Intellectual Output 1

A review of climate change impact on the built environment in coastal regions

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Table of Contents

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1 Introduction

The climate change impact highly threatens coastal regions. Coastal populations face a range of climate-related risks such as cyclones, sea-level rise, and coastal flooding. The built environment exerts considerable influence over the local climate and environment of coastal communities. Coastal areas being highly populated with urban centres being located near the coastal belts further increases the predicament. Considering this, developing tangible climate adaptation measures in the coastal built environments is vital. In developing suitable adaptation measures, it is essential to understand the impacts of climate change on the coastal built environment in detail. This research is conducted as a part of BEACON (Built Environment leArning for Climate adaptation), a collaborative research project co-funded by the EU Erasmus+ programme of the European Union. This study conducted a detailed review of the climate change impact on the built environment in coastal regions. This study was conducted at two levels: the global level and the next one at the individual country level. The global level review was done through a systematic literature review. The induvial country-level studies were based in the Partner countries United Kingdom, Sweden, Spain, Malta, and Sri Lanka.

A systematic literature review was conducted on three academic databases, Science Direct, Emerald Insight and Scopus. The synthesised data were analysed using the thematic analysis technique. The primary climate change evidence in coastal regions is sea level rise, weather conditions, and precipitation changes. The associated disaster risks and their physical and non-physical (economic, social, and environmental) impacts in the coastal regions have been summarised into a single framework. This could be used as a basis to develop tangible climate adaptation measures in the coastal built environment.

2 Background

Global climate change happens to be one of the greatest environmental threats affecting every country on every continent. Coastal regions are highly vulnerable to climate change because, in addition to changes in temperature, precipitation, and more frequent flooding, they will be affected by rising sea levels, wave heights, and accelerated coastal erosion (Fernandez-Bilbao et al. 2011).

According to the IPCC (Intergovernmental Panel on Climate Change) reports, by 2100, climate change-induced through anthropogenic actions will increase the global temperatures of 1.5 ◦C to 2 ◦C above pre-industrial levels (IPCC, 2018). Therefore, the climate change scenario is defined in the global context as follows.

According to IPCC (2014) , Climate change is a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and the variability of its properties and that persists for an extended period, typically decades or longer(IPCC, 2014a). Furthermore, UNFCC states a change of climate can be linked directly or indirectly to human activity that changes the conformation of the global atmosphere, resulting in natural climate variability observed over comparable periods (UNFCCC, 2011).

As a result, the built environment associated with the urban centres along the coastal belts is exposed to various natural and climate change-related hazards (Kumar & Taylor, 2015). At present, roughly 50 per cent of the world's population reside in cities (Bolay & Kern, 2019). One-third of the EU population lives within 50 km of the coast and often occupy high-risk areas (EC, 2019). On the other hand, coasts, which are known to be extensively populated, being focal points of trade, fishing, and tourism, become indispensable to the economy of any region with a coastline. Climate change, induced sea-level rise will have several physical and ecological effects on coastal systems, including direct inundation, flood and storm damage, loss of wetlands, erosion, saltwater intrusion, and rising water tables. In addition, extreme rainfall events and sea-level rise will induce fluvial and coastal floods. These conditions impose risk to critical infrastructure, including landfills, human habitats and the marine economy (Yahaya, Pereira, & Taha, 2021).

Recent evidence confirms a close liaison between natural and human-induced hazards and the built environment, as the built environment demonstrates a high fragility and vulnerability to hazardous situations(Nofal & van de Lindt, 2021). The built environment separates spaces from the natural environment. It includes manmade or modified structures, including the infrastructure used to deliver services created for living, working and recreational purposes (Goh, Jack, & Bajracharya, 2020). Accordingly, the built environment is frequently affected by natural hazards, whose frequency, range, and intensity are increased by climate change. (Zięba et al., 2020).

Much of the physical damage from climate change-related hazards is to the products of the construction industry. Therefore, the construction industry and built environment professionals have a vital role in rectifying physical damages of disasters (Ofori, 2002). Furthermore, the built environment comprises manmade structures that often constitute the weakest links and will be the most dangerous places during disasters. Therefore, the resilience level of the community and, ultimately, the national resilience depends on the ability of the built environment to maintain the functionality during and aftermath of a hazardous event(McAllister, 2013). Furthermore, the impact of disasters is primarily felt by inhabitants, communities, and countries mainly because the infrastructure remains complicated, interdependent, and connected (Havko, Mitašová, Pavlenko, Titko, & Kováčová, 2017).

The effects of climate change will have devastating effects on the vulnerable coastal built environment. It can inundate the existing built environment due to direct threats to properties, infrastructures, coastal industries, and marine ecosystems. Considering this, developing tangible climate adaptation measures in the coastal built environments is vital. The United Nations' Sustainable Development Goals highlight the need for multidisciplinary approaches in developing more holistic coordinated attempts to limit future climate change impacts (Islam & Zhang, 2019). Both biophysical and socioeconomic factors contribute to climate change impacts in coastal regions(Islam & Zhang, 2019). However, existing studies do not focus on the climate change impacts on the built environment in coastal regions.

Moreover, only a few studies on coastal climate change impacts, such as sea-level rise, are included in long-term development agendas, especially in developing countries. One of the reasons is the lack of scientific evidence that can convince development authorities to consider making it a part of long-term development programmes (Tursina, Syamsidik, Kato, & Afifuddin, 2021). Accordingly, the study carried out a detailed review of climate change impact and associated disaster risks on the coastal built environment. First, the following section will explain the research methodology of this study. Next, the results section will discuss the findings under topics of evidence of climate change in coastal regions, the climate change associated disaster risks in coastal regions, how these climate change impacts will affect the coastal regions and how these impacts will be linked to the built environment. Then the theoretical framework is presented at the end of the study with the study conclusions.

2.1 Country Overview

The study includes a global level review as well as country level reviews on the main partner countries United Kingdom, Sweden, Spain, Malta, and Sri Lanka. This section summarizes a country overview of the climate change impact in these countries.

2.1.1 United Kingdom

The United Kingdom can be named as a maritime nation. Over the last decade, the UK has experienced several severe natural hazards associated with climate change events with significant economic and human impacts on communities, properties, and infrastructure networks. For example, the 2007 summer floods affected 55,000 properties(Dale, 2021). They were estimated to cost £3.2 billion, while the 2013–2014 floods cost approximately £1.3 billion in insurance claims(Smith, 2013). In December

2015, during Storm Desmond, wind gusts of up to 81 mph and record-breaking volumes of rainfall were recorded across Northwest England. The storm, and its associated rainfall, is estimated to have flooded 8900 properties with over 100,000 properties left without power, with costs estimated at £1.3 billion(Hemingway & Gunawan, 2018). In addition, climate change will cause sea levels to rise continuously throughout the 21st century. Coastal and offshore infrastructure is also vulnerable to changing patterns of storm conditions(Poo et al., 2021). Around £150 billion of assets in the UK are at risk from coastal flooding. Damages to the UK from coastal flooding are estimated to be of the order of £500 million per year (Howard & Palmer, 2020). Due to coastal erosion, long-term morphological change is also evident in coastal areas, including extensive salt marsh loss (Nicholls et al., 2021). While these problems have various causes, climate change due to the anthropogenic greenhouse effect will worsen them (Nicholls, 2000). Sea levels have already risen around most British coasts during the 20th Century, inducing rising flood levels. This trend is expected to accelerate in the 21st Century, and by the 2080s, global sea levels could be between 18 and 99 cm. In addition, increased storminess and more giant waves have been observed since the 1970s. This has also contributed to an increased risk of storm damage and flooding in coastal areas(Nicholls et al., 2021).

2.1.2 Sweden

Sweden is an oblong country, stretching over 1,500 kilometres from its northernmost to its southernmost point. This means that climate and weather naturally vary a lot across the country, and the same is true for the conditions along the coastline. The Baltic Sea surrounds most of the Swedish coastline, except for the western coast, which borders the Atlantic. Conditions along the Swedish coastline are therefore dependent on what happens in the Baltic Sea and vice versa. Coastal and marine ecosystems are primarily intertwined, and activities on land may affect conditions in the water just as much as activities in the sea may affect life along the coast. While water levels and flows in great rivers and eutrophication of Swedish farmlands are among factors on land affecting water, blooming of algae and changing natural habitats of certain fish are among factors in the sea affecting life on land. In addition to supporting various ecosystems and species, the Swedish coastline is highly built up. It is also highly populated in proportion to the rest of the country. Sweden’s three largest cities (Stockholm, Gothenburg, and Malmö) are all by the sea, representing close to two million people alone (Statistiska Centralbyrån, 31 December 2021). While the Swedish coastline is long and the Swedish population is relatively small from an international perspective, pressure on the Swedish coastline in housing, recreation, tourism, and industries such as fishing, transport and energy is thus high (Boverket, 2006, p 23). Life along the coastline is also changing at a high pace, which means that the landscape may be altered, and the ecological, social, cultural, and economic conditions in the future may be different (Boverket, 2006, p 24).

2.1.3 Spain

Spain is predominantly a coastal country, with almost 8,000 km of coastline. The Spanish coast is considered a strategic area on the Mediterranean and Atlantic sides that gave the many zones great ecological, cultural, social, and economic value. Spain's coastal heritage is highly precious, and recent management attention has focused on conserving these landscapes (Ministry of Environment, 2004). Some of the main socio-economic activities are tourism, fisheries and aquaculture, ports, maritime transport, and energy, which depend on adequate conservation of coastal systems and waters. According to Abadie et al. (2020), Iberian coastal cities are subject to significant risks in the following decades due to climate change-induced sea-level rise. These risks are quite uncertain, depending on several factors. It is analyzed the expected accumulated damage costs if no adaptation actions take place and comparation is being made with an investment cost of implementation of some adaptation strategies. The results show that some adaptation strategies are less costly than the potential damage under inaction. In other words, it is economically rational to invest in adaptation even in a context of high uncertainty. Several threats arising from the effects of climate change on natural processes and dynamics, such as coastal flooding, increased extreme events, erosion, drought, desertification, and fires, as described throughout the document, are affecting coastal areas and coastal built environments in Spain.

2.1.4 Malta

As a small island state, Malta is particularly exposed to the threats and challenges of Climate Change (WHO, 2018). The Maltese Archipelago is located at the centre of the Mediterranean Sea [35.9375° N, 14.3754° E]. It consists of three inhabitant islands: mainland Malta, Gozo and Comino and other small uninhabited islands: Cominotto, Filfla and St. Paul's Islands. Due to the geological setting that results from tectonic activities, geomorphological processes and sea-level oscillations, the littoral along the Maltese islands is prone to marine-related and gravity-induced processes that may escalate with climate change (Rizzo et al 2020). The Maltese Islands do not have mountains and there are no rivers. 60% of the coast is considered inaccessible due to the relief and geological features.

The remaining 40% is highly urbanised, particularly close to the Harbour area (Micallef et al., 2017). In a small island state, demands for urban and industrial development, including tourism along the accessible coastline, increase (MEPA, 2015). Being a small island state where main connections with neighbouring counties are via maritime routes and considering the geomorphological set-up of the littoral that limits the accessible coastal areas, there is an ever-increasing land use conflict between different sectors and stakeholders (PAP/RAC, 2005). Tourism has occupied the northern and north-eastern parts of mainland Malta where there are gentle slopes and few sandy beaches. Marsamxett Harbour is also tourist-oriented, whereas the Grand Harbour is industrially surrounded by the historical heritage of the Three Cities. Despite the continuous threat from anthropogenic influences, the Maltese coast supports several essential habitats and species, including saline marshlands, coastal dunes, rupestral communities, low-lying maritime rock communities and marine benthic zones (PAP/RAC, 2005). This diversity in habitats reflects the varied environment enclaves that support rich biodiversity, including endemic species. Policies regarding coastal protection are carried out at a national level by several government-led institutions, including the Planning Authority and the Environment Resources Authority (Micallef et al., 2018).

2.1.5 Sri Lanka

Sri Lanka is an island surrounded by the Indian Ocean and located at the tip of the Indian Subcontinent. As a tropical nation, it is highly vulnerable to climate change. According to the Global Climate Risk Index 2019, Sri Lanka was ranked second among the most impacted by climate change in 2017(Eckstein et al., 2018). Furthermore, Sri Lanka is considered vulnerable to climate change impacts due to various political, geographic, and social factors, ranking 100th out of 181 countries in the 2017 ND-GAIN Index (The World Bank Group & The Asian Development Bank, 2020). The ND-GAIN Index assigns a ranking to 181 countries based on their vulnerability to climate change and other global threats, as well as their readiness to boost resilience. Indeed, for a small island like Sri Lanka, the coastal zone is a prominent landscape feature. Development activities in the fisheries sector and along the coast are critical to the country's economy. As a result, the coastal belt offers limitless advantages to coastal residents over a broad spectrum (Abeykoon et al., 2021; Climate Change Secretariat, 2016; Gopalakrishnan et al., 2020; Rajarathna & Nianthi, 2019). Sri Lankan coastline is about 1,620 km that covers the shoreline of bays and inlets but excludes lagoons. It can be many features along the coastal zone(Minister of Mahaweli Development and Environment., 2018; World Bank, 2017). Figure 2.4 shows the land coverage alone in the coastal belt. The Tsunami that struck on 26th December 2004 was probably the worst natural disaster in Sri Lankan history and showed how coastal habitats are vulnerable to disasters. The Tsunami left more than 38,000 people dead and another 7,100 missing and causing 208.2 billion USD damages to livelihood and other sectors(Coastal Conservation Department, 2004; Minister of Mahaweli Development and Environment., 2018; World Bank, 2017). According to Government figures, more than one million people were affected(Coastal Conservation Department, 2004; Koralagama, 2008). A study conducted by Bakker (2018) to assess the coastline recession along the Sri Lankan coast showed that a significant number of beaches in Sri Lanka are at risk of disappearing by 2100 (Gopalakrishnan, Kumar & Hasan, 2020). potential SLR impacts include elevated tidal inundation, accelerated coastal erosion, increased saltwater intrusion in groundwater, rising water tables, and changes in coastal ecosystems (Cazenave and Le Cozannet, 2014; Nicholls and Cazenave, 2010, as cited in Gopalakrishnan, Kumar & Hasan, 2020).

