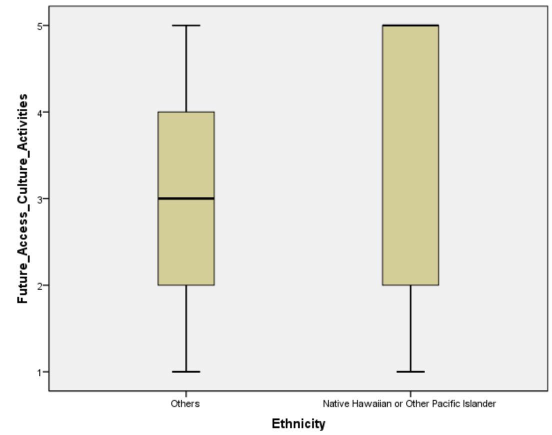


d) SLR impact on emergency service access

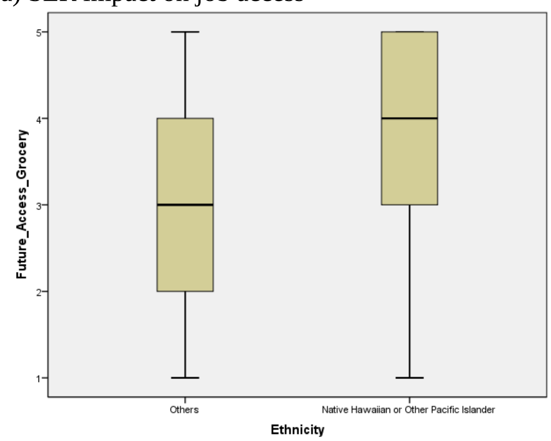
Figure 4.14 Expected SLR impacts on various accessibility and residential location



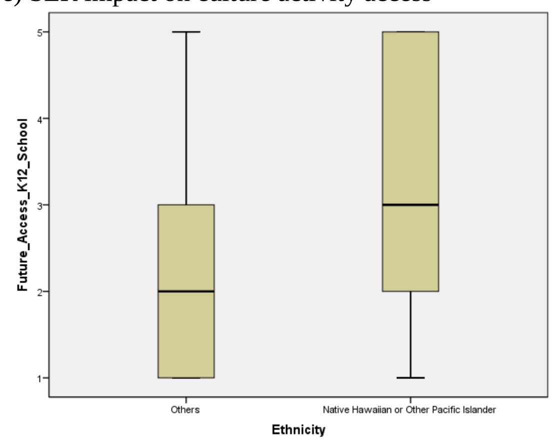
a) SLR impact on job access



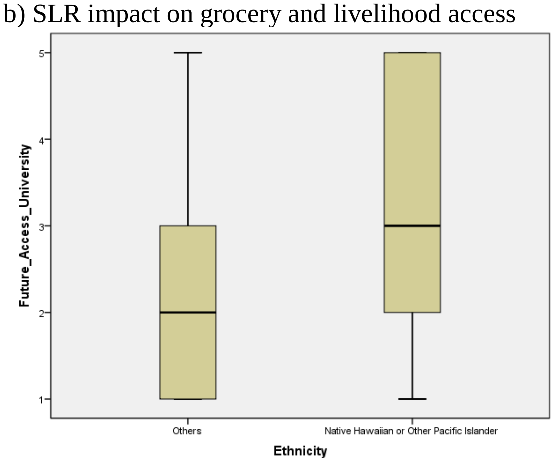
e) SLR impact on culture activity access



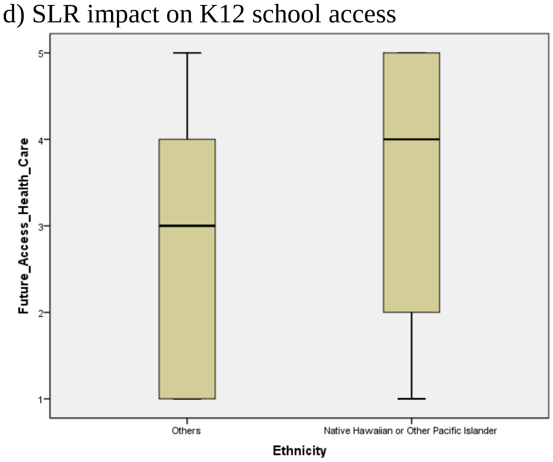
b) SLR impact on grocery and livelihood access



