ASSESSING MULTI-HAZARDS EXPOSURE AND RISK PERCEPTION - A CASE OF ROHINGYA REFUGEES IN COX'S BAZAR AND BHASHAN CHAR

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August 2022

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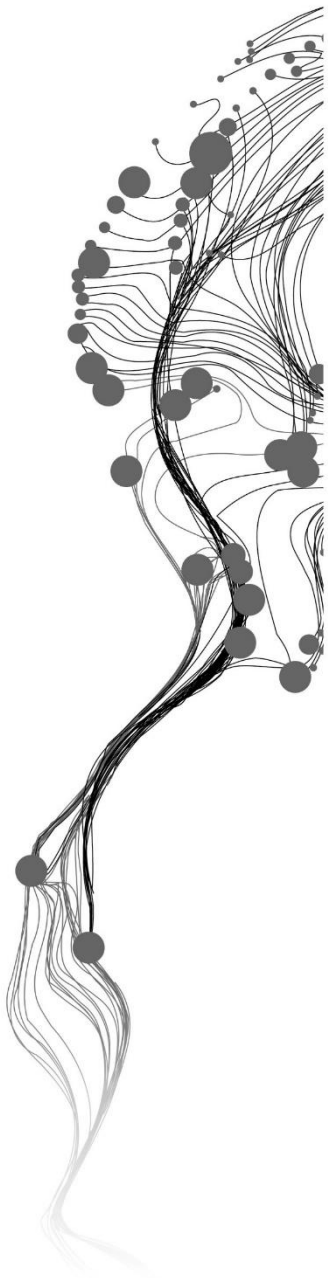

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RUHI BEGUM
Enschede, The Netherlands, August 2022

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
Specialisation: Urban Planning and Management

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ABSTRACT

Multiple hazards study is imperative because of the increasing frequency of natural calamities brought on by climate change. Evaluation of the element affected by numerous risks requires analysis of the exposed elements. Without the exposed elements, a hazard's severity cannot be comprehended. The impact of hazards also depends on the coping capacity of the exposed population. It has been noted that marginalised groups, like refugees, are more affected by dangers because they lack freedom and are subject to various restrictions imposed by the host nation. In 2016, a massacre carried out by Myanmar militants drove 700,000 Rohingyas from Myanmar to Bangladesh. They took refuge in the Cox's Bazar. Cox's Bazaar is a hilly terrain on the coast of Chittagong, Bangladesh. Its proximity to the Bay of Bengal and topography subject it to several risks, including cyclones, floods, and landslides. Therefore, an initiative was taken by the Government of Bangladesh to relocate Rohingya refugees to Bhashan Char-an island in the Bay of Bengal. Hence, the research focuses on the multi-hazard exposure analysis and risk perception of the Rohingya refugees at Cox's Bazar and Bhashan Char. The study employs the mixed method approach where quantitative information from secondary sources and qualitative knowledge from field survey and experts' interview is used to make a multi-hazards exposure index using Analytical Hierarchical Process (AHP). The resultant exposure index is used to quantify the shelter and population subjected to multi-hazards. The field survey data was utilised to generate income and employed with the exposure index to explore the relationship between multi-hazard Exposure and coping capacity. Geospatial methods such as Euclidian distance, Inverse distance weightage (IDW), Cost and Benefit Analysis (CBA), Spatial autocorrelation, and Zonal statistics were employed to prepare data for the AHP analysis. Then the field survey data and expert-written interviews were used to calculate the weightage of the indicators for AHP. The field survey results were utilised to understand how Rohingya refugees perceived Risk and made decisions concerning Bhashan Char. Various statistical techniques such as descriptive statistics, cross-table, and correlation analysis were used to analyse the survey data. The results identify multi-hazard exposure zone and individual shelters with a specific level of Exposure. The finding shows that the risk perception of Rohingya refugees depends on their socio-economic circumstances. The research's findings help disaster risk management organisations locate exposed shelters and deliver assistance in accordance with the degree of Exposure. The findings on risk perception help the government and NGOs comprehend the psychological and emotional drivers of people's attitudes toward risk perception and decisions to relocate.

Keywords: Multi-hazards, Exposure, Coping capacity, Risk perception, AHP, Relocation

This thesis is dedicated to my beloved sister
NAZIA
whose presence was a blessing for me!

ACKNOWLEDGEMENTS

"Thank you, Allah, for giving me the strength to complete my thesis."

I would like to express my sincerer gratitude to my esteemed supervisors, DR. Monika Kuffer and Andre DaSilva mano. Without their assistance, direction, and, most importantly, endurance (to put up with me), my desire to work with Rohingya refugees would never have come true. I highly appreciated your crucial feedback that made me think beyond the horizons. Your soft nature and critical attitude toward me, make me learn about new challenges.

I would like to thank Dr Funda Atun Girgin, my advisor, for her insightful advice that helped me define my objectives more clearly. I would like to thank DR Diana Reckien, the chair of my thesis assessment board, whose critical suggestions enlightened the path of my journey. I would like to thank Dr Julio César Pedrassoli my external examiner, for assessing my work. I would like to thank Dr Alak Pal, field supervisor in Bangladesh, for his support in conducting fieldwork. The contribution of Mr Wim Frenga is highly appreciated in the journey from India to Bhutan and then the Netherlands. I would like to appreciate the support Dr Islam in these two years.

I would like to acknowledge Dr Md Mustaquim and Dr Mallick Akram Hossain for collecting information in Bangladesh. I would like to thank professors and researchers from Paris Lordon University Salzburg for connecting with the key persons related to my research.

I would like to thank my "Ammi" for her love, gesture, trust and support. My deceased father's motivation that "you can do it" gives me strength in every situation. My brothers, siter-in-law affections, and my niece love to make me happy when I feel down.

I am thankful to my friends Abhishek, Vaibhav, Sri, Salar, Clara, Parvez and Rosemine, who always make me feel like a family.

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Abbreviation:

AHP:	Analytical Hierarchical Process
DEM:	Digital Elevation Model
EM-DAT:	Emergency Event Database
GFDRR:	Global Faculty to Disaster Risk Reduction and Recovery
GOB:	Government of Bangladesh
HDX:	Humanitarian data exchange
IOM:	International Organization for Migration
ISCG:	Inter-Sector Coordination Group
LULC:	Land use Land cover
MEI:	Multi-hazard Exposure Index
NDVI:	Normalized Difference Vegetation Index
RRRC:	Refugee Relief and Repatriation Commissioner
UNHC:	United Nations High Commissioner
UNHCR:	United Nations High Commissioner for Refugees
USAID:	United States Agency for International Development

1. INTRODUCTION

1.1. Background and Justification

Global warming and climate change cause an increase in the frequency and severity of hazards (CRED, 2019), resulting in fatalities, property damage, forced displacement, hunger, and epidemics (Zaman et al., 2020a). Furthermore, weather and climatic extremes are being influenced by human-induced climate change in every corner of the world. After the 5th Assessment Report of The Intergovernmental Panel on Climate Change (IPCC)in 2020, the increase in extreme events such as heatwaves, heavy precipitation, flood, droughts, and tropical cyclones, particularly their attribution to human activity, has strengthened (IPCC, 2021). Hazard is a natural phenomenon that negatively impacts human beings and the environment (UNISDR, 2009). Several studies have determined the impact of a single hazard on a specific region or group of individuals. Many parts of the world are vulnerable to multi-hazard occurrences, including interrelationships between hazards that affect the same area simultaneously. A couple of hazards that occurred in the same place is termed as multi-hazards. One hazard often leads to other hazards, such as rainfall-induced floods and landslides in hilly terrain (Gill and Malamud, 2014). The increase of multi-hazard events in various parts of the world has to serve impacts on humankind. The high frequency and intensity of hazards escalate the exposed threats to people and infrastructure. Hence, developing the necessity for assessing and identifying elements at risk exposed to multiple hazards. The population, structure and economy exemplify Exposure (Birkmann, 2006). The United Nations Office for Disaster Risk Reduction (UNDRR) defines Exposure as "The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas." (UNDRR, 2021). In other words, the things exposed to hazards are termed "Element-at-Risk". It could be a building, economy, person, or community (Westen, 1994). Exposure is a crucial contributing factor to disaster risk as there is no concept of risk in the absence of exposed elements. The exposed elements explain the intensity of a hazard in terms of loss and damage(Lavell et al., 2012)

1.1.1. Disaster risk in Low- income countries

According to UNDRR, Disaster Risk is defined as "The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period, determined probabilistically as a function of hazard, exposure, vulnerability and capacity" (UNDRR, 2021). Hazard is also one of the components of identifying risk in a specific area. Exposure is the different elements exposed during a hazardous event (Cardona et al., 2012). The term capacity describes the overall strength of an organisation to cope and reduce the risk of a disaster with available attributes and resources and enhance resilience (UNDRR, 2021).

Low-income countries are highly exposed to natural hazards and disasters due to poverty, social exclusion, low literacy rates, and environmental degradation (Barrantes, 2018). Countries are encountered different types of hazards, but the low-income countries are most vulnerable due to high exposure and minimal means to adaptation to climate change (Douglas et al., 2008). The community more affected by hazards and disasters is less responsible for climate change (Oxfam, 2014) and has a low adaptive capacity(CARE, 2015). The marginalised section of society, such as forcibly displaced people, minorities, refugees, and migrants, are highly susceptible to hazards (Zaman et al., 2020a). About 30 million people are forcibly displaced annually due to extreme weather and conflicts and took refuge in other host countries. (The White House, 2021). According to the report of the United Nations High Commissioner (UNHC) for refugees 2010, the term refugee may be defined as the person who is unable to return to their home country due to fear of being persecuted by a group of people based on their nationality, religion, race, being a member of a specific

social group or political opinion (Zaman et al., 2020a). In the research, we focussed on the Rohingya refugees, the world's largest community displaced due to armed conflicts (IOM, 2022).

1.1.2. Disaster Risk and Rohingya Refugees

Worldwide, most refugees are hosted by developing countries, surrounded by multiple hazards and disaster risks (Pollock et al., 2019). In 2017, Bangladesh hosted 932,200 stateless Rohingya refugees of Myanmar in the 'Cox's Bazar district, classified as having the 'world's largest and most densely populated refugee camps like Kutupalong with an average density of 75,000 individuals/ km^2 (B. Ahmed et al., 2020a; UNCHR, 2018). The Rohingya refugees are the stateless people of the Rakhine state of Myanmar. Since 1978, they have been fleeing from their home country to Bangladesh for survival due to the ongoing state-sponsored persecution (Ahmed et al., 2019). United Nations High Commissioner for Refugees (UNHCR) 2018 states 711,369 Rohingya people from the Rakhine state have been forcibly displaced since August 2017. Among them, 460,000 are children, and 217,000 are adult women residing in 34 camps in two districts, Ukhiya and Teknaf in Cox's Bazar. The two most important camps with high refugee density are Kutupalong and Nayapara (UNHCR, 2018a).

As a host country for refugees, Bangladesh ranked 8th in accommodating around 1 million Rohingya refugees (UNHCR, 2018a). Bangladesh's geographic and geomorphological location implies susceptibility to multiple hazards, particularly in the fringe areas near shorelands and islands. Two-thirds of the land is less than five meters above sea level, and the multiple hazards, high population density, and low economic strength make the country vulnerable (Ferdous et al., 2020). The Rohingya refugees live in fragile camps with limited access to basic aid and infrastructure. The hillocks surrounding the camps gave rise to a vast drainage network. Soil erosion brought on by deforestation makes cox's Bazar susceptible to multi-hazards such as flooding and landslides. The camp witnessed cyclones twice a year which caused heavy downpours. Besides, there are other issues that Rohingya refugees are witnessing, such as high population density, insufficient living space, and overcrowding. The influx of Rohingya refugees to Bangladesh in 2017 made the camp congested, and the high birth rate of the Rohingya refugees made the camp overcrowded (Zaman et al., 2020a).

The level of vulnerability varies from person to person based on their capability to combat hazards. Refugees and citizens perceive risk in very different ways. A citizen is free to move anywhere when it poses a risk, but refugees in a host nation are subject to several restrictions on accessibility and mobility (Kibreab, 2003). Hence, Rohingyas were relatively less vulnerable to their own country as a citizen due to their mobility, proper relief aid, access to evacuation, shelter, communication, medical aids, etc., during the hazards and disasters. However, the refugee camps in the host nation suffer from inaccessibility, a general problem that severely contributes to disaster risk. With high population density, lack of livelihood opportunities, exposed to multiple hazards at the present location, the Government of Bangladesh (GOB) decided to relocate around 1 million Rohingya refugees to a newly emerged island, "Bhashan Char." (Bremner, 2020). Since 2020, the relocation of Rohingya refugees to Bhashan Island is a matter of concern. The overpopulation and hazardous living conditions of Rohingya refugees at Cox's Bazar concern the Government of Bangladesh(GOB). The possible solution proposed by the GOB was to relocate 90,000 Rohingya refugees to a remote Island of Bhashan Char, which contains resilient houses and open space. Many organisations appreciated this approach, but many were against it. The reason behind the opposition was the hazard-prone location.

1.2. Research Problem and Research Gap

The literature study proved that previous works focused on the impact of single hazards, mainly anticipating and controlling. The negligence of human factors and exposed elements were found missing. Authors such as Bayes Ahmed et al. (2020), in his research, used the inventory landslide data and combined it with rainfall thresholds and susceptibility maps to develop landslide early warning systems using machine learning algorithms such as Self-organising maps and multiple regression. SRTM DEM (1 arc-second for global coverage) and Landsat Images were used to analyse the impact of a landslide on Rohingya Refugees at Cox's Bazar (B. Ahmed et al., 2020a). For better results, high-resolution satellite images and DEM can be used. Akhter Alam et al. (2020) consider risk a static phenomenon while assessing the cyclonic risk at Cox's Bazar and Rohingya Refugee camps. Nevertheless, most of his factors, such as rainfall, intensity, and cyclone frequency, are dynamic. He used the last 100 years' cyclone data to assess cyclone risk and also used ALOS

DEM (10mt) (Alam et al., 2020a). ALOS DEM provides 5-meter resolution data and can be used for good quality results. Nahian Ahmed et al. (2020) used high-resolution drone images to extract the building footprints using deep learning algorithms (N. Ahmed et al., 2020b). Erica L.Nelson et al.(2020) used Pareto Ranking and spatial statistics to model a gender-based vulnerability in Cox's Bazar Rohingya Refugee camp. As it is a gender-based vulnerability assessment, her focus group was women and girls. She used geospatial and socio-economic information to analyse the socio-economic vulnerability of the Rohingya female group (Nelson et al., 2020). The focus was mainly gender-oriented and neglected the other demographic cohoret. Shamrita Zaman et al.(2020) used surveying methods to analyse the multi-hazard vulnerability of Rohingya Refugees (Zaman et al., 2020a). Her work is based on individuals' risk perceptions at Rohingya refugee camps. Although she did not use satellite images and geospatial data, her work shows the risk perception of multiple hazards. She also shows the Rohingya Refugees' perceptions of resettlement on Bhashan Island.

Another work done by Hoque et al. (2019) in which he assessed cyclone risk at Cox's Bazar (Hoque et al., 2019a). The indicator-based approach was made by applying 14 indicators, a vulnerability map was produced. Other components of the risk were prepared individually, and then the overall risk of a cyclone was calculated. Following him, the cyclonic risk was assessed by Quader et al.(2017). The PCA method was used to quantify the regional risk and its impact on the community (Quader et al., 2017).

The literature showed that the focus was on analysing a specific hazard, vulnerability and risk using earth observation and geospatial data in Cox's Bazar. It is also evident from the literature that Cox's Bazar is affected by multiple hazards such as landslides, floods, cyclones, forest fires, and animal conflict. In October 2020 (from 14 June 2020 to 15 October 2020), 638 slope failures and 31 flood incidents were recorded (ISCG, 2020). The absence of multi-hazard exposure analysis is realised from the above discussion.

Therefore, to contribute to this gap, the present study will focus on the multi-hazard exposure analysis using earth observation and ground truth data (survey data) to identify the elements at risk in Rohingya refugee camps and investigate the risk perception of Rohingya refugees in Cox's Bazaar and Bhashan Char.

1.3. Research objective and Questions

The overall objective is to assess the multi-hazard Exposure and Risk perception of the Rohingya refugees in Cox's Bazar.

Sub-objectives

1. Identify multiple hazards affecting Rohingya refugees and related indicators for assessing multi-hazard Exposure.

i. What are the hazards that affect Rohingya refugees frequently?
ii. What are the commonly used indicators to assess multiple hazards Exposure?
iii. Which indicators are locally available based on primary surveys, expert interviews, and available data to measure the index of multiple hazards Exposure?
iv. Which method is suitable for assessing the multi-hazard exposure Index?

2. Identifying People and Infrastructure exposed to multiple hazards
i. Which Rohingya refugee camps are highly exposed to multiple hazards in Cox's Bazar?
ii. How many shelters and people are exposed to multi-hazards in each camp?
iii. Which demographic sections are highly exposed to multi-hazard?

3. To analyse the role of Coping capacity in reducing the impact of multi-hazard Exposure

i. What is the relationship between multiple-hazards Exposure and coping capacity?

4. To assess the risk perception of the Rohingya Refugee to multiple hazards
i. How do Rohingya Refugees perceive the Risk of multi-hazards at Cox Bazar?
ii. What are the different perspectives of Rohingya refugees for relocating from Cox Bazar to Bhashan Char?
iii. How socio-economic circumstances influence the relocating decisions of Rohingyas to Bhashan Char?

2. LITERATURE REVIEW

An intensive literature review has been done for this research to understand the different concepts such as multiple hazards exposure and risk perception and their relationship with the Rohingya Refugees.

2.1. Multiple hazards Exposure

The concept of multi-hazard assessment was first introduced at the Agenda-21[1] conference (UNEP, 1992). Agenda-21 is considered the complete guide for multi-hazard research (M. S. Kappes et al., 2012; Wang et al., 2020). After that, the need for assessing multiple hazards can reappear in reports such as the Johannesburg Plan, the Hyogo Framework of Action and the FEMA (UN/ISDR, 2005; UN, 2002). Climate change and global warming accelerate the occurrence of hazards and progress the need to investigate the impact of multiple hazards in a single location. Hence, the first definition of multi-hazards implies that all hazards' impacts should be considered in a specified area (Melanie S Kappes et al., 2012). However, it seems very difficult to evaluate all hazards in a defined area due to different terminologies used in multi-hazards risk, data irrelevancy, interdisciplinary approach, and conflict in definitions.

The first approach to overcome the multi-hazards analysis problem was initiated by Delmonaco (2006), who focused on analysing the characteristics of single hazards and their interrelation with the triggering events (Delmonaco et al., 2006). The problem with the approach was that interaction among hazards was a challenging task. The ARMONIA project (Applied Multi-Risk Mapping of Natural Hazards for Impact Assessment) defined a new method for assessing multi-hazard risk. The intensity of the hazards was analysed on a regional scale(Delmonaco et al., 2006). The Swiss guidelines initiated another similar approach for analysing and evaluating natural hazards, but here they include the frequency of the hazards with intensity (Kunz and Hurni, 2008). Potential multi-hazard hotspot analysis was also done by El Morjani et al.(2007), who identified areas highly exposed to multi-hazards (El Morjanil et al., 2007). He modelled each hazard separately and assigned weightage based on the impacts on human loss. He used EM-DAT records for the estimation of loss during hazards.

An indicator-based approach similar to El Morjani et al.(2007) for analysing Risk was made by Grieving (2006) and Dilley et al.(2005). Dilley et al.(2005) analysed Risk based on Hazard and Vulnerability by giving weightage hazard indicators (Dilley et al., 2005). Grieving(2006) compiled an integrated Risk Index using spatially interrelated hazards by assigning equal weightage to all risk components. Hence, the construction of indices reduces the heterogeneity of the data set and allows to analyse of the impacts of several hazards in a defined area. Therefore, this research also follows an indicator-based weightage analysis for constructing a multi-hazard Exposure index where weightage is assigned qualitatively based on a survey conducted for Rohingya refugees and experts.

2.2. Rohingya Refugees and multiple hazards Exposure

In 1951, the United Nations Convention defined the status of a refugee as an individual with a fear of being persecuted based on religion, race, nationality, ethnicity, membership of a specific group living in host country without any legal rights, and unable to avail of the protection of the country (Hein, 1993). In 2018 the global refugee population was 25.9 million, including 5.5 million Palestinian refugees and **1.1 million Rohingya refugees** (UNHCR, 2019). Rohingya Refugees are the ethnic, linguistic, and religious minority

[1] Agenda 21 is a comprehensive plan of action to be taken globally, nationally and locally by organizations of the United Nations System, Governments, and Major Groups in every area in which human impacts on the environment (Agenda 21 .:. Sustainable Development Knowledge Platform (un.org).

group of Northern Rakhine State, formerly known as Arakan in Myanmar (Burma). The Rohingya refugees are considered the descendent of Moorish, Arab and Persian traders, Moghul, Turk, Pathan, and Bengali soldiers and migrants (Ahmed, 2009). This minority group has been experiencing continuous shake of precaution and forced displacement since 1784 after the Burmese invasion of Arakan (Cheung, 2012). In 1784 the Burmese started deporting Arakanese and again in 1948 after the independence from the British government. The Myanmar government called the Rohingyas *illegal migrants* and pressured them to leave (Cheung, 2012). In 1974, the Rakhine State was established from the Arakan division. However, the Emergency Immigration Act did not provide the National Registration Certificate (NRC) but provided a Foreign Registration Card (FRC) at that time. In 1978, before the national census, all the citizens had registered, excluding the Rohingya Muslims, and it was the starting point of violence (Human Rights Watch, 1996). Around 2 million Rohingya Muslims were displaced and fled to Bangladesh. With the support of the United Nations, the GOB established 13 camps along the border of Bangladesh and Myanmar to support the influx of Rohingya Muslims from the Rakhine estate, Myanmar (Cheung, 2012). The status of Rohingya Muslims has changed since 1992. Before 1992, Bangladesh Categories Rohingya Refugees as "Asylum seekers", but after that, they were categorised as "Refugees" (Milton et al., 2017).

Figure 2.1: Rohingya refugees flee from Burma into Bangladesh in August 1978. Source: The US Holocast memorial museum

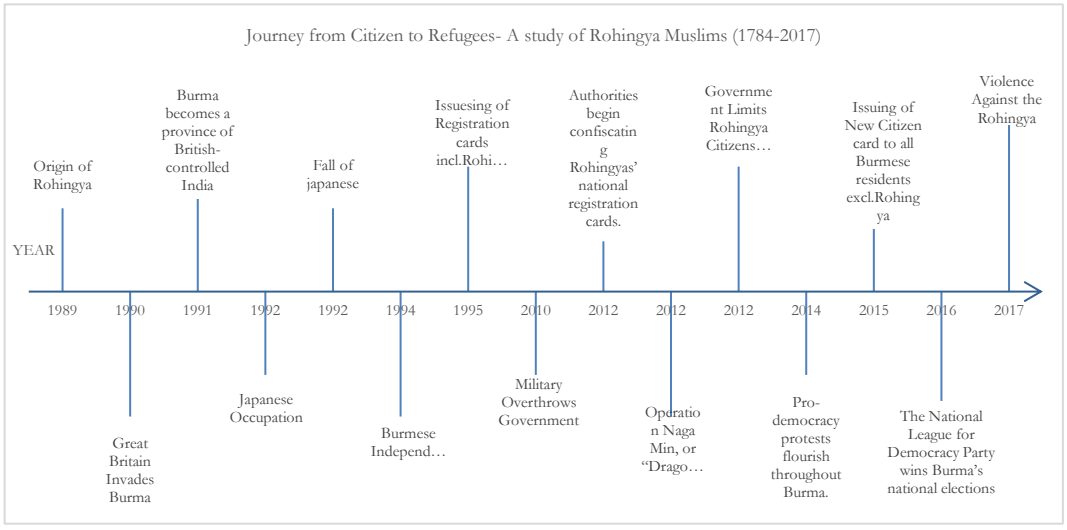


Figure 2.2: Time series – A journey from Citizen to Refugees Source: The US Holocast memorial museum

October 2016 to August 2017 was the most horrendous period for the Rohingya Muslims as the massacre caused hundreds of fatalities and assaults by the army. Besides, thousands of dwellings were burned, and Rohingya were forced to flee Bangladesh (Sohel, 2017). The GOB took the initiative and settled 1 million Rohingya refugees in Cox's Bazar. The area was covered with dense vegetation. A mass-level construction took place to provide shelters. The construction material used for shelter were bamboo frames, tarpaulin, and plastics. The construction materials and fuel for the Rohingya refugees were obtained from the forest resulting in several ecological damages such as deforestation, hill cutting, soil erosion, and slope failure (Quader et al., 2021). Those ecological imbalances also trigger other environmental crises such as landslides,

floods, forest fires, and soil erosion, making Rohingya refugees highly exposed to multiple hazards (B. Ahmed et al., 2020b). Besides the hazards, the density of Rohingya refugee camps is also a matter of concern.