3 Methodology

The study basically was conducted under two main levels. A global level review was conducted using a systematic literature review and parallelly country level reviews were conducted by partners individually. Both studies were conducted covering the main research problems identified in the following section and finally synthesizing the findings the frameworks were developed.

3.1 Aims of the study

Conducting a detailed review of climate change impact and associated disaster risks on the built environment in coastal regions was the aim of this study. Initially, the study framed the research questions as follows.

1. What is the evidence of climate change in coastal regions?
2. What are the disaster risks associated with climate change in coastal regions?
3. What is the impact of climate change in coastal regions?
4. What is the impact of climate change on the built environment in coastal regions?

The above questions guided the study at the global level systematic review as well as the induvial country level. Finally, the analysis was done under the key research questions and the results are presented in the subsequent sections of this report.

3.2 Systematic Literature Review

Systematic Literature Review is a process that allows the collection of appropriate evidence on a research area that fits the pre-specified eligibility criteria and answers the formulated research questions(Mengist, Soromessa, & Legese, 2020). Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed in conducting this study. PRISMA approach consists of four steps: identification, screening, eligibility, and inclusion (Saja et al., 2019), and Figure 1 elaborates the steps of this study.

The study was based on three scientific databases Scopus, Emerald Insight and Science Direct. The search strings included three keywords were climate change impact, built environment, and coastal region. The reason for selecting these databases was that they had extensive research articles with international publishers, including peer-reviewed journals.

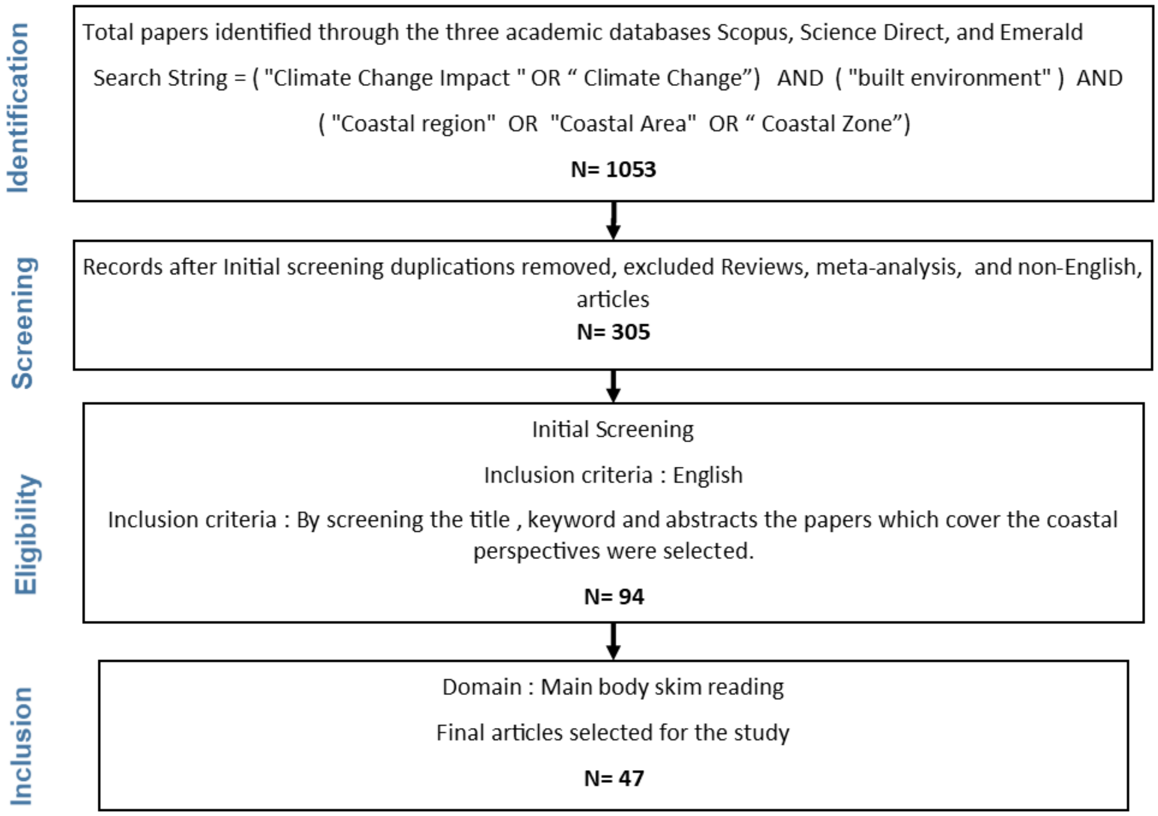

Figure 1: PRISMA flow diagram

Identification is a process to search any synonym, related terms, and variation for thestudy's main keywords, namely climate change impact, built environment, and coastal region. The keywords are developed based on the research question as suggested by Okoli (2015), and to expand the search, keywords and related terminologies were also used in the search string.

The search terms ("Climate change Impact" OR "climate change") AND ("Built Environment") AND ("Coastal Region" OR "Coastal Area" OR "Coastal Zone")

The inclusion criteria were including the key terms in the title keywords and abstracts. The journal articles, conference proceedings, book chapters were selected from the search criteria. Then the articles that mainly included the coastal perspective were selected at the initial screening as it was the focus of the study. The Non-English articles and the duplicated ones within the databases were excluded during the initial screening process. Then findings were analysed using thematic analysis, and the results are presented in the following sections.

4 Results

The results section summarises the study's findings under the four main research problems, the climate change evidence in coastal areas, the disaster risk associated with climate change, the climate change impacts in the coastal regions and their links to the built environment in the coastal regions. Under each of the sections, the global level findings and country-level findings are presented separately.

4.1 Climate change evidence in coastal regions- Global Review

The primary climate change evidence in the coastal areas is sea-level rise, higher atmospheric and oceanic temperatures, changing precipitation rates, and increased intensity of extreme events. Each of these is discussed separately in the following sections.

4.1.1.1 Sea Level rise

Sea-level rise is one of the most critical phenomena in the coastal regions, as predictions indicate an increase of 1.8 mm to 1.5 m by 2100(Sahin, 2019). Globally, sea-level rise will threaten 95% of the coastal regions during the twenty-first Century (Islam & Zhang, 2019). It is also highlighted as the most threatening challenge in the face of the small island states. The main drivers behind sea-level change are the thermal expansion of ocean waters and polar ice melting(Hens et al., 2018). According to the projections, up to half a billion residents worldwide in the low-lying coastal plains will be threatened by rising sea levels(Abdelhafez, Ellingwood, & Mahmoud, 2021).In the Southeast Asian and Pacific regions, the total population displaced due to sea-level rise increases from 8 million to 52 million(Thomas & Benjamin, 2018). In addition, the sea-level rise changes lead to coastal flooding and salinity intrusions, inundation of habitat land area, changes in coastal shorelines, damaged mangroves and wetlands and groundwater extraction in the coastal areas(Hens et al., 2018). These direct impacts will subsequently lead to the degradation of coastal ecosystems, human livelihoods and the essential community services in the coastal areas (Abdelhafez et al., 2021). The other effects of climate change, such as increased higher atmospheric and oceanic temperatures, changing precipitation rates, and increased frequency and intensity of coastal hazards, will also impact coastal systems, both directly and through interactions with increases in sea level.

Changes in the global mean sea-level change represent one of the most certain consequences of human-induced climate change. It can cause impacts on people, natural systems, and the built environment. However, the magnitude of future sea-level rise remains uncertain. (Nicholls et al., 2021). In addition, sea-level scenarios induce the magnitude and cause extreme events such as tides, surges, and waves (Dafforn et al., 2015; Hasan Tanim & Goharian, 2021; IPCC, 2014b; Romero Lankao

& Qin, 2011; Sajjad et al., 2021). Studies on risks have increased during recent decades due to predicted changes in winds, waves, or sea-level rise due to climate change (Graells et al., 2021).

The rising sea levels further have implications such as increased invasive species, damage to coral reefs, and increasing frequency of damaging hurricanes and other extreme weather conditions. Additionally, ocean acidification presents serious complications impacting shipping, shipbuilding, the fisheries industry, and coastal tourism. Sea level rise will affect human health and labour-intensive production activities, such as sea salt, sea fishing, and seawater use. (Martínez-Vázquez et al., 2021).

The density difference between seawater and fresh water in coastal aquifers triggers saltwater intrusion in the coastal areas. Projected increases in water consumption within coastal communities alongside sea level rise will intensify the phenomenon (Etsias et al., 2021). In addition, rising sea level also raises the compound flooding risk and causes coastal erosion (CCC, 2018; Hughes et al., 2021). Accordingly, the coastal built environment needs to accommodate the rising sea levels in future. (CCC, 2018).

4.1.1.2 Precipitation changes

The precipitation patterns, temperature, and evapotranspiration will alter the hydrological cycle in many regions, causing a change in extreme weather events such as drought and flooding, especially in coastal areas(Diaconu, Costache, & Popa, 2021; García Kerdan et al., 2019). Heavy precipitation, hydrological preconditions, and runoff generation processes induce flood situations and landslides. For example, rising temperatures and heavy precipitation affect the slope stability of rocks, which increases the frequency and intensity of shallow landslides. (Kumar et al., 2020). Additionally, droughts are categorised based on their triggering factor precipitation. The changes in precipitation lead to meteorological drought, causing agriculture and hydrological droughts. In addition, it will impact food production and water availability for human activities. (Kumar et al., 2021).

4.1.1.3 Change in climatic conditions

According to IPCC IPCC (2014b), global warming is one of the leading climate change challenges in coastal areas causing fundamental changes in coastal ecosystems, affecting species that inhabit these areas. The coastal waters are likely to increase by as much as 4 to 8°F in the 21st century. In the European regions, the phenomenon has been six times greater than in the global oceans in the past 25 years(CCC, 2018).

Climate change-induced weather anomalies, such as extreme droughts and intense rainfalls, have been increasingly observed in places where people are highly vulnerable to their various effects in recent years(Nicholls et al., 2021). In addition, many risks on the coast and coastal marine environments are affected by increased sea levels due to high tides, storm surges, and extreme wave conditions (IPCC, 2012). In addition to coastal-specific weather and extreme storms, coastal areas that inherit natural ecosystems have specific geological and biological environments constrained by tidal influence. These conditions can alter the climate sensitivities, and proxy opportunities of the tree-ring record closest to the coast, in some cases in direct contrast to records of the same species just a few more kilometres inland(Tucker & Pearl, 2021). For example, the precipitation of large volumes of rain in short periods, causing flooding, especially in denser and more impermeable areas and landslides(Neder et al., 2021). Furthermore, altered intensity-duration frequency curves, increased extreme rainfalls, more pronounced dry periods, and shifting rain/snow transitions will alter watershed hydrology and biogeochemistry(Lintern, McPhillips, Winfrey, Duncan, & Grady, 2020).

Highly urbanised cities are burdened by climate change-induced extreme events such as earthquakes, landslides, intense tropical cyclones, and associated flooding accounting for huge global costs (Sajjad, Chan, & Chopra, 2021; Tucker & Pearl, 2021). Moreover, the frequency and intensity of extreme weather and climate events have been increasing significantly, together with continuing development in flood-prone areas and natural riverbed siltation, strengthening the scale and degree of urban flood risk.(Yang, Scheffran, Qin, & You, 2015).

Winter storms are acknowledged as one of the catastrophic events leading to agricultural damage and loss. In farming regions, severe winter storms such as blizzards, unending snowfalls and extremely low temperatures can lead to building damage, animal losses, and reduction in milk production (Zhang & Liang, 2021). In addition, freezing weather causes animal loss as they are vulnerable to extreme temperature variations. Accordingly, reduced productivity, increased energy demands and disruption to logistics are triggered due to cold weather (Zhang & Liang, 2021).

The changes in seasonality, such as extended summertime, delayed arrival of the usual spring and summer storms followed by extreme rainfall events and mega heat waves, can also be attributed to climate change impacts in the long run(Bandh et al., 2021; IPCC, 2018). Additionally, the damage caused by extreme events such as severe droughts and heatwaves may further be increased by the subsequent wildfires, a retreat of glaciers (Bandh et al., 2021). Finally, prolonged exposure to very high temperatures can lead to thermal diseases, encompassing heat cramps, heat exhaustion, and heat stroke (Bandh et al., 2021).

Accordingly, the coastal areas experience a series of probable threats to inhabitants and the natural and built environment (Zahmatkesh & Karamouz, 2017). Assessing the vulnerability and unequal coping capabilities to climate change and weather events has been a focus of research attention in vulnerability to flooding, urban vulnerability to extreme heat, agricultural vulnerability to drought, climate change, and severe snowstorms(Zhang & Liang, 2021). Also, over time, the Sea Level rise phenomena have become more advanced with improvements in scientific knowledge. However, deep uncertainty remains crucial as broader sea-level consequences are possible, with extreme climatic changes expected in the coming few years. (Nicholls et al., 2021).