d) SLR impact on K12 school access

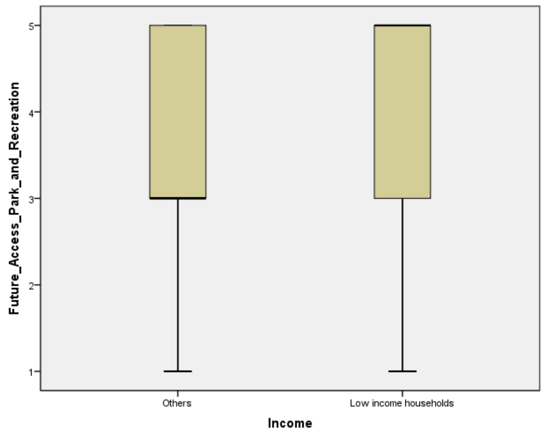


c) SLR impact on university and college access

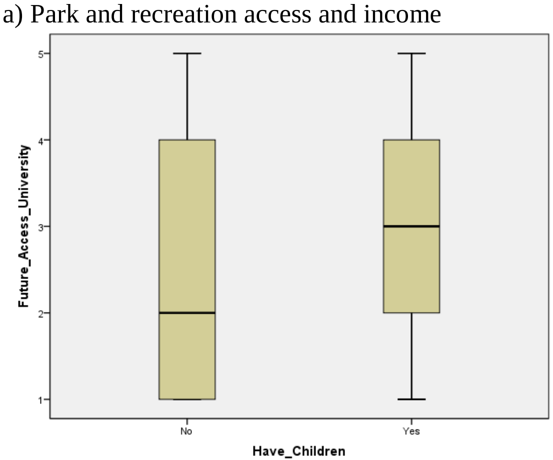


f) SLR impact on health care access

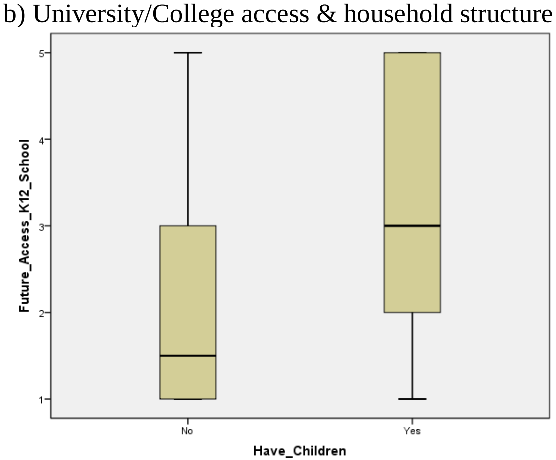
Figure 4.15 Expected SLR impacts on various accessibility and ethnicity



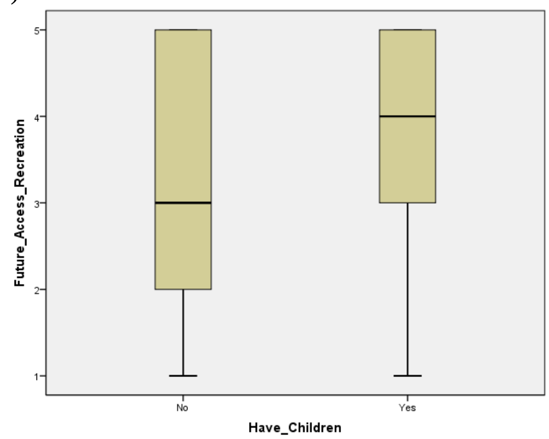
a) Park and recreation access and income



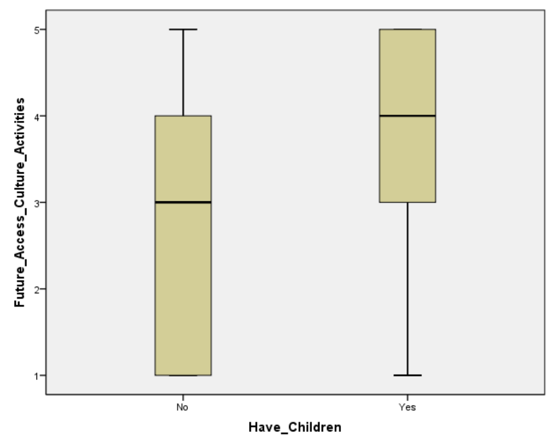
b) University/College access & household structure