2.3. Relocation and Bhashan Char

Relocation is a disaster risk reduction strategy in areas highly populated and exposed to hazards. It is a planned way to temporarily or permanently shift a group of exposed people from a hazardous site to a safer location (The White House, 2021). In 2015, GOB, along with the Office of the Refugee Relief and Repatriation Commissioner (RRRC), proposed the relocation of Rohingya refugees in Bhashan Char, an Island in the Bay of Bengal 30 km. away from the mainland. The only mode of transport to reach the island is a motorboat. Bhashan Char, a Bengali term for "Floating Island," emerged in 2006 from the sea (Banerjee, 2020; M. R. Islam et al., 2021). The island consists of fragile materials such as sand and silt deposited by Meghna and Brahmaputra Rivers with a total area of 7.5km^{2,} but the area is not constant due to continuous deposition and erosion phenomena (Braun et al., 2020). Another interesting fact about the island is its location. It lies in the path of almost all the tropical cyclones that originated in the Bay of Bengal. Besides, the island is subjected to soil erosion, sea-level rise, tidal surges, and flood. The soil is also infertile, made up of silt and sand (Banerjee, 2020; Braun et al., 2020; M. R. Islam et al., 2021).

In 2017, after the influx of 711,369 Rohingya refugees from Myanmar, the Govt implemented the plan after carefully analysing the prevailing hazards in the Bhashan Char (R. Islam et al., 2021). In due time the construction was completed in Bhashan Char. The GOB took several measures to protect the island from persistent hazards, such as constructing embarked walls around the settlement to protect it from flood water and tidal surges and providing multipurpose shelters to protect people from strong wind, which can stand at 240 km/h wind speed. Each house is built four meters above the ground level to stop entering tidewater. Sustainable measures such as Rainwater harvesting, solar power and biogas facilities were also done.

The GOB took a strategic decision to relocate Rohingya refugees with adequate amenities and protection for their safety and security, considering the present vulnerable condition at Cox's Bazar.

2.4. Rohingya refugees and Risk Perception

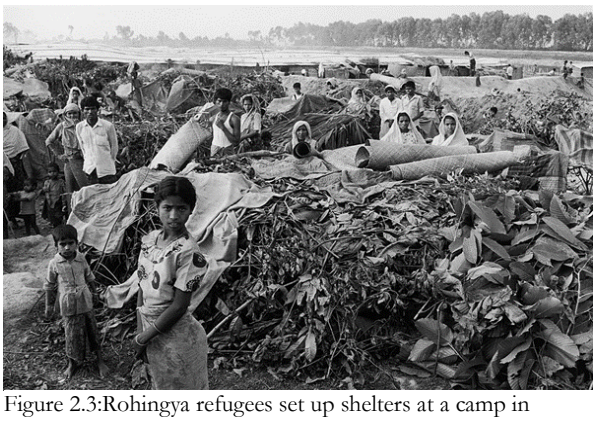


Figure 2.3:Rohingya refugees set up shelters at a camp in southern Bangladesh.

The Rohingya refugees in Cox's Bazaar encounter many disasters and are highly exposed to multiple hazards in the refugee camp (UNHCR, 2018b) due to the high population density at the camp and disastrous living conditions. However, the decision to relocate was not accepted by all the refugees due to insecurities. The research risk perception was analysed to understand the decision-making power of the refugees. Risk perception refers to people's beliefs, feelings, ideas, concerns, and attitudes toward risk associated with different hazards (UNISDR, 2009). The prevailing condition within a group or individual to perceive danger determines the intensity of hazards (UN/ISDR, 2004). The people's personality, culture, society, and circumstances also influence an individual's risk perception. Hence risk perception is considered an important aspect to minimise risk. The condition of Rohingya refugees is different in Cox's Bazar as compared to natives of Bangladesh. The freedom of movement within a country makes the locals less exposed than the refugees; a considerable difference can be observed in perceiving risk by both. (Zaman et al., 2020b). Therefore, the study investigates the risk perception of Rohingya refugees at Cox's Bazar and the relocation site.

3. STUDY AREA AND DATASET

The present work focuses on Cox's Bazar district of Bangladesh Fig-3.1, where one of the most populated refugee camps, "The Rohingya refugee camp", is located. According to UNCHR(2018), the average population density of the Rohingya refugee camp is 75,000 individuals/km2 (UNCHR, 2018). Kutapolong and Nayapara Refugee camps are two main state-run refugee camps in Cox's Bazar district (Honeth, 2018). Total 34 refugee camps with a 13 sq. km area situated in Ukhiya and Teknaf district of Cox's Bazar, Bangladesh(Alam et al., 2020a). Since 2017, the Rohingya Refugees are temporarily settled in Kutupolong, and Nayapara refugee camps in Ukhiya and Teknaf sub-district, living in poor housing conditions made up of bamboo and tarpaulin (Alam et al., 2020a). The study area experienced a sub-tropical climate. The average

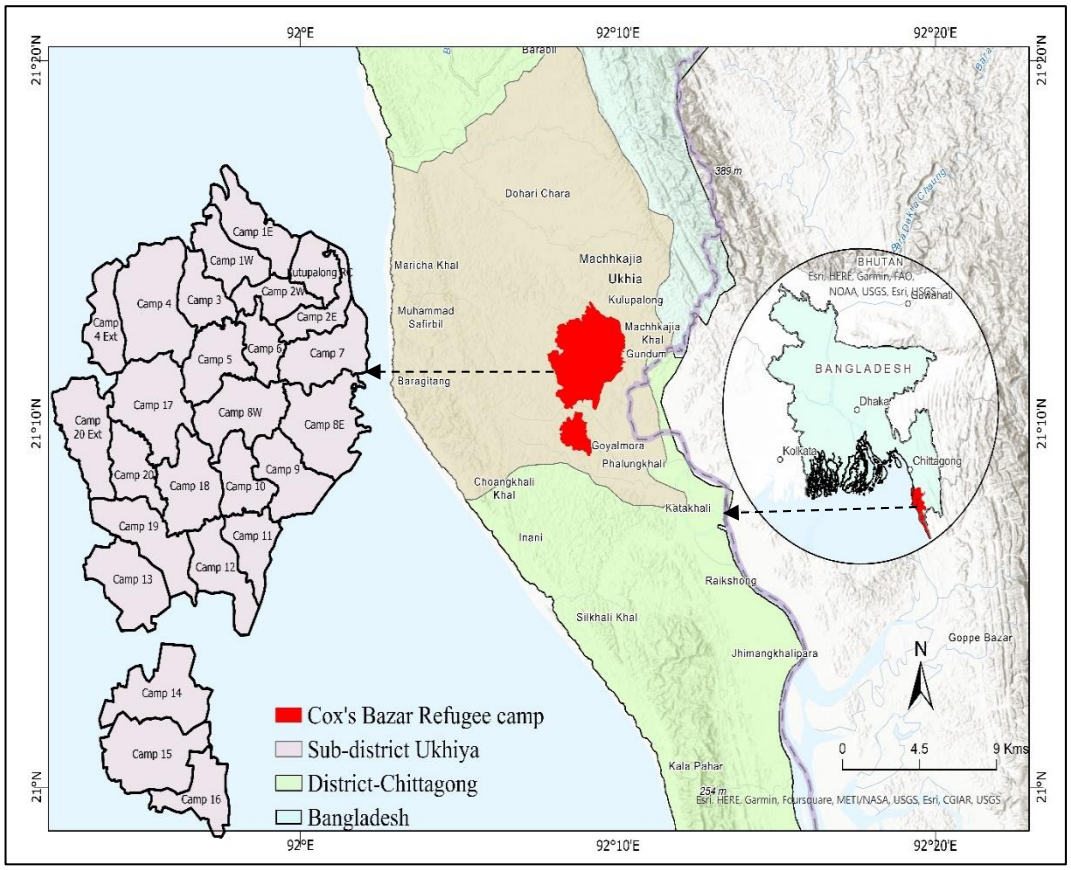


Figure 3.1: Study Area, Rohingya Refugee Camp, Ukhiya, Cox's Bazar, Chittagong, Bangladesh.

annual rainfall is 4,288 mm, with hilly terrain composed of unconsolidated sandstones, shales and silts (B. Ahmed et al., 2020a). Climate change impacted these refugee camps by increasing the intensity and frequency of hazards like heavy precipitation, cyclone, flood, landslides, etc. (IPCC, 2021).

In 1978, before the national census of Burma (present Myanmar), all the citizens were registered, excluding the Rohingya Muslims; it was the starting point of violence (Human Rights Watch, 1996). Due to the influx of Rohingya Refugees in 2017, massive deforestation occurred in the Ukhiya district of Cox's Bazar for shelter construction.

A Spatio-temporal analysis was done to understand the impact of the refugee influx on Land use Land cover (LULC). The following NDVI results Fig 3.2 show the development of camps or built-up areas from 2016 to 2022 in Cox's Bazar refugee camp.

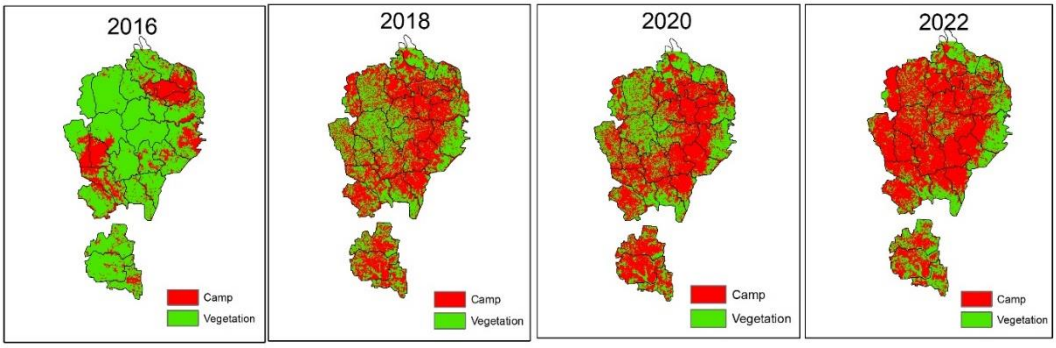


Figure 3.2: Land-use change detection as a result of Rohingya Refugees' influx.

Sentinal-2 images from planet images were used for generating NDVI. Here, band three and band four are considered IR (infrared) and R (red)(ESA, 2022).NDVI equations are as follows:

$$NDVI = (IR-R)/(IR+R)$$

NDVI values range from +0.1 to -0.1. The higher the NDVI values represent a higher vegetation density and vice versa. NDVI was calculated in Q-GIS using a raster calculator. Here we consider a threshold value of 0.5 for identifying the built-up areas. The areas with NDVI values 0.5 and above are considered vegetation; below 0.5 are counted as camps. Around 700,000 Rohingya Refugees travelled a five-day journey without any food with lactating babies and elders and reached Bangladesh's southern tip Cox's Bazar (Nelson et al., 2020). According to the UNCHR report (2019), 909,861 Rohingya Refugees were identified in two districts of Chittagong, namely Ukhiya and Teknaf (UNHCR, 2019). Table-1 and fig-3.3 show the demographic profile of Rohingya Refugees:

Table 3.1: Demographic profile of Rohingya Refugees

Individuals	Families	Male	Female	Children	Adult	Elderly
909,861	209,869	48%	52%	55%	42%	3%

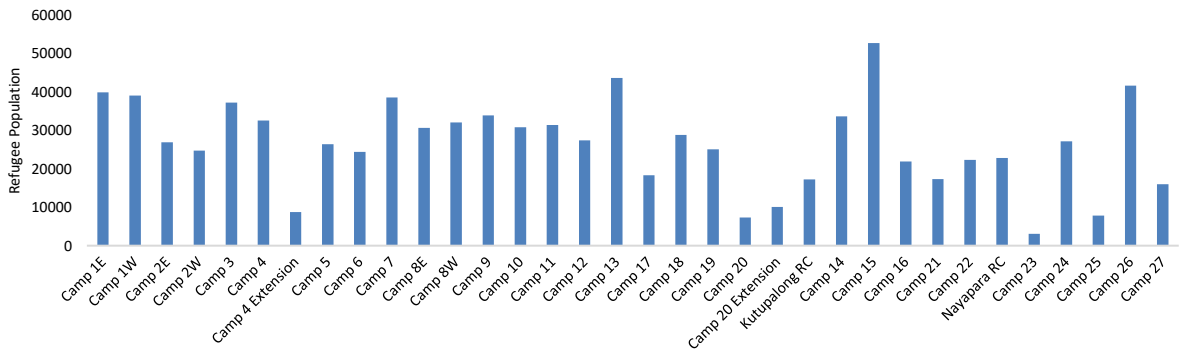


Figure 3.3: Camp wise population distribution.

Source : NPM report, 2017

Most Rohingya Refugees come from Myanmar's Maungdaw township (67%). Besides 26% from Buthidaung, 5% from Rathedung and 2% from other parts of Myanmar. 40% among them have a standard family size of 4-5 members. 31% of the families have been identified as vulnerable due to specific needs; 16 % of women are widows and single mothers, 5% have a severe medical condition, 4% of older people are at Risk, and 4% are disabled (NPM report, 2017).

3.1. Dataset and softwares

All the open source data was used to maintain the reproducibility of the research. The area of interest (AoI) is Cox's Bazar refugees camp boundary entirely in the Ukhiya sub-district. High-resolution drone imagery was acquired from an open aerial map (OpenAerialMap, 2022). Sentinel-2 cloud-free imagery has been obtained from the National Aeronautics and Space Administration (NASA) Earth Data Portal. Multispectral and temporal imagery from Planet scope earth online Data in collaboration with The European Space Agency. The Digital Elevation Model (DEM) has been prepared based on the contour generated from UAV images by International Organization for Migration (IOM) in collaboration with the Inter-Sector Coordination Group (ISCG). ESRI satellite images have been used in ArcGIS pro for making study area maps.

Rohingya refugee camp locations, building footprints, cyclone shelter locations, multiple hazard risk locations, roads(partly), rivers(partly), and significant cyclone tracks have been obtained from Humanitarian data exchange(HDX), IOM, and REACH initiatives (HDX, 2022).

Table 3.2: Data set description

	Data	*Description*	*Format*	*Spatial Resolution*	*Temporal range*	*Source*
Earth Observation data	Planet Scope data	Image	raster	3 meters	2016 to 2022	https://www.planet.com
	Sentinel-2	Image	raster	10 meters	2006 to 2021	https://glovis.usgs.gov
	DEM	UAV	raster	1 meter	2017	https://www.openaerialmap.com
	ESRI satellite	(Base map	-	-	-	
Geospatial data	Camp boundary	shapefile	vector	_	2018 to 2020	https://data.humdata.org
	Camp Location	shapefile	vector	_	2018 to 2020	https://data.humdata.org
	Roads	shapefile	vector	_	2018 to 2020	https://data.humdata.org https://www.openstreetmap.org
	Rivers	shapefile	vector	_	2018 to 2020	https://data.humdata.org https://www.openstreetmap.org
	Building Footprint	shapefile	vector	_	2018 to 2020	https://data.humdata.org
	Fault line	shapefile	vector	-		https://data.usaid.gov
	Landslide hazard map	GeoTIFF	raster	-	1980-2018	www.geonode-gfdrrlab.org
	Flood hazard map	shapefile	vector	-	2017	https://carto.com/platform
	Risk map	shapefile	vector	-	2017	https://carto.com/platform
Climate data	Precipitation	Rainfall intensity	table	_	2000 to 2020	https://www.coast.noaa.gov
	Precipitation	Average Rainfall	raster	0.1 x 0.1	2001 to 2022	
	Wind	Wind speed	table	_	2000 to 2020	https://www.coast.noaa.gov
	Wind	Wind speed	raster	1 km	Daily	https://www.globalwindatlas.info
	Cyclone	Cyclone track	table	_	1980to 2020	https://www.coast.noaa.gov
	Cyclone	Cyclone track	table	-	1996 to 2020	https://data.humdata.org
	Historical hazard data	Multiple hazards	table	-	1991-2021	www.emdat.be
Demographic data	Population size	Number of people per camp	table	_	2018 to 2021	https://data.humdata.org
	Population density	Number of people per km2	table	_	2018 to 2021	https://data.humdata.org

The United States Agency for International Development (USAID) has acquired the fault line to measure active landslide incidents. A global Landslide hazard map with a 100-year return period has been collected through the Global Faculty to Disaster Risk Reduction and Recovery (GFDRR). Cloud to Street Rohingya refugee. Flood maps based on Sentinel-1 Imagery June 2018 are collected from HDX created using a satellite image from the European Space Agency's Sentinel-1 sensor. The flood area extent map (2017) and Risk map created by the International Organisation of Migration (IOM) were also used for multi-hazard analysis obtained from the Carto data portal. This research used National Oceanic and Atmospheric Administration (NOAA) storm data and historical cyclone data from the Bangladesh Meteorological Department (BMD) to understand the historical pattern of the cyclone intensity in the Cox's Bazar district (CBD). A cyclone track shapefile has been used and obtained for preparing a multi-hazard index from HDX. Rainfall intensity data from NOAA and Average rainfall (2001 to 2020) from BMD have been collected. Wind speed has been obtained from Global Wind Atlas. Population density and building structure were used as vulnerability indicators and obtained from HDX. Camp boundary, roads, rivers, and water bodies were partly obtained from HDX and partly from the open street map.
Besides, primary data collection and expert interviews have been conducted in the Cox's Bazar study area with the help of the KOBO toolkit, and the Google meet platform has been used for surveyor training and interviews. Statistical analysis is conducted in MS-Excel and SPSS.

4. RESEARCH METHODS

4.1. Methodology overview

This section discusses the methodology employed in accessing Exposure and Risk perception to multi-hazard. The research is based on a mixed method approach. First, quantitative secondary data (Table 2) from various sources have been obtained to develop a Multi-hazard Exposure Index (MEI). Here qualitative information from field surveys and expert interviews will be in line with quantitative information and secondary data. The research utilizes an indicator-based approach for qualitative and quantitative analysis, namely Analytical Hierarchical Process (AHP) after Saaty (2005). AHP has been used for making Multi-hazards Exposure Index. In the AHP method, the weightage of the indicators is determined based on expert knowledge and refugee interviews. The resultant MEI will be used to quantify infrastructure at Risk. The risk perception will be analysed using a field survey and expert interviews.

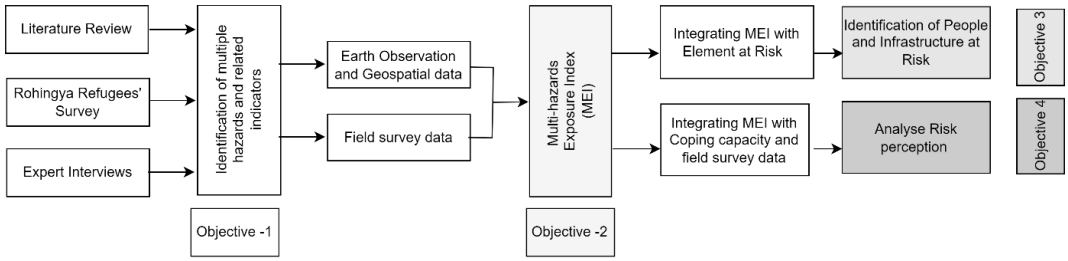


Figure 4.1: Research Process

Fig-4.1 shows the overall research process. Objective-1 is achieved by compiling the related literature, expert advice, and refugee survey information. In objective 2, primary and secondary information has been merged to make a multi-hazard exposure index. Lastly, in objective 3, the building footprint and population overlay with the MEI to understand the infrastructure at Risk, and in objective 4 the primary data analysis gives insight into the risk perception of Rohingya refugees.

4.2. Multiple hazards reported in Cox's Bazar

The first motive of the study is to understand the multiple natural hazards that affect the study area. The Historical reports of multi-hazard events are obtained from the Emergency Event Database (EM-DAT) to recognise the hazard's frequency and intensity in terms of fatalities in the study area Table-4.1. The world bank group report (2021) has been analysed to understand the relationship between hazards and climate in the next step. According to the report, Bangladesh is prone to tropical cyclones, floods, and landslides and is globally the most affected by those hazards. Due to its vast floodplain, 80% of Bangladesh is vulnerable to floods. The average precipitation in the south-eastern part (Cox's Bazaar) is 3000 mm per year. Heavy rainfall triggers other hazards such as Flood and landslides (World Bank Group, 2021)

Reports from United Nations Organizations (UNO) have been considered to understand the impact of natural hazards on Rohingya Refugees at Cox's Bazar. According to the United Nations Development Report (2018), Cox's Bazar is hilly terrain made-up of poorly consolidated sand and silt deposits. Due to heavy rainfall, the area becomes vulnerable to erosion, landslides, and floods (UNDP, 2018). Another report from the ISCG describes that (from 14 June 2020 to 15 October 2020) **31 flood incidents and 638 slope failures were recorded** (ISCG, 2020). Every year Cox's Bazar district is encountered by **tropical cyclones** that originated in the Bay of Bengal, causing severe damage to shelter and refugees (UNDP, 2018).

Table 4.1: Year-wise multiple hazard incidence recorded at Cox's Bazar, Bangladesh

Year	Disaster Group	Disaster Subgroup	Disaster Type	Disaster Subtype	Total Deaths
1991	Natural	Meteorological	Storm	Tropical cyclone	138866
1995	Natural	Meteorological	Storm		525
1997	Natural	Meteorological	Storm		100
2002	Natural	Meteorological	Storm		32
2004	Natural	Meteorological	Storm		153
2005	Natural	Meteorological	Storm		35
2007	Natural	Meteorological	Storm	Tropical cyclone	41
2008	Natural	Hydrological	Flood	Riverine Flood	16
2010	Natural	Hydrological	Landslide	Landslide	66
2011	Natural	Hydrological	Flood	Flash flood	10
2015	Natural	Meteorological	Storm	Tropical cyclone	45
2018	Natural	Hydrological	Flood		14
2019	Natural	Hydrological	Landslide	Landslide	2
2020	Natural	Meteorological	Storm	Tropical cyclone	26
2021	Natural	Hydrological	Flood		21

Source : *www.emdat.be*

Figure 4.2 shows the process of multiple hazard selection for identifying frequently affecting hazards in the study area. Here both primary and secondary data have been analysed. First, all the recent reports on Rohingya Refugees and climate hazards from the esteemed international organisation were reviewed. Multiple hazards frequency and intensity (based on no. of fatalities) were also considered recorded in the EM-DAT repository. After careful analysis of the secondary information, three natural hazards, such as landslides, floods, and cyclones, have been selected for further research.

Next, the selected hazards were used for the field survey and expert-written interviews. A well-defined questionnaire was prepared (Appendix 1) to understand the ground reality and validate the outcomes obtained from the secondary data. After getting responses from the Rohingya Refugees and experts from different parts of Bangladesh, Landslides, floods, and cyclones are finalised as our final hazards for the research.

4.3. Indicators for multiple hazard Exposure

After selecting the multiple hazards affecting Rohingya refugee camps, related indicators have been carefully chosen. As mentioned above, an indicator-based approach would be used to understand the multi-hazards Exposure in the Rohingya Refugee camp, Cox's Bazar. A systematic literature review was employed to select various indicators for producing multiple hazards exposure indexes.

Scopus and Google scholar has been chosen for literature analysis. Indicator selection was made in three steps Fig_4.3. In step 1, we searched literature concerned with multiple natural hazards and used earth observation data for the analysis. After carefully analysing those selected papers, desired indicators for multiple hazard analyses have been chosen. Step 2 involves the modification of indicators according to our research and study area. The selected indicators have been modified as questions for the primary survey and expert interviews. All the indicators obtained from the primary survey and expert interviews were considered to look for available data. Lastly, the indicators have been finalised based on the availability of data.

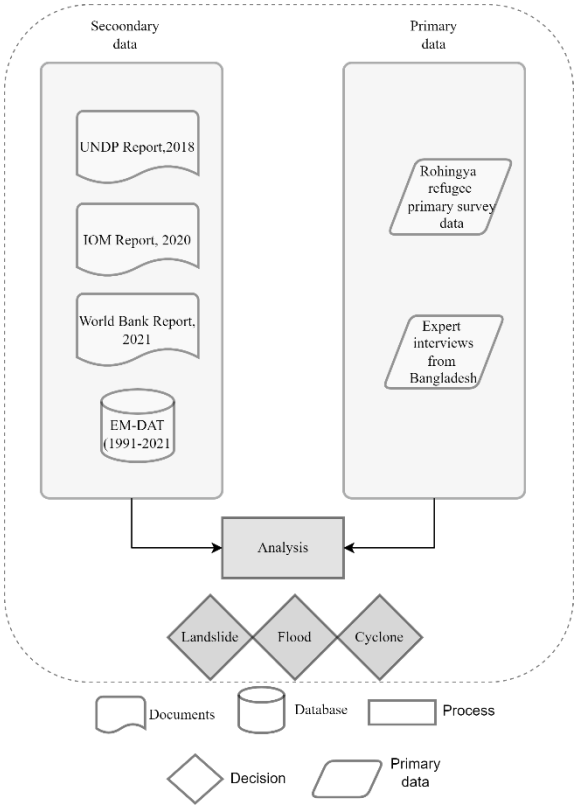


Figure 4.2: Process of identifying multiple hazards in the study area.

