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ASSESSMENT OF WAIANAE'S VULNERABILITY TO A CATEGORY 4 HURRICANE

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ABSTRACT: This research assesses the vulnerability of Waianae, a Census County Division on the northwest quadrant of Oahu, to a Category 4 hurricane. Combining socio-economic and risk assessment analyses, the study reveals that Waianae is highly susceptible to hurricane impacts, given its historical exposure and socio-economic disparities. The socio-economic vulnerabilities, including lower income, higher poverty rates, and increased unemployment, are compounded by physical vulnerabilities, such as limited access via Farrington Highway. Utilizing tools like HAZUS-MH and ArcGIS, the study quantifies potential damages, debris generation, social impacts, and economic losses in the event of a hurricane. The findings emphasize the urgent need for resilience-building measures, including local job creation, development of emergency shelters, and exploration of alternative evacuation routes. Addressing these vulnerabilities will enhance Waianae's preparedness and mitigate the potential impact of future hurricanes, fostering a more resilient and secure community.

Keywords: Hurricane Vulnerability, Socio-economic Disparities, Risk Assessment, Resilience Building

1. INTRODUCTION

1.1 Background

Hazards and disasters constitute a major and escalating issue [1]. In the early 1990s, [2] stated that approximately one-seventh of the global population lived in areas exposed to the risks of natural hazards. Given the continuous growth of the world population and the increasing trend of people settling in high-risk zones, such as coastal, slope, seismic, volcanic, and flood-prone areas, that figure has undoubtedly risen since then [3]. From 1970 to 2005, significant changes occurred in physical, biological, and human systems due to climate change [4]. A key concern is the rising surface temperature of the Earth, marked by extreme rainfall, heat waves, cold spells, droughts, intense tropical cyclones, and new types of natural disasters [5].

FEMA categorizes natural hazards into four main types: tectonic hazards, mass-movement hazards, hydrologic hazards, and meteorological hazards [6]. However, it's important to note that not every hazard becomes a disaster. A natural hazard only qualifies as a disaster if it occurs and has a significant human impact, disrupting community functioning. In such cases, local resources may become overwhelmed, necessitating assistance from other jurisdictions, the state, or even the federal government [7].

In history, Hawai'i has experienced numerous meteorological hazards, particularly hurricanes, making the state highly vulnerable to this type of threat. Figure 1 below illustrates the paths of hurricanes that have impacted Hawai'i since 1949. Two hurricanes, in particular, stand out for causing significant damage: Iwa and Iniki. Hurricane Iwa struck in 1982, devastating the northern Hawaiian Islands, including Kauai, Niihau, and Oahu. Approximately 500 people were internally displaced, and 120 individuals were treated for minor injuries [8]. The other notable hurricane, Iniki, occurred in 1992 and stands as the most powerful to hit Hawai'i. This hurricane made landfall on the south shore of Kauai, resulting in an estimated $3 billion in damages. Over 14,000 homes were affected, with 1,421 destroyed and 5,152 suffering major damages [9].

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Figure 1. Historical Hurricane Tracks Affecting Hawai'i (1949-2006) [10]

Given Hawai'i's extensive history of hurricanes, there is a possibility of similar or even more severe events occurring in the future. This research aims to conduct a risk assessment for hurricanes in a specific area on the Island of Oahu, namely Waianae.

Waianae is a Census County Division (CCD) within the City and County of Honolulu, situated on the northwest quadrant of the island (refer to Figure 2). The region is further divided into eight census tracts. Considering the historical impact of damaging hurricanes such as Iwa and Iniki, both striking the northwest side of the State of Hawai'i, Waianae emerges as one of the most vulnerable areas.

Compared to other CCDs in the City and County of Honolulu, Waianae exhibits a higher socio-economic vulnerability. The Leeward Coast Initiative Inventory Report (cited in the Department of Planning and Permitting, 2012) outlines the socio-economic conditions of Waianae as follows:

1. In 2000, the per capita income of Waianae community residents was approximately 61% of the state average.
2. The percentage of individuals in the Waianae community below the poverty level exceeded the state average in 2000.
3. Over the past twenty years, the unemployment rate in the Waianae community has consistently been significantly higher than the state average, with the gap widening.