c) K12 school access and household structure

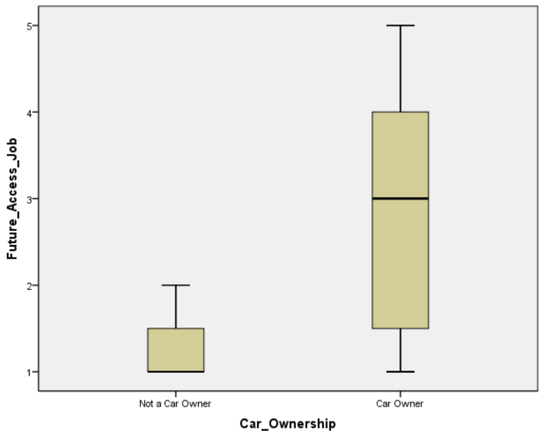


d) Park and recreational access and household structure

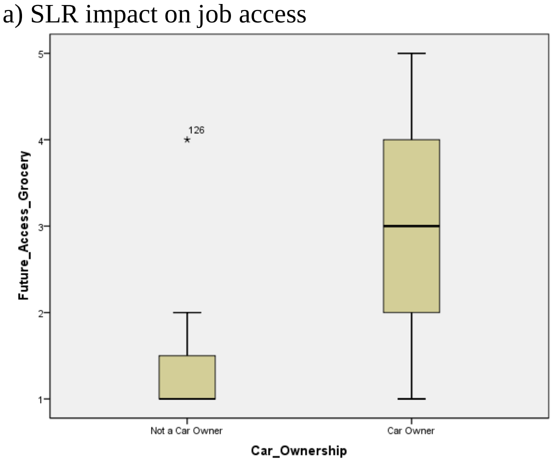


e) Access to culture activities and household structure

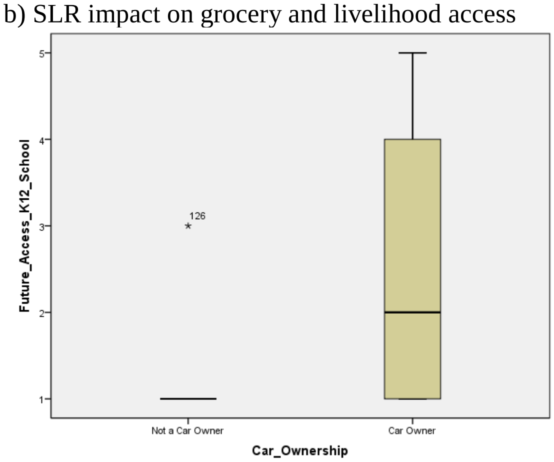
Figure 4.16 Expected SLR impacts on various accessibility and income, household structure



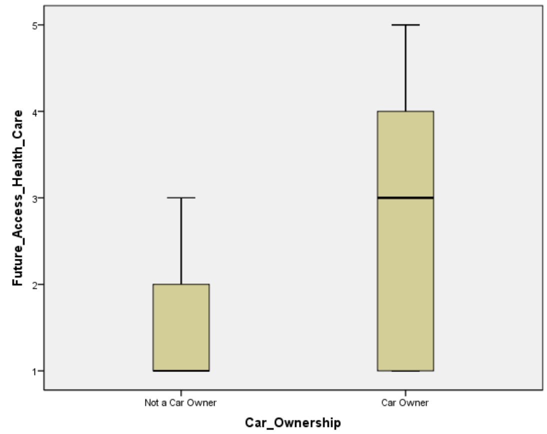
a) SLR impact on job access



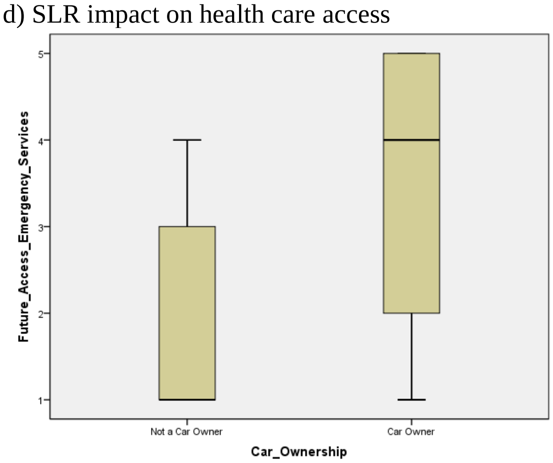
b) SLR impact on grocery and livelihood access