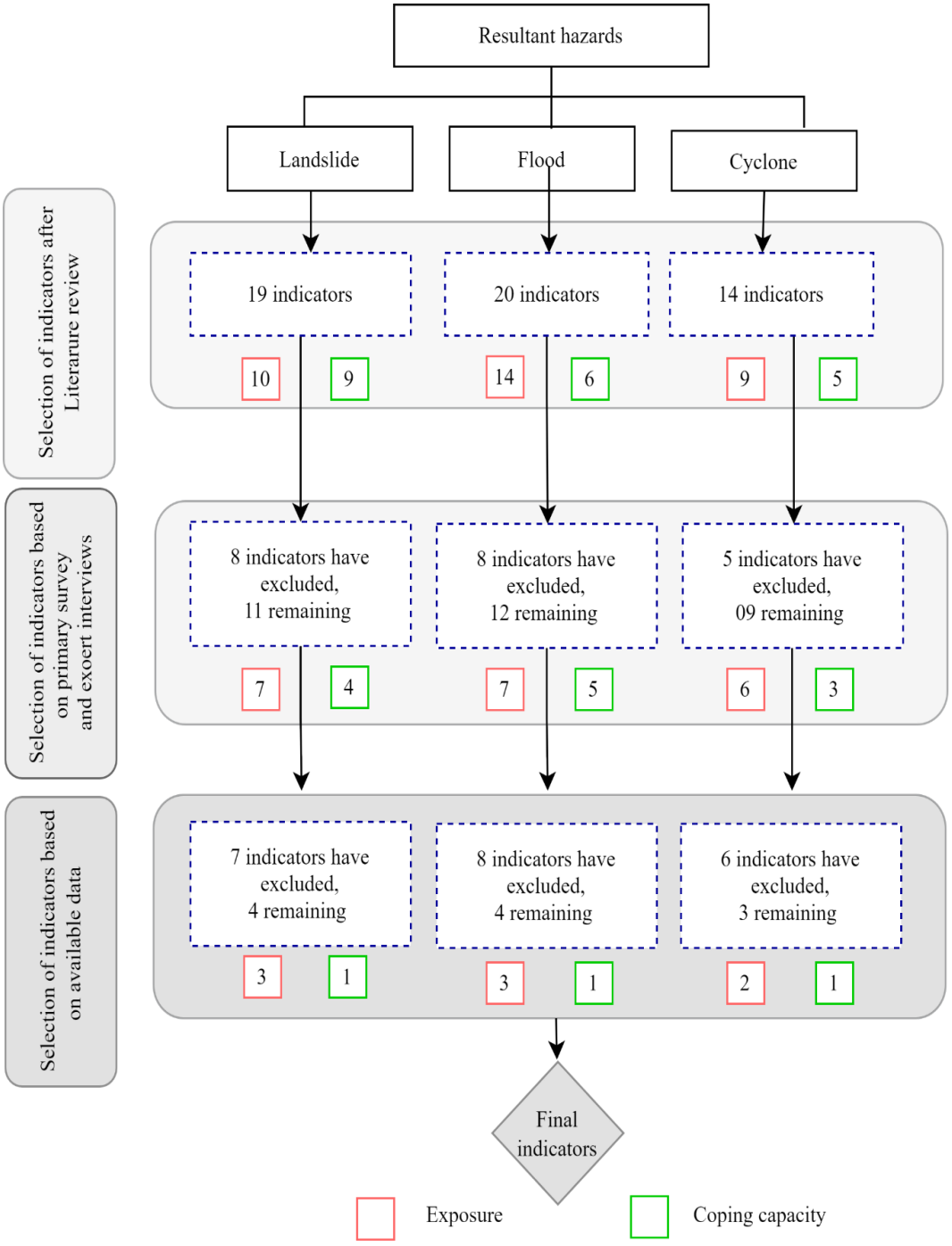


Figure 4.3: Indicator selection process.

4.4. An outline of the primary survey and expert interview

A shelter/household survey and expert-written interview have been conducted to understand the ground truth of the Rohingya refugee camp at Cox's Bazar with the help of Prof. and students from the University of Chittagong, Bangladesh. The shelter or household survey was conducted between 22 March 2022 - 27 March 2022. A total of 204 shelters (households) were surveyed. A total of 6 expert written interviews were conducted with the experts with different interests.

4.4.1. Sampling method

Sampling is a technique of selecting individual members or a subset of the total population of the selected area to make statistical judgments from them and analyse the whole population's characteristics (Taherdoost, 2016). Generally, sampling can be divided into two broad categories: Probability or random sampling and non-probability or non-random sampling. In the research, the random sampling method has been utilised for sample selection. The simple random sample can be defined as a probability sampling technique where every single member of the population size is chosen randomly. The probability of being chosen is the same for every individual in this technique (Khan, 2020).

The study area selection was based on the multi-hazard risk map prepared by REACH and UNOSAT. It is obtained from the CARTO data portal (www.carto.com.). The map is a multi-hazards repository showing the hazard's location. The Rohingya refugee camps are categorised into different types of Risk, which are as follows:

1- Camps have the Risk of both hazards (Landslide and Flood)
2- Camps having flood risk
3- Camps having Landslide risk
4- Camps without any risk

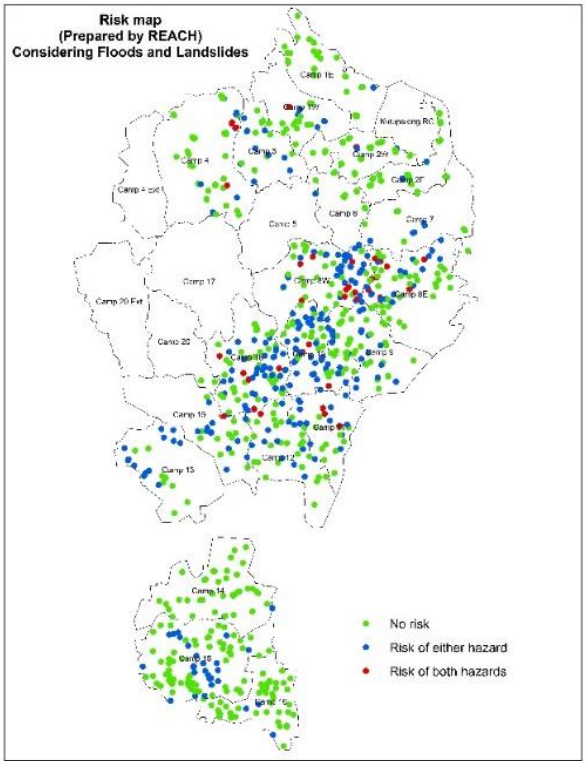


Figure 4.4: Risk map for site selection

The risk map shows areas that experienced floods and landslides and is labelled into three categories. The green dot shows areas with no risk of any hazard, the blue dot shows areas with a Risk of either flood or landslides, while the red dots denote those areas with the Risk of both hazards. We used the map to get our sample size. The methods of site selection are as follows:

- Identification of camps experiencing more than one hazard, only one hazard and no hazard
- Selection of those camps having the highest number of hazard risk point
- s and camps that do not have any risk points in case of no risk.
- Creating a 100-meter buffer from each risk point in the selected camps and no buffer in no-risk camps
- Randomly selecting 0.5% household of the total household within a 100-meter buffer and randomly selecting 0.5% of the population from no-risk camps. As shown in Table 4.2

Table 4.2: Selected Camps for the field survey, 2022.

Risk	Camp No	Total shelters	0.5% of total shelters
Landslide-Flood	8E	5411	27
	8W	6428	32
	10	5642	28
	18	6434	32
Only Flood	15	9204	46
Only Landslide	3	5252	26
None	20Ext	1508	8
	4Ext	1118	6
Total no.			205

4.4.2. Questionnaire design and Household survey

The questionnaire has been prepared with the help of the KOBO toolbox. Based on our objectives, the questionnaire has been divided into five categories. A total of 35 questions have been asked to Rohingya refugees to understand the insight of the camps (Annex 1). The first five questions were related to general information. Other 25 questions were designed to collect information about multi-hazard Exposure and Risk perception of Rohingya refugees at Cox's Bazar. The remaining questions were prepared to understand the people's perception of relocation to Bhashan Char.

The questions for demographic profile and house materials were closed-ended, while for multiple hazards exposure and risk perception, we used the Likert scale technique to facilitate its use further ahead in the AHP methodology. The Likert scale technique has been used to make household survey time efficient and easy as the target group is unaware of the scientific terms (Jebb et al., 2021). Coping Capacity was obtained through occupation. The questions for perception towards relocation to Bhashan char were open-ended to understand the story behind relocation.

Due to Covid-19 restrictions, the household survey was conducted remotely. All four surveyors were trained to collect data. A two-day, eight hours training workshop has been done remotely using the google meet platform. The objective of the survey has been clearly defined by the surveyors. There were various obstacles to conducting a household survey, such as massive morning and evening traffic jams on the way to Rohingya refugee camps, short duration of sunlight, extreme temperature, high humidity, undulating surface, poor internet connections, the women's privacy, and improper mode of transport. Some possible solutions have been identified to remove the constraint during the survey, such as an early start, staying nearby of the camps, keeping them hydrated, do not try to get responses from women, a survey in a group of two, keep us updated as soon as get connected with the internet, try to complete the survey, and leave the camp before dusk.

KOBO toolkit has been used to design the questionnaire. It was an essential task to make the surveyor familiar with the Kobocollect android version application for the data collection on the field. After assigning questions and possible answers in the Kobo toolkit, we deployed the questionnaire to get into the Kobocollect open-source android application. A dummy survey was conducted first to notice the surveyor's understanding of the Kobocollect app and validation of the results obtained from the dummy survey. Some mistakes have been identified. After correcting the mistakes, the questionnaire was again deployed. A second-round dummy survey has been conducted. After being satisfied with the results, the final HH survey has initiated in the Rohingya refugee camp.

Earlier, it was decided to complete the survey within four days, but due to unknown circumstances, the survey has been extended to six days. A total of 204 households have been surveyed, out of which 194 were male and only 10 were female. It was expected that the number of females would be less as the Rohingya refugees are Muslims and follow the "*Pardah*" system. A detailed description of the household respondent is as follows Table 4.3:

Table 4.3: General statistics of the selected camps for the household survey.

Level of Risk	Camp Name	Average Age	Total	Gender		Education Level		Duration of stay	
				Male	Female	Literate	Illiterate	0-5(yrs.)	5-10(yrs.)
More than one hazard	8E	36	27	26	1	8	19	26	1
	8W	38	33	30	3	10	23	27	6
	10	38	27	25	2	11	16	25	2
	18	38	31	30	1	16	15	28	3
One hazard	15	36	26	43	3	18	8	26	0
	3	36	26	26	0	18	8	25	1
No-Risk	20_EXT	39	8	8	0	3	5	4	4
	4_EXT	33	6	6	0	5	1	4	2

4.4.3. General information about the experts and written interview

Qualitative and quantitative information is required for the analysis. Hence, different expert perspectives are helpful in understanding the ground truth and assign weightage to the indicators. A different questionnaire has been designed for an expert-written interview (Annex 2). The written interview aims to understand their perspective on the multiple hazards risk experienced by the Rohingya Refugees and their perceptions towards relocation to Bhashan Char. A total of six experts were interviewed, Table 4.4

Table 4.4: Experts' details

Experts' designation	Area of interest	Organisation
Professor	International migration and refugees	Jagannath University (Dhaka)
Professor	Geography and environmental studies	Jagannath University (Dhaka)
Assistant Professor	Migration and disaster	Khulna University (Khulna)
Researcher	Hazard and migration, Climate change	Jagannath University (Dhaka)
Site Manager	Works as a disaster preparedness worker	IOM (Bangladesh, Cox's Bazar)
Site Manager	Works as a disaster preparedness worker	BRAC (Bangladesh, Cox's Bazar)

Due to the experts' unavailability, the interview was done by sending the questionnaire and getting their responses. The expert questionnaire was categorised into four broad divisions. Here, we used the Likert scale method to get the answer for multiple hazards exposure and risk perceptions. Every question has multiple answers, and a Likert scale from 1 to 5 has been assigned for the respondent's convenience. One denotes less importance, while 5 denotes significant importance. The perceptions towards relocation were asked based on open-ended questions. The Expert's responses were used to make a pair-wise comparison while making the AHP multi-hazard Exposure Index.

4.5. Data Analysis

All the resultant indicators have been pre-processed before using in the model. The spatial data related to the indicators was transformed into a WGS-1984 zone 46N projection. After reprojection, all the vector data set is converted into raster and resample to 1-meter resolution. As we focussed on 1 meter DEM obtained from very high resolution (1-meter) UAV images (HDX, 2022), all the data sets are resampled to 1 meter for further analysis. All the data are normalised using Cost and Benefit Analysis (CBA) Table 4.5.

The formula is as follows:

Benefit normalization formula: *[(value-min)/range]*

Cost normalization formula: *[1-((value-min)/range)]*

We got the resultant value from 0 to 1 (0 indicates the lowest intensity while 1 denotes high intensity). Normalisation of data is essential as it helps us to compare the indicators and reduces the complexity of the data (Belfield and Levin, 2010).

Table 4.5: Description of pre-processing of Multi-hazards exposure indicators

Multi-Hazards	**Exposure Indicators**	**Data**	**Resolution**	**Measurement**	**Actual data value**		**Normalised value**		**Function operated**
					Low	**High**	**Low**	**High**	
Landslide	Proximity to Fault-line	USAID data	vector	Euclidean Distance	2890 m	8305 m	0	1	**Cost Analysis**
	Steepness	Dem from High-resolution drone images	1 meter	Classified Values Steepness	0	51 degrees	0	1	**Benefit Analysis**
	Rainfall	Average Rainfall intensity from 2001-2020 from BMD	150 meters	IDW interpolation	171 mm	212 mm	0	1	**Benefit Analysis**
Flood	Proximity to River	OSM and HDX river network	vector data	Euclidean Distance	0	0.01 km	0	1	**Cost Analysis**
	Proximity to roads	OSM and HDX river network	vector data	Euclidean Distance	0	2848 m	0	1	**Benefit Analysis**
Cyclone	Proximity to cyclone track	HDX data	vector data	Euclidean Distance	3414 m	10495 m	0	1	**Cost Analysis**
	Proximity to the cyclone shelter	HDX data	vector data	Euclidean Distance	0	0.03 km	0	1	**Benefit Analysis**

4.6. Methods for assessing multi-hazard Exposure Index

In the research, Analytical Hierarchical Process(AHP) has been employed for the criteria weightage proposed by (Saaty, 1977)). It considers qualitative and quantitative information for decision-making. After selecting hazards and related indicators, a questionnaire was prepared. The questions were designed to collect information about the factor's importance. We used the Likert scale to understand the significance of indicators and their correlation among themselves. First, the factors maps were prepared based on selected indicators in ArcGIS. Then the factor maps were normalised with the Cost and Benefit Analysis(CBA) technique (Robinson, 1993). A pair-wise comparison matrix was prepared based on the Likert scale obtained from the field survey and Expert's interview using an AHP add-in in ArcGIS. The pair-wise comparison matrix uses a 1 to 9 continuous scale to show the positive relationship among variables, while the reciprocal of 1 to 9 shows the hostile relationship among them. With the help of the matrix, the Eigenvalues and Eigenvector was calculated. The next step was calculating the Consistency ratio(CR) to validate the eigenvector value. Saaty(1977) states that a comparison matrix is consistent when the largest eigenvalue equals the comparison matrix. Then he proposed the concept of Consistency Ratio. **Consistency Ratio (CR)** denotes the reliability of pair-wise matrix comparison. Higher CR values lower would be consistent among variables, whereas lower values show higher consistency among variables(Pauer et al., 2016). Generally, the AHP model considers consistency if the CR value is less than 0.1; otherwise, the model would be discarded (Saaty, 1977). If the CR value is more than 0.1, there is a need to revise the weightage. Here multiple hazard exposure index has been calculated with the help of AHP. A trial-and-error method was used to get an appropriate **CR (less than 0.1)** value. To check the validity of the model ROC-AUC method has been used.

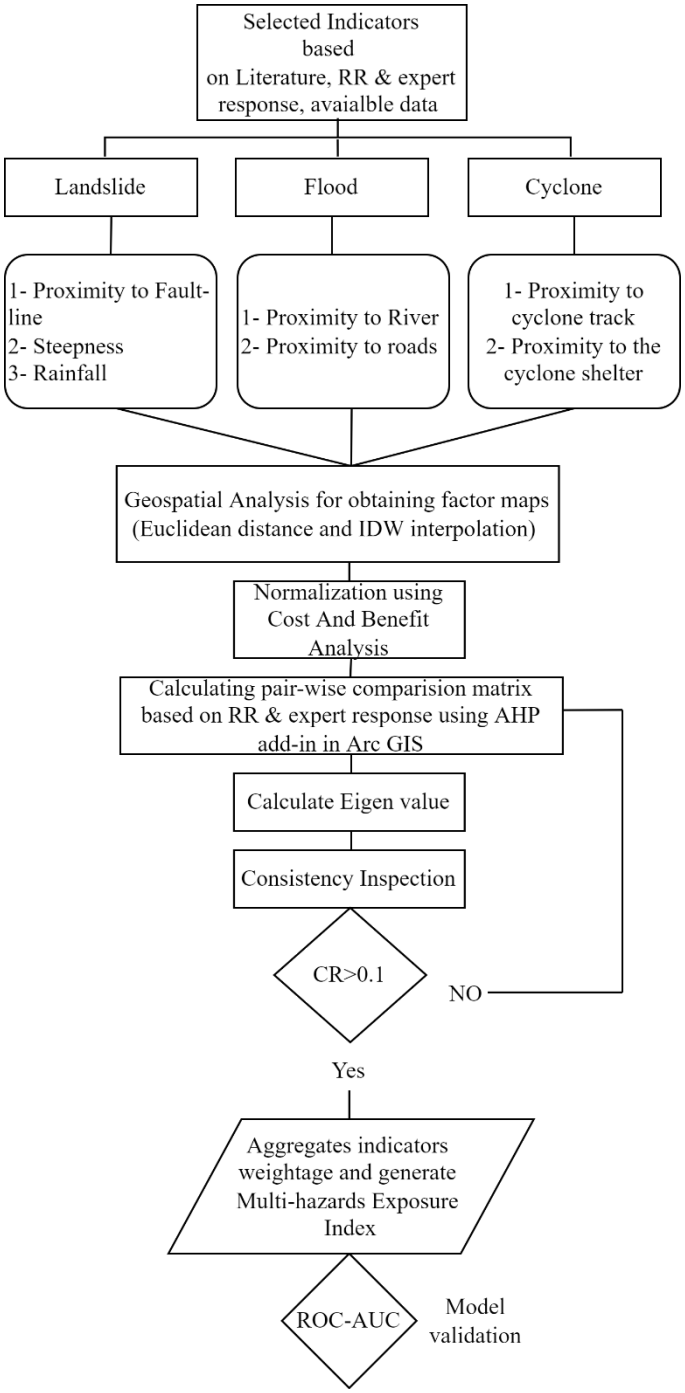


Figure 4.5: Process for the construction of multi-hazard Exposure index

4.7. Evaluating the Multi-hazards Exposure model performance

Understanding the model performance concerning ground truth data is essential. The machine learning models can be evaluated using a variety of tools. One of them is the AUC-ROC method. However, the AHP is not a machine learning model but rather based on the ground knowledge. Still, the AUC_ROC method has been used to check the performance of the AHP model. "Area Under the Curve" (AUC) of the "Receiver Characteristic Operator" (ROC) curve helps to visualise model performance. It depends on the actual value and predicted values.

Figure 4.6 : ROC curve performance (adapted from google images)

The sensitivity analysis or True Positive rate or Recall identifies the classified positive classes, while the Specificity or True Negative Rate describes the correctly classified negative classes by the classifier (Hajian-Tilaki, 2013). The model performance can be judged based on AUC values. It should be greater than 0.5. A higher AUC value represents a better performance of the model(Nahm, 2022). The AUC-ROC curve did the model performance of the AHP model. The ground truth of hazards location points was obtained from a multi-hazard repository map produced by REACH and UNOSAT (Fig 4.4). The analysis was done in the R-studio. The data was prepared for using it in the R environment (Code 1). The ground truth data was divided into True positive values and True negative values. Then certain thresholds were set to check at what level the model performance is best. After several attempts, the model performance was evaluated.

4.8. Identifying People and infrastructure exposed to multiple hazards

From the term infrastructure here, we mean building or shelter footprints. It should be noted that in Rohingya refugee camps, the houses or huts are temporary dwellings, hence known as shelter. The term shelter footprints will be used in the research instead of building footprints. A box plot analysis was used to identify the infrastructure and population highly exposed to multiple hazards in Rohingya refugee camps. Box plot is one of the widely used techniques for exploratory data analysis. It uses the median value, the lowest and the highest data point and the approximate quartile to define the data's level, spread and distribution (Williamson et al., 1989).

A spatial zone between shelter footprints and resultant multi-hazards exposure index was done in the Q-GIS with zonal statistics tools. The calculation uses each shelter's mean, median, counts and sums in relation to the multi-hazard Exposure index. The median values were used in R-studio (CODE 2) to generate a camp-wise distribution of exposed shelters. The multi-hazard Exposure Index was categorised into Extreme (>0.7), High (0.6-0.7), Medium (0.5-0.6) and Low (<= 0.5). Then all the camps associated with each zone were identified.

Again, the spatial distribution of shelters based on exposure zone was calculated. The same data set was used. The number of shelters in each exposure zone was identified, and gave a colour code to identify each shelter falling under different exposure zones. The exposed population was calculated by multiplying the number of shelters in each zone by the average family size of the Rohingya refugee camps. Camp-wise total exposed area was also calculated.

To determine which population segment is most exposed to multiple hazards, field survey data and expert-written interviews were employed. The five-point Likert scale has been considered to understand the impact of multiple hazards on the specific demographic section. The five-point scale consists of the categories

starting from 1 – Very Low, 2-Low, 3-Medium, 4-High and 5- Very High. The demographic group is also categorised based on their age starting from 0-12 yrs.-Children, male and female-below 50yrs and male and female-above 50 yrs. The questionnaire contains separate responses for each demographic section for each hazard. All the responses were transformed into mean values in the transform tool in SPSS and used in descriptive statistics to understand the highly affected demographic section in the study area. The highest statistical value in the data set was four, and the lowest was 1. Based on that values Likert scale mean has been calculated

4.9. Coping Capacity as a measure to reduce the impact of multiple hazards

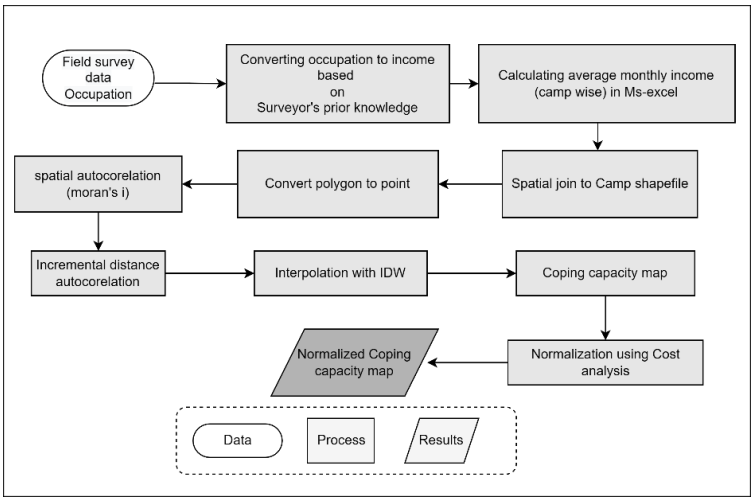


Figure 4.7: Coping capacity generation process.

Studying association among variables is an essential part of statistical analysis. The association between two variables is generally analysed with the Bi-variate correlation method (Bertani et al., 2018). Any changes in one variable will impact the value of the other variable since the two variables in the bi-variate relationship are associated with one another. A bi-variate relationship can be used to examine the role that coping capacity plays in reducing the impact of hazards.

One objective is to find the correlation between multi-hazard Exposure and Coping capacity. In the research, we used two quantitative data: 1) multi-hazard Exposure and 2) Coping capacity to find the relationship; therefore, the most applicable bi-variate method is a correlation, and simple regression has been used (Bertani et al., 2018).