Another report from Townscape (2010) revealed that, in 2007, Waianae had over 6,000 homeless individuals. Communities with higher socio-economic vulnerabilities are significantly more likely to bear the brunt of the consequences of a disaster. In addition to socio-economic vulnerabilities, the Waianae communities also face physical vulnerability. Farrington Highway serves as the sole access to West Oahu, and it is not connected to other major roads (refer to Figure 2). The yellow line on the map represents the major highway in Oahu. Any incident or issue along Farrington Highway has the potential to impede mobility in and out of Waianae.

Based on those evidences, this research attempts to analyze the impact of a category 4 hurricane in Waianae community. We identify which areas of Waianae are more susceptible and to arrange the strategy to build the resilience within the communities.

Figure 2. The Island of Oahu
(Source: Google Earth Pro, 2015)

1.2. Hurricane and Hawaii

Hawaii is, perhaps, one of the most isolated communities globally, and its geography renders it particularly susceptible to natural disasters such as hurricanes, tsunamis, and floods. In the past, the category 4 Hurricane Iniki inflicted significant damage across the islands. Hurricanes of any size and duration pose threats to local infrastructure, the environment, and the economy, adversely affecting the daily lives of Hawaii's residents. These impacts are exacerbated by Hawaii's geographic isolation, the vulnerability of its critical infrastructure, and the time required for transporting and delivering additional resources, assets, and capabilities during a response. Addressing the catastrophic impacts caused by a hurricane in Hawaii demands a coordinated, joint effort involving county and state agencies, the Federal Government, NGOs, and private sector organizations.

The 2015 Hawaii Catastrophic Hurricane Plan addresses the “physical effects and operational impacts that a Category 4 hurricane would cause throughout the State of Hawaii. The Plan focuses on three operational priorities and eight operational objectives that support those priorities as described below in the Concept of Operations section. The joint response actions include the actions state agencies and other organizations will take to support county disaster planning and response activities. Include the actions the Federal Government will take to support the State of Hawaii under a Stafford Act declaration. Include efforts organized in a phased approach to initiate a scalable and appropriate response prior to the catastrophic hurricane’s impact and with a focus on the first 72 hours post-impact. Set the conditions for recovery and sustained response through the first 60 days.” [12]

The Central Pacific hurricane season spans from June 1 to November 30 each year, with peak activity typically occurring in late summer when ocean temperatures are at their warmest. Although not all tropical cyclones in the Central Pacific escalate to hurricane status, many remain potent weather systems, classified as tropical depressions or tropical storms. Despite their categorization, these storms still pose a substantial threat, capable of causing significant damage and economic loss. This was exemplified by Tropical Storm Iselle's impact on Hawaii County in August 2014, underscoring the importance of preparedness and vigilance during the hurricane season in the region.

1.3. Resilience

Resilience is an important term in disaster literature. In general, communities which are more resilient have better chances to recover after a disaster. The city resilience framework defines, resilience is a term that emerged from the field of ecology in the 1970s, to describe the capacity of a system to maintain or recover functionality in the event of disruption or disturbance.

Resilience has emerged as a pivotal concept that connects disaster risk reduction with climate change adaptation efforts. Unlike traditional disaster risk management, which relies on risk assessments tied to specific hazards, resilience acknowledges the potential for a variety of disruptive events—both stresses and shocks—that may not be entirely predictable. Rather than solely aiming to prevent or mitigate the loss of assets from individual events, resilience emphasizes enhancing the overall performance of a system when confronted with multiple hazards. This approach enables communities and systems to better withstand and recover from diverse challenges, contributing to greater overall adaptability and sustainability in the face of uncertainty. [13].

Resilience as a term has evolved because of the change in the field of disaster management. The shift from disaster response to disaster preparedness has played a crucial role in making resilience significant. "There has been a significant shift in attitude in addressing the challenges of disasters. For too long disasters have been seen as one-off events that were addressed through humanitarian response and relief efforts. For a few decades there was a clear move towards strengthening preparedness, and ensuring a more effective and efficient response. From the 'preparedness saves lives' approach came the insight that economics played a significant role and a recognition that a longer-term approach was required to reduce disaster risk and build resilience. Often missing in the analysis was the causal link between disaster risk and development, or more precisely the impact of poor development that often created increased vulnerability" [14].