c) SLR impact on K-12 school access



d) SLR impact on health care access



d) SLR impact on emergency service access

Figure 4.17 Expected SLR impacts on various accessibility and car ownership

CHAPTER 5. CONCLUSION

Using data collected from a community survey, this study provides an in-depth understanding of Hawai'i coastal residents' current experience of coastal flooding and risk perception regarding sea level rise's potential impacts on transportation. The survey results show currently Hawai'i coastal residents are most frequently affected by indirect effects of rising sea levels such as storm surge, coastal erosion, and construction/maintenance on coastal roads compared to direct coastal flooding, king tides, or inland ground inundation. Construction and maintenance on coastal roads are most frequently experienced with the highest level of impact rating by respondents in the study area, indicating the necessity to further explore sea level rise's potential impacts on infrastructure degradation, maintenance, and the associated system impacts. The detours caused by maintenance and repairs may increase congestion levels and accident rates on alternative routes. Without considering secondary impacts, sea level rise's impacts on the transportation system may be greatly underestimated. While king tides, groundwater inundation, and maintenance on coastal roads are equally experienced by respondents with different backgrounds, in general, storm surge, coastal erosion, and other types of coastal flooding are more frequently experienced by residents in rural areas, the elderly, households with children, and Native Hawaiians and Pacific Islanders. Similar patterns exist regarding the level of impact. Higher levels of impacts of coastal road maintenance, storm surge, and coastal erosion are experienced by Native Hawaiian and other Pacific Islanders, rural residents, and households with children.

The findings also reveal how people who travel by different transportation modes are sensitive to different types of impacts. For example, people who drive or take transit are most sensitive to construction and maintenance on coastal roads given most of the roadways in the study area are in coastal areas and how such events may cause significant traffic delays or detours. In addition to construction and maintenance on coastal roads, transit users are also sensitive to storm surge and king tide flooding, implying the exposure of transit facilities and routes in coastal areas. People who travel by motorcycle are more sensitive to coastal erosion and flooding caused by intense rainfall or storm given their potential preference for scenery and sensitivity to weather. Bicyclists experienced much more groundwater inundation compared to other modes, indicating bike facilities could be at risk in inland low-lying areas.

In terms of the types of trips and accessibility affected, it is interesting to find that while work trips are the most frequently affected among all trip purposes, access to parks and recreation are rated as the most severely affected at the present and was the major concern regarding sea level rise. It is also interesting to compare the findings with previous transportation modeling results of tidal flooding impacts at 1% annual exceedance probability levels (Shen and Kim, 2020). While the survey discloses that people currently experience more impacts of tidal flooding on park and recreation access, job access, and grocery access, the model shows that actually education, health care, and emergency service have the worst accessibility at the moment. With the projected sea level rise, people are most concerned about the park and recreational access, emergency services, culture, and traditional activities access, and grocery access, while the model reveals access to education, grocery, health care, and jobs will be the most affected (Table 5.1). Comparing the study results with the modeling results helps to reveal the coastal community's preferences and their most demanding needs.

Table 5.1 Risk Perception vs. Model Outcome

	Survey results						Model results					
Level of Impacts on Accessibility	Current			SLR			Current Level			SLR		
	Rank	Mean (1-5)	SD	Rank	Mean (1-5)	SD	Rank	Mean	SD	Rank	Reduction %	SD
Park and recreation	1	2.64	1.311	1	3.72	1.322	2	0.31	1.32	7	2.96	9.11
Emergency services	5	1.75	1.315	2	3.43	1.451	6	0.10	0.21	6	3.59	12.23
Grocery and livelihood activities	3	1.93	1.205	4	3.08	1.396	1	0.35	0.94	2	4.19	14.04
Traditions/culture activities	4	1.86	1.249	3	3.12	1.488		N/A	N/A	N/A	N/A	N/A
Job	2	1.96	1.414	6	2.93	1.449	3	0.20	0.42	4	4.15	12.63
Health care	7	1.65	1.202	5	2.96	1.471	4	0.13	0.38	3	4.19	13.28
University/College Education	6	1.67	1.19	7	2.66	1.558	5	0.13	0.73	1	6.04	16.08
K-12 school	8	1.46	0.965	8	2.47	1.5	7	0.07	0.12	5	3.67	12.5

* Model results comes from Shen and Kim (2020)

Furthermore, the project makes a unique contribution to aid in understanding how different groups are being affected by the current coastal flooding and their concerns with the projected sea level rise from an environmental equity perspective. The findings indicate that the adverse impacts of coastal flooding and sea level rise on travel may affect more households who need child care, k-12, and college access, elderly population, rural residents, Native Hawaiians, and other Pacific Islanders. It is worth noting most of the impacts and concerns are regardless of the respondents' income or car ownership in general. It implies the transportation vulnerability may be more attributed to the location of residence or needed facilities or the exposure of roads accessing these locations than the inherent socioeconomic conditions. The findings could be used to develop more targeted adaptation strategies that help to improve resilience, especially for the most vulnerable groups. Residential locations, workspace, school, health care, emergency facilities, and their access roadways should be carefully planned to avoid being cut off by future sea level rise, stressing the importance of integrating land use planning into transportation adaptation to sea level rise. It also shows that park and recreational access, as well as cultural and traditional activities, are highly valued by residents across the island. Future sea level rise adaptation should discuss how to protect or relocate the parks, recreational facilities, cultural heritage sites, and places important for traditional activities in coastal areas to ensure future access.