The multi-hazards Exposure Index is already generated with AHP. Now the next step was to calculate coping capacity to understand the ability of Rohingya refugees to deal with the hazards. Coping capacity is defined as "the ability of people or an organisation to reduce the adverse impact of a hazard" (UNDRR, 2022). There are various indicators for calculating the coping capacity of a vulnerable population, such as *Red Cross Volunteers(IFRC)*[2], *Mitigation Projects (World Bank)*[3], *Global Urban indicators 1998 (UN-Habitat)*[4], *and Echo Disaster risk index*[5] (Billing, 2005). However, only income was considered to calculate the people's coping capacity due to the unavailability of data and ethical concerns of the Rohingya Refugee. After the field survey, the occupation was transformed into income with the help of the surveyor's prior knowledge. The average monthly income of the respondents was used to generate a coping capacity map in the ArcGIS environment with the Spatial autocorrelation tool Fig-4.7. The values have been normalised to get a 0 to 1 scale to make it comparable with the multi-hazards Exposure Index. Both the raster data sets have been converted into multi points to use in the SPSS for bi-variate correlation analysis. First, a dispersion diagram Fig-4.8. or scatter plot was generated using multi-hazards

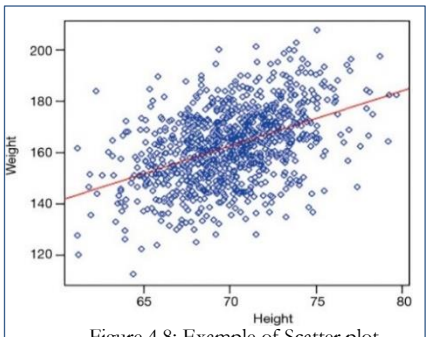


Figure 4.8: Example of Scatter plot adapted from (Bertani et al., 2018).

[2] http://www.ifrc.org/publicat/profile/index.asp.
[3] http://www.worldbank.org/hazards/projects/mitigation.htm.
[4] http://www.unchs.org/programmes/guo/qualitativedata.asp
[5] For details cf. ECHO's DIPECHO evaluation 2003, page 29-32

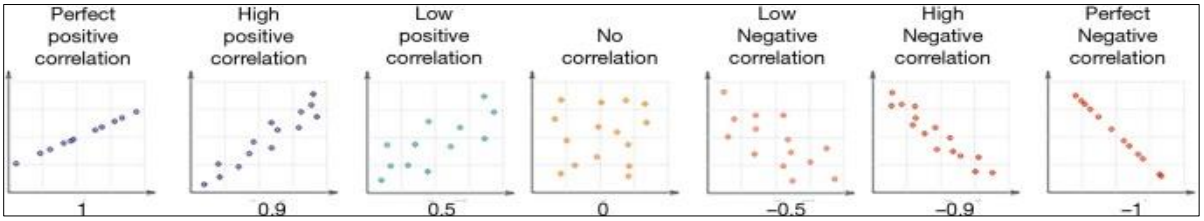


Figure 4.9: Example-linear Correlation adapted from (Bertani et al., 2018).

Exposure and Coping capacity to show the quantitative variables' graphical representation in the bi-variate model. It illustrates the linear or no-linearity among the quantitative variables in the model but cannot calculate the intensity of the causative impact. A correlation analysis has been done to measure the linear bond between multi-hazard Exposure and Coping capacity. This can be shown on a scale ranging from +1 to -1. The value +1 depicts the positive correlation while -1 denotes an opposing relationship between the variables Fig- 4.9.

4.10. Risk perception of Rohingya refugees

The refugee's survey responses were used to identify how they perceived exposure and risk at the cox's Bazar and their concerns about relocation. The risk perception was categorised into different sub-sections, such as perception towards security, awareness, food availability, and health care. The multiple response questions were set to determine their risk perception of multiple hazards at Cox's Bazar. The multiple responses 'Yes' and 'No' was changed into 1 and 0 to make a statistical analysis. The camp-wise analysis was done in SPSS with those responses. The responses were changed into a Bar graph by cross tab in the descriptive statistic Fig-4.10.

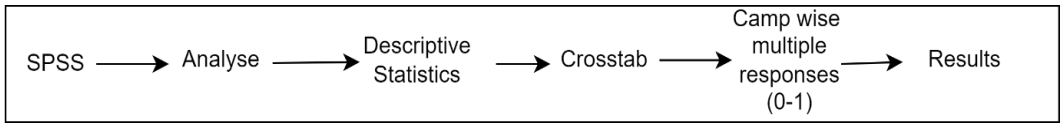


Figure 4.10: Methods to analyse multiple responses

The role of Govt. and NGOs during a hazard was also assessed. Some questions were also prepared to extract information from Rohingya refugees about the help and assistance Govt. and NGOs provided. The motivation behind asking those questions was to understand the perception of Rohingya refugees towards the Govt. and NGOs. Those are also multiple response questions, and the same method (Fig_4.10) was used to analyse the responses.

Finally, the perception of relocation to Bhashan char was analysed. One direct question was asked whether they wanted to relocate to Bhashan Char or not. Actual counts of multiple responses have been used to analyse the willingness of Rohingya refugees to relocate. A simple pie chart was used to visualise the results. The question is further supported by another multiple-option question to understand their willingness and unwillingness to relocate. Actual counts of the responses were used to recognise the reasons. Experts' perception was also considered to analyse the motive behind relocation and the multi-hazard exposure level at the Rohingya refugee camps.

An individual's decision-making is significantly influenced by their socioeconomic level (Cuaton, 2019). To further understand how socioeconomic factors affected people's decisions to move to Bhashan Char, the sample size was divided into several social and economic groups. Based on respondents' social status (literacy and illiteracy) and economic position (employment and unemployment), data about the relocation of Rohingya refugees were analysed.

5. RESULTS

5.1. Resultant multiple hazards from Primary and secondary data analysis

The first research question was to investigate the multiple hazards frequently affecting the Rohingya refugee camps in Cox's Bazar. After analysing historical data from EM-DAT, reports from IOM, UNDP, World Bank, and some academic journals, Landslide, Floods, and cyclone has been selected as persistent hazards.

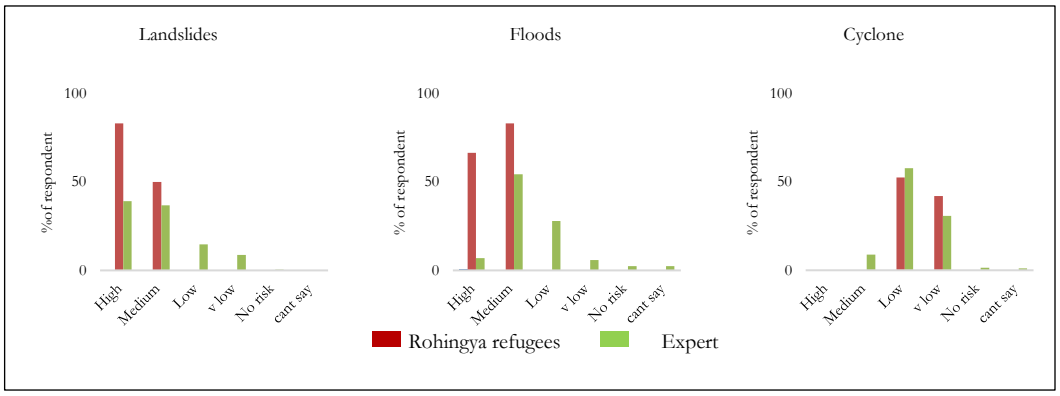


Figure 5.1: Frequency of Multiple hazards reported from Field survey and Expert Knowledge.

Fig-5.1 shows the frequency of multiple hazards in the study area based on Rohingya Refugees' responses and expert knowledge. The frequency of hazards is classified into six categories: High, Medium, Low, Very Low, No Risk, and Cannot say. It can be understood from fig-14 that 35%-40% of Rohingya Refugees respondents reported a high frequency of landslides, while 50% to 55% reported floods as a widespread event. According to Rohingya refugees, although cyclones are a problem, it is less affecting than the above hazards. From the expert perspective, the area is highly prone to landslides and moderately affected by floods. 83% of experts responded to the high frequency of landslides, while 66% agreed with the high frequency of floods. The frequency of the cyclonic events goes from Low to Very Low.

After analysing primary and secondary data, all the information was compiled into a table. Table 5.1 illustrates the multi-hazard events experienced by the Rohingya Refugee camp in Cox's bazaar. The red ticks denote those hazards that affect the refugees severely, while the blue ticks depict the moderate impact of the hazards.

Table 5.1: Hazards reported in Cox's Bazar from primary and secondary data analysis

Multi hazards	Literature[1]	Expert- interview[2]	Rohingya Refugee survey[3]
Landslide	✓	✓	✓
Flood	✓	✓	✓
Cyclone	✓	✓	✓

[1]-(IOM, 2021), (EM-DATA, 2021), World Bank Report (2020), ISCG (2020), (BANERJEE, 2020)

[2] -6 experts from Bangladesh.

[3] -204 Rohingya refugee's interview

☑ Severely affecting
☑ Moderately affecting

The next step, indicator selection, has been initiated based on the primary and secondary data analysis results in Table_5.1.

5.2. Resultant multi-hazards exposure indicators

The multi-hazards reported in the study area are landslides, floods, and cyclones. The next step was to select suitable indicators for the multi-hazard exposure index. Literature review, Rohingya Refugees' survey, and expert knowledge have been considered for choosing the relevant indicators. The resultant indicators from various literature can be seen in Fig-5.2. The detailed literature description of individual hazards can be

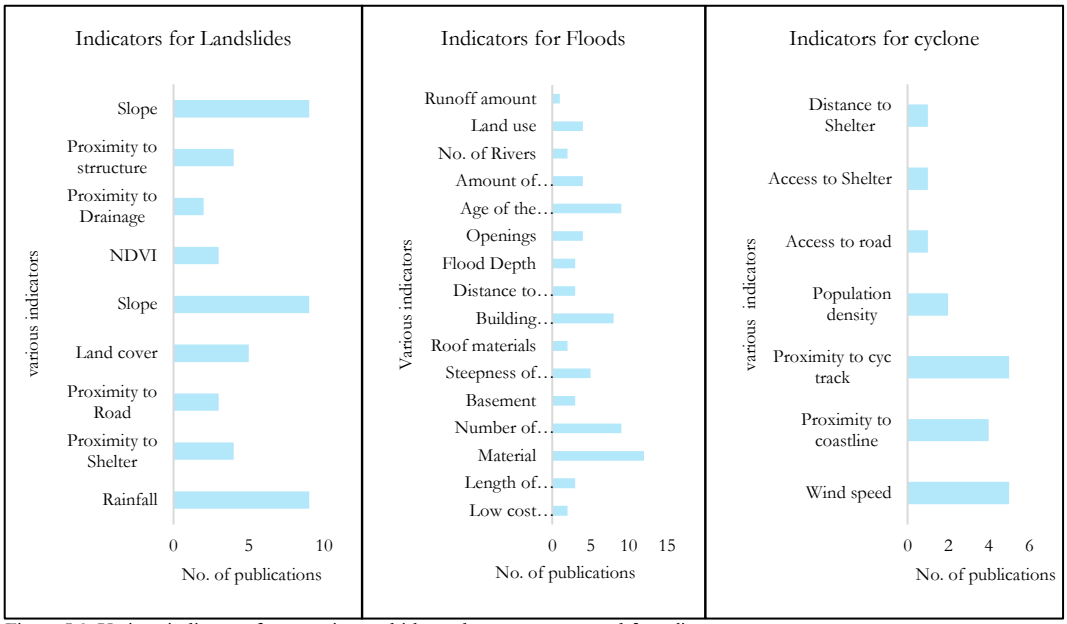


Figure 5.2: Various indicators for assessing multi-hazard exposure reported from literature.

found in (Annex 3). After the literature survey, the next step was to search for the required datasets. The selected indicators were again refined based on the data availability for the multi-hazards Exposure model. Then the remaining indicators were used in the refugees and expert questionnaire survey to understand the indicator or variable importance. Several questions related to hazards and Exposure have been designed and put on the survey questionnaire. A Likert scale from 1 to 5 was used to rank the answers. Hence 1 indicates very low importance while 5 depicts very high importance. After the refugee and expert survey, the final muti-hazard Exposure indicators were selected. Fig-5.3 shows the percentage of Rohingya refugees and experts' responses to the different multi-hazards indicators for assessing multi-hazards Exposure.

For both groups, rainfall, steepness and proximity to landslide zones are considered significant factors for assessing the landslide's Exposure to the study area, while nearness to river and rainfall appears to be the most significant indicators for assessing flood exposure. Proximity to cyclone tracks, shelter, and vegetative cover is deemed relevant for assessing Exposure to cyclones.

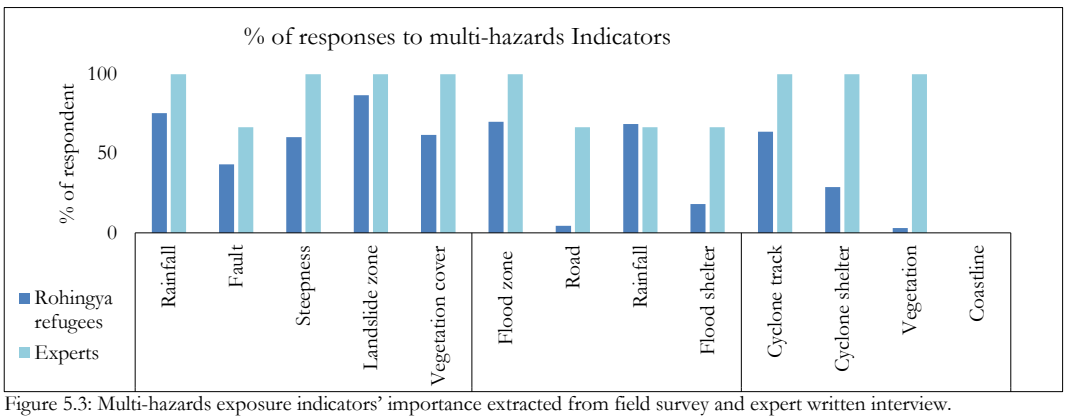


Figure 5.3: Multi-hazards exposure indicators' importance extracted from field survey and expert written interview.

However, some indicators were relevant for the analysis, but we did not consider them for model shelter. Such as nearness to the landslide zone is a valid indicator per experts and Rohingya Refugees for exposure analysis. Nevertheless, using them in the model creates ambiguity due to its overwhelming influence on other indicators. Thus, only those datasets that are spatially explicit to each other and score higher were used. A total of 7 indicators (Annex-5) have been chosen to construct the exposure index.
All the selected indicators were used to produce the required data set for AHP analysis using the ArcGIS environment. Geospatial analysis, such as Euclidian distance for roads, rivers, cyclone tracks and fault lines applied for producing factor maps. Inverse Distance weightage (IDW) and classified values of steepness were used for rainfall, wind, and slope, respectively. The values of the resultant factor maps have been normalised from 0 to 1.

5.3. Multi-hazard Exposure Index using AHP

A multi-hazard Exposure index has been calculated to identify the highly exposed location in Cox's bazaar. The AHP method was used to build a pair-wise comparison matrix among indicators. As already mentioned, the AHP allows us to use quantitative and qualitative information to build the desired model for assessment. The information from the field survey and expert-written interviews have been used to make a matrix. That information was utilised for ranking the indicators in the pair-wise matrix. All the indicators were ranked from 1 to 9 based on their importance Table_5.2. After calculating the Eigen value and Eigen vector, the pair-wise matrix produced weightage for the development of the AHP model. The pair-wise comparison matrix for the exposure index provides the highest weightage for rainfall (27.09).

In comparison, proximity to cyclone shelter(6.62) got substantially less weightage. The indicators ranking has been modified by trial and error to achieve a CR value of less than 0.1. Lastly, we got a 0.05 CR value for the exposure index and considered it acceptable for the AHP model (Wedley, 1993).

Table 5.2: Pair-wise comparison matrix for multi-hazard exposure index

PAIR-WISE COMPARISON MATRIX BASED ON REFUGEE'S RESPONSE AND EXPERT KNOWLEDGE

FACTOR MAPS	Pair-wise comparison 9 points continuous rating scale							Eigen value	Eigen vector of largest Eigen value	Criteria Weightage
	1/9 1/7 1/5 1/3		1	3, 5, 7, 9		2,4,6,8				
	Less important		Equal importance	More Important		Intermediate importance				
	RF	**SLOPE**	**PR**	**PF**	**PRD**	**PCT**	**PCS**			
RF	1	3	3	3	2	2	2	7.7684	0.54	27.09
SLOPE	1/3	1	2	3	4	2	2	0.0902	0.54	21.02
PR	1/3	1/2	1	4	2	2	2	0.0902	0.40	16.54
PF	1/2	1/2	1/4	1	2	2	2	0.2627	0.33	10.87
PRD	1/2	1/4	1/2	1/2	1	2	2	0.2627	0.22	9.28
PCT	1/2	1/2	1/2	1/2	1/2	1	1/2	0.2116	0.23	8.29
PCS	1/2	1/2	1/2	1/2	1/2	2	1	0.2116	0.16	6.88

PR= Proximity to river, RF= Rainfall, PF= Proximity to fault line, PRD= Proximity to road, PCT=Proximity to cyclone track, PCS = proximity to cyclone shelter

Consistency Ratio(CR)= 0.0593 (acceptable)

The normalised factor maps and multi-hazard Exposure index shown in Fig 5.4. To understand how much area is spatially exposed to multiple hazards exposure index was calculated with the help of 7 exposure indicators: proximity to water, proximity to the fault line, proximity to cyclone track, average rainfall, and

proximity to roads, slope, and proximity to cyclone shelter. Here the Red shade denotes the high severity of the indicators

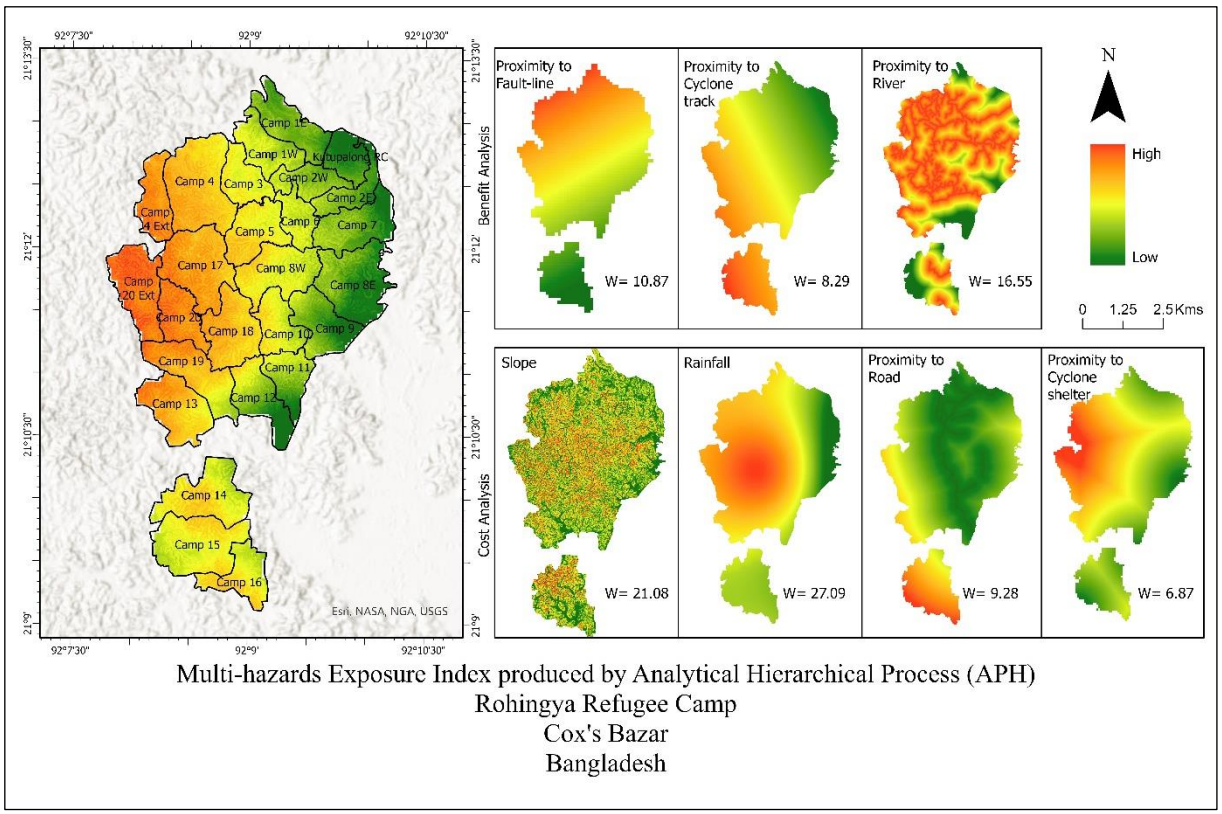


Figure 5.4: Multi-hazard Exposure Index and normalized factor maps

exposed, while green signifies less severity. The CBA technique was applied to normalise the data for better performance. Proximity to the river, fault line and cyclone track were normalised using COST analysis as the larger the data set values, the less would be the impact, though BENEFIT analysis was used to normalise the average rainfall, proximity to roads and cyclone shelter, as well as slope data set. All the indicators have assigned weightage based on expert knowledge and the Rohingya refugees survey to generate a multi-hazard exposure index of the Rohingya refugee camps, Cox's Bazar. The green zones signify the less exposed area to multi-hazards comprising camps 1E, Karamojong, 2W, 2E, 7, 8E, 9 and 12. The red zones indicate the highly exposed areas consisting of camp-20 and camp-20 Extension, 4 Extension, 17 and 19. Camp -4, 17, 18, 15,16 and 13 lie under the moderately exposed area to multi-hazards. Camp 8W, 1W, 3, 5, 6,10,11 is considered safe as per MEI values (0.2-0.3).

5.4. Validation of the AHP model using the AUC-ROC method

The performance of the multi-hazard Exposure model was checked with the help of the ROC curve. Various

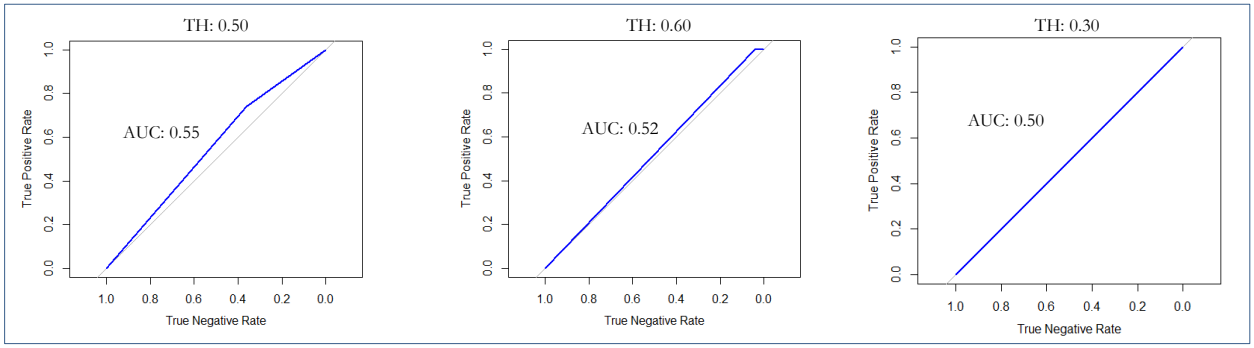


Figure 5.5: Different ROC curve produced for multi-hazard Exposure model with different Thresh hold values.

thresholds were set for the multi-hazard Exposure model to check the model performance. As for the Actual values, there is 0 for no and 1 for yes. Fig-5.5 demonstrate the different ROC curves produced after setting different thresholds. 0.3, 0.5 and 0.6 TH values were chosen to check the model performance, and we got the resultant AUC values 0.50, 0.5504and 0.5192, respectively.
The figure shows that the model performs Best at the 0.50 threshold level as the AUC value obtained at that level is 0.55. Here again, the recall precision has been checked with the help of the confusion matrix. The TRP and confusion matrix of the multi-hazard exposure index is as follows:

	FN	TP
FN	203	359
TP	95	264

$$TRP = \frac{TP}{TP + FN}$$
$$=264/(264+95)$$
$$= 0.738$$

The AHP model performance was evaluated by using AUC-ROC analysis. In the research, the AHP model got an AUC value of 0.55; the reason behind the low accuracy would be the insufficiency of the ground truth hazard points. The ground truth data used here did not consider all the camps and ignored camps such as 4, 4E, 20,20 E, 17 and 5, even though the AHP model identified those ignored camps as highly exposed to multi-hazard.
The true positive (TP) point identified by the AHP model was 264, which is higher than the 203 false positive (FP). The total recall precision obtained by the model is 0.738; thereby, the model correctly identifies 73 % of the exposure points in the model. Therefore, the model correctly predicts the exposure location. The model performance could improve if good quality and precise ground truth data were available.