4.1.2 Climate change evidence in coastal regions - United Kingdom

An assessment of the vulnerability of several European countries to SLR has shown that the UK is one of the most vulnerable European countries to SLR. Without adaptation, the UK could experience significant impacts on coastal flooding from sea-level rise. The assessment showed that 10-15% of the UK's coastline comprises 10 km long stretches below 5 m elevation, and that 3009 km (16%) is subject to erosion. The study also calculated that 69% of GDP is located within 50 km of the coast and that 78% of the country's population live within this zone. At present, 414,000 people are exposed to sea-level rise in the UK (CCA, 2021). Sea Level Rise impacts Changes in tidal range, Changes in storm surges, Vertical land motion introduce significant regional differences in relative sea-level rise around the UK, with much of southern Britain sinking and much of northern Britain rising relative to the sea(Gehrels & Long, 2008). In addition, sea level extremes, storm surges and large waves are expected to increase in height and frequency across UK (Gawith, 2005).

The changing weather patterns for the UK suggest that higher temperatures, combined with changing precipitation patterns, will lead to hotter, possibly drier summers and milder, wetter winters. Since the 1970s, there has been an increase in storminess and wave heights around Britain. This has caused a re-evaluation of the design standards required for sea and coastal defence(Nicholls et al., 2021). Furthermore, Changing patterns of precipitation will result in wetter winters, by up to 15% by the 2020s (up to 25% by the 2050s) for some regions and scenarios, drier summers, by up to 20% by the 2020s (up to 40% by the 2050s) for some regions; and significant decreases in snowfall(Gawith, 2005).

4.1.3 Climate change evidence in coastal regions – Sweden

In summarizing the climate change evidence in Sweden, coastal areas sea level rise is a significant impact. Globally, sea levels have risen at an average of 1.9 centimetres per decade, a trend reflected in Swedish coastal areas (Sveriges Vattenmiljö, n.y. a). Increasing sea levels are coupled with an increase in surface water temperature in Swedish coastal waters. Here, Swedish increases do not reflect increases globally but rather surpass them. Whereas a future global average increase of 0.09-0.13 degrees Celsius per decade is expected, temperatures in Swedish waters will increase by 0.2-0.5 degrees Celsius per decade (Sveriges Vattenmiljö, n.y. a). However, specific evidence of climate change has been observed across the country, including in coastal regions, and will increase in the future. Changing weather patterns caused by climate changes relate primarily to changes in precipitation and temperature (Naturvårdsverket, 22 June 2020). During the past Century, temperature variations in Sweden essentially mirror global variations (e.g., temperatures at the end of the 19th century were colder than during the 20th century). Overall, the warm-up has been more severe in Sweden than globally (Naturvårdsverket, 19 February 2021). An increase in precipitation has been observed over the past 100 years (Naturvårdsverket, 19 February). Precipitation is expected to increase by 10-20% (Länsstyrelserna, 2012 p 18).

4.1.4 Climate change evidence in coastal regions – Spain

Along the Spanish coast in the previous century, sea level has risen 2-3 mm/year, with variations in the Mediterranean due to regional effects. On the Atlantic coast, the sea level raised between 1.5 and 1.9 mm/year from 1900 to 2010 and between 2.8 and 3.6 mm/year from 1993 to 2010 (MAPAMA, 2016). Since 1993, SLR has been higher in the Strait of Gibraltar, Canary Islands, and the Atlantic coast (MITECO, 2020). To estimate the rise in local sea level on the Spanish coasts, it is necessary also to consider subsidence effects, which are of particular relevance in the Ebro Delta and the mouth of the Guadalquivir River. The most updated results provided by the last special report of the IPCC (IPCC, 2019) entitled Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC) indicate that SLR projections are worsened than the projections presented in previous IPCC reports.

Regarding the wave climate changes, a significant increase of up to 0.8 cm/year in the Cantabrian Sea has been observed in the highest waves and a decrease in the Mediterranean and the Canary Islands. In addition to the sea level and wave climate, other variables contribute to shaping coastal regions, as river flows, sea surface temperature (SST) or seawater pH. These variables produce changes in coastal processes and, therefore, in coastal areas' use and activities. Furthermore, average annual precipitation ranges from barely 300 mm in southeaster areas to over 2,000 mm in the Pyrenees and Galicia. Rainfall has a notable seasonality, more pronounced in the southern half of the peninsula. It lowers in the northeast, with an apparent decrease in precipitation in summer. In the last 50 years, there has been a slight decrease in annual precipitation in Atlantic basins. Still, there are no significant **trends** in Mediterranean basins and Balearic Islands. The decrease of precipitation during February and March in central and southwest is also remarkable, and a decrease in the interannual precipitation variability in the Mediterranean coast (MAPAMA, 2017).

Spain's rugged terrain and geographic location produce substantial climate variability. Differences in annual average temperatures of over 18 ºC are recorded at separate sites on the mainland. According to Sanz et al., 2020, the latest climate change scenarios prepared for Spain by the AEMET project increases in the annual scale of maximum temperatures of between 2 °C and 6.4 °C towards the end of the century (depending on the RCP used), more pronounced in summer, with more significant increases in the interior and smaller increases in the north and northwest of the peninsula. An increase in the number of warm days is also expected, and heatwaves will lengthen. From 1980 onwards, the frequency of summer tropical nights has increased in the southeast of Spain (+3.8 days/decade grew). The frequency of summer days has increased in Southern Spain (+2.3 days/decade) (Fernández-Montes and Rodrigo, 2012). Finally, it is remarkable that the average temperature has risen slightly more in Spain than in Europe or globally. The average temperature rise in the previous century was between 1.2-1.5 ^{0}C in Spain whereas the increase was 0,74 ^{0}C globally and 1 ^{0}C in Europe, in the same period (Comisión de Coordinación de Políticas de Cambio Climático, 2007).

4.1.5 Climate change evidence in coastal regions – Malta

The Mediterranean is considered one of Europe's leading ‘climate change hotspots (EEA, 2017). Projections suggest substantial warming and increased heat waves, dry spells, and droughts in the region (EEA, 2017). According to the SRES scenarios, sea-level rise on a global scale by the end of the 21st century is expected to be in the range of 0.18-0.59m above the reference level corresponding to the decade 1980-1999. Based on recent satellite observations, global sea level trends in the last 15 years are about 3.1 mm/year, almost double the sea-level rise rate in the last century. Analysis of the atmospheric pressure around Malta shows an increasingly positive trend by 0.6 hPa since 1951 as registered at Luqa Airport. This trend points towards calmer and fairer weather, with the possibility of an increase in ambient temperature and a lower in humidity due to atmospheric air subsidence. Changes in air pressure can significantly affect the weather since they can alter rainfall, temperature, winds, and degree of storminess. The rate of temperature change in Malta is more significant than what the Intergovernmental Panel on Climate Change (IPCC) reports for the global 100-year linear trend (1906-2005) of 0.7°C ± 0.2°C (IPCC, 2007). Yearly recorded maximum temperatures have gone up by close to 3°C over 100 years.

In contrast, minimum temperatures have tended to overall cooler temperatures. However, the absolute lowest temperatures occurred earlier to 1980, and the coldest days in recent years have not gone below the 2°C thresholds. Rainfall in the Maltese Islands is unpredictable, and the rainfall pattern fluctuates, but the highest precipitation rates occur between November and February. On average, precipitation has decreased over the years.

4.1.6 Climate change evidence in coastal regions – Sri Lanka

Sri Lanka's coastal area is vulnerable to increases in sea level since it is a small island in the Indian Ocean. The tsunami of 2004 demonstrated that low-lying coastal plains would be vulnerable to potential SLRs(Climate Change Secretariat, 2016). The findings from the Palamakumbure et al. (Palamakumbure et al., 2020) shows that there will be significant SLR south and southwest coastal area in Sri Lanka. The data collected from 2006 to 2017 shows that the sea level has increased with the rate of 0.288± 0.118 mm / month in Sri Lanka. Due to climate change, the Sri Lankan weather profile has changed over the last few decades. Significantly, the precipitation level in Sri Lanka shows a complex and spatial variability over the past years, which makes estimation of change over time difficult. Monsoon winds highly influence the precipitation in Sri Lanka in the Indian Ocean and depressions and cyclones in the Bay of Bengal (Zubair, 2003). From the findings of the studies, it can be concluded that there is a significant variation in the precipitation level in Sri Lanka during recent years.

Recent studies have shown that the annually averaged mean minimum temperatures are increasing across most of Sri Lanka. The difference between maximum and minimum temperatures, diurnal temperature range is decreasing, indicating that the minimum temperatures increase faster than the maximum temperature(Jayawardena et al., 2018). Furthermore, a study carried out by De costa in 2008 (De Costa, 2008) provides significant evidence for the change of the temperature as an indication of the climate change in Sri Lanka. Findings from this study have shown that decadal mean air temperatures of all selected locations except Kandy are a highly significant and linear increase over 1869-2007.

Also, rainfall patterns are varied spatially and temporally significantly. On the other hand, this could lead to the change of the margins of the climatic zones of Sri Lanka as well. The findings from the recent studies have shown how the rainfall has been changed temporarily and spatially manner. For example, a recent study showed that the eastern, southeastern, northern, and north-central part of Sri Lanka has been experiencing an increase in rainfall over the past 31 years (1987-2017). On the other hand, also there has been a decrease in the trend of rainfall in the western, northwestern, and central parts of the country.

4.2 Disaster Risk and climate change

The climate change impact increases the disaster risk in the coastal areas. Therefore, disaster risk is a combined effect of hazards, exposure and vulnerability (X. Wang, Xu, Cui, & Wang, 2020).

Disasters triggered by hazards are caused by the intervention of natural phenomena such as climate change(Monte, Goldenfum, Michel, & Cavalcanti, 2021). Climate-influenced hazards or climatic hazards refer to a range of hydro-meteorological hazards due to heavy rains, strong winds, typhoons, floods, coastal storm surge, tsunamis, and sea-level rise, as well as all subsequent disasters attributed to the phenomena (Lin, Sun, Nijhuis, & Wang, 2020; Phan et al., 2020; Yahaya et al., 2021). Climate change impacts induce coastal region hazards such as tropical cyclones, hurricanes, and storm surge in terms of their frequency and severity. Tropical cyclones are an example of this, and they are among the costliest coastal natural hazards. They severely affect the built environment, coastal areas and cause extensive economic losses and social disruptions (C. Wang & Zhang, 2018).

Hurricanes are rotating low-pressure weather systems that form in warm seawaters. Storm surge is an unexpected rise in water, driven primarily by wind intensity and, to a lesser degree, by a hurricane low-pressure and can persist for a few minutes up to a few days (Abdelhafez et al., 2021). The rising sea levels worsen the severity of all these hazards. These high-water levels, such as storm surge along coasts during low-pressure weather systems, cyclones, or storm winds combine with high tides, causes the inundation. Inundation drives seawater onshore. Variations of tide also have a significant influence on tsunami inundation areas and human exposure. The tide variations will have more enormous impacts on human exposure in the future when the effects of the tsunami are combined with impacts of climate change, induced sea-level rise. The tide variations will also potentially shorten tsunami arrival times, which is essential in saving lives (Tursina et al., 2021).

The subsequent impacts of the coastal hazards include land erosion, coastal floods, waterlogging, salinity intrusions, drought, earthquakes, arsenic contamination and shortages of drinking water, ecosystem degradation, and environmental pollution (Islam & Zhang, 2019; X. Wang et al., 2020). In addition, increased surface water temperatures will trigger coral bleaching and the loss of and migration of coastal species in the ecosystems. Changes in precipitation will make alterations in the storm patterns and the risks of flooding and storm damage. Ocean Acidification due to higher levels of CO2 absorbed from the atmosphere further enhance the predicament (Travers, Elrick-Barr, & Kay, 2010).

In the context of climate change, the vulnerability towards disasters has been identified as the increased exposure of groups and individuals due to social and environmental conditions(Zacarias, 2019). Around 10% of the world population have their residence and livelihoods in the low-lying coastal regions (Abdelhafez et al., 2021). The physical infrastructure around the coastal areas is often susceptible to disaster risks due to its deteriorated quality and lack of maintenance(DeYoung, Lewis, Seponski, Augustine, & Phal, 2020). Small island developing states receive significant attention due to their physical exposure and socioeconomic features(Thomas & Benjamin, 2018). Population concentration in the coastal belts, limited land usage, isolated geographic conditions, scarcity of resources and high dependence on tourism and fisheries further contribute to the vulnerabilities of the coastal regions(Reguero, Beck, Agostini, Kramer, & Hancock, 2018; Yang et al., 2015). In the context of the built environment, vulnerability is considered a lack of capacity to resist external stresses, more specifically, to withstand or accommodate potential adverse hazard impacts, e.g., the lack of ability to resist coastal inundation without damage (X. Wang et al., 2020).

According to these findings, the final section of the study establishes the climate change impacts in the coastal regions and their subsequent linkages to the built environment.

4.2.1 Disaster Risk and climate change -United Kingdom

Numerous natural hazards are experienced in the UK, such as flooding, heatwaves and wildfires, which can cause significant human, economic, environmental and infrastructure damage(Stock & Wentworth, 2020). These range in different scales from small-scale local occurrences (e.g., landslides), regional incidents (e.g., flooding), to significant high impact, low probability events. For example, winter flooding in the UK during 2015–2016 cost the UK economy approximately £1.6 billion. Furthermore, other than direct impacts, events like the 2010 eruption of the Icelandic Eyjafjallajökull volcano restricted UK airspace for several weeks, stranding travellers around the world(Stock & Wentworth, 2020).

One of the most dangerous challenges to UK settlements is flooding(Percival & Teeuw, 2019). Currently, 5.2 million properties in England and Wales are experiencing a risk of flooding, and less than 10% of those are conscious of this risk level(Percival & Teeuw, 2019). Coastal areas are especially vulnerable to climate change due to several factors. These areas tend to depend on coastal ecosystems, seasonal employment related to tourism and other transient groups, coastal infrastructure and communications. Additionally, coastal floods can lead to differential levels of impacts such as loss of life, impairment to the built and natural environments, or disruption to the coastal livelihoods due to varying extents of physical and socio-economic vulnerabilities (Percival & Teeuw, 2019).