Finally, we acknowledge that the sample data collected in this study may not be a representation of the whole population on the island of Oahu. However, the findings still reflect diverse opinions of residents across the island, especially in coastal areas, as we tried to reach out to communities in different regions. It is also worth noting that the differences in people's reported experience, risk perceptions, and modeling results (Shen and Kim, 2020) have two possible explanations. First, despite certain accessibilities being affected more severely than the others, people are concerned about certain resources and opportunities (e.g. park and recreational access, job, and grocery) more than the others (e.g. emergency, hospital, college access, K-12). This finding may be attributed to people using park and recreation facilities, going to the workspace, and doing grocery shopping much more frequently than using emergency and hospital services. It could also be because that more people use the park and recreational facilities, go to workspace and grocery stores than people who use emergency, hospital, college, or K-12 facilities. Second, an alternative explanation could be certain accessibilities (e.g. park, job, grocery) are indeed more affected more severely than other types (e.g. emergency, hospital, college access, K-12) but the model results did not reflect this because certain impacts (e.g. congestion, maintenance, and detour) are not well understood or accurately estimated in the transportation model. The gap between people's perception and model results could also be because of a combination of the above two explanations. More research is needed to validate the model assumptions and results, and to explore which explanation is the case.

REFERENCES

Asadabadi, A. and Miller-Hooks, E. 2017. Assessing strategies for protecting transportation infrastructure from an uncertain climate future. *Transportation Research Part A: Policy and Practice* 105 27-41.

Ayyub, B.M., Braileanu, H.G. and Qureshi, N. 2012. Prediction and impact of sea level rise on properties and infrastructure of Washington, DC. *Risk Analysis: An International Journal* 32(11) 1901-1918.

Azevedo de Almeida, B. and Mostafavi, A.J.S. 2016. Resilience of infrastructure systems to sea-level rise in coastal areas: Impacts, adaptation measures, and implementation challenges. 8(11) 1115.

Barry, R. 2016. *Study predicts rise in sea level impacting Jacksonville* [*online*]. Available at: https://www.news4jax.com/news/2016/04/22/study-predicts-rise-in-sea-level-impacting-jacksonville/ [Accessed April 12 2021].

Becken, S. 2005. Harmonising climate change adaptation and mitigation: The case of tourist resorts in Fiji. *Global environmental change* 15(4) 381-393.

Blaikie, P., Cannon, T., Davis, I. and Wisner, B. 1994. At risk. *Natural hazards, people's vulnerability and disasters*.

Bloetscher, F. and Romah, T. 2015. Tools for assessing sea level rise vulnerability. *Journal of Water and Climate Change* 6(2) 181-190.

Bloetscher, F. et al. 2012. Identification of physical transportation infrastructure vulnerable to sea level rise. *Journal of Sustainable Development* 5(12) 40.

Bronen, R. 2010. Forced migration of Alaskan indigenous communities due to climate change. *Environment, forced migration and social vulnerability*. Springer. pp. 87-98.

Burkett, V.R. 2002. Potential impacts of climate change and variability on transportation in the Gulf Coast/Mississippi Delta region. *The potential impacts of climate change on transportation* 103.

Cutter, S.L., Boruff, B.J. and Shirley, W.L. 2003. Social vulnerability to environmental hazards. *Social science quarterly* 84(2) 242-261.

Ekstrom, J.a.M., S., 2012. Sea-Level Rise Impacts and Flooding Risks in the Context of Social Vulnerability: An Assessment for the City of Los Angeles. Susanne moser Research & Consulting.

Felsenstein, D. and Lichter, M. 2014. Social and economic vulnerability of coastal communities to sea-level rise and extreme flooding. *Natural hazards* 71(1) 463-491.

Flanagan, B.E. et al. 2011. A social vulnerability index for disaster management. *Journal of homeland security and emergency management* 8(1).