5.5. People and shelters Exposed to multiple hazards

After identifying the areas exposed to multiple hazards and validating with the ground truth data, the next task was calculating the exposed population and infrastructure. It should be noted that the building footprints in the Rohingya refugee camp are recognised as "SHELTER." Hence, exposed shelters were calculated based on the multi-hazard Exposure index. A Box plot was prepared for the spatial distribution of the shelter footprints in the multi-hazard exposure zones Fig 5.6. With the help of zonal statistics tools, the median values of the MHE have been calculated following the shelter footprints. The resultant map has been used to generate the box plots to summarise the shelters' distribution concerning multi-hazards Exposure Fig 5.7. Here, fewer outliers can be seen compared to the multi-hazards Exposure index. The values of the exposed shelter are highly inlined with the median values of the box plot. From graph 5.6 and table 5.3, it can be concluded that camp 20 and 20 extensions are highly exposed to multiple hazards, although 1E, 2E, 2W, 7, 8E, 9, and Kutapolong RC are significantly less exposed. The values have been categorised into four zones based on the multi-hazard exposure index. Each shelter was classified based on the exposure zone in each camp. This analysis gave the camp-wise number of shelters exposed and the location of each shelter in each exposure zone. Spatial analysis was used to identify people and infrastructure (shelter) exposed to a specific Exposure zone. Various attempts have been made to identify the level of Exposure of each shelter in every camp. First, the model gave the camp-wise exposure zone in which each

camp was associated with a level of Exposure. The MHE show that every shelter in each camp is experiencing a different level of Exposure, so camp-wise, Exposure was not feasible for the analysis. Again, shelter-wise exposure level was calculated. It takes much time as the file contains 152492 shelter footprints. Finally, each shelter is classified according to the level of Exposure. A different colour code was given to each shelter. The red shelters are recognized as extremely exposed, the orange shelter as highly exposed, the yellow shelters as moderately exposed and the green shelter is considered relatively safe.

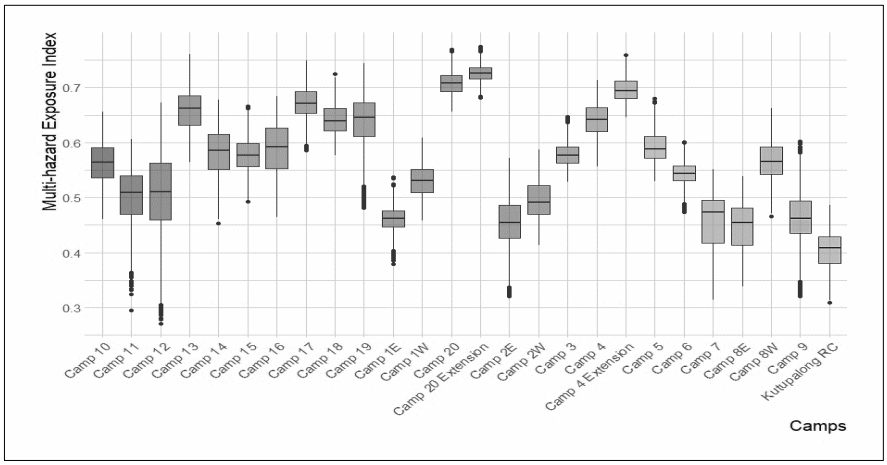


Figure 5.6: Camp-wise distribution of exposed shelters to multi-hazards

Table 5.3: Camp-wise Distribution of shelter in the multi-hazard's exposure zone based on Box plot

Multi-hazard exposure Index values	Exposure zone	Camps
>= 0.7	extreme	20 and 20E
0.6 to 0.7	High	13, 17, 18, 19, 4 and 4E
0.5 to 0.6	medium	10, 11, 12, 14, 15, 16, 1W, 5, 6, 8W
<0.5	low	1E, 2E, 2W, 7, 8E, 9, Kutapolong RC

Shelter, population and area were calculated in each multi-hazard zone to make the results more imperative and precise. The calculation depicts that 107,833 shelters are highly exposed to multiple hazards. The average family size of each shelter reported from the Need and Population site management survey is 4 people per shelter. Hence, 431,332 people are highly exposed. On the contrary, 6696 shelters lie under extreme exposure zone, followed by 26784 exposed populations. A total of 4.78 km^2 is reported to be exposed to multiple hazards. Fig-5.7 shows the exposed shelter based on the level of Exposure. Shelters in each camp are exposed to different levels of Exposure (Red = Extreme, Orange= High, Yellow = Medium and Green = Low). The map facilitates the identification of each shelter based on the level of Exposure. A Camp-wise distribution of shelters exposed to different exposure levels is shown in the Fig 5.7to support the building-wise exposure map. The figure showed that most of the camp-15 shelters lie in the high exposure zone and the number of populations is also highly exposed. Camp-1 , 3 and Kutupolong lies in safe zones.

Table 5.4: Shelters, population and area exposed to multiple hazards

Multi-hazard Exposure Zone	Shelter	population	Area in Km2
Low	37963	151852	1.44
Medium	61135	244540	1.90
high	46698	186792	1.27
Extreme	6696	26784	0.17
Total	152492	609968	4.78

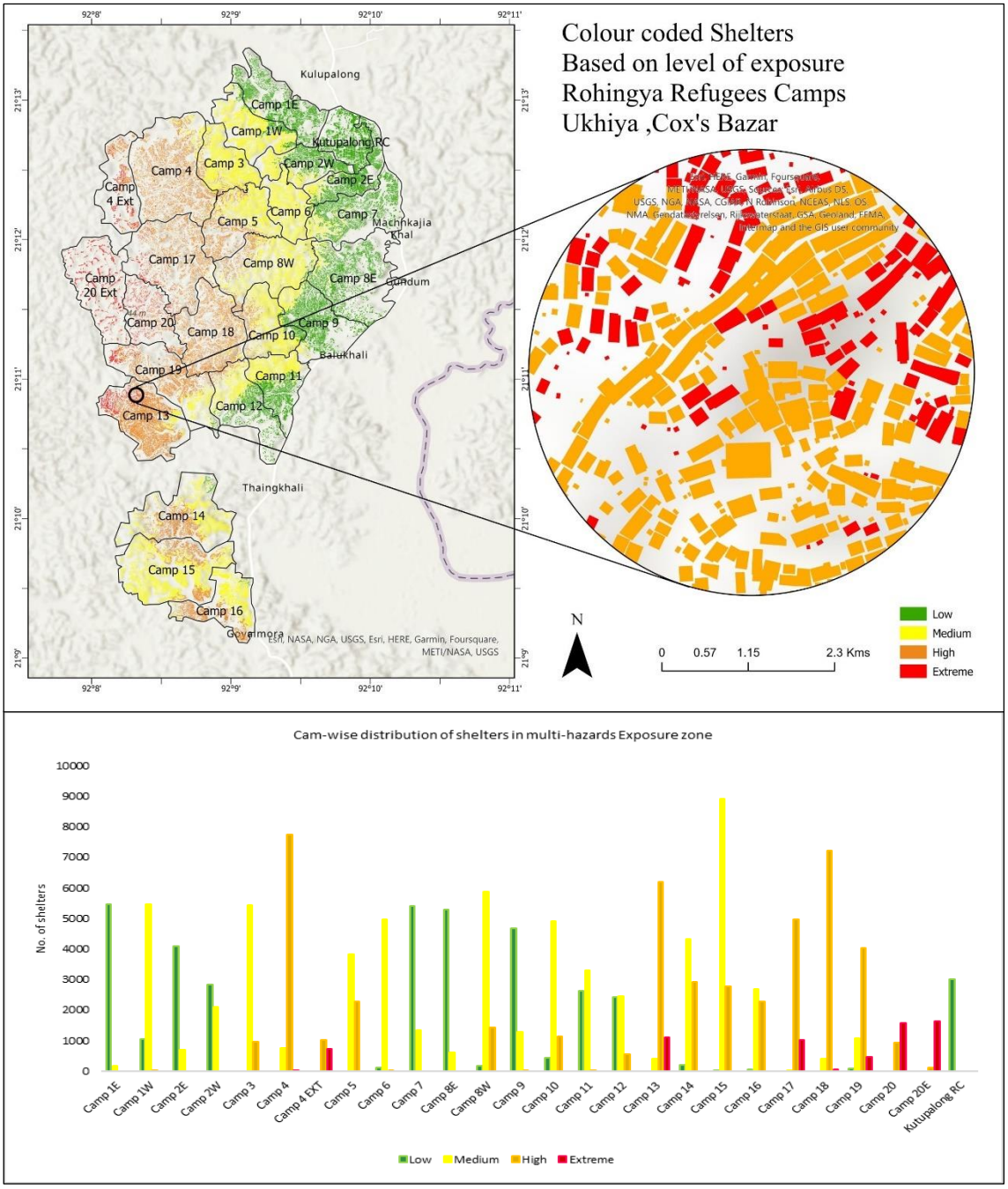


Figure 5.7: Distribution of shelters in different camps based on the level of exposure.

Another objective of the study was to identify the exposed population based on age and gender. The questions for the shelter survey were used to understand the highly affected demographic section in the study area. The five-point Likert scale was considered to understand the impact of multiple hazards for each specific demographic cohort. The demographic cohort is also categorised based on age, starting from 0-12 yrs.- Children, male and female below 50yrs and male and female above 50 yrs.

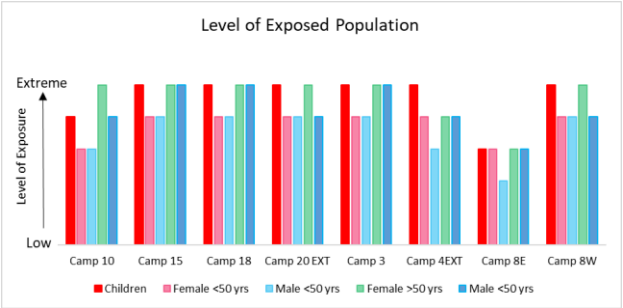


Figure 5.8: Exposed population based on age and gender

The Fig 5.8 depicts the outcomes of the Rohingya refugees' responses to the exposed demographic section in the sample camps. It can be seen that in camp-15, 18 and 3, children and females below 50 age group are highly exposed. It is also proven from the multi-hazard Exposure index that the population in camps 13, 15, 18 and 8E are highly exposed. As 55% of the Rohingya population are children, hence it can be concluded that children are highly exposed to multiple hazards, followed by elderly women.

Table 5.5: Mean value based on Likert scale responses of Rohingya refugees

Demographic Category	Age	Mean
Children	(0-12) yrs.	2.5980
Female	Below 50 yrs.	2.8693
Male	Below 50 yrs.	2.0686
Female	Above 50 yrs.	3.1797
Male	Above 50 yrs.	2.2451

The questionnaire contains separate responses for each demographic section for each hazard. All the responses have been transformed into mean values in the transform tool and used in descriptive statistics to understand the highly affected demographic section in the study area.

The highest statistical value in the data set was four, and the lowest was 1. Based on that values Likert scale mean has been calculated from Table-5.5. , it can be recognised that the mean value for females above 50 years is 3.1797 and for female below 50 years is 2.8693; in comparison, it is lowest for young males in the study area.

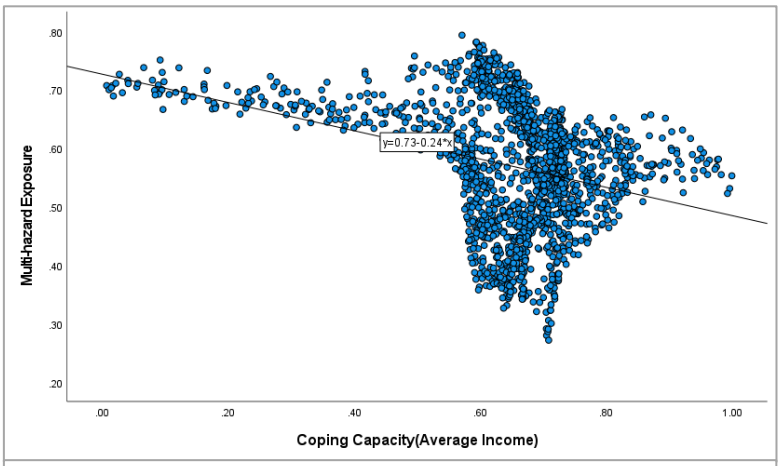
Table 5.6: Mean value based on Likert scale responses of Expert

Demographic Category	Age	Mean
Children	(0-12) yrs.	3.3333
Female	Below 50 yrs.	2.8333
Male	Below 50 yrs.	1.2778
Female	Above 50 yrs.	3.7222
Male	Above 50 yrs.	2.9167

The expert's written interview also validated the refugees' response that children below 12 years and females above 50 years are highly vulnerable to multi-hazards in the study area. The mean value for the children is reported as 3.333, and for females above 50 is reported as 3.722 Table-5.6. Although the number of experts here is minimal, their responses were based on their scientific knowledge of the study area.

5.6. Relationship between multi-hazards Exposure with Coping Capacity

Based on expert and surveyors' knowledge, the monthly income of the respondent was inferred from the declared occupation. The monthly income was utilised to prepare a coping capacity map. A bi-variate model has been run to evaluate the relationship between multi-hazard Exposure and coping capacity. The scatter plot shows a negative relationship among the variables—the higher the coping capacity (income), the lower the index value. Nevertheless, many data points also lie in highly exposed areas.



Correlation

	Pearson Correlation	Sig. (2-tailed)
Coping capacity-Multi-hazard Exposure	-.321	<.001

Figure 5.9: Coping capacity in relation with multi-hazard Exposure

The average income calculated here is 20000 BT (around 200 euros) per month. The correlation coefficient matrix illustrates a negative relationship between multi-hazard Exposure and coping capacity as the coefficient value is -.321. For a strong correlation, the value should be near +1 and -1. The variables are favourably or negatively associated in the vicinity of +1 or -1. Values close to zero signify an unstable connection.

Camp 4 is reported for the highest income and employment and camps 15 and 10 with the lowest income Fig-5.11 and Fig-5.12. It should be noted that according to the multi-hazards exposure index, camp 4 lies in the extreme exposure zone, but there this camp shoeing economically strong while 100% of the respondent were employed in camp 4. Camp-15 shows the lowest income and lies under the high exposure zone in our multi-hazards exposure index, which validates the results of box plot analysis that the lower the , the more vulnerable will be.

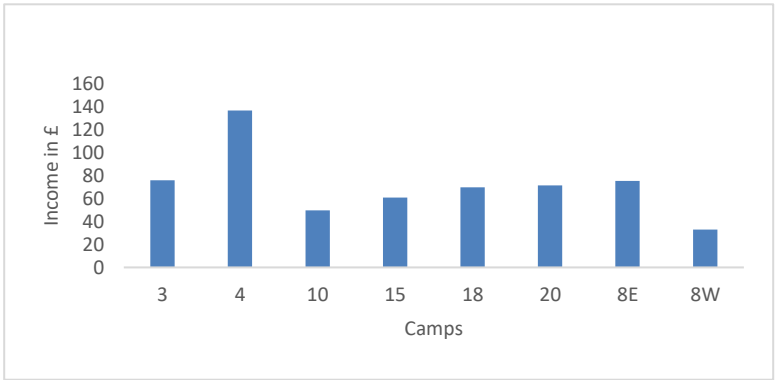


Figure 5.11: Refugees income in sample camps

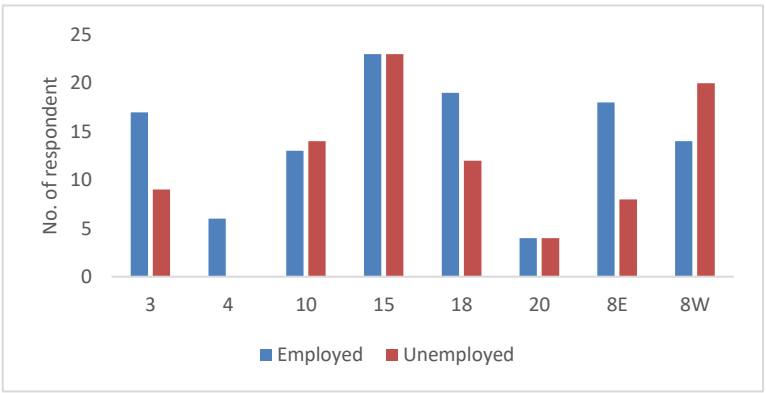


Figure 5.10: Refugees economic status in sample camps

5.7. Assessing risk perception of the Rohingya Refugee to multiple hazards in Cox's Bazar and Bhashan Char

Another interesting assessment would be to understand how people perceive the risk and exposure they are subject to and to what extent the steps relate to the model we develop.

A field survey has been conducted to understand the Rohingya refugee's perception of residing at Cox's Bazar and relocating to Bhashan Char. Various questions have been formulated to extract information about risk perception at Cox's Bazar and Bhashan Char. The first question was about the feeling of insecurity during a hazard. Fig-5.13 shows the camp-wise responses of the Rohingya refugee and depicts that most respondents found themselves in an unsafe situation during a hazard. Camp-10, 3 and 8W are highly unsafe categories, while camp-15, 18, 3, 8E and 8W reported little safety during a hazard. Their responses portray the fact that there is fear of unsafety during a hazard at Cox's Bazar Rohingya refugee camp. Then next were to assess the awareness of the people before a hazard. The question about early warning has been asked to know the people's perception of awareness before a hazard. It was a multi response question containing YES, NO and DO NOT KNOW responses. The responses were highly appreciated as most respondents were aware of the early warning system Fig-5.12. The next question was to know their reaction after the early warning sign.

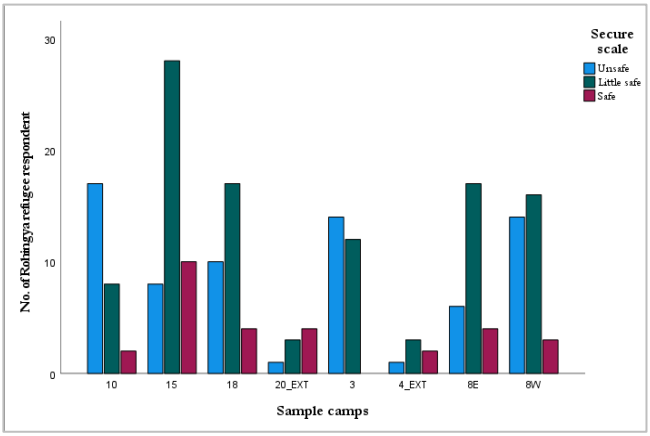


Figure 5.12: Rohingya refugees' perception about safety during a hazard.

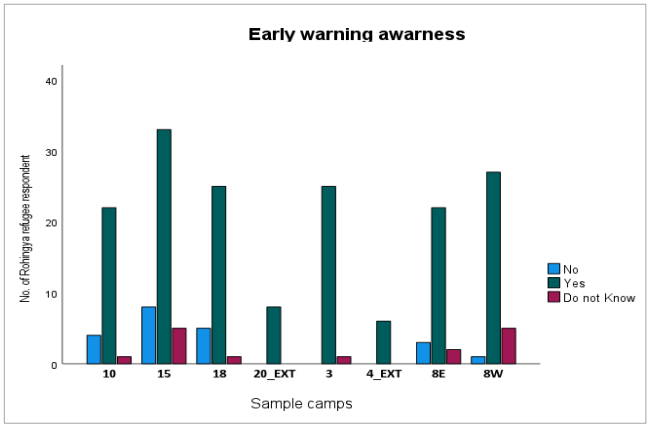


Figure 5.14: Rohingya refugees' perception towards Early warning

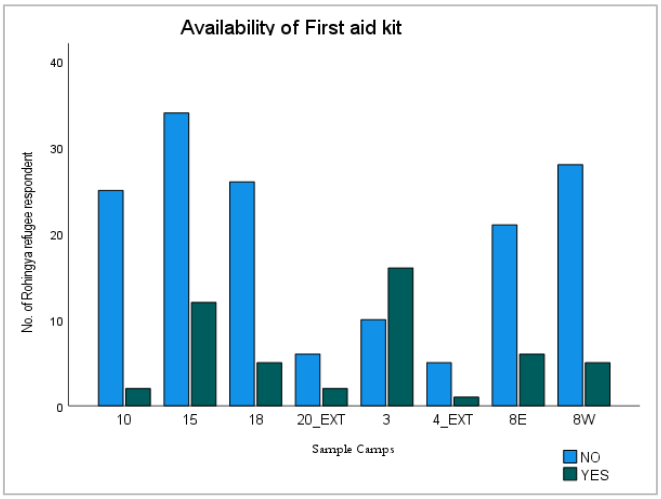


Figure 5.13: Rohingya refugees' response to health care perception

Mobility is impossible during a hazard, and the concerning issue is food. Several questions were asked to understand food security's perception during a hazard. One of the questions was whether the Rohingya refugees store food after early warning Fig-5.14. The respondent from camp-10, 15,8E and 8W show an adverse reaction, whereas camp-18, 3, and 4 EXT seem more concerned about food security before a hazard. The availability of first aid kits Fig-5.15 was inquired about to understand their concern towards healthcare during a hazard. The responses were negative; most people did not even know what a first aid kit was. Comparing all the sample camps, only Camp-3 shows a good response about the first aid kit. Camp 10, 15, 18, 8E and 8W portrayed negative responses regarding the availability of the first aid kits. Next, the Government and NGO aid during a hazard

was assessed to understand people's perception towards Govt. and Non-Govt organisation help. The following table shows various questions asked to the Rohingya refugees to understand the Government and NGO's role during a hazard.

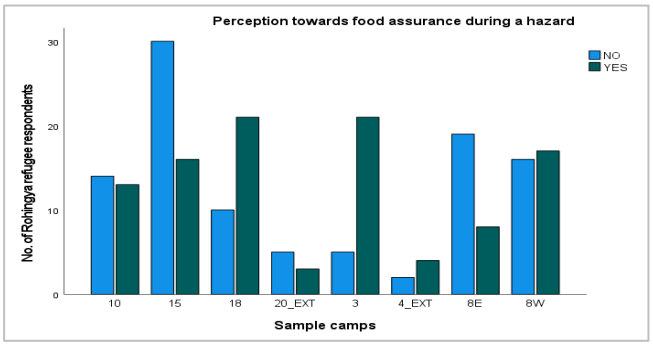


Figure 5.15: Rohingya refugees' perception towards food assurance

Table 5.7: Role of Govt. and Non-Govt. organisation

Questions:	*Yes*	*No*	*Total*
Did you get food during the last hazard?	140	64	204
Did you get cash assistance during the last hazard?	0	204	204
Do you get medical help during a hazard if you cannot move?	123	81	204
Do you allow to go to a safer place beyond the camp boundary during a hazard?	77	127	204

The table-5.7 reveals that Rohingya refugees are not getting any cash assistance during and after a hazard, as (100%) of respondents (204) gave a negative answer to the question. Regarding getting food during a hazard, 140 out of 204 affirmatively answered, while 64 complained about food insufficiency during a hazard. Perception of health has already been assessed and the responses were not satisfactory. Hence, assessing Govt. and NGOs' role in providing healthcare facilities during and after a hazard was necessary.123 respondents out of 204 confirmed they get medical assistance from Govt. and NGOs' whereas 81 responses were against the help provided by the Govt. and NGOs.

The social media and press considered "Bhashan Char" *a 'golden cage[6]'* due to its inaccessibility to the rest of the world. A report published in the magazine *'The Diplomat[7]'* stated that the isolated location of Bhashan Char is like a prison; people cannot escape during a severe hazards due to inaccessibility and remoteness (Nguyen and Lewis, 2022). Access to a safer place during a hazard was asked to understand the evacuation system and mobility outside the camp in Cox's Bazar. 127 respondents of 204 negatively responded, although 77 said they could move within the camp border. Hence, intercamp mobility was possible, but refugees could not move outside their camp for a safer location during a hazard.