4.2.2 Disaster Risk and climate change -Sweden

In Sweden, due to the country's abundant coastline, many hazards identified for Sweden also affect Swedish coastal areas. Climate change-induced hazards include the risk of inundation and flooding, coastal erosion, increase in heat waves (Naturvårdsverket, 22 June 2020; Boverket, 22 December 2020). Furthermore, as a direct consequence of the changes in temperatures, Swedish glaciers seem to be shrinking. Changes have been observed regarding when the ice is melting in big lakes and rivers (Naturvårdsverket, 19 February 2021). The spreading of pollutants and contamination comes as a risk from inundation, heavy rainfall, and elevated water levels in watercourses (SOU 2007:60, p 340). The spreading of pollutants poses a hazard to, among other things, sensitive ecosystems, the quality of drinking water, the fishing industry, and farmlands.

Sweden is surrounded by the Baltic Sea, whose flora and fauna are vulnerable to changed weather conditions and climate changes due to the Baltic Sea's unique conditions. The Baltic Sea, in general, is highly industrialised, which further contributes to the vulnerability of the ecosystem in the Baltic Sea. Old roads and other infrastructure are vulnerable to precipitation, and climate changes as changes in pressure caused by altered water levels were not considered when constructing this infrastructure (SOU 2007:60, p 199). Furthermore, specific infrastructure is located near or below predicted sea levels in the future. This puts them at risk for inundation. For instance, rising sea levels threaten low lying roads and tunnels in the south of Sweden (SOU 2007:60, p 201). As a result, certain areas of Sweden are more exposed to rising sea levels, inundation, erosion, and landslides. Around 40% of the Swedish coast accommodates buildings less than 100 meters from the shoreline, corresponding to around 120,000 buildings within such coastal areas (Länsstyrelserna, 2012 p 21). Around 3.2 million buildings are situated within five kilometres from the coastline (SOU 2007:60, p 333). Along the western, southern, and south-eastern coasts of Sweden and in the Stockholm archipelago, many buildings are situated less than five meters above current sea levels (SOUR 2007:60, p 297). In Skåne, this amounts to around 30% of the total surface accommodating buildings. Although current forecasts predict sea levels to rise only by 0.8-2.0 meters (SOU 2007:60, p 297), it is easy to imagine the potentially devastating risk that rising sea levels and following climate change-induced disasters such as inundations, erosion, and landslides poses to the Swedish building stock.

4.2.3 Disaster Risk and climate change -Spain

Expected changes in environmental variables as increased soil dryness, increased air temperatures, Sea level rise, etc., increase the hazards in Spanish coastal areas. These hazards include increased coastal flooding (in relative terms on the Mediterranean coast. In absolute terms, an increase on the Atlantic coast and the Canary Islands). In addition, sea-level rise will exacerbate the intensity and frequency of extreme flooding events. Furthermore, increased extreme climatic events, continued erosion, increased drought and desertification risk and increased fire hazard are further results of the climate change evidence in Spain. In terms of the vulnerability of Spain, as stated in MAPAMA (2014) and MAPAMA (2016), it is a predominantly coastal country with a very long and rich coastline, with numerous ecosystems and stunning landscapes. Furthermore, the Spanish livelihoods and economy depend primarily on the coast and its seas as beaches occupy 24% of the Spanish coastline and account for around 1,900 km of coastline. Also, many livelihoods are attached to fishing, beach tourism, services, maritime transport, aquaculture, waves, wind and tidal energy, water desalination, etc.

Considering Sea level rise trends in the North Atlantic coast, the population affected in 2040 by permanent flooding will be around 2-3% of the total population of the provinces of Coruña, Cantabria and Guipúzcoa (referring to the 2008 census population). For an increase of 50 cm of mean sea level, the number of people per province affected in 2100 along the North Atlantic coast varies between 1% and 4% of the population in 2008 (these projections have been estimated without considering adaptation options). Regarding land use and goods exposed, infrastructures are the main asset exposed in all the provinces studied. For example, in Galicia, in 2100, more than 10% of the land corresponding to infrastructures could be affected in the Galician provinces by 85 cm of sea-level rise.

4.2.4 Disaster Risk and climate change – Malta

The United Nations Framework Convention on Climate Change (UNFCCC) considers small island developing states (SIDS) the most vulnerable to the extreme weather events arising from climate change. The National 2014 Communication of Malta to the UNFCCC lacked any detailed study on specific coastal area susceptibility to coastal hazards; it did highlight predicted the sea-level rise and increasing extreme weather events as a considerable threat to the island's highly populated coastal areas due to the potential impacts of inundation, coastal erosion and damage by storm surges, waves, and high winds (Micallef et al., 2018). The Maltese Islands are exposed and vulnerable to various natural hazards produced by tectonic, geological/geomorphological, and climatic processes. This is evident even from historical records. Yet, irrespective of hazardous historical events, drought is becoming a persistent threat to the islands (Main et al., 2018) due to the over-extraction of groundwater reserves to supply various sectors, including Tourism, the change in the amount of precipitation as a result of climate change but also the extent of the surfaced area that allows for the replenishment of the aquifer. As a small island state, Malta is considered prone to increased vulnerability to the impacts of climate change compared to other countries. It is estimated that 1.11 km2 or 0.36% of the island's coastline is susceptible to sea-level rise, with beaches particularly prone to erosion. Coastal development, protected areas, ports, infrastructures and roads were highlighted as particularly vulnerable to sea-level rise. In contrast, a more comprehensive range of primarily coastal land-uses was considered as vulnerable to climate change in general (MRA, 2017).

4.2.5 Disaster Risk and climate change Sri Lanka

Sri Lanka has experienced climate-related hazards, including droughts, heatwaves, and cyclones. Cyclones can result in flood and landslide situations. According to Wijetunge and Marasinghe (2015), Sri Lanka is vulnerable to cyclones generated mainly in the Southern part of the Bay of Bengal (Chandrasekara et al., 2018). In May 2017, the arrival of the precursor system to Cyclone Mora with the depression at the Bay of Bengal worsened flooding due to the southwest monsoon in 15 out of 25 administrative districts in Sri Lanka (Chandrasekara et al., 2018). Ensuing floods and landslides claimed nearly 212 lives and left 79 people missing (International Organization for Migration, Sri Lanka, 2017; Wikipedia, 2017, as cited in Chandrasekara et al., 2018). The Jaffna Peninsula has been identified as the most vulnerable region in Sri Lanka to changing climate in terms of living standards by the World Bank report (Mani et al., 2018, as cited in Gopalakrishnan, Kumar & Hasan, 2020). Sea-water intrusion has already become a pressing issue in coastal areas of the Jaffna Peninsula (Gopalakrishnan, Kumar & Hasan, 2020) because the community depends on groundwater for their livelihoods as there are no perennial rivers or permanent water supply systems in the Jaffna Peninsula. The coastal areas of Sri Lanka that are vulnerable to coastal intrusion are densely populated, with much of the urban cities, including Colombo's capital city, located there (Nianthi & Shaw, 2015; Baba, 2010). The coastal areas also contain many industries and industrial hubs that could be destroyed by extreme climatic events and coastal intrusion (Nianthi & Shaw, 2015), thus increasing vulnerability. Furthermore, vulnerabilities of the coastal community in Sri Lanka to hazards and extreme events that are associated with climate change are exacerbated by many various factors such as; lack of trust in authorities who disseminate Early Warning, limited knowledge of evacuation routes and shelters in residential areas, lack of efficient and sustainable resilience mechanisms focused on the coastal communities, lack of efficiencies and effectiveness of national policies and frameworks related to coastal hazards and lack of alignment with the post-2015 global standards, lack of capacity and preparedness of the coastal communities, lack of exposures and awareness to the modern technology, the administration process also disregarding indigenous knowledge regarding the EW mechanism, lack of interest of the coastal communities in evacuation planning and safety drill (Hippola et al., 2018; G. P. Jayasiri, Siriwardena, et al., 2018b, 2018a; Jayasooriya et al., 2018; C. Perera et al., 2020; Rathnayake et al., 2020)

4.3 Climate change Impact in coastal regions

The climate change evidence negatively affects the ecosystem functioning, agriculture and food security, durability of infrastructure, water resources, human health and causes many other impacts (Hossain et al., 2019). The impact of climate change in the coastal regions was identified mainly under two physical and non-physical.

4.3.1 Physical Impact

Impacts on critical infrastructure in the coastal regions are one of the critical concerns of climate change. Due to coastal hazards, the essential infrastructure experiences complete or partial direct damages(DeYoung et al., 2020).

Transportation systems become an essential part of the public infrastructure as it provides access to emergency facilities such as police, fire, and healthcare. When the access routes are interrupted or damaged by hazards, the community response and recovery are also impossible(Zahmatkesh & Karamouz, 2017). Moreover, seaports cannot function properly without integrated transportation systems. Seaports are another critical infrastructure highly threatened due to climate change impact in coastal regions. A recent study shows that coupling 100-year coastal floods with the predicted Sea Level Rise by 2080 will likely decrease roadway accessibility by 28% and double emergency response time due to highway interruption in New York (Abdelhafez et al., 2021). The seaports consist of coastal infrastructure (access channels, seawalls, breakwaters), terminal infrastructure (berths and docks), intermodal ground transportation (railway or roadway) connecting the port to inland modes of distribution, harbour superstructure (cranes, vehicles, warehouses), and operating facilities (buildings, water supply and power plant) (Abdelhafez et al., 2021). All these systems will be affected by the coastal hazards and climate change impacts.

In addition, the ion-based salts cause corrosion in the concrete and steel structures on bridges, roadways, and sidewalks leading to the risk of failure and potential for injuries and fatalities. Furthermore, contamination of Pb and rising concentrations of Cl- will induce corrosion of infrastructure pipes. On the other hand, road salt corrosion contaminants risk private wells and drinking water infrastructure in coastal regions (S. S. Kaushal et al., 2021; Pieper et al., 2018). Freshwater Salinization Syndrome is triggered by saltwater intrusion resulting from chemical interactions between consequences on the natural, social, and built environment and salt ions and chemical, biological, and geologic parameters(Haq, Kaushal, & Duan, 2018; Sujay S Kaushal et al., 2019). It, directly and indirectly, impacts coastal infrastructure. Built structures in cities are built with concrete, limestone, gypsum, and other building materials, distributing major ions during weather changes.

Another aspect of critical infrastructure affected by climate change is the wastewater treatment plants in coastal areas. Increased flooding, reduced capacity for outflow and raised groundwater tables, all related to sea-level rise, is likely to affect the treatment plants and their functionality. In addition, being located on low-lying coastal land makes them particularly exposed to coastal flooding from sea-level rise (Hummel, Berry, & Stacey, 2018).

The construction process of the built environment also has dual effects on climate change and vice versa. Impact of future climate, land-use change, and mitigation strategies on air temperature, heating and cooling energy needs to be incorporated into the design process of the built environment (Garshasbi et al., 2020). In the coastal regions, the structural changes to the built environment imply physical actions and engineering-based solutions. These include building seawalls and breakwater arms, water recycling systems, water waste treatment plants, and beach nourishment sand pumping(Hafezi, Sahin, Stewart, & Mackey, 2018). Furthermore, the capacity of drainage systems needs to be increased to withstand the extreme weather conditions resulting from climate change impacts (Rahayu et al., 2019).

The architecture of the built environment has evolved through the human development process. Presently, changing climatic conditions demand more environmentally friendly and adaptive built environment architecture(Nematchoua et al., 2020). Environmental impact assessment mechanisms encourage that the resort accommodation buildings align to better access to passive climate interventions of tree shade and prevailing sea breezes. This approach provided good micro-climatic orientation and built environment efficiency. In addition, the design of areas around the buildings enhanced the environmental qualities of external spaces by using landscaping for microclimate control and zonal planting for efficient maintenance (Moore, 2014).

The construction process releases ions to the surrounding environment while extracting building material from existing bedrocks. Furthermore, the urban drainage systems often occupy high levels of carbonates and ions. During extreme weather events and long-term climate change impacts such as saltwater intrusion, the behaviour of these materials changes over time. The mechanisms in which saltwater intrusion impacts the different soils and geologic materials need further study and research (S. S. Kaushal et al., 2021). However, the stormwater management infrastructure can retain salt ions in soils, sediments, and groundwater and mobilise other contaminants concurrently through changes in ion exchange, pH, and biogeochemical processes (S. S. Kaushal et al., 2021).

The built environment will have considerable impacts due to climate change during the post-disaster recovery period. In addition to removing debris from the earthquake and tsunami and rebuilding damaged housing and infrastructure, recovery has entailed decontamination in the affected areas to manage the radioactive matter. Decontamination actions include: removing deposits from roofs and ditches; wiping off roofs and walls; high-pressure washing of hard surfaces; removing fallen leaves and lower branches from gardens, trees and forests; and stripping topsoil from parks and farmland (Ministry of Environment, 2018). In addition, green and open spaces require selective decontamination to restore a safe living environment (Mabon, 2019). Generally, the construction of structural flood control measures, such as polders, shapes the pattern of human settlements and land use, which impacts the extent of flood risk(Adnan, Abdullah, Dewan, & Hall, 2020).

Furthermore, post-disaster recovery planning represents an opportunity to 'build back better by integrating nature-based solutions, resilience-building, Eco-DRR (Ecosystem-based disaster risk reduction), and broader greening initiatives into urban rebuilding (Mabon, 2019). Eco-DRR refers to a set of actions associated with sustainable management, preservation, and ecosystem rebuilding to mitigate climate change and associated disaster risk(Dalimunthe, 2018). In addition, there will be governance and institutional changes such as improvement and reinforcement of management plans and restrictions in decision-making, such as creating a coastal buffer zone or revising land use plans (Hafezi et al., 2018). Accordingly, urban planning and reconstruction in response to climate change impacts need to accommodate local ownership of the climate adaptation strategies (Hens et al., 2018).