Green, D., Jackson, S. and Morrison, J. 2009. *Risks from climate change to indigenous communities in the tropical north of Australia*: Department of Climate Change, Commonwealth of Australia.

Grinsted, A., Moore, J.C. and Jevrejeva, S. 2010. Reconstructing sea level from paleo and projected temperatures 200 to 2100 AD. *Climate dynamics* 34(4) 461-472.

Haines, A., Kovats, R.S., Campbell-Lendrum, D. and Corvalán, C. 2006. Climate change and human health: impacts, vulnerability and public health. *Public health* 120(7) 585-596.

Han, Y. et al. 2017. When the tides come, where will we go?: Modeling the impacts of sea level rise on the Greater Boston, Massachusetts, transport and land use system. *Transportation Research Record* 2653(1) 54-64.

Hardy, R.D. and Hauer, M.E. 2018. Social vulnerability projections improve sea-level rise risk assessments. *Applied Geography* 91 10-20.

Hawaiʻi Climate Change Mitigation and Adaptation Commission 2017. Hawaiʻi Sea Level Rise Vulnerability and Adaptation Report. Prepared by Tetra Tech, Inc. and the State of Hawaiʻi Department of Land and Natural Resources, Office of Conservation and Coastal Lands

Heim, J. 2017. *National study puts timeline on impact of sea-level rise in Maryland and Virginia* [*online*]. Available at: https://www.washingtonpost.com/local/national-study-puts-timeline-on-impact-of-sea-level-rise-in-maryland-and-virginia/2017/07/14/c3c4fd6e-67d8-11e7-a1d7-9a32c91c6f40_story.html?utm_term=.ebaaa46b1429 [Accessed May 1st 2021].

Hoozemans, F., Marchand, M. and Pennekamp, H. 1993. A global vulnerability analysis: vulnerability assessment for population, coastal wetlands and rice production on a global scale. Delft Hydraulics, the Netherlands.

Intergovernmental Panel on Climate Change 2007. The physical science basis. *Contribution of working group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* 996.

Jacob, K., V. Gornitz, C. Rosenzweig, 2007. *Vulnerability of the New York City metropolitan area to coastal hazards, including sea-level rise: Inferences for urban coastal risk management and adaptation policies.* Elsevier.

Karl, T.R., Melillo, J.M., Peterson, T.C. and Hassol, S.J. 2009. *Global climate change impacts in the United States*: Cambridge University Press.

Keener, V.W. et al. 2012. *Climate change and Pacific islands: indicators and impacts: report for the 2012 Pacific Islands Regional Climate Assessment (PIRCA)*: Washington, DC: Island Press.

Koetse, M.J. and Rietveld, P. 2009. The impact of climate change and weather on transport: An overview of empirical findings. *Transportation Research Part D: Transport and Environment* 14(3) 205-221.

Lindsey, R. 2019. Climate change: global sea level. *ClimateWatch Magazine*.

Lu, Q.-C. and Peng, Z.-R. 2011. Vulnerability analysis of transportation network under scenarios of sea level rise. *Transportation Research Record* 2263(1) 174-181.

Lu, Q.-C., Peng, Z.-R. and Zhang, J. 2015. Identification and prioritization of critical transportation infrastructure: Case study of coastal flooding. *Journal of Transportation Engineering* 141(3) 04014082.

Mitchell, M. et al. 2013. Recurrent flooding study for Tidewater Virginia.

National Research Council, Committee on Climate Change and US Transportation Research Board 2008. *Potential impacts of climate change on US transportation: Special report 290*: Transportation Research Board.

National Research Council Ocean Studies Board 2012. *Sea-level rise for the coasts of California, Oregon, and Washington: past, present, and future*: National Academies Press.

New York City Panel on Climate Change 2009. Climate risk information.

Office for Coastal Management. 2021. *Social Vulnerability Index (SoVI) for the U.S. Coastal States based on the 2010 Census Tracts* [*online*]. Available at: https://www.fisheries.noaa.gov/inport/item/48239.

Pachauri, R.K. et al. 2014. *Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change*: Ipcc.

Parris, A.S. et al. 2012. Global sea level rise scenarios for the United States National Climate Assessment.

Peterson, T.C. et al. 2008. Climate variability and change with implications for transportation. *Transportation Research Board* 90 2.3.

Phil O'Keefe, K.W., Ben Wisner 1976. Taking the naturalness out of natural disasters. *Nature* 260 566-567.

Portier, C.J. et al. 2013. A human health perspective on climate change: a report outlining the research needs on the human health effects of climate change. *Journal of Current Issues in Globalization* 6(4) 621.