[6] Rohingya accuse Bangladesh officers of abuse over hunger strike | Rohingya News | Al Jazeera

[7] Bhasan Char and Refugee 'Warehousing' – The Diplomat

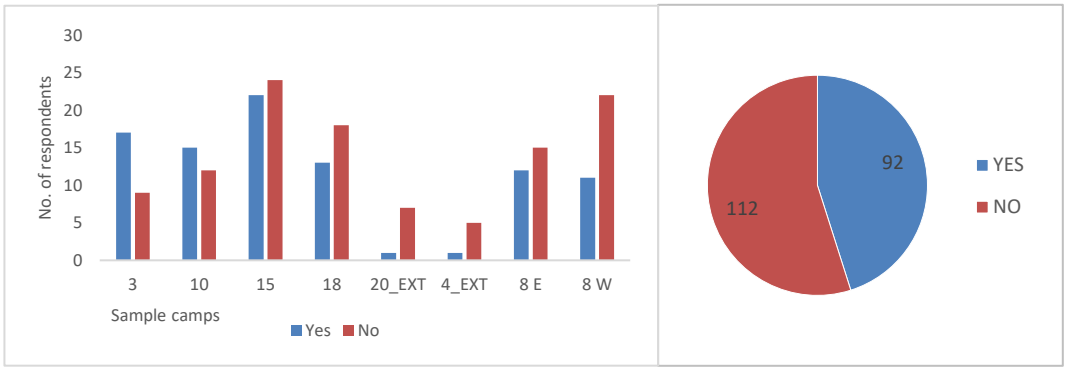


Figure 5.16: Refuges' responses for relocation to Bhashan Char

Another objective was to analyse the risk perception of Rohingya refugees toward relocation to Bhashan Char. The field survey questionnaire has proven vital in achieving the objectives mentioned above. Significant responses have been obtained from the Rohingya refugees. Fig-5.16 illustrates the Rohingya Refugee's positive and negative responses toward relocation to Bhashan char.92 out of 204 respondents are willing to move to a new island. The reason is Good quality Houses (90), Sufficient living space(88), living with own community (76), and resilient houses (83).In contrast, 112 respondents show their Fig-5.17

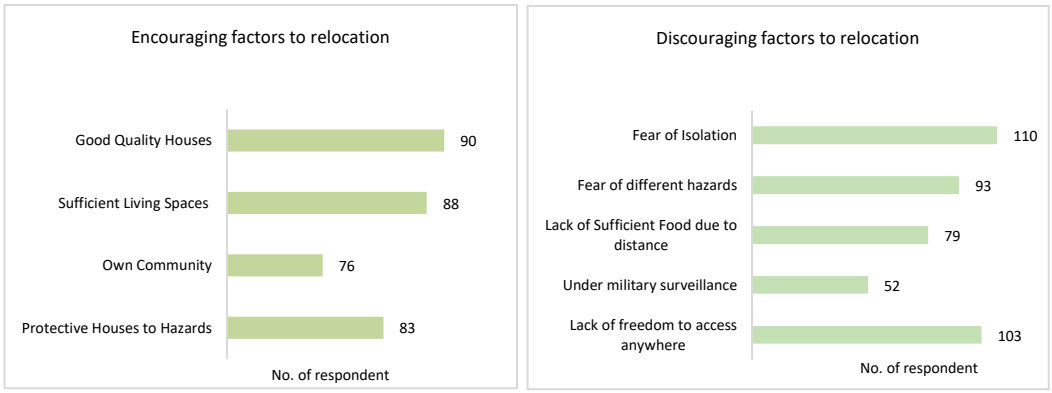


Figure 5.17: Perception towards relocation based on social status

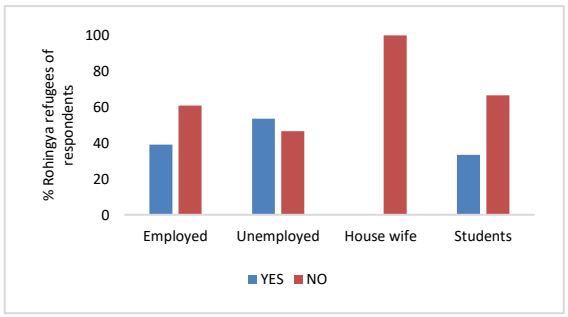


Figure 5.18: Perception towards relocation based on economic status

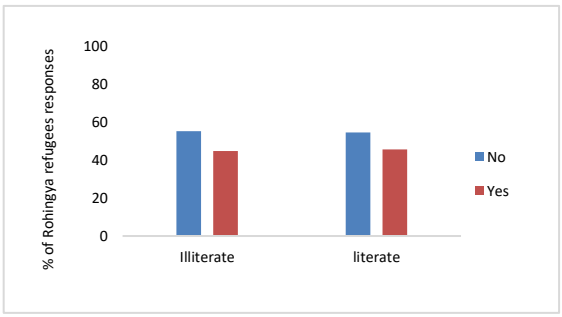


Figure 5.19: Perception towards relocation based on educational status

unwillingness to relocate. They also have some concrete reasons, such as fear of isolation(110), fear of an unsafe place (93), Lack of sufficient food (79), under military surveillance (52) and inaccessibility (103).
The camp-wise responses showed that refugees from camp-15, 18, 20Ext and 4 Ext negatively responded. The responses are surprising as those camps lie in extremely exposed zones, thereby the highest threat to livelihood. A comparative analysis was also employed to understand why their responses showed their unwillingness to relocate to Bhashan Char. Here, the responses have been analysed based on the education level and occupation. Fig-5.18 reveal the relationship between economic status and responses to the

relocation to Bhashan Char. The percentage of responses to the total respondent has been used there. 55% of the illiterate respondents answer in favour of relocation.
In contrast, the same social group fig-5.19 shows their unwillingness to relocate. 56% of the illiterate population do not seem willing to go there. This analysis also reveals that most of the respondents in the camps are illiterate. While analysing the response with occupational structure, a unique relationship was obtained. It was noticed that 50% of the unemployed respondents were willing to relocate, while most of the employed people showed unwillingness due to their occupation. Homemakers (housewives) and students have been excluded from the unemployed section to make the comparison fair. From the analysis, it can be concluded that occupation plays a vital role in the respondent's perception of relocation

6. DISCUSSION

The research goal was to assess multiple hazards Exposure and relates that exposure to the risk perception of refugees and how that affects their choice to relocate to Bhashan Char. The study identifies that although the Rohingya refugee camps are highly exposed to different hazards, Landslides, Floods, and cyclones account for the highest number of fatalities annually. The secondary statistics and literature indicate that cyclones are a major cause of fatalities; however, the Rohingya refugee respondent stated that landslides and floods significantly impact their lives. According to experts, the sharp edges of flying objects during cyclone seasons make people vulnerable. The roof of the shelters almost all over the Rohingya camps is made up of '*tin*', a sharp edge light material. During a cyclone, the high wind velocity uprooted those roofs, causing flying in the sky and made people injured. Another essential factor considering cyclones for assessing Exposure to multiple hazards was their trigger effect on other hazards. The experts also confirm the impact of the triggering factor. The study area comes under humid tropics experiencing tropical cyclones every year. Those cyclones poured heavy rain, causing flash floods and resultant landslides and slope failure. The expert scientific knowledge and Rohingya refugee's ground experience supports the fact obtained from the literature. The findings from the literature search, ground reality acquired from the field survey, and experts' knowledge are highly compatible.
A wide range of literature was reviewed to extract suitable indicators for developing a multi-hazard exposure index. A total of 132 scientific journals were examined for multi-hazards indicator selection. Out of 132, 74 was related to flood, 37 was to landslide, and 21 was to a cyclone. These journals gave us a total of 31 exposure indicators consisting of 8 for landslides, 16 for floods and 7 for cyclones. After selecting indicators from the literature, the next step was looking for a relevant dataset for further analysis. Based on the size of the study area (13 sq.km.), the main issue was the availability of good quality data set for the analysis. Most of the relevant data set was available in coarse resolution (1 km, 90 meters and 10 meters). Some finer resolution (1meter) data sets were found in the HDX web portal but were insufficient for all the selected indicators from the literature. To fulfil the research's reproducibility criteria, it was ensured that the data used should be freely available. Therefore, only open-source data was used in the analysis.

Due to the unavailability of desired resolution open-source data, some coarse resolution data was also taken for the analysis. The conversion from coarse (90 meters) to fine (1 meter) affects the result's quality. The slope and river were generated with a 1-meter contour; hence the influence of those data sets can be seen in the exposure map. Therefore, for future work in this context, it would be recommended to avoid downscaling(data transformation) from very coarse to finer resolution.
The field survey is the most challenging task of the research, especially in areas which are restricted for the common people for which special permissions and approvals are required from the regional administrations.

Due to COVID 19 regulations from the institution, it did not permit conducting fieldwork in person; hence, the survey was done remotely with the help of a field supervisor and surveyors. The situation, as mentioned above, also resulted in extra efforts and prolonged delay as it took time to familiarize the surveyor with the questionnaire and make them understand the importance of ethical contingencies. Group discussion, online training and precautionary measures were conducted before going to the field. A lesson was learnt from the survey that proper planning, coordination among the group, and time management are essential for conducting a field survey. The gathered information was as desired for answering different research questions as the data could be easily validated with the predefined hazards.

The surveys were conducted to collect the Rohingya refugee's experiences with multi-hazard, and the experts' scientific knowledge was used to inter-validate the responses, which became the research base. Further, eight indicators from existing literature were used for the pair-wise comparison, ranked by the respondents and the experts, to develop the multi-hazard exposure index. The pair-wise comparison matrix gives the highest weightage to rainfall and slope, which is evident in the survey and the available literature.

> *"The undulating topography, deforestation and unplanned construction of shelters paved the way for the development of creeks and gullies after a sudden rainfall, resulting in a flash flood in the Rohingya refugee camps. The area is highly exposed to rain due to mass deforestation for building refugee shelters. Even a little spell caused slope failure and resultant landslides". By- expert*

Rainfall, slope, and proximity to (river, fault line, roads, cyclone shelter and cyclone track) are the factors used for framing the multi-hazard Exposure index. Rohingya refugees are aware that slope failure mainly occurs on steep slopes and may cause loss of life, property, cattle, and agriculture. Infrastructure and the population residing on steep slopes are exposed to landslides; experts have confirmed that steep slopes experience more slope failures than gentle slopes. Proximity to the river is crucial as the topography of the camp is highly influenced by rills, creeks, and gullies, as per experts. These creeks and gullies are flooded even after a short spell. It is also witnessed in responses from the survey that during monsoon season, rills are filled with water, overflowing, resulting in flash floods, and this makes circumstances for the Rohingya refugees more difficult as their shelters are inundated by flood water.

Areas near an active fault line are usually prone to earth and soil displacement, due to which landslides are triggered; hence refugee shelters on the fault or nearby are highly exposed. Refugees in proximity to roads are less exposed to hazards such as severe rain, flash flood, water logging and slope failure than those in the distance to roads. Nearness to the road is also a benefit for the refugees as all roads are well connected with the basic facilities such as healthcare and food distribution centre.

The tropical cyclones emerging from the Bay of Bengal hit vast areas of Bangladesh twice a year, and Rohingya refugee camps are located near these tracks, leading to the loss of lives and shelters. It is due to the type of construction material used for the shelters. For the relief camps, the administration has constructed resilient cyclone camps where the refugees can take shelter in times of emergency.

The multi-hazards Exposure index identified highly exposed areas such as camps 4, 4 Extension, 13, 17, 18, 19, 20, and 20 (fig-6.1); reasons for high Exposure vary as the camps are highly affected by floods and landslides because of the huge river network and high rainfall that loosens the soil and causes landslides. Also, the intensity of cyclones reduces as moving far away from the cyclonic path. Most camps in the extreme exposure zone are located in the south-eastern part of the study area. The influence of cyclones is strong in those areas due to the nearness to the coast. The camps in the northeast part of the Ukhiya, such as Kutapolong RC, Camp 1E, 2W, 2E,7, 8E, and 9 are located far from the cyclone path, hence less affected by the cyclone as the cyclone's intensity reduced; thereby, those camps are shown less affected by the multi-hazards. The analysis was area-specific and identified specific zones subjected to a certain level of Exposure.

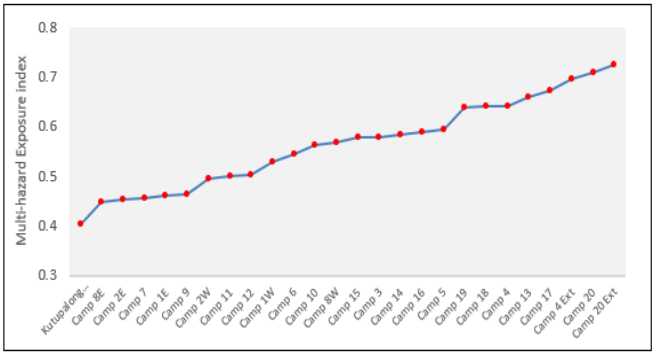


Figure 6.1: Exposed camps to multiple hazards in Cox's Bazar (Source-Self)

The results obtained from the AHP model is validated with the multi-hazard Exposure analysis done by the ARSET-NASA. It uses weather and climate variables such as mean monthly precipitation, temperature anomaly, humidity, soil moisture, slope, flow accumulation, and friction to develop the exposure Index. They considered variables available in Google Earth Engine (GEE) for the analysis and used Coarse-resolution data by employing uniform weightage schemes in GEE to calculate the Exposure. Fig-6.1 displays the multi-hazard Exposure in camps, 4, 4 extensions, 20, 20 extensions, and 8E lie under the high Exposure zone (By ARSET-NASA). That validates the results of my analysis (fig.6.1) as the multi-hazards Exposure index calculated in my research also identified the camps mentioned above under the extreme Exposure zone as, 4,4 extension, 20, 20 extensions, and 8E.

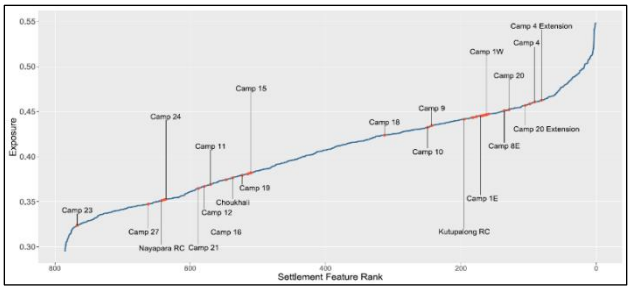


Figure 6.2: Exposed camps to multiple hazards in Cox's Bazar (Source: ASTER-

Camps 4,13, and 15 are densely populated, but the difference in Exposure is also relative to the coping capacity of the camps; as explained in the results that camp 4 has a high coping capacity as refugees are involved in economic activities that enable them to access better health facility and other daily needs in comparison to the refugees of camp 13 and 15. the number is less; hence, fewer people are exposed. The camps 13, 15, and 4 is considered extremely exposed to multiple hazards as the number of shelters, people per shelter, and the area is higher among all the camps.

Post validation of the exposed camps, it was also interesting to know the Exposure of each shelter in different camps; hence using index values of extreme to low Exposure made it possible to identify the Exposure of each shelter which can be used for the planning and policymaking by the stakeholders and also for the resilience.

The primary survey and expert knowledge were used to make the analysis more specific. The response from the questionnaire survey is used to identify gender and age-wise populations at Risk. Their responses reveal that children from 0 -12 years and women above 50 years are highly vulnerable to multiple hazards.

According to the NPM site assessment report 2017, more than 55% of the Rohingya refugees are children and women(NPM report, 2017). The birth rate in Rohingya refugee camps is extremely high. There are several reasons, such as illiteracy, lack of awareness, religion, unemployment, and early age of marriage. The major challenge for the Refugee is to carry children, particularly new-borns. They are highly exposed due to health issues, illiteracy, communication gap, lack of proper knowledge to cope with the hazards, and the language barrier.

> *"Children are highly exposed to multiple hazards and their after-effects in the form of diseases. Children in the Rohingya refugee camps are malnourished with a low immune system due to a lack of proper nutrition. Although Govt. and NGOs regularly monitor the refugees' health and hygiene, managing the world's largest refugee camp in harsh climatic conditions is challenging." (By-Expert)*

Coping capacity is an essential aspect of mitigating Risk. Here Coping capacity was used to analyse the ability of refugees to cope with the hazards. As already mentioned, there are several ways to calculate people's coping capacity, such as social, emotional, mental, and economical. The research considered only income to know peoples' financial ability during a hazard. The income estimated from the occupation was declared in the survey. The Bi-variate relationships show a negative relationship between the level of Exposure and income. As the income increases, Exposure reduces and vice-versa. According to the field survey 2022, 90 % of the employed Rohingyas are daily wage workers. The highest average income of 13666.67 BT (euro-136) per month was reported in camp 4. The camp-8W has the lowest average income, around 3000 BT (euro-30). The field survey showed that although camp four is highly exposed, it is economically strong due to its high average income. On the contrary, camps 8W,15, and 10 are moderately exposed but economically deprived, with high population density and low income. During a hazard, they cannot earn and face difficulties if did not get assistance from Govt. and NGOs'. However, some are NGO workers and site managers with fixed salaries. Hence, they are economically more potent than their other fellows. The analysis describes that although they are highly exposed to hazards, the Risk can be curbed if proper employment and other aids are provided.

> *We are daily wage workers who cannot work during floods and cyclones. Life becomes complicated as we have small kids who need food. During a hazard, the Govt sometimes provides food and other aid, but most of the time, it is complicated for us to survive without help. (By-a refugee)*

The results of risk perceptions were surprising as most of them feel insecure during a hazard. Refugees from camp-15, 18, 10, 8E and 8W felt insecure. Our analysis also confirms that those camps lie under the highly exposed zone per the MHE index. The main reason for their insecurity is the fragile houses of bamboo, hey and plastics. Refugees living on gentle slopes and near the river feared water logging due to heavy rainfall. Refugees living in the shelters at the foothills encounter slope failure and landslides after a sudden rain. Refugees near the coast fear uprooting their shelters due to high wind speed during a cyclone. In spite of all the difficulties faced, the refugees of Camp-15 and 10 (Highly exposed) showed their unwillingness to relocate.

The surveyor comments on insecurity at Cox's Bazar:

> *"During a cyclone, they fear uprooting; during a flood, they fear water logging and landslides demolishing their shelter."*

Besides understanding awareness and perception towards self-care among the refugees, we asked about some small measures which can be taken during hazards, such as the availability of first aid kits, knowledge about the early warning and food storage after an early warning. Eighty per cent of refugees are aware of early warning systems. On the other hand, there were responses, as mentioned in the quote below.

> *Before the last hazard, I did not hear anything from anyone. While returning from my workplace, the weather seemed strange as the wind blew very fast, and the sky was covered with clouds.*
> *However, no one announced the lousy weather, and I did not take it seriously. But after an hour, it turned into a severe cyclone. We experienced heavy rain with strong winds within an hour. It was a cyclone "Titli".*

Although people answered affirmatively, their statements do not support their responses. There is no digital early warning system practising in the camp. Only megaphones, hand siren, and loudspeaker is employed to inform the refugees. It is crucial to make a digital early warning system because sometimes, due to high wind speed and inaccessibility, CIC workers cannot move inside the camps to inform every Refugee.

However, most refugees know about the early warning system but are unwilling to store food. We asked whether the food was provided by the Govt. and NGOs to understand the reason for their unwillingness to store food before a hazard. Most of the refugees' answers were negative, but some confirmed that food is made available by the Govt and NGOs during a hazard. Another reason not to store food was the hand-to-mouth economy, as most are daily workers. Besides, we also inquired about medical facilities and cash assistance during a hazard. They were not given any cash assistance, but health care centres are in each camp, and each Majhi block (smaller camp unit) provides medical aid. However, there is no mobile ambulance and a medical unit that could assist refugees living in distant places from the health care unit. In 2019, after the failure of the repatriation mission, the GOB prohibited NGOs from providing cash assistance (Banerjee, 2020).
After knowing, we also asked whether they had a first aid kit at their shelter. In an emergency, they can use and survive until administrations provide aid. The answers were surprising as some refugees did not know what a first aid kit is. In that case, 80% of the respondent does not have any first aid kit. It was a critical finding regarding the health perception of Rohingya refugees at Cox's Bazar. Lastly, we asked, in case of emergency during a hazard, are you allowed to move to a safer place? The quoted statement below is the response recorded.

> *No, we are not allowed to go in any case. One of my relatives lived in the Kutapolong RC, the largest camp with many refugees. When the fire incident happened, he could not move to other safer places and died.*

The surveyor asked the site manager why mobility was not allowed outside the camp to validate the response of the Rohingya refugee. According to the site manager, due to the high number of criminal incidences outside the camp, Govt imposed strict rules for inter-camp mobility. During a hazard, it is their responsibility to evacuate people and send them to safer places. From the analysis, it can be assumed that Rohingya refugees are unsafe at Cox's Bazar refugee camp. The reasons are fragile shelter, improper early warning system, lack of awareness, health concerns, improper medical facilities, and restrictions to access safer places.

The perception behind the relocation of the population from cox Bazar to Bhashan char is in 40: 60 ratios. This is perceived based on the type of accommodation, healthcare, unemployment in the present place and the feeling of being in one community given in the Bhashan char compared to situations and facilities provided in Cox's Bazar. On the other hand, the rest perceived that they would be disconnected from the mainland and had to travel long distances for necessities. The origin of the island is also a question, and local people called it "*Bhashan Char",* meaning a floating island. Rohingya refugees have a fear that it could sink with time. The island soil is infertile. They have to depend on food provided from the mainland by the Govt. They cannot do cultivation there due to impoverishing soil. They have the fear that they cannot get food during a cyclonic season. The source of income restricts Rohingya refugees from relocation. If Govt. would provide a good source of income, health facilities, and education at Bhashan Char, people might relocate.

Bhashan Char is prone to multiple hazards such as cyclones, tidal surges, floods, and sea level rise but the Govt. took a robust initiative to make the island safe by building resilient houses and stronger cyclone shelters, food storage centres, hospitals, and school. The Rohingyas live in a pity condition at Cox's Bazar, surrounded by multiple hazards. The shelters at Bhashan Char are far better than Cox's Bazar. Now the world-renowned NGOs are moving to Bhashan Char to provide aid to the Refugees.

The only alternative to relocation reported is **Repatriation**. The Rohingya refugees neither want to relocate nor stay at Cox's Bazar; instead, they want to return to their homeland as citizens.
A refugee's word:

> ***I have been living here for the last 15 years as a refugee; I do not have any identity, home, or rights. I'm thankful to Bangladesh Govt. to provide us shelter, food and assistance, but I want to die in my homeland and be buried there as a citizen, not as a refugee."***

Although the research gave insight into the Rohingya refugees and their perceptions of risk, the research faces a lot of shortcomings, such as the unavailability of good quality datasets. As the datasets were not available freely, important indicators cannot be included. If other factors were used, the results of multi-hazards exposure would be precise. The restriction and limited time restrict the research only to a few nearby camps. For a clear picture, sample collection should be done in each camp. Apart from that, our surveyors were male, and it was difficult to interview females. If I could go, more unique results could be obtained. In the survey, simple random sampling was used; if any other method of samling would be used, heterogeneity responses could be collected that might give research new findings. The expert interviews were also limited to written ones, and I couldn't understand their view properly due to their unavailability and no scope to discuss the further leads that were observed and analysed. The availability of the internet to conduct the survey was also a restrictive factor that complicated the survey. Administrative restrictions that did not allow the surveyor to conduct a survey in Bhashan char resulted in a lack of meaningful and critical perception of people currently residing in Bhashan char.

7. CONCLUSION

The research identifies landslides, floods, and cyclones as highly impactful hazards in the Rohingya refugee camps. From the study, it is found that various factors made the Rohingya refugees vulnerable and exposed to multiple hazards such as extreme rain, nearness to the river, deforestation, living near the slope of the mountain, fragile housing material, low income, societal exclusion, improper aid from Govt. and NGOs' due to the dense population, illiteracy, unemployment and high population density, lack of awareness and self-perception towards risk. The AHP model identifies areas exposed to multi-hazards in Rohingya refugee camps. The combined results of muti-hazards exposure and shelter footprints enable us to identify each shelter based on the level of exposure. The analysis found that camps 4, 4E, 20 and 20E are highly exposed to multiple hazards. Although those camps are highly exposed, the population density is low. These camps are new extensions, well-organized, and well-managed shelters. Among all camps, camp-15 and camp-4 were found to be highly exposed in terms of population and shelter. The total population exposed in both camps was calculated to be 46888 and 34244. Among which 55% constitute children and females as per the present research. Rohingya refugees' income was used to analyse their ability to cope with hazards. It was noticed that the refugees in the high exposure zone are also economically deprived as the income of those camps was low. Although camp-4 comes under a high exposure zone, the average income of the camp is the highest among all, making it less economically deprived. Economically and socially, camp 15 was found to be deprived, as 50 per cent of the camp population was reported to be unemployed with an average income of 6086.89 BT (euro-60). It can be concluded that the refugees in camps-15 and camp-4 are highly exposed to multi-hazards and requires more concern to mitigate risk for such a large population.

The Rohingya found themself at very high-risk zone surrounded by multiple hazards. The research recognises a lack of awareness, self-care, and inadequacy in risk perception. The extended stay in the Cox's Bazar with inadequate facilities and restrictions imposed by the host country make refugees stultify. Some of them have been residing in Bangladesh since 1990. The prevailing circumstances also characterised their decision-making to relocate to Bhashan Char. Despite the possible threats in Bhashan Char, some agreed to relocate due to the terrible living conditions at Cox's Bazaar. The research found that the prime reason for the relocation is the resilient and spacious houses at Bhashan Char and the exhaustible living environment in Cox's Bazar. Nevertheless, more than 50% of the respondents were unwilling to relocate; instead, they favour **repartition.** The fear of isolation is one of the major reasons to stay at Cox's Bazar.

The research employed a mixed method approach and envisaged the contribution of the affected people and expert experience in defining an exposed location to the threat. The mixed method approach integrates the multi-hazards exposure, coping capacity and risk perception of the Rohingya refugees to investigate the ground reality. The outcome of the research is very imperative for disaster risk reduction. Identifying a specific shelter with a particular level of hazards is one of the crucial findings of the research. The colour-coded shelter footprints with the level of exposure could help stakeholders and planners with systematic planning and relief allocation during a hazard. The study also unveils numerous issues that Rohingya refugees face in Cox's Bazar. The findings also help disaster preparedness programmes by considering various refugee problems. It also contributes to preparing a camp-wise disaster risk reduction framework at the local level. The safety and security analysis were the prime focus of the study, hence contributing toward UN sustainable development goals 10.3 and 10.7 to ensure the safety of the refugee population and reduce their disaster risk.

8. RECOMMENDATION AND INTERVENTIONS

The research aim was to find the problems that Rohingya refugees are experiencing in the study area. Several problems were identified, such as hazardous location, fragile shelters, high density, inadequate facilities, lack of awareness, etc. The government and NGOs are working day and night in the challenging environment to solve those issues in the Rohingya refugee camps in Cox's Bazaar. Then why are the refugees still in misery? My research suggests that the interventions should be implemented at the local level. The average number of shelters in each is 5000. Managing such a huge community is a challenging task. Although the camp is also divided into majhee blocks still, the problem of management is prevailing. The refugee camps need grass-root level planning by dividing the shelters into a group of 50 and assigning a site manager from the GOB and one from the Rohingya refugee.