Another significant impact on the built environment due to climate change rises in its usage and occupancy. The impacts of the local climate on the energy needs of buildings in the tropical coastal regions are well known. Often 50% of the total energy budget is allocated for air conditioning (Angeles, González, & Ramírez, 2018). Furthermore, urban climates are highly influenced by urban overheating resulting from the interaction of the urban heat island effect and regional synoptic systems (Garshasbi et al., 2020). Therefore, climatic considerations must be made to assess the quality of indoor built environments (Nematchoua et al., 2020). Moreover, urban overheating bears significant energy consequences for urban systems, including the electric network and building energy for cooling purposes(Garshasbi et al., 2020).

New buildings require the indoor temperature to be comfortable, with minimal fluctuation in temperature during the day (Nematchoua et al., 2020). Hence, these demands increased energy production and improved energy infrastructure due to a warmer climate(Angeles et al., 2018). For example, the primary determinant of energy consumption in resorts typically centres on accommodation, visitor infrastructure and administration. Determination of the level of usage is by the prevailing climatic conditions in which the facility is located. In general, to maintain the same level of indoor comfort, facilities operating in a hot or cold climate will consume more energy than those in temperate climates(Moore, 2014).

Presently, the building sector demands up to 40% of the total energy and is responsible for 35% of the carbon dioxide emitted into the atmosphere (Nematchoua et al., 2020). Moreover, the trend is expected to grow, and buildings are predicted to be the largest source of emissions by 2040. Accordingly, the relationship between building energy use, environmental pollution and the vice versa impact on future climate change receives more attention (Li, Sun, Hu, & Sun, 2021).

There are possibilities to mitigate urban overheating with high albedo materials, greenery, and other technologies (Akbari et al., 2016) adapt to climate change by improving the thermal-energy performance of buildings. The introduction of solar panels on roofs is a highly cost-effective way to increase renewable energy production and reduce greenhouse gas emissions (Nematchoua et al., 2020). The application of renewable energy in buildings is seen as a necessary step toward reducing the use of fossil fuels and mitigating climate change (Nematchoua et al., 2020). The new technological advancements which will develop heat transfer processes and building energy efficiency include solid-state cycles, electro-mechanical systems and nanoscale energy savings materials (Angeles et al., 2018). In addition, thermochromic surfaces (Garshasbi and Santamouris, 2019), electrocaloric materials (Ulpiani et al., 2019), and radiative coolers (Feng et al., 2020) can achieve surface temperatures below the ambient temperature even during daytime (Garshasbi et al., 2020). Ahangari and Maerefat (2019) propose applying phase change materials in walls, ceilings, and floor areas. It contributes to energy saving and improves indoor environments' comfort requirements under different climatic conditions (Nematchoua et al., 2020). Rainfall is one of the leading and significant factors in defining outdoor thermal conditions. However, due to the rapid climate change and variations in wet and dry days, rainfall events may affect thermal conditions differently. The impact of global warming on rainfall pattern changes and the effect of rain events on changing outdoor comfort conditions are yet to be fully discovered. Nevertheless, these measures are helpful in the public health and well-being sector, tourism industry and outdoor spaces design and construction in coastal regions(Roshan & Moghbel, 2020).

4.3.1.1 Physical Impact -United Kingdom

Climate change induces issues across the UK, while some are geographically specific issues. However, in all cases, the exact nature of the impacts reflects regional differences in climate change and vulnerability. The most widely recognised problems associated with headline changes in climate include: an increase in the risk of riverine and coastal flooding and erosion; increased pressure on drainage systems; a potential increase in winter storm damage; habitat loss; summer water shortages, low stream flows and water quality problems; increased risk of subsidence in subsidence prone areas; and increasing thermal discomfort in buildings and health problems in summer(Gawith, 2005).

Sea level rise causes an impact on coastal infrastructure assets. Some urban areas In the UK and their infrastructure are already below average high-water levels(Esteban et al., 2020). Saltwater has already intruded into some coastal aquifers. The Thames Barrier has been shut more frequently in recent years due to extreme weather events. Increased rainfall affects infrastructure assets already located in areas susceptible to river or rainwater flooding. Flooding of infrastructure assets can lead to service disruptions. In addition, it can have knock-on implications for the movement of goods and people(Pregnolato, Ford, Wilkinson, Dawson, & environment, 2017).

Extended periods of low rainfall can lead to the failure of public water supplies, and impermeable surfaces in urban areas disrupt natural processes. Additionally, it increases surface water flows and augments the risk of flooding(Dawson, 2015). Temperature changes result in railway track buckles, and road tarmac can rut and melt during hot weather(Hunt & Watkiss, 2011). Overhead power and communication lines can sag during hot days with low winds, reducing operational efficiency. Performance of mechanical and electrical systems such as Information Communication towers, flood gates, power generation turbines are sensitive to temperature. Maintenance and construction cannot be carried out in very hot or cold temperatures. Passengers using public transport experience heat stress on the hottest days(King & van den Bergh, 2017).

Additionally, windstorms, lightning, humidity, solar radiation also causes damage and disruption to all infrastructure services. High winds lead to bridge closures and pose problems for high sided vehicles, and wind turbines cannot operate at very high wind speeds. Windstorms can disrupt infrastructure systems: directly by damaging infrastructure assets and indirectly by toppling trees or blowing other debris around. Furthermore, lightning strikes cause faults in Information Communication Technology and electrical systems. Corrosion is more severe in humid environments than in dry ones, and humidity and solar radiation influence demand for infrastructure services(Dawson, 2015).

4.3.1.2 Physical Impact -Sweden

Increases in precipitation followed by an increased risk of inundation and flooding impose several physical impacts on the coastal regions (Naturvårdsverket, 22 June 2020; Livsmedelsverket, 21 January 2021). Since the year 2000, Sweden has experienced many cases of inundation caused by increased periods with precipitation and instances of heavy rainfall (SOU 2007:60, p 132). The possible consequences following an increased risk of inundation are evident. Apart from direct implications on the built environment in terms of buildings, roads, railways and sewage systems, drinking water sources also risk becoming affected (Naturvårdsverket, 22 June 2020). In addition, water sources risk becoming polluted by flooding, and pipelines risk destruction. Then erosion along the coast poses a potentially devastating problem to many areas accommodating houses of varying types. Calculations made predict that a total of 1,135 km^2 of land lies within the risk zone for erosion from 2071-2100, corresponding to 222 km^2 of low buildings, 84 km^2 of holiday homes, 62 km^2 of industries and 0.5 km^2 of high buildings (the rest being cultivated land, etc.) (SOU 2007:60, p 317). In large parts of Sweden, this has increased the lowest and highest groundwater levels from 1975-2014. Most significant increases have been observed in coastal areas (Sveriges Geologiska Undersökning, 17 January 2018).

4.3.1.3 Physical Impact -Spain

The physical impacts of climate change on Spanish coastal areas mainly include coastal flooding, coastal retreat/loss of beaches, decrease in water resources, loss of coastal resources and saltwater intrusion. According to Sanz et al. (2020), extracted from Losada (2014), the 2040 inundation level could increase by 8% in the Atlantic coast and Alboran Sea: 6% in the Canary Islands 3% along the Mediterranean coast. As for extreme events, their frequency and intensity are expected to increase in the future. For example, in Bilbao, the intensity (measured as a change in flood height) could increase from 3.85 meters in 2010 to 4 meters in 2040. Its frequency will increase from once every 50 years (2010) to once every 15 years in 2040. In Barcelona, however, no changes in intensity are expected, and the increase in frequency is also more minor (the return period goes from 50 to 40 years).

Regarding the coastal retreat and loss of beaches considering only regular regime (not extreme events) and a 6 cm SLR, coastal retreat in the Atlantic coast and the northern Canary Islands will be at least 3 m in 2040, 2 m in Cadiz Gulf and between 1 and 2 m in other coastal areas in Spain. Furthermore, the quantity and quality of available water resources are decreased, with implications for agriculture and livestock, urban supply, hydroelectric production, and ecosystems, particularly affected, in the latter case, by ecological processes, species and habitats linked to aquatic ecosystems. Sea level rise and increased coastal storms produce various impacts on the coastline, as a coastal retreat and changes in sediment transportation, with effects on coastal ecosystems, such as sandbanks, deltas, and estuaries. Saltwater intrusion, especially in the Ebro delta, is triggered due to the combination of Sea level rise and river flow decrease.

4.3.1.4 Physical Impact -Malta

The study published in 2017 about coastal erosion with the use of the Coastal Hazard Wheel11 (CHW) identified coastal erosion as the highest levels of threat to the Maltese coastline. The coast along the western, north-western, and north-eastern area of mainland Malta is characterised by varying geological formations and configuration. This geo-physical context explains why all 4 levels of erosion hazards were identified in this zone. One cannot ignore that coastal vegetation contributes also to coastal stability by influencing the coastal sediment balance and erosion. Since local vegetation land-cover is highly susceptible to the influence by climate change it is important to consider coastal vegetation as an important factor in any study considering the hazard levels presented by erosion (Micallef et al, 2018).

Groundwater is the only natural source of water in Malta. This is replenished when rainwater infiltrates through the permeable sedimentary formations. The abstraction of groundwater currently amounts to approximately 34 million m3 of groundwater each year. This is estimated to be 11 million m3 more than is considered to be sustainable or equal to recharge (Spiteri et al, 2015). The over extraction of groundwater has reduced water quality as it is becoming increasingly saline, with chloride levels exceeding 2000 mg/L, this is turn is compromising the crop yield (Hartfiel et al, 2020). Climate change is expected to aggravate the situation. The increase in temperatures that will lead to further extraction for irrigation and the episodes of extreme storms with torrential rains that will not allow enough lag-time for infiltration and groundwater replenishment will intensify the current situation. Moreover, with the expected sea-level rise, the saltwater in the aquifer will also rise hence limiting the freshwater lens (Hartfiel et al, 2020). Water scarcity and the resulting dependency on desalinization plants is also creating food and energy security challenge (Hartfiel et al, 2020).

4.3.1.5 Physical Impact -Sri Lanka

Climate change's potential effects, especially global warming's impact on sea temperatures and Sea level rise and increased frequency and severity of tropical storms and other extreme events, would have negative consequences for coastal processes, habitats, and human well-being. The major problem associated with climate change is Sea level rise. Due to that, most of the small islands and deltas within the coastal belt will be inundated. In addition, storm surges result in many deaths and property damage to coastal infrastructure, as well as agricultural losses(S. K. Dube et al., 2009). Rain, high winds, and storm surges are the leading causes of destruction from landfalling cyclones(S. K. Dube et al., 1997). Coastal erosion is another significant and ongoing issue in Sri Lanka, with socioeconomic and environmental consequences. Both natural and anthropogenic factors cause erosion, and it has both public and private costs. Beaches are being lost, leisure and tourism activities are being disrupted, and public and private property and infrastructure are being damaged.

4.3.2 Economic Impact

Seaports are vital national economic assets, as more than 80% of global goods and commodities are traded by sea (Shi and Li, 2017). Unfortunately, one-third of seaports worldwide are in areas at risk to severe tropical cyclones (Becker et al., 2012). Seaports are also prone to inundation, weather transient because of hurricane storm surge caused by rising sea levels. Nevertheless, the marine economy is responsible for a considerable proportion of the national GDP and employment in many coastal countries. In the United States, ports contribute to one-quarter of the national GDP, directly and indirectly, employs more than 30 million people (Abdelhafez et al., 2021). In China, seaports contribute to 10% of GDP and 10% national employment (Zhao, Guan, & Sun, 2019). The cost of port adaptation for future trade expansion and facing the sea level increase and construction of new areas would have a global investment expense of between $223 and $768 billion by 2050 (Abdelhafez et al., 2021).

Extreme weather fluctuations, sea-level rise, and other climatic changes will affect marine-based industries such as tourism, fisheries, aquaculture and reduce food security and coastal employment (DeYoung et al., 2020). The impact on the tourism industry is another economic impact of climate change in coastal regions. The Mediterranean basin is one of such affected areas as these could change holiday target destination preferences and demand shifting to more desirable or stable climate conditions (Torres-Bagur, Ribas Palom, & Vila-Subirós, 2019). Also, severe weather conditions will damage the coastal industry capital, such as boats, tools and other equipment and the critical infrastructure such as housing, hospitals, roads, and schools(DeYoung et al., 2020).

The change in climatic conditions and the subsequent impacts will affect the planning process of economic development and human livelihoods in the coastal regions(Zacarias, 2019). Small island developing states will face numeral development issues on climate change impacts such as reduced tax bases, diminishing reserves and credit ratings and increased borrowing during reconstruction(Thomas & Benjamin, 2018). Furthermore, considerable GDP could be diverted to other developmental needs such as education, health, and poverty reduction(Thomas & Benjamin, 2018).

Loss of coastal income sources, economic depression will affect the psychological stability of the coastal communities (DeYoung et al., 2020). Socio-cultural benefits from ecosystem services cannot override the need to rebuild schools, medical facilities, transport links, or remove harmful radiation as part of full recovery. These are actions that require sustained and coordinated investment from the national government (Mabon, 2019). Accordingly, the World Economic Forum in 2018, ranked extreme weather events and failed to adapt to climate change's likely impacts as the two most significant threats to humanity (IPCC, 2018).

4.3.2.1 Economic Impact -United Kingdom

UK coastal areas face deprivation and associated socio-economic challenges that make them particularly vulnerable to climate change. From an economic standpoint, coastal areas are often considered by fragile economic conditions, including low incomes, high unemployment rates, high numbers of people claiming benefits, cyclical employment and pressure on services during the summer months due to tourism (Kantamaneni, 2016; Sayers, Penning-Rowsell, & Horritt, 2018).