DFID explains resilience in a broader context of assets pyramid. The key idea of developing resilience is the way these assets within a community can be developed. "A key determinant of exposure, sensitivity and adaptive capacity is the set of resources and assets that can be utilised in the face of a stress or shock. As such, resilience enhancing activities can be usefully classified using the 'assets pentagon' from the sustainable livelihoods framework – social, human, physical, financial, and natural" [15].

The research is based on the City Resilience Wheel from Rockefeller Foundation. Minimal human vulnerability is a key component in this research. This relates to the extent to which everyone's basic needs are met. Minimizing underlying human vulnerabilities enables individuals and households to achieve a standard of living which goes beyond mere survival. Another major part of this research is integrated development planning. This is indicated by the presence of a vision, an integrated development strategy, and plans that are regularly reviewed and updated by cross-departmental groups. Integrated plans create a formalised framework to deal with multidisciplinary issues, such as climate change, disaster risk reduction or emergency response [13].

2. METHOD

2.1 Tools, Datasets, and Data Sources

The main tools used in this research is HAZUS-MH, ArcGIS, and Ms Excel. HAZUS-MH is a nationally applicable standardized-based model for estimating potential losses from earthquake, flooding, and hurricane. HAZUS-MH utilizes both deterministic and probabilistic scenarios to generate loss estimation results.

Deterministic analysis relies on the principles of physics or on correlations derived from empirical data or testing to forecast the outcome of a particular hazard scenario. It seeks to provide a precise prediction of the impact based on known parameters and relationships. On the other hand, probabilistic analysis assesses the statistical probability of a particular hazard scenario occurring and affecting the areas under observation. It considers various factors, such as historical data, climate patterns, and geographical characteristics, to determine the likelihood of different events and their potential impacts. By combining these two approaches, HAZUS-MH offers a comprehensive understanding of the potential losses and risks associated with different hazard scenarios, allowing for more informed decision-making and effective disaster preparedness and response measures.

HAZUS-MH is coupled with geographic information systems (ArcGIS) technology to produce maps showing the impact of a particular hazard. HAZUS-MH can estimate the impacts of a hazard on buildings and other structures. Yet, this estimation does not specifically identify which buildings are impacted. The estimations are overall impacts that are intended to guide mitigation

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efforts. In addition, to develop maps using ArcGIS several datasets, such as shapefiles and Digital Elevation Model (DEM), are obtained from several websites, namely Honolulu Land Information System (HoLIS) and The Office of Planning GIS Program.

The datasets used for social assessment were collected from the American Community Survey, 2015. Through the American FactFinder, census data was collected at Sub County Level. These data included tables by American Community survey, 2015. The data on racial minorities, education level, income, and age.

2.2. Research Framework

Two analyses were conducted in this research, socio-economic and risk assessment. For the socio-economic assessment, Social Vulnerability Index is developed for the City and County of Honolulu. We compared each sub-county within the City and County of Honolulu. The data was extracted from the American Community Survey, 2015 for the census sub-county level. The data extracted include:

a. Percentage of individuals who are less than 18 years old (+)
b. Percentage of people below poverty line. (+)
c. Average Household Size (+)
d. Percentage of Native Hawaiian and Pacific Islander Population (+)
e. Percentage of people with a college degree (-)
f. Median Household Income (-)

These indicators are ranked through AHP analyses and Social Vulnerability Index was developed.

Risk assessment was conducted using HAZUS-MH through four main steps: identify hazards, profile hazards, inventory assets, and estimate losses. Identifying hazards begins with defining the study area and then followed by identifying the principal hazards in selected study region. The second step is profiling hazard. In this step, we need to consider hazards likelihood of occurrence, potential magnitude, and past impacts on study region. The third step is to inventory assets. This step is to consider the assets that can be impacted by hazards. Inventory may include general building stock, essential facilities, hazardous material facilities, high potential loss facilities, transportation facilities, utility lifeline system, and demographic. The last step is to estimate losses. This step evaluates our hazard event and inventory results for our study region. Figure 3 below summarizes these four steps in this research [16].