Rahmstorf, S. 2007. A semi-empirical approach to projecting future sea-level rise. *Science* 315(5810) 368-370.

Romah, T. 2012. *Advanced methods in sea level rise vulnerability assessment*: Florida Atlantic University.

Romine, B.M. et al. 2013. Are beach erosion rates and sea-level rise related in Hawaii? *Global and Planetary Change* 108 149-157.

Rotzoll, K. and Fletcher, C.H. 2013. Assessment of groundwater inundation as a consequence of sea-level rise. *Nature Climate Change* 3(5) 477-481.

Savonis, M.J., Burkett, V.R. and Potter, J.R. 2008. Impacts of climate change and variability on transportation systems and infrastructure: Gulf coast study, Phase I.

Shen, S. and Kim, K. 2020. Assessment of transportation system vulnerabilities to tidal flooding in Honolulu, Hawai'i. *Transportation Research Record* 2674(11) 207-219.

Suarez, P., Anderson, W., Mahal, V. and Lakshmanan, T. 2005. Impacts of flooding and climate change on urban transportation: A systemwide performance assessment of the Boston Metro Area. *Transportation Research Part D: Transport and Environment* 10(3) 231-244.

Titus, J. 2002. Does sea level rise matter to transportation along the Atlantic Coast? *The potential impacts of climate change on transportation* 135.

Tompkins, F. and DeConcini, C. 2014. Sea-level Rise and its Impact on Virginia. Washington, DC:, World Resources Institute.

Upton, J. 2014. *Sea level rise making floods routine for coastal cities* [*online*]. Available at: https://www.climatecentral.org/news/coastal-flooding-us-cities-18148 [Accessed May 31st 2021].

Vermeer, M. and Rahmstorf, S. 2009. Global sea level linked to global temperature. *Proceedings of the national academy of sciences* 106(51) 21527-21532.

Wang, Z. et al. 2015. Recent advances in modeling the vulnerability of transportation networks. *Journal of infrastructure systems* 21(2) 06014002.

Wu, Y.-J., Hayat, T., Clarens, A. and Smith, B.L. 2013. Climate change effects on transportation infrastructure: scenario-based risk analysis using geographic information systems. *Transportation Research Record* 2375(1) 71-81.

Wuebbles, D.J. et al. 2017. Climate science special report: Fourth national climate assessment (NCA4), Volume I.

Zhang, K. 2011. Analysis of non-linear inundation from sea-level rise using LIDAR data: a case study for South Florida. *Climatic Change* 106(4) 537-565.

Zuzak, C., D. Kealey, E. Goodenough, and C. Stanton, 2020. National Risk Index Technical Documentation. Washington, DC., Federal Emergency Management Agency.

APPENDIX A SURVEY QUESTIONS

1. **By checking this box, you are agreeing that, "I consent to this survey and understand I can stop at any time without penalty."**
   ☐ I Agree

2. **Have any of the following conditions ever affected your travel?** Please check all that apply.
   ☐ King tides
   ☐ Storm surge
   ☐ Inland ground water inundation (Sunny-day flooding)
   ☐ Coastal erosion
   ☐ Construction/maintenance on coastal roads
   ☐ Other coastal flooding (Specify)
   ☐ None of the above (If none of the above, please skip to Question 11).

3. **Your travel is most affected by which of the above conditions and could you briefly explain how?**
   ____
   ____

4. **These conditions have affected my travel by…**
   Please check all that apply

	Bike	Walk	Car	Motorcycle	Transit	Other (Specify)
Transportation	☐	☐	☐	☐	☐	☐

5. **If you choose "King tides" or "Other coastal flooding" in Q2, has coastal flooding affected your travel in the following ways?** Please check all that apply.
   ☐ Flooded trip origin/destination
   ☐ Flooded route
   ☐ Reduced Service
   ☐ Other (Specify)
   ☐ None of the above

6. **If you choose "Storm Surge" in Q2, has storm surge affected your travel in the following ways?** Please check all that apply.
   ☐ Flooded trip origin/destination
   ☐ Flooded route
   ☐ Reduced Service
   ☐ Other (Specify)
   ☐ None of the above

7. **If you choose "inland groundwater inundation" in Q2, has it affected your travel in the following ways?** Please check all that apply.
   ☐ Flooded trip origin/destination
   ☐ Flooded route
   ☐ Reduced Service
   ☐ Other (Specify)
   ☐ None of the above