Extreme weather, sea-level rise, and coastal erosion will increasingly affect critical infrastructures such as transport and housing and vital economic sectors, including fisheries, agriculture, and recreation/ tourism(Dawson, 2015; Marengo et al., 2017). In terms of flood risk, roughly 3.1 million properties across the UK (2.6 million properties in England, 357,000 properties in Wales, 46,000 properties in Northern Ireland and nearly 100,000 properties in Scotland) are at direct risk of flooding from flooding rivers or the sea. As a result, housing quality and property values are affected, followed by high insurance costs (Mary Zsamboky, Amalia Fernández-Bilbao, David Smith, & Allan, 2011).

Climate change impacts will consequence for the UK marine industries such as commercial fishing, which is the primary livelihood and source of employment for coastal communities(Peck, Pinnegar, & aquaculture, 2019). Another key industry in coastal suburbs is agriculture. Climate changes, including increased temperature and precipitation variability, could negatively affect UK agriculture. Additionally, weeds, pests and associated diseases will expand as temperatures rise, and farmers will struggle to adapt to new climate conditions. Also, the agricultural sector will be affected by the increased incidence of saltwater intrusion in irrigation systems(Harrabin, 2019).

Increased erosion and sea-level rise will affect beaches which in some places could disappear altogether, obviously affecting seaside tourism(Becken, Whittlesea, Loehr, & Scott, 2020). In addition, an over-dependence on tourism for employment could also worsen the economic vulnerability of coastal communities if coastal erosion or high temperatures discourage people from visiting the beach. However, regional scoping studies suggested that tourism, leisure and recreation activities would benefit from the warmer summers expected with climate change(Gawith, 2005).

4.3.2.2 Economic Impact -Sweden

One of the main economic impacts in Sweden due to climate change is attributable to impacts on maritime industries. The use of Swedish coastal areas is increasing in maritime industries such as fishing, shipping, offshore energy, electricity distribution, housing, and tourism (Boverket, 1 April 2020b). The Swedish fishing industry is mainly dependent on the conditions in the Baltic Sea. Therefore, when the Baltic Sea is negatively impacted by climate changes or human behaviour, this also can potentially impact the Swedish fishing industry. While the Swedish tourism industry may benefit from climate change and warmer temperatures, coastal areas will experience increased pressure from foreign and Swedish tourists, escaping hotter temperatures along the Mediterranean and inland Sweden (Boverket, 1 April 2020c). However, the built environment along the Swedish coast is threatened by increasing sea levels, erosion, inundation, and landslides, which means that the built environment and tourism is at risk. Erosion is increasing the most along sandy beaches. Some places may disappear entirely, having a devastating impact on the Swedish tourism industry. Accordingly, climate change and the many devastating events that potentially follow it will pressure local and national governments alike in preventive, mitigating, adaptive, and reparation measures.

Costs for reparation damages to roads and bridges by landslides washed away roads or inundation is estimated at 80-200 million Swedish kronor annually and may increase as much as 9-13 billion kronor by 2100. Furthermore, costs related to pure maintenance of buildings as caused by climate change) amount to around 100 billion Swedish kronor up until 2080 (SOU 2007:60, p 485). Costs to prevent damages from erosion and inundation on the built environment will result in the short-term amount to 150-500 million Swedish kronor (SOU 2007:60, p 205). Likewise, costs to prevent landslides will amount to at least 200 million Swedish kronor. By the end of the 21st century, the number of buildings located within areas prone to landslides is estimated at 22 000, at a value of 320 billion Swedish kronor (SOU 2007:60 p 489).

4.3.2.3 Economic Impact -Spain

By the end of the century, permanent flood damage in the Cantabrian Sea could reach EUR 1 billion and 8 billion, between 0.05% and 0.6% of GDP (2008) for each province. Moreover, the damage could double if extreme weather events are considered. The provinces most affected would-be Bizkaia and Gipuzkoa. However, Cantabria would be so in relative terms. In terms of land use, infrastructure would be the asset most affected by coastal flooding, followed by industrial activities. On the Atlantic coast (A Coruña and Pontevedra), between 15% and 20% of the infrastructure area is at risk.

There will be impacts on tourism, including impacts on critical coastal resources as beaches and dunes, impacts of coastal infrastructures as promenades, and impacts on tourism demand due to heatwave or increased temperatures. Furthermore, loss of recreational value of beaches such as, in Asturias, the results show that in 2100 a return period event of 50 years could generate losses of more than EUR 670 million (Toimil et al., 2018). Also, fisheries and aquaculture will be affected. Sea Level Rise, there will be a decrease in the time adequate for port operation in all Spanish harbours. Changes in wave climate will impact port operation downtimes in ports in the Atlantic coast, southeast Canary Islands, and north Mallorca if no adaptation measures are implemented. In the Mediterranean, the port operation could be increased due to wave climate changes. Also, there will be decreased reliability of coastal structures along the Spanish coast, except in some areas of the Mediterranean façade due to wave climate trends. Finally, changes in energy production and consumption will also happen due to climate change impacts. Changes in production due to changes in wind, water flow, transportation and storing of energy. Changes in consumption: decrease in heating but increased use of air conditioning.

4.3.2.4 Economic Impact -Malta

Historically, agriculture was a very important economic activity in Malta. Manufacturing and services sectors are important sectors of the country's economy with investment in microelectronics and pharmaceuticals. The Mediterranean region is projected to be affected by losses of agricultural yields. In parts of the Mediterranean area, the cultivation of some crops may shift from the summer season to the winter season, which could offset some of the negative impacts of heat waves and droughts during summer (EEA, 2017). A preliminary evaluation on the economic vulnerability and potential for adaptation to climate change show moderate to strong impacts on agriculture. Agriculture is a complex, skilled, and highly evolved sector. It is directly dependent on climate, given that heat, sunlight, and water are the main drivers of crop growth. The impact of climate change on the agricultural sector will be substantial. The impact of climate change on aquaculture and fishery stocks includes the increased influx of alien species. The effects in changing sea temperature and other possible shifts in currents and nutrient flows are recognized as being a significant threat to species of key economic importance. The natural and cultural heritage of the Mediterranean makes it the largest tourism region (EEA, 2017). However, its attractiveness and competitiveness may be compromised due to the increasing air temperatures (EEA, 2017). Moreover, the shift to warmer temperatures in the northern European countries may be detrimental to the north- south tourist flow (EEA, 2017).

Rise in temperature is considered as one of the most important impact of climate change that will affect Maltese tourism (Palmieri, 2014). With the shift of warmer temperatures to the North, potential tourists may be less inclined to travel to destinations as Malta. The need to diversify the sector and extend the seasonality is a survival approach rather than a way to address vulnerabilities related to the increase in temperature (Doods & Kelman, 2008). Small islands are often poorly connectable to external economic markets, continental energy grids and other production and/or distribution systems, due to their physical distinctiveness, remoteness and peripherality. Efficient logistical communication linkages are therefore mandatory for a thriving island economy: something which can also be seen as an opportunity (as in the case of tourism). But such a drive to enhance connectedness often depends on the local environment, micro-climate and atmospheric conditions that can potentially affect the level of connectivity.

4.3.2.5 *Economic Impact -Sri Lanka*

Sea level rise and hazard situations caused by climate change can cause damage and destruction of infrastructure. Infrastructure is a significant asset to the economies, and modern economies rely on moving goods, people, and information safely and reliably (Little, 2002). Hence, the flow of services provided by a nation's infrastructure is needed to continue unimpeded in the face of hazards (Little, 2002). However, infrastructure failure can be catastrophic when interconnected impacts, such as power outages, water mains or fires, co-occur (Little, 2002). There are several industries located in the coastal area of Sri Lanka, including coconut and fisheries-based industries, quarrying and mining (both sand and coral) and tourism (Nianthi &Shaw, 2015). The concentration of industries in the coastal zone is much higher than in other regions of the country, with over eighty per cent of the industrial units located in and around Colombo alone (Nianthi &Shaw, 2015). The large majority of Sri Lanka's tourism economy is also located along the coastal zone (World Bank Group & the Asian Development Bank, 2020). Tourism infrastructure, major commercial ports, fisheries, harbours and anchorage are some of the infrastructures situated in the coastal areas (Nianthi & Shaw, 2015). According to Baba (2010) coastal belt is one of the significant lifelines in Sri Lanka's economy. Sri Lanka has been experiencing coastal erosion and coastline recession at a fast rate in the past years (Baba, 2010; Nianthi & Shaw, 2015; Dastgheib et al., 2018). In addition, coastal hazards threaten the coastal environment and wetland ecosystems, such as in the touristic beaches of the Trincomalee district (Dastgheib et al., 2018). Tourist infrastructure and natural coastal tourism assets, such as beaches and coral reefs, will be the most vulnerable to climate-induced shoreline change (Philips & Jones, 2006; Scott et al., 2012, as cited in Tam, 2019). Storm surge has revealed a retreat distance of between 37 and 262 m along Sri Lanka's East coast, and this has high economic costs (Dastgheib et al., 2018, as cited in World Bank Group & the Asian Development Bank, 2020). The following significant economic impact is relocation and reconstruction cost. Human settlements could become dislodged due to flooding, as seen during the tsunami of 2004 and the flooding of the Ratnapura District in May 2003, where the whole town was submerged, creating a national emergency (Baba, 2010). As mentioned earlier, the coastal zone of Sri Lanka is highly populated and urbanised (Nianthi &Shaw, 2015).

Increasing coastal hazards and seawater intrusion inland means that housing and other infrastructure will be reconstructed, incurring more costs. In addition to the cost of relocation and reconstruction, there would be psychological and socio-economic stresses on displaced communities.

On the other hand, the collapse of eco-systems and destruction of biodiversity will result in specific resources becoming scarce. For example, in Sri Lanka, which depends largely on hydroelectricity, water shortages and erratic rainfall could also lead to shortages of energy production. Lack of resources could be simultaneously met with increased demand for resources (World Bank Group & the Asian Development Bank, 2020).

According to the IPCC report, populations at higher risks from drastic climate changes include marginalised communities, indigenous people, and local communities dependent on agriculture and fisheries (IPCC, 2018, 9). In addition, agricultural and fisheries sectors could face severe fallbacks because of climate variations. Hence, the livelihoods of people depending on agriculture and the fisheries industry is directly under threat. Various levels of socioeconomic vulnerability among people (Demel et al., 2019) cause the levels of coping with differing.

4.3.3 Social Impact

A study on climate change in sustainable livelihoods of coastal areas of the Red River Delta in Vietnam Reduction concludes that agricultural productivity and livestock productivity have decreased over time due to increased droughts, floods, and saline intrusion(Vieira, Salgueiro, Soares, Azeiteiro, & Morgado, 2019). The rainfall and temperature are primary drivers of crop productivity, while extreme climatic conditions, soil salinity in coastal areas, pests' issues and diseases will further increase the predicament. Furthermore, these adverse effects on agriculture will lead to food insecurities in urban and rural communities(Hossain et al., 2019). Accordingly, appropriate, and sustainable food control measures should be designed, considering potential future conditions, such as climate and land cover. Consequently, the protection against foods will be more efficient and less costly(Kefi, Mishra, Masago, & Fukushi, 2020). Furthermore, nature-based solutions can free up resources to respond to change by reducing energy consumption or facilitating agriculture. Also, socially, nature-based solutions can enhance the ability to cope with changing conditions by improving coastal communities' physical and mental well-being (Pearce et al., 2016) or increasing social cohesion and support networks (Mabon, 2019).

Tourism is concentrated mainly around parks and rivers, whereas aesthetic appreciation and inspiration with culture are often associated with parks, flowering plants, and individual/street trees. Moreover, parks and recreational spaces resemble spiritual experience and a sense of place; therefore, after a disaster, the establishment of 'reconstruction memorial parks' in coastal townships becomes necessary (Mabon, 2019). Also, the cultural values of coastal communities are affected by the discharge of raw wastewater causes a significant loss of cultural values. Additionally, the increase of pathogens from human waste will restrict the usage of sea waters for recreational activities. Impact on natural waterways will deteriorate traditional land, river and sea based activities, and eventually loose cultural identity and other indigenous cultures in coastal areas (Hughes, Cowper-Heays, Olesson, Bell, & Stroombergen, 2021).

The threat of permanent inundation will displace and lose the livelihoods (Hens et al., 2018) of the coastal communities(Hens et al., 2018). Human migration or human mobility, which is both a voluntary and involuntary strategy in response to environmental changes, has a considerable influence from the implications of climate change (Upadhyay et al., 2015). Voluntary migration due to slow-onset changes such as decreased water resources, changes in weather patterns, rising temperatures, coastal erosion (Vieira et al., 2019). Forced displacement is also called distress migration due to extreme weather conditions and hazards (Schwan & Yu, 2018; Upadhyay et al., 2015). Population displacement and migration will increase pressure on urban infrastructure and services, economic growth rate, potential risk of increased human conflicts resulting in human unrest and increased health risk (Vieira et al., 2019). Additionally climate variations will induce negative health conditions such as heat-related morbidity including asthma, heatstroke, heat exhaustion, respiratory difficulties, and lung failures will be i (Beheshtian, Donaghy, Gao, Safaie, & Geddes, 2018).

Social protection programmes that become important safety nets can be proactive approaches to handle climate-induced human migration (Schwan & Yu, 2018).

Together with global warming, population growth will drive a further spike in electricity demand (Santamouris, 2016) and anthropogenic heat emissions, primarily contributing to an increase in turbulent sensible heat fluxes (Garshasbi et al., 2020). The fresh-water availability around the coast could be affected by saltwater intrusion due to sea-level increases, global warming and thermal expansion of water (S. S. Kaushal et al., 2021). Saltwater intrusion in coastal areas will threaten human health. It increases the mobility of substances that impose cancer risks, especially for young children (S. S. Kaushal et al., 2021).