In this research, the risk assessment was conducted in Waianae CCD. Considering the history of hurricanes in Hawai'i, a scenario of category 4 hurricane that moves from the southwest to the northwest of Oahu (See Figure 4) was designed. Using HAZUS-MH, the impacts of this category 4 hurricane on Waianae CCD at census tract level were analyzed and evaluated.

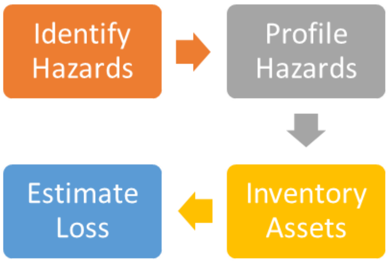

Figure 3. Risk Assessment Framework

Figure 4. The Track of Hurricane Model

3. RESULTS AND DISCUSSION

This section explains the findings obtained from HAZUS-MH analysis, including building inventory, building damage, debris generation, social impact, and economic loss of Waianae CCD community. Our analysis begins with exploring the social vulnerability of Waianae CCD compared to the sub counties within the City and County of Honolulu.

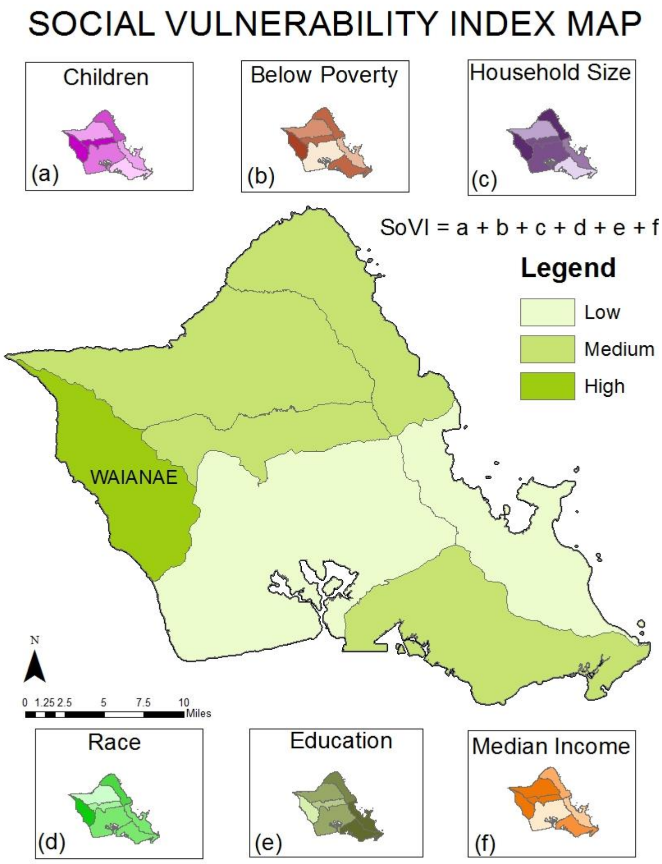

Figure 5. Social Vulnerability Map of City and County of Honolulu

Table 1. Building Exposure by Occupancy Type

Occupancy	Exposure ($1000)	Percent of Total
Residential	3,063,639	89.9%
Commercial	177,846	5.2%
Industrial	16,354	0.5%
Agricultural	58,999	1.7%
Religious	54,229	1.6%
Government	25,749	0.8%
Education	9,666	0.3%
Total	**3,406,482**	**100%**

3.1 *Social Vulnerability Index*

The results indicated that among the seven subdivisions of the Honolulu County, Waianae subdivision is the most vulnerable. The Social vulnerability index map is shown in Figure 5 above.

3.2 *General Building Stock*

After running the analysis, the result shows that there are 10,494 buildings in Waianae CCD. Of these, approximately 96% are associated with residential housing. The other buildings are commercial, industrial, agricultural, religious, government, and education. These buildings have an aggregate total replacement of $3.4 billion. Table 1 presents the relative distribution of the value with respect to the general occupancies.

3.3 *Building Damage*

HAZUS-MH predicted and classified structural and nonstructural damage into slight (minor),

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moderate, extensive (severe), or complete state (destroyed) [17]. The definition of these damage states is presented in Table 2 below.