8. **If you choose "coastal erosion" in Q2, has it affected your travel in the following ways?** Please check all that apply.
   ☐ Reduced Service
   ☐ Detour because of road closure
   ☐ Canceled travel plan
   ☐ Reduced Parking
   ☐ Other (Specify)
   ☐ None of the above

9. **If you choose "construction/maintenance on coastal road" in Q2, has it affected your travel in the following ways?** Please check all that apply.
   ☐ Reduced Service
   ☐ Detour because of road closure
   ☐ Canceled travel plan
   ☐ Reduced Parking
   ☐ Other (Specify)
   ☐ None of the above
   Could you draw on the map where your travel has been affected and briefly note the causes and impacts on the map? (Feel free to use any of the following maps)

10. **What was the original purpose of the affected trips?** Please check all that apply.
    ☐ Work ☐ Recreation/Leisure ☐ Groceries ☐ Other shopping ☐ Returning home
    ☐ School ☐ Family/Social ☐ Other (Specify)

11. Do you think Sea Level Rise (SLR) will increase the frequency of coastal flooding?
    ☐ Yes ☐ No ☐ Maybe

12. Are you concerned that frequent coastal flooding could affect your travel in the future?
    ☐ Yes ☐ No
    Could you draw on the map (next page) where are the areas you are most concerned about with future coastal flooding on SLR? (Feel free to use any of the following maps)

13. Is there anything else you are concerned about SLR to affect your future travel plans?
    ____

____

14. To you, are the impacts of coastal flooding and SLR acceptable and manageable?

☐ Yes ☐ No

15. What would be your strategy or suggestions to adapt to frequent coastal flooding impacts?

____

____

16. What is your gender?

☐ Female ☐ Male ☐ Prefer not to say

17. What is your age?

☐ 18-24
☐ 25-34
☐ 35-44
☐ 45-54
☐ 55-64
☐ 65 +
☐ Prefer not to say
☐ Other: _________________

18. What ethnicity(s) would you consider yourself? Please check all that apply.

☐ Hawaiian
☐ Other Pacific Islander
☐ Hispanic or Latino
☐ African American or Black
☐ Caucasian or White
☐ Asian
☐ Other: _________________

19. Does your household own a car?

☐ Yes ☐ No

20. Are you a resident of a Hawaiian Island or a resident of Oahu?

☐ Resident of Hawai'i but not Oahu
☐ Resident of Oahu
☐ Visitor
☐ Other: __________________

21. Are you in a household with children under 18?

☐ Yes ☐ No ☐ Maybe ☐ Other

22. How many children (under 18) do you have?

☐ 0-3
☐ 4-5
☐ 6-12
☐ 13-16
☐ 17-18

23. How long have you stayed on Oahu?

_______________years ________________months

24. What is your home address zip code?

____

25. What is your household income?

☐ 0-30,000
☐ 30,000-60,000
☐ 60,000-90,000
☐ 90,000-120,000
☐ >120,000
☐ Other

26. Please rate how coastal flooding and erosion have affected your access to the following opportunities.

	1	2	3	4	5
	Not at all	Very little	Somewhat	Quite a bit	Very much
Job	○	○	○	○	○
Grocery and livelihood activities	○	○	○	○	○
University/College Education	○	○	○	○	○
K-12 School	○	○	○	○	○
Park and Recreation	○	○	○	○	○
Traditions and Culture Activities	○	○	○	○	○
Health Care	○	○	○	○	○
Emergency Services	○	○	○	○	○

27. How do you think SLR will affect your access to the following opportunities?

	1	2	3	4	5
	Not at all	Very little	Somewhat	Quite a bit	Very much
Job	○	○	○	○	○
Grocery and livelihood activities	○	○	○	○	○
University/College Education	○	○	○	○	○
K-12 School	○	○	○	○	○
Park and Recreation	○	○	○	○	○
Traditions and Culture Activities	○	○	○	○	○
Health Care	○	○	○	○	○
Emergency Services	○	○	○	○	○

28. Could you rate how they affect your travel?

	1	2	3	4	5
	Not at all	Very little	Somewhat	Quite a bit	Very much
King tides	○	○	○	○	○
Storm Surge	○	○	○	○	○
Inland ground water inundation	○	○	○	○	○
Coastal erosion	○	○	○	○	○
Construction/maintenance on coastal roads	○	○	○	○	○
Other coastal flooding	○	○	○	○	○

29. Could you describe where on Oahu you have experienced these impacts?

____

____

30. Could you describe where on Oahu you are most concerned about the impacts of future SLR on transportation infrastructure?

____

____