4.3.3.1 Social Impact -United Kingdom

One of the primary social impacts of climate change in the UK is displacement and loss of neighbourhoods. Estimations of future flood risks in the UK show that nearly 2 million properties in flood plains along rivers, estuaries, and coasts are potentially at risk. River flooding is projected to affect 250 000 to 400 000 additional people and their neighbourhoods annually by 2080(Munro et al., 2017). Accordingly, the seasonal effects of climate change will also alter tourism demand around the UK and its coastal and marine environments impacting coastal livelihoods and local income sources (Coles, 2020). Climate change-related circumstances hotter summers, heat waves, milder winters, pollen, air pollution, flooding, emerging infections, and food safety influence human health in the UK. Climate change is expected to increase the annual mean temperature by 2–5°C and increase the frequency and intensity of heatwaves in the UK by 2100.

Heat-related excess deaths occur primarily because of respiratory and cardiovascular illnesses. In England and Wales, mortality increases 2.1% for each 1°C increase in temperature above the 93rd percentile of average yearly temperature. The excess deaths caused by increased temperature can include substantial mortality displacement or “harvesting”. On the other hand, Cold weather causes thousands of excess deaths in the UK annually. Many of them are caused by cardiovascular and respiratory illnesses aggravated by cold spells(Paavola, 2017).

Additionally, climate change can also directly impact systems and facilities of health and social care and have indirect impacts on health via changing prices of food and energy. Direct health impacts of flooding include drowning, electrocution and other accidental deaths and injuries. Indirect health impacts can occur due to contamination and loss of water supply and loss of access to transport, electricity supply and communications (Curtis, Fair, Wistow, Val, & Oven, 2017).

4.3.3.2 Social Impact -Sweden

For social impacts, mainly Sweden experiences displacement and neighborhood loss, employment loss, and physical and mental health impacts. Human health is affected by the increased frequency of periods with extreme temperatures. Periods with extreme temperatures are increasing in Sweden, which can cause increased fatalities, especially amongst already vulnerable groups such as the elderly (SOU 2007:60, p 439). Days with extreme temperatures increase proportionally compared with the rise of average temperatures, especially in the south and mid-Sweden and along Norrlandskusten (SOU 2007:60, p 441). While increased temperatures in extreme cases cause fatalities, they also bring with them many other inconveniences. Increased temperatures entail increased body temperatures, blood circulation and sweating, which stresses the heart and increases the risk for dehydration (Centrum för Arbets- och Miljömedicin, 20202 p 4). The risk for heat strokes and heart failure similarly increases. In addition to temperature changes, changes in the natural habitats of certain species may bring with them potential issues for human health (Naturvårdsverket, 27 October 2020). To exemplify, pollen allergies may be exacerbated as the length and intensity of the pollen season changes with warmer temperatures, and the habitats of pollen-producing species may change. Ticks and their diseases are other problems aggravated by changing temperatures. The spread of diseases is also affected by the increased risk of inundation and landslides, which may increase the risk of pollution of drinking water (SOU 20067:60, p 452). Extreme incidents such as inundation and landslides also increase the risk for accidents where people may get injured. Mental health issues that come with experiencing natural disasters such as inundation or landslides; also experience a sense of hopelessness and anxiety with regards to facing climate change, a struggle that seems desperate and hopeless for many individuals (Centrum för Arbets- och Miljömedicin, 20202 p 5). These will be the results of climate change impact on neighbourhoods. It would ultimately lead to the displacement of those living there. Furthermore, the fishing industry in Sweden is heavily impacted by changing conditions in the Baltic Sea. The Swedish fishing fleet has already decreased significantly as decreasing fish populations means decreasing livelihood resources for many fishers.

4.3.3.3 Social Impact -Spain

Projections for 2040 estimate that the population exposed to permanent flooding on the Cantabrian coast could reach 2% -3% in Cantabria, Gipuzkoa or A Coruña. If extreme events are also considered, in Cantabria, 9% of the population would be exposed, followed by Bizkaia and A Coruña, with around 4% of the population. There will be impacts on human health through the effects of climate change by heatwaves and other extreme events, such as floods and droughts. Also, increased air pollution and aeroallergens, change in the distribution of disease-transmitting vectors, loss of water or food quality will impact human health. In the Canary Islands, the possible eastward movement of the Azores anticyclone would favour the arrival of African winds with Saharan dust.

Also, there will be social changes, including direct impacts and the consequences of the adaptation measures applied to deal with them. These impacts are related to the economy and employment, culture, heritage and identity values, governance, population distribution in the territory, social cohesion, conflict associated with natural resources, social inequality, including gender inequality, etc. Finally, there will be impacts on cultural heritage. Some of the effects of climate change on cultural heritage are already visible. For example, many cultural and historical complexes are affected by rising sea levels, changes in the water table, or atmospheric pollution. In addition, there are climate change impacts on cultural landscapes, in practices and knowledge related to agricultural activities and traditional ways of life caused by the increase in population, desertification, floods, and extreme events.

4.3.3.4 Social Impact -Malta

Research suggests that there is a lack of knowledge on climate change among the Maltese population (Debono & Calleja, 2010, p. 147. Palmieri, 2014) and the impacts of climate change are not evident to everyone (Palmieri, 2014). Temperature increases will certainly impact the number of heat-related deaths and respiratory and cardiovascular diseases. The most vulnerable are the elderly and one cannot ignore that the percentage of elderly people in Malta is increasing due to the increase in life expectancy (MRA, 2017). Coastal flooding and flash floods from heavy rainstorms may have an indirect effect on health care services if it impacts infrastructure or access to hospitals, clinics, and pharmacies. Particular sectors will also be affected through increased occupational health and safety concerns, for example construction workers and those working in the primary industries (agriculture, fisheries) and exposed the high temperatures, rainfall, and extreme weather events. The 'Human cost' of these climatic events depends directly on the vulnerability of the people exposed. Social and environmental determinants of health, such as poverty, support systems, concurrent environmental stresses (including polluted water, unprotected waste disposal or polluted air) and displacement, all contribute to population vulnerability.

4.3.3.5 Social Impact -Sri Lanka

USAID (2018) has recognized increased temperature, increased drought frequency and duration and increased storm frequency and intensity as climate stressors that affect human health in Sri Lanka. They further alarm the risks of shifts in vector and water-borne diseases such as dengue, decreased nutrition and food security, reduced availability and increased disruption of health services, reduced water quality and availability and difficulty maintaining sanitation and practices climate change-related health in Sri Lanka. The World Bank Group and the Asian Development Bank (2020) predicts that there will be approximately 73 climate-related deaths per million populations due to malnutrition in Sri Lanka by 2050. An increase in disasters can also increase mental distress and mental illnesses. Studies revealed high amounts of post-traumatic stress disorder (PTSD) cases among children in the aftermath of the tsunami in Sri Lanka (Neuner et al., 2020). The PTSD symptoms were explained by the trauma exposure and family loss and previous traumatic events, such as the war that ranged in the Northern and Eastern Provinces (Neuner et al., 2020). As per the World Bank Group and the Asian Development Bank (2020), many of the climate change predictions are likely to affect the poorest groups in Sri Lanka in various manners. For example, as per Kjellstrom et al. (2016), heavy manual labour jobs are common among the lowest paid whilst being most at risk of productivity losses due to heat stress. In addition, poorer businesses are least able to afford air conditioning as a remedy for heat stress.

Poorer farmers and communities cannot afford local water storage, infrastructure for irrigation, and technologies for adaptation (World Bank Group and the Asian Development Bank, 2020). SLYCAN Trust (2020) further recognizes climate change as one of the main reasons leading to human mobility in Sri Lanka. They discuss the impact of both sudden onset and slow-onset disasters on human mobility. Sudden onset disasters such as floods and landslides make people lose their land, homes, and properties and make them move out of affected areas into temporary shelters. While some may return to their original settings, many will have to permanently relocate (SLYCAN Trust, 2020).

4.3.4 Environmental Impact

Sea level rise and global warming, rising atmospheric CO_2, ocean acidification, and other climate extremes directly damage ecosystems, salt marshes, mangrove forests, seagrass beds, soft sediments, kelp forests, coral reefs, and oyster reefs (He & Silliman, 2019). Warming coastal waters destroys the natural suitable habitats for temperature sensitive species and make them shift poleward(IPCC, 2014b).

The degradation of the mangrove ecosystem is a growing concern induced by sea-level rise, extreme weather events in coastal hazards, changes in precipitation, and increased CO2 levels in the water. Mangrove systems act as sea defence systems protecting the coastal line, controlling the water flow speed and reducing the impact on coastal infrastructure as buffers for the incoming waters (Vieira et al., 2019). Furthermore, mangroves facilitate fish nurseries and havens of biodiversity and carbon storehouses due to their capacity to balance the ecosystems (Iqbal, 2020). The ability of the mangrove ecosystem to reduce the damages of storms is identified as an essential ecosystem service in coastal areas (Akber, Patwary, Islam, & Rahman, 2018)

The precipitation deficiencies over time could cause increased frequency and severity of droughts and heat stresses that will fundamentally alter forests' composition in many regions. (Vieira et al., 2019). In addition, the coastal forests will be stressed by the saltwater intrusion because of climate change conditions. As a result, they will reduce the ability of the coastal landscapes to seize carbon content (S. S. Kaushal et al., 2021).

Additionally, ocean acidification and temperature variations also contribute to the damages to the coastal ecosystems. The increase in ocean temperatures has have induced decreased productivity, diversity, and resilience of nearshore marine ecosystems over the past few decades. In addition, air pollution from gas flaring can affect coastal areas and ecosystems through acid rains. Carbon dioxide, methane, particulates, benzene, and nitrogen oxides contribute to anthropogenic climate change and its impacts, including coral bleaching, sea-level rise, and ecosystem transformations such as fish migration and algae blooms (Andrews et al., 2021; UNFCCC, 2011).

Saltwater intrusion causes complex interrelationships between salt ions, chemical, biological, geologic parameters, and consequences on the natural, social, and built environments and this is named Freshwater Salinization Syndrome. It has direct and indirect impacts on surface, ground and drinking water quality, aquatic and terrestrial ecosystem function, human health, and food production(S. S. Kaushal et al., 2021).

The municipal solid waste landfills are also affected by the changing climatic conditions. The hazards include landslides and flooding due to intense rainfall or coastal inundation, which cause transport and dispersal of toxic substances with the potential to harm the surroundings or result in a situation involving exposure to danger (Yahaya et al., 2021). Landfills located in hillslope areas are susceptible to slope failure triggered by rainfall, resulting in environmental damage such as river blockage and pollution of subsoil and groundwater (Blight 2008; Duggan et al. 2017). Landfills in low-lying areas such as floodplains and coastal zones are susceptible to erosion, flooding, and off-site mobilisation of wastes, which then contaminate rivers, groundwater, soil, and crops affecting the livelihood of farmers and local economies (Gan et al. 2019; Deng et al. 2020) (Yahaya et al., 2021). The health and well-being of nearby communities are at risk due to these impacts. Also, they will damage built assets, degradation of the surrounding coastal ecosystem, and long-term productivity loss for the agricultural sector (Yahaya et al., 2021).

4.3.4.1 Environmental Impact -United Kingdom

UK climate is changing and will continue to change as a result of greenhouse gas emissions. The Met Office's central England temperature series shows that the 21st century has so far been warmer than the previous three centuries(EA, 2018). Coastal ecosystems, such as salt marshes and coastal grazing marshes, will also respond to climate change. For example, significant saltmarsh losses have been widely reported in parts of Britain over the last few decades, including North Kent and Essex (Nicholls et al., 2021). In addition, sea-level rise will alter wetland habitats, in some cases changing them into entirely different environments. The pressures of climate change are already beginning to impact agriculture and forestry in England(Pace, 2021).

In terms of biodiversity loss, there are four threats to the biodiversity in the London city: competition from exotic species; the squeeze on salt marsh habitats from rising sea levels; the effect of drought on wetlands, and the changing phenology of different species as earlier springs occur more frequently (Britton, Hewison, Mitchell, & Riach, 2017; Ennos, Cottrell, Hall, O'Brien, & Management, 2019; McKinley, Ballinger, & Beaumont, 2018). Additionally, climate change will affect river flows directly through changes in rainfall and evaporation and indirectly through changes in vegetation and soil structure.

4.3.4.2 Environmental Impact -Sweden

Species and ecosystems respond to the physical and chemical changes in their environment caused by climate change. Current predictions expect the Baltic Sea to be even more affected by climate changes during the following decades. Therefore, the effects on marine ecosystems and biological diversity in Swedish waters and around Swedish coasts are highly probable (Sveriges Vattenmiljö, n.y.

a). The above-described changes in precipitation and temperature levels have impacted vulnerable ecosystems along the coastline and the Baltic Sea. In addition, they have caused changes in natural habitats for certain species. For example, increased temperatures and heat waves have caused a change in the habitat of several species of fish, which have migrated northwards (Sveriges Vattenmiljö, n.y. a). As habitats and ecosystems are affected by climate change, effects on biodiversity follow. In the sea, biodiversity is disturbed through increasing temperatures, eutrophication, and changes in salinity. In addition, the ice in the Baltic Sea is shrinking. Among species affected by these changes are cod, as its reproduction areas, dependent on salinity and oxygen levels, are shrinking (SOU 2007:60, p 386).

Also, biodiversity in Swedish coastal areas is impacted by changes in land use for cultivation, as facilitated by warmer temperatures and increases in precipitation (Naturvårdsverket, 17 February 2021). Furthermore, algae are affected along the Swedish coast, both in terms of blooming and the composition of algae species (Livsmedelsverket, 21 January 2021). Finally, Skåne and Gotland are the Swedish counties that boast the largest agricultural land proportion (45% of the total area for Skåne and 36% for Gotland) (Statistiska Centralbyrån, 15 October 2020). Climate changes have Sweden affected agriculture both negatively and positively. On the positive side, increasing temperature and a hotter climate improve cultivation conditions, with possibilities for increased yields and for being able to farm crops for more extended periods (Naturvårdsverket, 22 June 2020). On the other hand, warmer winters increase the risk for pests and carriers of diseases, which generally would be mitigated by the cold weather. Impacts on ecosystems changed climate zones and shifting natural habitats also increase the risk for invasive species and weed (Mobjörk, 2011 p 20-22).