In this research, HAZUS-MH estimates that, of 10,494 buildings in Waianae CCD, about 7,999 buildings will be at least moderately damaged. This is over 76% of the total number of buildings in the region. There are an estimated 4,095 buildings that will be completely destroyed. Table 3 and Table 4 below summarize the expected damage by general occupancy and by general building type for the buildings in Waianae CCD.

Table 2. HAZUS-MH Damage States Definition

Damage States	Definition
Minor	The structures have experienced some damage to both their structure and contents but remain habitable without needing immediate repairs. Additionally, the damage to items essential for habitability is lower than the minimum requirement set by the Disaster Housing Program and Home Repair Grant.
Moderate	Structure is damaged and uninhabitable, yet it could be restored to habitable condition within a brief timeframe through home repairs. Minor damage may include any of the following: • Repairs can be completed within a 30-day period. • The structure possesses over \$100 worth of eligible habitability items as per the Disaster Housing Program and Home Repair Grant, yet falls short of \$10,000 worth of such items through the Disaster Repair Program and Home Repair Grant. • The costs for repairing the damage amount to less than 50% of the total value of the house.
Severe	The structure has suffered structural or significant damage, rendering it uninhabitable and necessitating extensive repairs. Major damage may include any of the following: • Substantial failures to structural elements of the residence (e.g., walls, floors, foundations); • Damage to the structure exceeds the Disaster Housing Program, Home Repair Grant maximum (\$10,000); • General exterior property damage exceeds the Disaster Housing Program Home Repair Grant maximum (e.g., roads and bridges, wells, earth movement) and has more than 50% damage to the structure. • Damage will take more than 30 days to repair.
Destroyed	The structure is considered a total loss or has been damaged to an extent where repairs are not financially viable. Any of the following conditions may indicate a state of destruction: • Repair of structure is not economically feasible; • Structure is permanently uninhabitable; • There is a complete failure of major structural components (collapse of walls or roof); • Unaffected structure will be required to be removed or demolished

Table 3. The Expected Damage by General Occupancy for The Buildings in Waianae CCD

	None		**Minor**		**Moderate**		**Severe**		**Destruction**	
Occupancy	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**
Residential	1039	10.32	1360	13.51	1880	18.68	1719	17.07	4070	40.42
Commercial	27	10.94	28	11.46	58	23.84	119	48.89	12	4.88
Industrial	6	10.28	6	11.37	12	22.92	28	49.4	4	7.02
Agricultural	4	9.97	5	13.33	8	21.33	15	38.41	7	16.96
Religious	5	10.26	6	11.91	12	22.64	27	51.71	2	3.48
Government	3	13.29	2	10.27	4	19.83	11	53.58	1	3.04
Education	1	11.31	2	11.98	3	22.12	7	50.86	0	0
Total	1085		1410		1978		1926		4095	

Table 4. The Expected Damage by Building Type for The Buildings in Waianae CCD

Building	None		Minor		Moderate		Severe		Destruction	
Type	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	27	9.18	22	7.39	79	26.38	169	56.52	2	0.54
Masonry	104	12.43	129	15.42	200	23.98	221	26.41	182	21.76
MH	7	18.92	3	7.35	6	15.3	3	6.85	19	51.58
Steel	12	10.3	8	6.74	28	23.67	61	50.92	10	8.38
Wood	931	10.13	1276	13.88	1639	17.83	1405	15.29	3942	42.88

3.4 *Debris Generation*

Hazus estimates the quantity of debris generated by a category 4 hurricane. The model categorizes debris into four main types: Brick/Wood, Reinforced Concrete/Steel, Eligible Tree Debris, and Other Tree Debris. This classification facilitates appropriate handling of the debris by identifying the different types of material handling equipment needed.