Disaster Risk Reduction is a three-phase planning approach. Hence the following intervention is suggested to mitigate the impact of multiple hazards and make Cox's Bazar safe and secure for the Rohingya refugees.

Table 8.1: Proposed intervention for Disaster Risk Reduction at Cox's Bazar Rohingya Refugee Camps.

		Intervention for mitigation risk	Hazards			Actor responsible
			L	F	C	
PREPARED	Structural	Afforestation	✓	✓	✓	RRRC and GOB
		Installation of digital devices in each *majhee* block (Early Warning)	✓	✓	✓	RRRC and GOB

		Wetland growth	✓	✓	✓	RRRC and GOB
		Floating houses retrofitting		✓		RRRC and GOB
		Local rainwater harvesting		✓	✓	RRRC, GOB, NGOs
		Net Sieve for garbage collection		✓		RRRC and GOB
		Slope labelling	✓			RRRC and GOB
		Construction of resilient shelters	✓	✓	✓	RRRC and GOB
	Non-structural	Providing first aid kits	✓	✓	✓	RRRC and GOB
		Storage of blew-up boats	✓	✓	✓	RRRC and GOB
		Engage refugees in decision-making, especially women	✓	✓	✓	RRRC, GOB, NGOs
		Spread of awareness (Disaster Risk Perception)	✓	✓	✓	NGOs'
		Participatory and collaborative planning	✓	✓	✓	NGOs'
		Education to all	✓	✓	✓	NGOs'
		Provide employment	✓	✓	✓	RRRC and GOB
		Evacuation of refugees from highly exposed region	✓	✓	✓	RRRC and GOB
RESPONSE	Non-structural	Provide health care	✓	✓	✓	RRRC, GOB, NGOs
		Food assistance	✓	✓	✓	RRRC, GOB, NGOs
		Engage refugees in Evacuation	✓	✓	✓	RRRC, GOB, NGOs
		Provide psychological support	✓	✓	✓	RRRC, GOB, NGOs
		Provide emergency health care	✓	✓	✓	RRRC, GOB, NGOs
RECOVERY	Non-structural	Garbage cleaning	✓	✓	✓	RRRC, GOB
		Checking water quality	✓	✓	✓	RRRC, GOB
		Provide hygienic food	✓	✓	✓	RRRC, GOB, NGOs
		Provide medicines and supplements	✓	✓	✓	RRRC, GOB, NGOs
		Temporary repairing of shelters	✓	✓	✓	RRRC, GOB, NGOs
		Provides health assistance to injured	✓	✓	✓	RRRC, GOB, NGOs
		Psychological support	✓	✓	✓	RRRC, GOB, NGOs

LIST OF REFERENCES

Adelekan, I.O., 2011. Vulnerability assessment of an urban flood in Nigeria: Abeokuta flood 2007. Nat. Hazards 56, 215–231. https://doi.org/10.1007/s11069-010-9564-z

Ahmed, B., 2015. Landslide susceptibility modelling applying user-defined weighting and data-driven statistical techniques in Cox's Bazar Municipality, Bangladesh. Nat. Hazards 79, 1707–1737. https://doi.org/10.1007/s11069-015-1922-4

Ahmed, B., Rahman, M.S., Sammonds, P., Islam, R., Uddin, K., 2020a. Application of geospatial technologies in developing a dynamic landslide early warning system in a humanitarian context: the Rohingya refugee crisis in Cox's Bazar, Bangladesh. Geomatics, Nat. Hazards Risk 11, 446–468. https://doi.org/10.1080/19475705.2020.1730988

Ahmed, B., Rahman, M.S., Sammonds, P., Islam, R., Uddin, K., 2020b. Application of geospatial technologies in developing a dynamic landslide early warning system in a humanitarian context: the Rohingya refugee crisis in Cox's Bazar, Bangladesh. Geomatics, Nat. Hazards Risk 11, 446–468. https://doi.org/10.1080/19475705.2020.1730988

Ahmed, I., 2009. The Rohingyas: From Stateless to Refugee.

Ahmed, N., Firoze, A., Rahman, R.M., 2020a. Machine learning for predicting landslide risk of Rohingya refugee camp infrastructure. J. Inf. Telecommun. 4, 175–198. https://doi.org/10.1080/24751839.2019.1704114

Ahmed, N., Islam, M.N., Hasan, M.F., Motahar, T., Sujauddin, M., 2019. Understanding the political ecology of forced migration and deforestation through a multi-algorithm classification approach: the case of Rohingya displacement in the southeastern border region of Bangladesh. Geol. Ecol. Landscapes 3, 282–294. https://doi.org/10.1080/24749508.2018.1558025

Ahmed, N., Mahbub, R. Bin, Rahman, R.M., 2020b. Learning to extract buildings from ultra-high-resolution drone images and noisy labels. Int. J. Remote Sens. 41, 8216–8237. https://doi.org/10.1080/01431161.2020.1763496

Alam, A., Sammonds, P., Ahmed, B., 2020a. Cyclone risk assessment of the Cox's Bazar district and Rohingya refugee camps in southeast Bangladesh. Sci. Total Environ. 704, 135360. https://doi.org/10.1016/j.scitotenv.2019.135360

Alam, A., Sammonds, P., Ahmed, B., 2020b. Cyclone risk assessment of the Cox's Bazar district and Rohingya refugee camps in southeast Bangladesh. Sci. Total Environ. 704. https://doi.org/10.1016/j.scitotenv.2019.135360

Ali, S.A., Khatun, R., Ahmad, A., Ahmad, S.N., 2020. Assessment of Cyclone Vulnerability, Hazard Evaluation and Mitigation Capacity for Analyzing Cyclone Risk using GIS Technique: a Study on Sundarban Biosphere Reserve, India. Earth Syst. Environ. 4, 71–92. https://doi.org/10.1007/S41748-019-00140-X/FIGURES/12

Anbalagan, R., Kumar, R., Lakshmanan, K., Parida, S., Neethu, S., 2015. Landslide hazard zonation mapping using frequency ratio and fuzzy logic approach, a case study of Lachung Valley, Sikkim. Geoenvironmental Disasters 2. https://doi.org/10.1186/s40677-014-0009-y

Banerjee, S., 2020. From Cox ' s Bazar to Bhasan Char : An Assessment of Bangladesh ' s Relocation Plan for Displaced Rohingyas. Obs. Res. Found. Br. 1–16.

Barrantes, G., 2018. Multi-hazard model for developing countries. Nat. Hazards 92. https://doi.org/10.1007/s11069-018-3239-6

Belfield, C., Levin, H.M., 2010. Cost-benefit analysis and cost-effectiveness analysis. Int. Encycl. Educ. 199–203. https://doi.org/10.1016/B978-0-08-044894-7.01245-8

Bernard, A., Long, N., Becker, M., Khan, J., Fanchette, S., 2021. Bangladesh's vulnerability to cyclonic coastal flooding. https://doi.org/10.5194/nhess-2021-8

Bertani, A., Di Paola, G., Russo, E., Tuzzolino, F., 2018. How to describe bivariate data. J. Thorac. Dis. 10, 1133. https://doi.org/10.21037/JTD.2018.01.134

Billing, P., 2005. Coping Capacity: towards overcoming the black hole. Eur. Comm. 18–22. https://doi.org/t http://europa.eu.int/comm/echo/evaluation/thematic_en.htm

Birkmann, J., 2006. Measuring Vulnerability to Natural Hazards.

Braun, A., Höser, T., Delgado Blasco, J.M., 2020. Elevation change of Bhasan Char measured by persistent scatterer interferometry using Sentinel-1 data in a humanitarian context. https://doi.org/10.1080/22797254.2020.1789507 54, 1–18. https://doi.org/10.1080/22797254.2020.1789507

Bremner, L., 2020. Sedimentary logics and the Rohingya refugee camps in Bangladesh. Polit. Geogr. 77, 102109. https://doi.org/10.1016/J.POLGEO.2019.102109
Brody, S.D., Highfield, W.E., Ryu, H.C., Spanel-Weber, L., 2006. Examining the relationship between wetland alteration and watershed flooding in Texas and Florida. Nat. Hazards 2006 402 40, 413–428. https://doi.org/10.1007/S11069-006-9003-3
Cardona, O.-D., van Aalst, M.K., Birkmann, Jörn, Fordham, Maureen, McGregor, Glenn, Perez, Rosa, Pulwarty, R.S., Lisa Schipper, E.F., Tan Sinh, B., Décamps, H., Keim, M., Davis, I., van Aalst, M., Birkmann, J, Fordham, M, McGregor, G, Perez, R, Pulwarty, R., Schipper, E., Sinh, B., Barros, V., Stocker, T., Qin, D., Dokken, D., Ebi, K., Mach, K., Plattner, G., Allen, S., Tignor, M., Midgley, P., 2012. Coordinating Lead Authors: Lead Authors: Review Editors: Contributing Authors:: Determinants of risk: exposure and vulnerability. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation 2 Determinants of Risk: Exposure and Vulnerability.
CARE, 2015. CARE Climate Change.
Chanu, M.L., Oinam Bakimchandra, ·, 2022. Landslide susceptibility assessment using AHP model and multi resolution DEMs along a highway in Manipur, India. Environ. Earth Sci. 81, 156. https://doi.org/10.1007/s12665-022-10281-4
Chen, W., Zhang, S., Li, R., Shahabi, H., 2018. Performance evaluation of the GIS-based data mining techniques of best-first decision tree, random forest, and naïve Bayes tree for landslide susceptibility modeling. Sci. Total Environ. 644, 1006–1018. https://doi.org/10.1016/J.SCITOTENV.2018.06.389
Cheung, S., 2012. "Migration control and the solutions impasse in South and Southeast Asia: Implications from the Rohingya experience." J. Refug. Stud. 25, 50–70. https://doi.org/10.1093/jrs/fer048
CRED, 2019. Natural Disasters. Cent. Res. Epidemiol. Disasters.
Cuaton, G.P., 2019. Ginbert Permejo Cuaton | Post-Disaster Relocation of Urban Coastal Communities in the Post-Disaster Relocation of Urban Coastal Communities in the Philippines Ginbert Permejo Cuaton | Post-Disaster Relocation of Urban Coastal Communities in the Philippine VIII, 143–153. https://doi.org/https://doi.org/10.25077/ajis.8.2.143-153.2019
Delmonaco, G., Margottini, C., Spizzichino, D., Rome, S.C., 2006. ARMONIA PROJECT (Contract n° 511208) APPLIED MULTI-RISK MAPPING OF NATURAL HAZARDS FOR IMPACT ASSESSMENT Report on new methodology for multi-risk assessment and the harmonisation of different natural risk maps SUSTAINABLE DEVELOPMENT, GLOBAL CHANGE AND EC.
Dilley, M., Chen, R.S., Deichmann, U., Lerner-Lam, A.L., Arnold, M., 2005. Natural Disaster Hotspots: A Global Risk Analysis. Nat. Disaster Hotspots. https://doi.org/10.1596/0-8213-5930-4
Douglas, I., Alam, K., Maghenda, M., Mcdonnell, Y., Mclean, L., Campbell, J., 2008. C L I M A T E , F L O O D I N G A N D U R B A N P O O R I N A F R I C A Unjust waters: climate change, fl ooding and the urban poor in Africa. IIED) 20, 187–205. https://doi.org/10.1177/0956247808089156
El Morjanil, Z.E.A., Ebener, S., Boos, J., Abdel Ghaffar, E., Musani, A., 2007. Modelling the spatial distribution of five natural hazards in the context of the WHO/EMRO Atlas of Disaster Risk as a step towards the reduction of the health impact related to disasters. Int. J. Health Geogr. 6. https://doi.org/10.1186/1476-072X-6-8
ESA, 2022. PlanetScope - Earth Online [WWW Document]. URL https://earth.esa.int/eogateway/missions/planetscope (accessed 7.11.22).
Ferdous.M, Mondal.B, R.., 2020. Integrated Flood Resilience Programme + C IFRC + C IFRC. Dhaka.
Gill, J.C., Malamud, B.D., 2014. Reviewing and visualizing the interactions of natural hazards. Rev. Geophys. 52, 680–722. https://doi.org/10.1002/2013RG000445/FORMAT/PDF
Godfrey, A., Ciurean, R.L., van Westen, C.J., Kingma, N.C., Glade, T., 2015. Assessing vulnerability of buildings to hydro-meteorological hazards using an expert based approach – An application in Nehoiu Valley, Romania. Int. J. Disaster Risk Reduct. 13, 229–241. https://doi.org/10.1016/J.IJDRR.2015.06.001
Hajian-Tilaki, K., 2013. Receiver Operating Characteristic (ROC) Curve Analysis for Medical Diagnostic Test Evaluation. Casp. J. Intern. Med. 4, 627.
Haque, M. M., Islam, S., Sikder, M. B., & Islam, M.S., 2021. Assessment of Flood Vulnerability in Jamuna Floodplain: A Case Study at Jamalpur District, Bangladesh. Res. Sq. 1–18.
HDX, 2022. HDX - Humanitarian Data Exchange [WWW Document]. URL https://data.humdata.org/organization/hdx (accessed 5.21.22).

Hein, J., 1993. Refugees , Immigrants , and the State Author (s): Jeremy Hein Source : Annual Review of Sociology , 1993 , Vol . 19 (1993), pp . 43-59 Published by : Annual Reviews Stable URL : https://www.jstor.org/stable/2083380 REFERENCES Linked references are ava 19, 43–59.
Hernández, M.L., Carreño, M.L., Castillo, L., 2018. Methodologies and tools of risk management: Hurricane risk index (HRi). Int. J. Disaster Risk Reduct. 31, 926–937. https://doi.org/10.1016/j.ijdrr.2018.08.006
Honeth, M., 2018. An Investigative EIA of Kutupalong Refugee Camp and Surroundings, Bangladesh. Swedish Civ. Contingencies Agency.
Hoque, M.A.A., Pradhan, B., Ahmed, N., Roy, S., 2019a. Tropical cyclone risk assessment using geospatial techniques for the eastern coastal region of Bangladesh. Sci. Total Environ. 692, 10–22. https://doi.org/10.1016/J.SCITOTENV.2019.07.132
Hoque, M.A.A., Pradhan, B., Ahmed, N., Roy, S., 2019b. Tropical cyclone risk assessment using geospatial techniques for the eastern coastal region of Bangladesh. Sci. Total Environ. 692, 10–22. https://doi.org/10.1016/j.scitotenv.2019.07.132
Human Rights Watch, 1996. The Rohingya Muslims: Ending a Cycle of Exodus? | HRW [WWW Document]. URL https://www.hrw.org/report/1996/09/01/rohingya-muslims-ending-cycle-exodus (accessed 1.21.22).
IOM, 2022. IOM Bangladesh Appeal 2021.
IPCC, 2021. IPCC, 2021, IPCC.
ISCG, 2020. Monsoon Response in Rohingya Refugee Camps | 12 June To 15 October 2020 | HumanitarianResponse.
Islam, M.R., Islam, M.T., Alam, M.S., Hussain, M., Haque, M.M., 2021. Is Bhasan Char Island, Noakhali district in Bangladesh a sustainable place for the relocated Rohingya displaced people? An empirical study. SN Soc. Sci. 1, 1–24. https://doi.org/10.1007/s43545-021-00281-9
Islam, R., Md, ·, Islam, T., Mohammad, ·, Alam, S., Hussain, M., Muhammad, ·, Haque, M., 2021. Is Bhasan Char Island, Noakhali district in Bangladesh a sustainable place for the relocated Rohingya displaced people? An empirical study. SN Soc Sci 1, 277. https://doi.org/10.1007/s43545-021-00281-9
Jebb, A.T., Ng, V., Tay, L., 2021. A Review of Key Likert Scale Development Advances: 1995–2019. Front. Psychol. 12, 1–14. https://doi.org/10.3389/fpsyg.2021.637547
Jeong, S., Yoon, D.K., 2018. Examining vulnerability factors to natural disasters with a spatial autoregressive model: The case of south Korea. Sustain. 10, 1–13. https://doi.org/10.3390/su10051651
Jun, S.M., Kang, M.S., Hwang, S., Park, J., Song, J.H., 2020. Flood vulnerability assessment for prioritizing and evaluating rehabilitation of ungauged reservoirs considering climate change. Water (Switzerland) 12. https://doi.org/10.3390/w12071901
Kappes, M. S., Gruber, K., Frigerio, S., Bell, R., Keiler, M., Glade, T., 2012. The MultiRISK platform: The technical concept and application of a regional-scale multihazard exposure analysis tool. Geomorphology. https://doi.org/10.1016/j.geomorph.2012.01.024
Kappes, Melanie S, Keiler, M., von Elverfeldt, K., Glade, T., 2012. Challenges of analyzing multi-hazard risk: A review. Nat. Hazards 64, 1925–1958. https://doi.org/10.1007/s11069-012-0294-2
Khan, N., 2020. Critical Review of Sampling Techniques in the Research Process in the World. SSRN Electron. J. https://doi.org/10.2139/ssrn.3572336
Kibreab, G., 2003. Citizenship rights and repatriation of refugees. Int. Migr. Rev. 37, 24–73. https://doi.org/10.1111/j.1747-7379.2003.tb00129.x
Konrad, C.E., Perry, L.B., 2010. Relationships between tropical cyclones and heavy rainfall in the Carolina region of the USA. Int. J. Climatol. 30, 522–534. https://doi.org/10.1002/JOC.1894
Kunz, M., Hurni, L., 2008. Hazard Maps in Switzerland State-of-the-Art and Potential Improvements. 6th ICA Mt. Cartogr. Work. Mt. Mapp. Vis. 133–138.
Lavell, A., Oppenheimer, M., Diop, C., Hess, J., Lempert, R., Li, J., Muir-Wood, R., Myeong, S., Moser, S., Takeuchi, K., Cardona, O.D., Hallegatte, S., Lemos, M., Little, C., Lotsch, A., Weber, E., 2012. Climate Change: New Dimensions in Disaster Risk, Exposure, Vulnerability, and Resilience. Manag. Risks Extrem. Events Disasters to Adv. Clim. Chang. Adapt. Spec. Rep. Intergov. Panel Clim. Chang. 9781107025066, 25–64. https://doi.org/10.1017/CBO9781139177245.004
Leal, M., Reis, E., Pereira, S., Santos, P.P., 2021. Physical vulnerability assessment to flash floods using an indicator-based methodology based on building properties and flow parameters. J. Flood Risk Manag. 14, 1–19. https://doi.org/10.1111/jfr3.12712

Malgwi, M.B., Fuchs, S., Keiler, M., 2020. A generic physical vulnerability model for floods: Review and concept for data-scarce regions. Nat. Hazards Earth Syst. Sci. 20, 2067–2090. https://doi.org/10.5194/nhess-20-2067-2020
Mebarki, A., Valencia, N., Salagnac, J.L., Barroca, B., 2012. Flood hazards and masonry constructions: a probabilistic framework for damage, risk and resilience at urban scale. Nat. Hazards Earth Syst. Sci. 12, 1799–1809. https://doi.org/10.5194/NHESS-12-1799-2012
Milton, A.H., Rahman, M., Hussain, S., Jindal, C., Choudhury, S., Akter, S., Ferdousi, S., Mouly, T.A., Hall, J., Efird, J.T., 2017. Trapped in Statelessness: Rohingya Refugees in Bangladesh. Int. J. Environ. Res. Public Heal. 2017, Vol. 14, Page 942 14, 942. https://doi.org/10.3390/IJERPH14080942
Miranda, F.N., Ferreira, T.M., 2019. A simplified approach for flood vulnerability assessment of historic sites. Nat. Hazards 96, 713–730. https://doi.org/10.1007/S11069-018-03565-1/FIGURES/9
Nahm, F.S., 2022. Receiver operating characteristic curve: overview and practical use for clinicians. Korean J. Anesthesiol. 75, 25. https://doi.org/10.4097/KJA.21209
Nasiri, H., Yusof, M.J.M., Ali, T.A.M., Hussein, M.K.B., 2019. District flood vulnerability index: urban decision-making tool. Int. J. Environ. Sci. Technol. 16, 2249–2258. https://doi.org/10.1007/s13762-018-1797-5
Nelson, E.L., Saade, D.R., Gregg Greenough, P., 2020. Gender-based vulnerability: Combining Pareto ranking and spatial statistics to model gender-based vulnerability in Rohingya refugee settlements in Bangladesh. Int. J. Health Geogr. 19, 1–14. https://doi.org/10.1186/s12942-020-00215-3
Nguyen, H., Lewis, T., 2022. Bhasan Char and Refugee 'Warehousing' – The Diplomat [WWW Document]. Dipl. URL https://thediplomat.com/2022/02/bhasan-char-and-refugee-warehousing/ (accessed 8.15.22).
NPM report, 2017. Npm R6 Report.
OpenAerialMap, 2022. OpenAerialMap Docs [WWW Document]. URL https://docs.openaerialmap.org/ecosystem/ (accessed 7.14.22).
Pakhtunkhwa, N.K., Nazeer, M., 2019. Flood Vulnerability Assessment through Different Methodological Approaches in the Context of North-West Khyber Pakhtunkhwa, Pakistan. Sustain. 11, 18.
Papathoma-Köhle, M., 2016. Vulnerability curves vs. vulnerability indicators: application of an indicator-based methodology for debris-flow hazards. Hazards Earth Syst. Sci 16, 1771–1790. https://doi.org/10.5194/nhess-16-1771-2016
Papathoma-Köhle, M., Schlögl, M., Fuchs, S., 2019. Vulnerability indicators for natural hazards: an innovative selection and weighting approach. Sci. Rep. 9, 1–14. https://doi.org/10.1038/s41598-019-50257-2
Pauer, F., Schmidt, K., Babac, A., Damm, K., Frank, M., Von Der Schulenburg, J.M.G., 2016. Comparison of different approaches applied in Analytic Hierarchy Process – an example of information needs of patients with rare diseases. BMC Med. Inform. Decis. Mak. 16. https://doi.org/10.1186/S12911-016-0346-8
Paul, B.K., 2009. Why relatively fewer people died? The case of Bangladesh's cyclone sidr. Nat. Hazards 50, 289–304. https://doi.org/10.1007/S11069-008-9340-5/FIGURES/5
Pollock, W., Wartman, J., Abou-Jaoude, G., Grant, A., 2019. Risk at the margins: A natural hazards perspective on the Syrian refugee crisis in Lebanon. Int. J. Disaster Risk Reduct. 36, 101037. https://doi.org/10.1016/j.ijdrr.2018.11.026
Quader, M.A., Dey, H., Malak, M.A., Sajib, A.M., 2021. Rohingya refugee flooding and changes of the physical and social landscape in Ukhiya, Bangladesh. Environ. Dev. Sustain. 23, 4634–4658. https://doi.org/10.1007/s10668-020-00792-0
Quader, M.A., Khan, A.U., Kervyn, M., 2017. Assessing risks from cyclones for human lives and livelihoods in the coastal region of Bangladesh. Int. J. Environ. Res. Public Health 14. https://doi.org/10.3390/ijerph14080831
Rahman, G., Atta-Ur-Rahman, Samiullah, Collins, A.E., 2017. Geospatial analysis of landslide susceptibility and zonation in shahpur valley, eastern hindu kush using frequency ratio model. Proc. Pakistan Acad. Sci. Part B 54, 149–163.
Robinson, R., 1993. Cost-benefit analysis. Br. Med. J. 307, 924–926. https://doi.org/10.1136/BMJ.307.6909.924
Saaty, T.L., 1977. A scaling method for priorities in hierarchical structures. J. Math. Psychol. 15, 234–281. https://doi.org/10.1016/0022-2496(77)90033-5
Santos, C., Ferreira, T.M., Vicente, R., Mendes da Silva, J.A.R., 2013. Building typologies identification to

support risk mitigation at the urban scale – Case study of the old city centre of Seixal, Portugal. J. Cult. Herit. 14, 449–463. https://doi.org/10.1016/J.CULHER.2012.11.001
Shano, L., Raghuvanshi, T.K., Meten, M., 2021. Landslide susceptibility mapping using frequency ratio model: the case of Gamo highland, South Ethiopia. Arab. J. Geosci. 14, 1–18. https://doi.org/10.1007/S12517-021-06995-7/TABLES/2
Silva, M., Pereira, S., 2014. Assessment of physical vulnerability and potential losses of buildings due to shallow slides. Nat. Hazards 72, 1029–1050. https://doi.org/10.1007/S11069-014-1052-4/TABLES/3
Sohel, M.S., 2017. Saudi Journal of Humanities and Social Sciences The Rohingya Crisis in Myanmar: Origin and Emergence. https://doi.org/10.21276/sjhss.2017.2.11.1
Stephenson, V., D'Ayala, D., 2014. A new approach to flood vulnerability assessment for historic buildings in England. Nat. Hazards Earth Syst. Sci. 14, 1035–1048. https://doi.org/10.5194/NHESS-14-1035-2014
Taherdoost, H., 2016. Sampling Methods in Research Methodology; How to Choose a Sampling Technique for Research. Int. J. Acad. Res. Manag.
Tehrani, F.S., Hüsken, L., 2019. Landslide susceptibility mapping of refugee camps in Bangladesh. 2nd Int. Conf. Nat. Hazards Infrastruct.
The White House, 2021. Report on the Impact Ofclimate Change on Migration.
UN/ISDR, 2005. Building the Resilience of Nations and Communities to Disasters, International Strategy for Disaster Reduction.
UN/ISDR, 2004. Living with risk: a global review of disaster reduction initiatives, UN Publications. https://doi.org/9211010640
UN, 2002. Plan of Implementation of the World Summit on Sustainable Development Contents.
UNCHR, 2018. Global trends: Forced displacement in 2017. Glob. Trends 76.
UNDP, 2018. Extreme Weather and Disaster Preparedness in the Rohingya Refugee Response - Monsoon Season 2018 Lessons Learnt.
UNDRR, 2022. Global Assesment Report on Disaster Risk Reduction. UN Publ. 1, 1–28.
UNDRR, 2021. UNDRR [WWW Document]. URL https://www.undrr.org/terminology/disaster-risk (accessed 11.11.21).
UNEP, 1992. United Nations Conference on Environment & Development. United Nations Sustain. Dev. 1, 7.61.
UNHCR, 2019. Global Trends Forced Displacemnet in 2018.
UNHCR, 2018a. Trends at a Glance.
UNHCR, 2018b. Culture , Context and Mental Health of Rohingya Refugees, UNHCR: The UN Refugee Agency.
UNISDR, 2009. UNISDR Terminology on Disaster Risk Reduction.
van Westen, C., 1994. 5.3 Vulnerability.
Wang, J., He, Z., Weng, W., 2020. A review of the research into the relations between hazards in multi-hazard risk analysis. Nat. Hazards 104, 2003–2026. https://doi.org/10.1007/s11069-020-04259-3
Wedley, W.C., 1993. CONSISTENCY PREDICTION FOR INCOMPLETE AHP MATRICES. Mathl. Comput. Model. 17, 151–161.
Williamson, D.F., Parker, R.A., Kendrick, J.S., 1989. The box plot: A simple visual method to interpret data. Ann. Intern. Med. 110, 916–921. https://doi.org/10.7326/0003-4819-110-11-916
World Bank Group, 2021. Bangladesh : Finding It Difficult to Keep Cool [WWW Document]. URL https://openknowledge.worldbank.org/handle/10986/36534?locale-attribute=es (accessed 5.25.22).
Zaman, S., Sammonds, P., Ahmed, B., Rahman, T., 2020a. Disaster risk reduction in conflict contexts: Lessons learned from the lived experiences of Rohingya refugees in Cox's Bazar, Bangladesh. Int. J. Disaster Risk Reduct. 50, 101694. https://doi.org/10.1016/j.ijdrr.2020.101694
Zaman, S., Sammonds, P., Ahmed, B., Rahman, T., 2020b. Disaster risk reduction in conflict contexts: Lessons learned from the lived experiences of Rohingya refugees in Cox's Bazar, Bangladesh. Int. J. disaster risk Reduct. IJDRR 50. https://doi.org/10.1016/J.IJDRR.2020.101694
Zhou, Y., Li, N., Wu, W., Wu, J., 2014. Assessment of provincial social vulnerability to natural disasters in China. Nat. Hazards 71, 2165–2186. https://doi.org/10.1007/S11069-013-1003-5

APPENDIX

Annex-1

Rohingya Refugees-Household Survey

General Information

1. Gender

লিঙ্গ

Observe and Write

- ◯ Female-মহিলা
- ◯ Male-পুরুষ

2. Age-বয়স

Observe and Write-পর্যবেক্ষণ করুন এবং লিখুন

_____

3. Education-শিক্ষা

- ☐ Read
- ☐ Write
- ☐ Primary
- ☐ Secondary
- ☐ illiterate

4. Occupation-পেশা

5. For how long have you been living in the camp?

- ◯ 0-5
- ◯ 5-10
- ◯ 10-15
- ◯ 15-20
- ◯ >20

House Material- (Observe and Write)

6-Floor type

Observe and Write

- ☐ Kacha
- ☐ Semi Pakka
- ☐ Pakka

7- Roof type

- ☐ Plastic
- ☐ Bamboo+Hay
- ☐ Concrete

. 8-Wall material

- ☐ Bamboo
- ☐ Mud+Bamboo
- ☐ Concrete

Multiple Hazard

9-. According to your experience, which hazard is more severe? *আপনার অভিজ্ঞতা অনুযায়ী, কোন বিপদ বেশি গুরুতর?*	Very Low	Low	Medium	High
Flood-বন্যা	◯	◯	◯	◯
Cyclone-ঘূর্ণবাত	◯	◯	◯	◯
Landslide-ধস	◯	◯	◯	◯

10. If there is any other hazard which you think more deadly than the above mentioned, Please specify?

_____

11. Please grade the following elements concerning how much they contribute to flooding.	V. Low	Low	Medium	High
Heavy Rainfall	◯	◯	◯	◯
Nearness to River	◯	◯	◯	◯

12. Please grade the following elements concerning how much they contribute to make you vulnerable to Flooding?	V. Low	Low	Medium	High
Blocked Drainage	◯	◯	◯	◯
Distance to Flood shelter	◯	◯	◯	◯
Distance to health care center	◯	◯	◯	◯
Poor health facilities	◯	◯	◯	◯

13. Which of the following more affected by the Flood water?	V.Low	Low	Medium	High
Children (0 - 12)	◯	◯	◯	◯
Female (Below 50)	◯	◯	◯	◯
Male (Below 50)	◯	◯	◯	◯

Elderly -Female (Above-50)	◯	◯	◯	◯
Elderly- Male (Above-50)	◯	◯	◯	◯
Floor	◯	◯	◯	◯
Roof	◯	◯	◯	◯
Wall	◯	◯	◯	◯
Roads	◯	◯	◯	◯
14. Please grade the following elements concerning how much they contribute to Cyclone.	V. Low	Low	Medium	High
Wind Velocity	◯	◯	◯	◯
Extreme Rainfall	◯	◯	◯	◯
Cyclone Surge (Height of the Seawater)	◯	◯	◯	◯
15. Please grade the following elements concerning how much they contribute to make you vulnerable to Cyclone?	V Low	Low	Medium	High
Distance to Coastline	◯	◯	◯	◯
Distance to Cyclone Shelter	◯	◯	◯	◯
Distance to Health care facility	◯	◯	◯	◯
16. Which of the following more affected by the Cyclone?	V. Low	Low	Medium	High
Children (0 - 12)	◯	◯	◯	◯
Female (Below 50)	◯	◯	◯	◯
Male (Below 50)	◯	◯	◯	◯
Elderly -Female (Above-50)	◯	◯	◯	◯

Elderly- Male (Above-50)	◯	◯	◯	◯
Floor	◯	◯	◯	◯
Roof	◯	◯	◯	◯
Wall	◯	◯	◯	◯
Roads	◯	◯	◯	◯
17. Please grade the following elements concerning how much they contribute to Landslide?	V Low	Low	Medium	High
Rainfall	◯	◯	◯	◯
Hill	◯	◯	◯	◯
Steep slope	◯	◯	◯	◯
Ridge	◯	◯	◯	◯
18. Please grade the following elements concerning how much they contribute to make you vulnerable to Landslide?	V Low	Low	Medium	High
Nearness to Landslide zone	◯	◯	◯	◯
Nearness to River	◯	◯	◯	◯
Vegetation Cover	◯	◯	◯	◯
Distance to Healthcare facility	◯	◯	◯	◯
19. Which of the following more affected by the Landslider?	V Low	Low	Medium	High
Children (0 - 12)	◯	◯	◯	◯
Female (Below 50)	◯	◯	◯	◯
Male (Below 50)	◯	◯	◯	◯

Elderly -Female (Above-50)	◯	◯	◯	◯
Elderly- Male (Above-50)	◯	◯	◯	◯
Roads	◯	◯	◯	◯
House structure	◯	◯	◯	◯
20. What was your biggest loss during the Last year (2021) flood?	V Low	Low	Medium	High
Bed	◯	◯	◯	◯
Mattress	◯	◯	◯	◯
Clothes	◯	◯	◯	◯
Food	◯	◯	◯	◯
Documents	◯	◯	◯	◯
Monetary assets	◯	◯	◯	◯
Others	◯	◯	◯	◯
21. . What was your biggest loss during the Last year (2021) Cyclone?	V Low	Low	Medium	High
Bed	◯	◯	◯	◯
Mattress	◯	◯	◯	◯
Clothes	◯	◯	◯	◯
Food	◯	◯	◯	◯
Documents	◯	◯	◯	◯
Monetary assets	◯	◯	◯	◯
Others	◯	◯	◯	◯

22. What was your biggest loss during the Last year (2021) Landslide?	V Low	Low	Medium	High
Bed	◯	◯	◯	◯
Mattress	◯	◯	◯	◯
Clothes	◯	◯	◯	◯
Food	◯	◯	◯	◯
Documents	◯	◯	◯	◯
Monetary assets	◯	◯	◯	◯
Others	◯	◯	◯	◯

23. If Others Specify.

Coping Capacity

24. How safe do you fell during a Hazard in your Jhupri?	unsafe	Little safe	Safe	Very Safe
Secure scale	◯	◯	◯	◯

25. Is there any early warning system to warn refugees before a hazard?

- ◯ Yes
- ◯ No
- ◯ I do not know

26 .Do you store food after an early warning?

- ◯ Yes
- ◯ No

27. Did you get Food during the last Hazard?

- [ ] Yes
- [ ] No
- [ ] Prepare own Food
- [ ] Ready to eat food

28. Did you get cash assistant during the last hazard?

- ◯ Yes
- ◯ No

29. Do you have a first aid kit in your house?

- ◯ Yes
- ◯ No

30. . Do you get medical help during a hazard, if you cannot move?

- ◯ Yes
- ◯ No

31. Do you allowed to go a safer place beyond the camp boundary during a hazard?

- ◯ Yes
- ◯ No

Perception regarding Relocation to Bhashan Char

32. Do you want to move to Bhashan Char?

- ◯ Yes
- ◯ No

33. If yes

- [ ] Good Quality Houses
- [ ] Sufficient Living Spaces
- [ ] Own Community
- [ ] Protective Houses to Hazards
- [ ] Others

Specify Other?

---

34. If no

- [ ] Fear of Isolation
- [ ] Fear of different hazards
- [ ] Lack of Sufficient Food due to distance
- [ ] Under military surveillance
- [ ] Lack of freedom to access anywhere
- [ ] Others

Specify Other?

---

35. If you were given the opportunity to go anywhere where would you like to go?

- ◯ Your Own Country
- ◯ Other Places

Reason

Annex_2

Rohingya Refugees- Expert interview

General Information

Designation

_____

Experties

_____

Perception towards Cox's Bazar Rohingya Refugee Camp

1- According to your experience, which hazard is more severe in Rohingya Refugee camp? *আপনার অভিজ্ঞতা অনুযায়ী, কোন বিপদ বেশি গুরুতর?*	Very Low	Low	Medium	High
Flood-বন্যা	◯	◯	◯	◯
Cyclone-ঘূর্ণবাত	◯	◯	◯	◯
Landslide-ধস	◯	◯	◯	◯

2. If there is any other hazard which you think is deadly , Please specify?

_____

3. To your understanding, all the Rohingya Refugees are equally affected by those hazards?

_____

What do you think which camp in the Ukihya Upzilla is more affected by the combined action of all hazards?

_____

4. Do you think Rohingya Refugees are Vulnerable to multiple hazards at Cox's Bazar?

- ◯ Yes
- ◯ No

5. If yes, please explain the reasons as per your expertise?

_____

6. If No, please specify?

_____

8. Please grade the following elements concerning how much they contribute to flooding.	V. Low	Low	Medium	High
Heavy Rainfall	◯	◯	◯	◯
Nearness to River	◯	◯	◯	◯

9. Please grade the following elements concerning how much they contribute to make you vulnerable to Flooding?	V. Low	Low	Medium	High
Blocked Drainage	◯	◯	◯	◯
Distance to Flood shelter	◯	◯	◯	◯
Distance to health care center	◯	◯	◯	◯
Poor health facilities	◯	◯	◯	◯

10. Please grade the following elements concerning how much they contribute to Cyclone.	V. Low	Low	Medium	High
Wind Velocity	◯	◯	◯	◯
Extreme Rainfall	◯	◯	◯	◯
Cyclone Surge (Height of the Seawater)	◯	◯	◯	◯

11. Please grade the following elements concerning how much they contribute to make you vulnerable to Cyclone?	V Low	Low	Medium	High
Distance to Coastline	◯	◯	◯	◯
Distance to Cyclone Shelter	◯	◯	◯	◯
Distance to Health care facility	◯	◯	◯	◯

12. Please grade the following elements concerning how much they contribute to Landslide?	V Low	Low	Medium	High
Rainfall	◯	◯	◯	◯
Hill	◯	◯	◯	◯
Steep slope	◯	◯	◯	◯
Ridge	◯	◯	◯	◯

13. Please grade the following elements concerning how much they contribute to make you vulnerable to Landslide?	V Low	Low	Medium	High
Nearness to Landslide zone	◯	◯	◯	◯
Nearness to River	◯	◯	◯	◯
Vegetation Cover	◯	◯	◯	◯
Distance to Healthcare facility	◯	◯	◯	◯

14. Which demographic section of Rohingya Refugees is most affected by those hazards?	Option	Option
Children (0–12)	◯	◯

Elderly Female (above-50)	◯	◯
Elderly Male (above-50)	◯	◯
Female (below-50)	◯	◯
Male (below-50)	◯	◯

15. According to your experience, what is the best way to mitigate the consequences of those hazards in Rohingya Refugee camp at Cox'sBazar??

- ☐ Building resilient houses
- ☐ Allocation of more hazard shelter
- ☐ Afforestation
- ☐ Refuges' Participation in Policy making (Community based approach)
- ☐ Improvement in Early Warning system
- ☐ Provide training to Refugees
- ☐ Relocation
- ☐ Others

16. If others, please specify?

Perception towards Bhashan Char Rohingya Refugee Camp

1. Which hazard and disaster mostly affect Bhashan Char?	High	Medium	Low
Cyclone	◯	◯	◯
Strome surges	◯	◯	◯
Sea Level Rise	◯	◯	◯
Flooding	◯	◯	◯
Coastal Erosion	◯	◯	◯
Others	◯	◯	◯

Specify Other?

---

2. What is your opinion about the quality of infrastructure and facilities in the Bhashan Char?	Good	Standard	Poor	N/A
Buildings	◯	◯	◯	◯
Roads	◯	◯	◯	◯

Medical Facilities	◯	◯	◯	◯
Security	◯	◯	◯	◯
Accessibility	◯	◯	◯	◯
Soil	◯	◯	◯	◯
Education System	◯	◯	◯	◯
Farming	◯	◯	◯	◯
Connectivity	◯	◯	◯	◯

3. What is reason behind choosing Bhashan Char as a relocation site?

_____

4.Is there any other place where Rohingya Refugees might be relocated besides Bhashan Char?

_____

5.As an expert, what is your opinion regarding the relocation of Rohingya Refugees to Bhashan Char?

_____

CODE_1

```
library(rgdal)
library(ggplot2)
library(raster)
library(sp)

hi <- raster('HI.tif')
hi@extent

hi.reproject <-projectRaster(hi, crs=crs(ahp))

training_data  = as.data.frame(extract(hi.reproject, a))
names(training_data) <- c('risk')
training_data$risk <- ifelse(training_data$risk>0.4, 1, 0)
pred <- training_data$risk
ind <- as.vector(which(is.na(pred)))
pred.na <- pred[-ind]
resp.na <- a$risk_of_ei[-ind]
resp.na <- ifelse(resp.na=='No', 0, 1)
par(new=TRUE)
plot(roc.obj, main='roc', col='blue')
plot.roc(roc.obj, col = 'blue',xlab = 'True Negative Rate', ylab='True Positive Rate', main='ROC Curve')
auc.obj <- auc(roc.obj)
auc.obj
```

CODE_2

```
library(rgdal)
library(ggplot2)
library(geom)
setwd()
a <- readOGR('Color_Building.shp')

data <- data.frame(
  name= a$MEAN,
  camp= a$cmp_name
)

data%>%
  ggplot(aes(x=camp, y=name, fill=camp))+
  geom_boxplot()+
  scale_fill_viridis(discrete = TRUE, alpha=0.6) +
  theme_ipsum() +
  theme(
    legend.position="none",
    plot.title = element_text(size=12),
    axis.title.x = element_text(size=15),
    axis.title.y = element_text(size=15),
    axis.text.x = element_text(size =12, angle = 45, vjust = 1, hjust = 1),
 ) +

 xlab("Camps") + ylab("Multi-hazard Exposure Index")
```

Annex_3

Indicators to assess multi-hazard Exposure to landslide

Sl. no	Indicators	Publications	No. of Publications
1	slope	(Chanu and Oinam Bakimchandra, 2022), (B. Ahmed et al., 2020a),(N. Ahmed et al., 2020a), (Tehrani and Hüsken, 2019),(Chen et al., 2018), (Shano et al., 2021),(Ahmed, 2015),(Rahman et al., 2017),(Anbalagan et al., 2015)	9
2	elevation	(Chanu and Oinam Bakimchandra, 2022), (N. Ahmed et al., 2020a), (Tehrani and Hüsken, 2019), (Chen et al., 2018), (Shano et al., 2021), (Ahmed, 2015)	7
3	distance to road	(Chanu and Oinam Bakimchandra, 2022),	2
4	distance to streams	(Chanu and Oinam Bakimchandra, 2022), (Ahmed, 2015)	2
5	distance to faults	(Chanu and Oinam Bakimchandra, 2022), (B. Ahmed et al., 2020a),(Tehrani and Hüsken, 2019), (Chen et al., 2018),(Shano et al., 2021), (Ahmed, 2015), (Rahman et al., 2017),(Anbalagan et al., 2015)	9
6	LULC	(Chanu and Oinam Bakimchandra, 2022), (B. Ahmed et al., 2020a),	2

7	NDVI	(Chanu and Oinam Bakimchandra, 2022),(B. Ahmed et al., 2020a), (N. Ahmed et al., 2020a), (Tehrani and Hüsken, 2019), (Chen et al., 2018), (Ahmed, 2015)	6

Annex_2

Indicators to assess hazards and Exposure to floods

Sl no	Indicators	Publications	No.of publications
1	The proportion of low-cost buildings	(Nasiri et al., 2019), (Melanie S Kappes et al., 2012)	2
2	Length of drainage system	(Nasiri et al., 2019) (Brody et al., 2006),(Zhou et al., 2014)	3
3	Material	(Papathoma-Köhle et al., 2019), (Melanie S Kappes et al., 2012), (Malgwi et al., 2020), (Leal et al., 2021), (Miranda and Ferreira, 2019), (Stephenson and D'Ayala, 2014), (Mebarki et al., 2012), (Silva and Pereira, 2014) , (Pakhtunkhwa and Nazeer, 2019), (Haque, M. M., Islam, S., Sikder, M. B., & Islam, 2021),(Jeong and Yoon, 2018), (Adelekan, 2011)	12
4	Number of floors	(Papathoma-Köhle et al., 2019), (Melanie S Kappes et al., 2012), (Leal et al., 2021), (Papathoma-Köhle, 2016), (Miranda and Ferreira, 2019), (Stephenson and D'Ayala, 2014), (Mebarki et al., 2012), (Godfrey et al., 2015), (Silva and Pereira, 2014), (Zhou et al., 2014),	9
5	Existence of basement	(Papathoma-Köhle et al., 2019), (Melanie S Kappes et al., 2012), (Godfrey et al., 2015)	3
6	Steepness of the ground	(Papathoma-Köhle et al., 2019), (Melanie S Kappes et al., 2012), (Godfrey et al., 2015), (Brody et al., 2006), (Jeong and Yoon, 2018)	5
7	Roof materials	(Papathoma-Köhle et al., 2019), (Kappes et al., 2012)	2

8	Building Condition	(Malgwi et al., 2020), (Leal et al., 2021), (Papathoma-Köhle, 2016), (Miranda and Ferreira, 2019), (Stephenson and D'Ayala, 2014), (Jeong and Yoon, 2018), (Mebarki et al., 2012), (Godfrey et al., 2015), (Pakhtunkhwa and Nazeer, 2019)	8
9	Distance to Channel	(Malgwi et al., 2020), (Leal et al., 2021), (Adelekan, 2011)	3
10	Flood Depth	(Malgwi et al., 2020), (Leal et al., 2021), (Adelekan, 2011)	3
11	Openings	(Leal et al., 2021), (Papathoma-Köhle et al., 2019), (Malgwi et al., 2020), (Godfrey et al., 2015)	4
12	Age of the Building	(Leal et al., 2021), (Papathoma-Köhle et al., 2019), (Malgwi et al., 2020), (Papathoma-Köhle, 2016), (Miranda and Ferreira, 2019), (Stephenson and D'Ayala, 2014), (Santos et al., 2013), (Godfrey et al., 2015), (Zhou et al., 2014),	9
13	Amount of rainfall	(Nasiri et al., 2019), (Brody et al., 2006), (Jun et al., 2020), (Jeong and Yoon, 2018)	4
14	No. of River	(Nasiri et al., 2019), (Brody et al., 2006),	2
15	Land use	(Nasiri et al., 2019), (Papathoma-Köhle et al., 2019), (Melanie S Kappes et al., 2012), (Jeong and Yoon, 2018),	4
16	Runoff amount from rainfall regards to different land uses	(Nasiri et al., 2019)	1

Indicators to assess vulnerability and Exposure to cyclone

Sl no.	Indicators	Publications	No.of Publications
1	Wind speed	(Konrad and Perry, 2010),(Hernández et al., 2018),(Ali et al., 2020),(Paul, 2009),(Hoque et al., 2019b),(Hoque et al., 2019a)	5
2	Distance from cyclone track	(Ali et al., 2020), (Hernández et al., 2018) , (Hoque et al., 2019), (Hoque et al., 2019a),	5
3	Distance from coastline	(Ali et al., 2020), (Hernández et al., 2018),(Ali et al., 2020), (Hoque et al., 2019	4
4	Health care facility	(Konrad and Perry, 2010)	2
5	Population density	(Quader et al., 2017), (Ali et al., 2020)	2
6	Access to road	(Bernard et al., 2021)	1
7	Access to shelter	(Alam et al., 2020b)	1
8	Distance to shelter	(Alam et al., 2020b)	1

Annex-4

Multi-hazards exposure indicators reported from Literature, RR and expert surveys, and available data.

Multihazards	**exposure indicators**	**Literature**	**Expert-interviews**	**Rohingya refugee survey**	**Available data**
Landslide	Rainfall	✓	✓	✓	✓
	Fault	✓	✓	×	✓
	Steepness	✓	✓	✓	✓
	Vegetation cover	✓	✓	×	✓
	Landslide zone	✓	✓	×	✓
Flood	Flood zone or river	✓	✓	✓	✓
	Road	✓	✓	✓	✓
	Rainfall	✓	✓	✓	✓
	Flood shelter	✓	×	×	×
	Healthcare centre	✓	×	×	×
	Poor health care facilities	✓	×	×	×
Cyclone	Cyclone track	✓	✓	×	✓
	Cyclone shelter	✓	✓	✓	✓
	Vegetation	✓	✓	×	✓
	Coastline	✓	×	×	×
	Health care facilities	✓	×	×	✓

Selected indicators

Annex_5

Camp name	Multi-hazard Exposure zone				Total Shelters	Total Population
	Low	Moderate	High	Extreme		
Camp 1E	5455	172	0	0	5627	22508
Camp 1W	1069	5479	6	0	6554	26216
Camp 2E	4082	699	0	0	4781	19124
Camp 2W	2828	2096	0	0	4924	19696
Camp 3	0	5443	981	0	6424	25696
Camp 4	0	759	7758	44	8561	34244
Camp 4 EXT	0	0	1014	738	1752	7008
Camp 5	0	3845	2294	0	6139	24556
Camp 6	111	4975	2	0	5088	20352
Camp 7	5398	1336	0	0	6734	26936
Camp 8E	5304	612	0	0	5916	23664
Camp 8W	179	5892	1422	0	7493	29972

Camp 9	4687	1286	2	0	5975	23900
Camp 10	443	4908	1146	0	6497	25988
Camp 11	2623	3294	6	0	5923	23692
Camp 12	2431	2448	547	0	5426	21704
Camp 13	0	418	6187	1113	7718	30872
Camp 14	204	4330	2929	0	7463	29852
Camp 15	7	8927	2788	0	11722	46888
Camp 16	59	2704	2297	0	5060	20240
Camp 17	0	37	4977	1018	6032	24128
Camp 18	0	399	7231	63	7693	30772
Camp 19	79	1076	4048	477	5680	22720
Camp 20	0	0	937	1589	2526	10104
Camp 20E	0	0	126	1654	1780	7120
Kutupalong RC	3004	0	0	0	3004	12016
Total						