The model predicts that a total of 359,434 tons of debris will be generated by the hurricane. Among this, 95,540 tons (27%) is attributed to Other Tree Debris. Of the remaining 263,894 tons, Brick/Wood accounts for 93% of the total, Reinforced Concrete/Steel accounts for 3%, and the rest comprises Eligible Tree Debris. Converting the building debris tonnage to estimated truckloads, it will require 10,109 truckloads (at 25 tons per truck) to remove the building debris produced by the hurricane. The number of truckloads needed for Eligible Tree Debris will vary depending on how the 11,171 tons of Eligible Tree Debris are collected and processed. Generally, the volume of tree debris ranges from about 4 cubic yards per ton for chipped or compacted tree debris to about 10 cubic yards per ton for bulkier, uncompacted debris.

3.5 Social Impact

Our model estimates the number of households that are expected to be displaced from their homes due to the hurricane and the number of displaced people that will require accommodations in temporary public shelters. The model estimates that there are around 11 thousand households in Waianae CCD. Of these, 7,784 households will be displaced due to the hurricane. These households are spread in eight regions: Makua Valley, Makaha, Waianae Kai, Lualualei Camp Waianae, Lualualei Halona Road, Lualualei Transmitter, Maili, and Nanakuli. Among these regions, Maili is expected to have the highest number of displaced households with 1795 households. Additionally, of the total population in Waianae (around 48 thousand people), 1,984 people will seek temporary shelter in public shelters. Figure 6 shows the map of displaced households in Waianae CCD.

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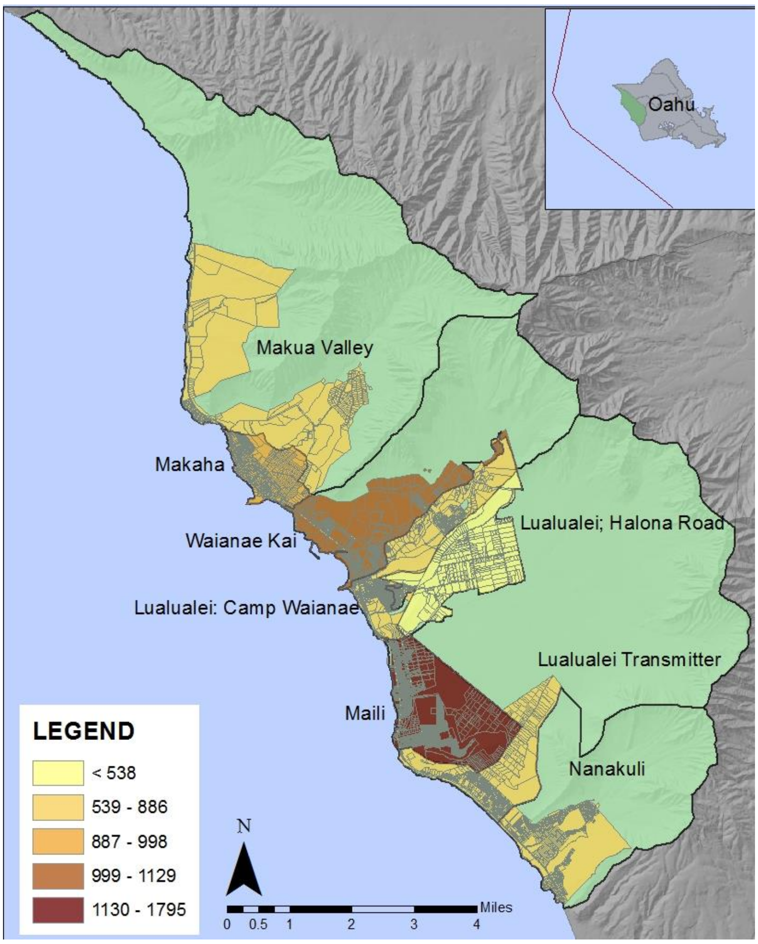

Figure 6. Displaced Households in Waianae due to Category 4 Hurricane

Table 5. Building-Related Economic Loss Estimates (Thousands of Dollars)

Category	Area	Residential	Commercial	Industrial	Others	Total
Property Damage						
	Building	1,673,373.85	57,943.39	5,628.59	48,830.69	1,785,776.52
	Content	721,980.48	50,108.17	5,281.69	37,281.22	814,651.56
	Inventory	0	771.65	694.6	1,591.14	3,057.38
	Subtotal	2,395,354.33	108,823.20	11,640.88	87,703.05	2,603,485.46
Business Interuption Loss						
	Income	408.49	9,051.89	64.16	680.48	10,205.02
	Relocation	174,503.6	5,742.88	275.97	6,604.59	187,127.03
	Rental	67,315.76	3,549.46	45.52	842.59	71,753.33
	Wage	958.65	10,513.33	110.6	1,085.82	12,667.86
	Subtotal	243,186.5	28,857.56	495.7	9,213.48	281,753.24
Total						
	Total	2,638,540.83	137,680.76	12,100.58	96,916.53	2,885,238.7

3.6 *Economic Loss*

HAZUS-MH categorizes building-related losses into two main groups: direct property damage losses and business interruption losses. Direct property damage losses refer to the estimated costs required to repair or replace the damage inflicted upon the building and its contents due to the hurricane. Business interruption losses encompass the financial losses incurred due to the inability to operate a business as a result of the hurricane-induced damage. These losses also cover temporary living expenses for individuals displaced from their homes due to the hurricane.

The total property damage losses amounted to $2,885 million. Of this total, 3% of the estimated losses were attributed to the business interruption in the region. The majority of the losses were incurred by residential occupancies, accounting for over 91% of the total loss. A summary of the losses associated with building damage is provided in Table 5.

Our model shows that the total economic losses on Waianae CCD due to a category 4 hurricane are $ 2.88 billion. Of the total buildings built in Waianae, almost 8,000 building are severely damaged. Given that 96% of the buildings in this region are residential buildings, thus the highest economic losses come from residential with $ 2.6 billion.

Our result also shows a high number of Internally Displaced Persons (IDPs) in Waianae CCD. Of the total households (around 11,000), approximately 71% of them will be displaced. In addition, of the total population, almost 2,000 people will seek shelter in public shelters. Among eight regions in Waianae CCD, Maili is the region with the highest number of displaced households and people who will seek shelter.

Socio-Economic vulnerabilities should be addressed in the development planning of Waianae. There should be more local job opportunities within Waianae. This will help in reduction of poverty and homelessness. Waianae needs local jobs, including industrial jobs within a light industrial park with moderately priced lease rent simple prices for industrial lots. Local small businesses and light industrial operations play a vital role in providing employment opportunities for the people of Waianae. Maintaining a healthy presence of small local businesses is crucial for the local economy. It not only sustains job opportunities but also helps reduce the volume of commuter traffic, which often leads to severe congestion on Farrington Highway during morning peak traffic periods. By fostering local businesses, the community can mitigate the need for residents to commute long distances for work, contributing to a more sustainable and less congested transportation system.

Development of more emergency shelters in centralized location is recommended. School planners should recognize the multifaceted role that schools play within the community. In addition to their educational function, schools serve as primary emergency shelters during hurricanes, tsunamis, and other large-scale emergency events. Given these diverse responsibilities, it is essential to consider the strategic placement of new schools. Centralized locations that are easily accessible to a significant portion of the population should be prioritized. This ensures that schools can effectively fulfill their role as emergency shelters, providing refuge and support to residents during times of crisis.

Development of alternative emergency evacuation routes should be considered for Waianae. Especially, as this region of the island is dependent mostly on Farrington Highway. In recent years, with the increase in the Waianae District's population, and the general trend of more automobile use by most citizens, traffic congestion on Farrington Highway has grown progressively worse. The Emergency Bypass Road would go from Farrington Highway, up Lualualei Naval Road, and through the Kolekole Pass to Kunia Road. It would only be opened in times of emergency.

4. CONCLUSION

In conclusion, this research has conducted a comprehensive assessment of Waianae's vulnerability to a Category 4 hurricane, focusing on socio-economic factors and the potential impact on the community. The findings reveal that Waianae, located on the northwest quadrant of Oahu, is particularly susceptible to the devastating effects of hurricanes, as evidenced by historical events like Hurricane Iwa in 1982 and Hurricane Iniki in 1992. The socio-economic vulnerabilities of Waianae, including lower per capita income, higher poverty rates, and increased unemployment compared to the state average, contribute to the community's heightened risk. Physical vulnerabilities, such as limited access to West Oahu via Farrington Highway, further amplify the challenges faced during and after a hurricane.

The risk assessment, conducted using tools like HAZUS-MH and ArcGIS, highlights the potential damages, debris generation, social impact, and economic losses that may occur in Waianae due to a Category 4 hurricane. The results underscore the urgent need for proactive measures to enhance the resilience of the community. Recommendations include local job creation to address socio-economic vulnerabilities, the development of emergency shelters in centralized locations, and the exploration of alternative evacuation routes to alleviate traffic congestion during emergencies. By addressing these vulnerabilities and implementing strategic planning measures, Waianae can better prepare for and mitigate the impact of future hurricanes, ultimately fostering a more resilient and secure community.

5. REFERENCES

[1] A. L. Peek and D. S. Mileti, “The History and Future of Disaster Research,” in *Handbook of Environmental Psychology*, 2002, pp. 511–524.

[2] F. H. Norris, “Epidemiology of trauma: Frequency and impact of different potentially traumatic events on different demographic groups.,” *Journal of Consulting and Clinical Psychology*, vol. 60, no. 3. American Psychological Association, US, pp. 409–418, 1992, doi: 10.1037/0022-006X.60.3.409.

[3] D. M. Ronan, K. R., & Johnston, *Promoting community resilience in disasters: The role for schools, youth, and families*. New York: Springer, 2005.

[4] IPCC, *Adaptation needs and options in Climate Change 2014: Impacts Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. United Kingdom and New York, NT, USA: Cambridge University Press, 2014.

[5] A. Fathiyaturahma, “Analysis of Prediction of Economic Losses due to Flood Disaster Hazards in Industrial Estates in Karawang Regency,” *Int. J. Disaster Manag.*, vol. 5, no. 3, pp. 203–212, 2023, doi: 10.24815/ijdm.v5i3.29740.

[6] W. Boy, R. Imani, M. Chari, W. Purba, and J. Melasari, “Risk assessment of housing reconstruction project community-based construction after the earthquake,” *J. Phys. Conf. Ser.*, vol. 1339, no. 1, 2019, doi: 10.1088/1742-6596/1339/1/012001.

[7] B. D. Phillips, *Disaster Recovery*, 1st ed. Auerbach Publications, 2009.

[8] The New York Times, “Damage to 3 islands severe,” *The New York Times*, 1982. .

[9] The Weather Channel, “Hawaiian direct hit: Hurricane Iniki remembered,” *Weather Channel*, 2015, [Online]. Available: https://weather.com/news/news/remembering-hurricane-iniki-20120911.

[10] Jesse, “Hurricane Season on Maui,” 2015. https://mauiexclusiverealestate.com/hurricane-season-on-maui/ (accessed Oct. 15, 2024).

[11] I. Townscape, “Technical Report for the Wai‘anae Sustainable Communities Plan,” Honolulu, 2010.

[12] Hawaii Emergency Management Agency, “Hawaii Catastrophic Hurricane Plan.” 2015, [Online]. Available: https://dod.hawaii.gov/hiema/files/2016/03/2015Hawaii_Cat_Plan.pdf.

[13] City Resilience Framework, “City Resilience Framework.” 2014, [Online]. Available: https://resilientcitiesnetwork.org/downloadable_resources/UR/City-Resilience-Framework.pdf.

[14] United Nations Department of Economic and Social Affairs (UN DESA), “Disaster Risk Resilience: A Policy Brief on the United Nations Development Framework.” 2012, [Online]. Available:

https://www.un.org/en/development/desa/policy/untaskteam_undf/thinkpieces/3_disaster_risk_resilience.pdf.

[15] DFID (Department for International Development), "Defining Disaster Resilience: A DFID Approach Paper." 2011, [Online]. Available: https://www.fsnnetwork.org/sites/default/files/dfid_defining_disaster_resilience.pdf.

[16] FEMA, *Using HAZUS-MH for Risk Assessment*, no. August. 2004.

[17] Y. Muntafi, N. Nojima, and A. U. Jamal, "Damage Probability Assessment of Hospital Buildings in Yogyakarta, Indonesia as Essential Facility due to an Earthquake Scenario," *J. Civ. Eng. Forum*, vol. 6, no. 3, p. 225, 2020, doi: 10.22146/jcef.53387.