4.3.4.3 Environmental Impact -Spain

The main environmental impacts of climate change identified in Spanish coastal areas are reducing beach and dune areas and marshes and wetlands. In Asturias, at the end of the century, beach retreat is estimated around 31, 56 m +/- 11.64 m. In Cataluña, considering 4.5 and 8.5 RCP scenarios, beach retreat is about 47 and 65 m, respectively (Sanz et al., 2020). Loss of *Posidonia* meadows in the Mediterranean Sea with an average increase of 3,4±1,3º C, density of *Posidonia* meadows could decrease 90% in about 30 years. Also, changes in demography, phenology is experienced in Spain. Furthermore, change in behaviour of species and expansion of invasive species. As habitat degradation and loss of ecosystem services occur, regulation services goods (as food, energy, raw materials, etc.) and cultural and recreational services (as learning, relaxing, etc.) are affected.

4.3.4.4 Environmental Impact -Malta

Climate change is influencing the physical dynamics and the hydrological structure of the Mediterranean basin (EEA, 2017). This is related to acidification of seawater, rising water levels and changes in the currents. Sea temperatures are increasing even in deep waters (PAP/RAC, 2005). These climate changes have different ecological consequences. The warming of the Mediterranean Sea will modify the climate of the Maltese islands. The increase in temperature may lead to the shift of terrestrial and marine species and change their life cycles. Moreover, the increase in water temperature will lead to a reduction of dissolved oxygen mainly due to changes in both water stratification and thus water circulation, these changing circumstances will add stress on the local marine and coastal ecosystems (ERA, 2018). In 2012, the Department of Biology of the University of Malta updated its local list of alien marine species that have been recorded since 1990. The presence of those identified in local waters has been mainly attributed to the general warming trend of Mediterranean waters, increased marine traffic and aquaculture activities. As explained above, the limited freshwater resources available in Malta are already significantly stressed, making it more susceptible to climate change. The shift in precipitation patterns including increase in drought episodes could bring about variations in both water flow patterns in vulnerable valley systems and recharge of the aquifer, with detrimental effects on valley ecosystems.

4.3.4.5 Environmental Impact -Sri Lanka

According to Baba (2010), Sri Lanka has been experiencing coastal erosion at the rate of 0.30-0.35 meters a year, with the North and East region, highlighted as more vulnerable. Rising SLR is already impacting the lives and livelihoods of Sri Lankans along the coast through the salinization of soils and groundwater in the coastal zones (World Bank Group & the Asian Development Bank, 2020). It is predicted that narrow rivers entrances with flanking sand bars such as Gin Ganga, Bentara Ganga, Kalu Ganga, and Maha Oya in Sri Lanka will be affected by the rising sea levels. It can destroy the sands bars, resulting in a widening of the inlet. This would increase the volume of seawater entering an estuary or lagoons and cause the peripheral agricultural crops and lands to become salinized (Nianthi, 2005, as cited in Nianthi & Shaw, 2015).

Coastal environments can include beaches and dunes and mangroves, coral reeves, and coastal wetlands, which are rich in biodiversity and natural resources. Seawater intrusion can affect low-lying inundation areas of the coastal region and damage such coastal habitats, including estuaries, lagoons, mangroves, salt marshes, beaches, dunes, coral reefs, seagrass beds, deltas, islands, barrier beaches and spits (Ministry of Mahaweli Development and Environment, 2016). Coastal disasters can uproot natural vegetation (Satyanarayana et al., 2017) and can destroy coastal forests. However, different coastal plant species were affected differently by the tsunami in 2004 (Satyanarayana et al., 2017).

Loss of natural habitat and collapsing of eco-systems would naturally result in the perishing of flora and fauna that inhabit these environments. Sri Lanka is known to be a biodiversity hotspot (De Silva & Yamao, 2007). According to De Silva & Yamao (2007), the changing temperatures and rapid urbanisation will impact terrestrial forest cover near urban settlements. Besides, climate change is expected to influence the introduction and spread of invasive alien species in future (Kariyawasam, Kumar, & Ratnayake, 2020). The existing flora and fauna would be affected by such invasions, and possibly some species would face extinction. Thus, the rich and diverse biodiversity of Sri Lanka would suffer irreparable losses. Also, the acidification of the oceans and destruction of coral reeves in Sri Lanka is predicted to result in stock changes in economically important species, which would, in turn, impact fishers' livelihoods (Ministry of Mahaweli Development and Environment, 2016). Destruction of corals can also lead to reduced tourism (IPCC, 2018) in future.

5 Climate Change Impact on Built environment in coastal regions

In defining coastal regions, the coastal boundaries all over the world show a great variety of ranges. Some of the different criteria are the natural physical criteria, natural processes, coastal morphology, and human coastal uses in marine and land-based activities. Some other contexts establish political-administrative limits for coastal boundaries(Milanés Batista, 2018).

The built environment exerts considerable influence on their local climate and environment (Wilby, 2014), responsible for up to 30% of the global greenhouse gas emissions (RICS, 2019). Human activities relating to different aspects of the built environment, such as transportation systems and infrastructure, building construction and operation and land-use planning, are underlying forces behind climate change. The built environment is most generally defined as the part of the physical environment constructed by human activity (Forrest & Kearns, 2001) can be identified as the context for all human endeavours (Bartuska & Young, 2007). The built environment consists of structures and facilities that are built in urban and suburban areas. These include roads, utility systems, schools, subdivisions, housing, hospitals, playgrounds, public spaces, open spaces, green areas, well-built street layouts, and accompanying physical features (Anderson, 2018).

From another perspective, a built environment encompasses life's infrastructure that protects and enhances our ethical and societal needs, reflects the quality of human life, and contributes to our vulnerabilities (Bosher, Carrillo, Dainty, Glass, & Price, 2007). According to ISDR (2010), vulnerability is determined by physical, social, economic, and environmental factors or processes that increase a community's susceptibility to the impact of climate change and subsequent hazards (Malalgoda, Amaratunga, & Pathirage, 2010). Therefore, the quality of a built environment is a critical aspect as the components of a low-quality built environment can be a disaster waiting to happen (Malalgoda, Amaratunga, & Haigh, 2013).

The continued development efforts worldwide, the growing population, and the increased probability of extreme climate change-induced hazards have adversely affected natural and built environments(Zahmatkesh & Karamouz, 2017). The exposed built assets may have a different degree of vulnerability to coastal hazards resulted in the loss of functionality, serviceability, or integrity (S. Wang et al., 2017). Vulnerability is the susceptibility of assets to a given degree of a hazard and is measured as a likely loss. The loss could be measured in terms of loss of functionality, serviceability, or integrity (X. Wang et al., 2020). For built assets, vulnerability is considered a lack of capacity to resist external stresses, more specifically, to withstand or accommodate potential adverse hazard impacts, e.g., the lack of ability to resist coastal inundation without damage. Vulnerability can often be evaluated regarding the extent of damage to the hazard intensity. In a study done for an urban system, the vulnerability of the urban system towards coastal inundation is described using the multi-dimensions of the loss of built, socioeconomic, and ecological systems (X. Wang et al., 2020). In another study, the nexus between climate change and the built environment is complex and intertwined. The existing built environment is vulnerable to climate-related extreme events (Beheshtian, 2016) and, consequently, how society interacts with these infrastructures(Chappin & van der Lei, 2014). The vulnerability of the built environment to climate change can be categorised into four aspects; impacts on building structures, impact on building construction, impact on building material properties and impact on indoor climate/energy use temperatures, as elaborated by Hacker et al. (2005) and Hrabovszky-Horváth et al. (2013). As witnessed through the past decade's extreme-weather-episodes, the stressed or under attack infrastructure of hamper not only the pre-and-post-disaster emergency tasks but also interrupted the recovery process that may be in effect for several months following an extreme event(Beheshtian et al., 2018). Therefore, developing defensive infrastructures becomes essential in the face of climate change and the associated threats to coastal communities(Micheal et al., 2019).

In the years to come, some coastal communities and infrastructure are likely to be unfeasible for usage in their current state (CCC, 2018). The climate change evidence such as sea-level rise, heavy downpours, extreme heat, and other climate-related phenomena are already causing damages to buildings and infrastructure, and these damages are projected to increase with continued climate change. For example, in the context of expected extreme precipitation and continuing urbanisation, waterlogging is increasingly possible for city centres due to fast rainwater accumulation and in old city areas due to poor local drainage. Although drainage projects' construction helps mitigate waterlogging, it cannot be eliminated as extreme rainstorms may happen or drainage channels may be blocked(Yang et al., 2015). Therefore these potential impacts of climate change should need to be incorporated in the location and design of major infrastructure projects(Wentz, 2015).

Beheshtian et al. (2018) summarise some climate change impacts on built environments as; increased street, basement, and sewer flooding; reduction of water quality, equipment damage from corrosion, and contaminant leaching and runoff; more debris in the waterways, water quality violation, and failure of drainage and wastewater treatment systems, encroachment of salt/fresh-water sources. Furthermore, sea-level rise will inundate the low-lying areas, developed lands, communities, and infrastructures such as communication, energy, solid waste facilities, roads, public transportation, motor fueling supply chain, interrupted critical infrastructures; public health consequences; impassable roads (Beheshtian et al., 2018). Additionally, the built structures will experience building subsidence on clay soils, potential ground movement, and reduced comfort and productivity due to climate change variations(Wilby, 2007). Furthermore, the built areas experience an urban heat island effect, and the temperature increase is reported to escalate to even 5-6°C warmer than the countryside(Wilby, 2007). As a result, increased peak electricity loads in summer resulted in higher frequency in utility outages, rising water peak demand flow, and potential water scarcity(Beheshtian et al., 2018). Adaptation options include costly structural modifications such as substituting material and building techniques and codes so that houses are more comfortable for occupancy and more resistant to flood and extreme weather events (IPCC, 2018).

There has also been mounting pressure for built environment professionals, including planners and architects, to the built environment in a more energy and water-efficient manner, reducing risks to human and environmental health (Wilby, 2007). However, climate change effects on interconnected energy, transport, and built infrastructures remain less studied in the scientific literature (Chappin & van der Lei, 2014).

5.1 Climate Change Impact on Built environment in coastal regions- United Kingdom

As discussed in the previous sections, current predictions for the UK suggest that both temperature and sea level are rising. Many of England's coastal defences are likely to be at risk of failure as sea levels rise. For example, a sea-level rise of 0.5 m is predicted to make a further 20% of England's coastal defences vulnerable to failure(CCC, 2018). Climate change-induced floods could wipe out popular holiday destinations and access roads in the UK coastal belts. Global trends in sea-level rise affect the UK, particularly along the Norfolk and Suffolk coastlines in southeast England, where data exhibits a rising trend throughout history(Kantamaneni, 2016). Coastal and low-lying areas vulnerable to flooding could be completely submerged in water in thirty years if action is not taken. Parts of North Wales and eastern England are likely to be underwater by 2050 due to rising sea levels, washing away railways, swamp farmland, and holiday resorts. This increased rainfall, as well as rising sea levels, means there could be as many as one million homes with a high risk of flooding by 2050. While a significant investment of £2.5 billion is set for flood defences between 2015-2021, most will be coastal flooding. (CCC, 2018).

The M4 motorway submerged close to the Severn Bridge would badly affect coastal areas and river valleys in the south. (Cathy Owen, 22 Jun 2021). A recent study by the Chartered Institute of Building Services Engineers (CIBSE) modelled a range of impacts on building design and operation by examining changes to average and extreme temperature and humidity levels up to the 2080s (CIBSE, 2004). Many older buildings, traditionally constructed in heavy materials, with small windows and good ventilation (both controlled and uncontrolled), have performed well during recent heatwaves. But many late-

20th-century buildings are constructed by lightweight, poorly insulated construction, large expanses of unshaded glazing and poor ventilation in summer(Gething & Puckett, 2019). As a result, coastal infrastructure is likely to be unviable in its current form in the future, which needs urgent adaptation and climate change response plans throughout the coastal regions.

5.2 Climate Change Impact on Built environment in coastal regions- Sweden

As we have seen, 40% of the Swedish population lives within five kilometres of the coastline, and many buildings are similarly located close to the Swedish coast. Critical infrastructure such as roads and railways are often located close to watercourses, which means they are vulnerable to increasing precipitation, inundation, flooding, and landslides (Naturvårdsverket, 31 March 2021). Increasing temperatures and shortened periods with frost may likewise affect this infrastructure in places where such conditions have been considered during construction. As with roads, railroads are sensitive to precipitation, increasing the risk of inundation, erosion, and landslides. Increased precipitation increases the risk of infiltration and erosion of ballast and constructions under the tracks, whose carrying capacity decreases (2007:60, p 210). Low lying tunnels are sensitive to inundation, as are electronic devices and arrangements supporting the railways. Seafaring is not significantly impacted by the climate changes, except in the north, where it may be positively affected by decreasing ices, facilitating navigation and shipping.

On the other hand, port infrastructure is affected in various ways depending on where along the coast it is located (Naturvårdsverket, 31 March 2021). Increased precipitation creates good conditions for Swedish waterpower, especially for expanding already existing infrastructure (SOU 2007:60, p 234). For buildings in general, increased temperatures, rising sea levels and precipitation changes bring an increased risk for inundation. Also, an increased risk for mould and problems with moisture in buildings increased pressure on current sewerage systems, and an increased need for maintenance in general (Länsstyrelserna, 2012 p 23). Many buildings and essential infrastructure have a lifespan of 50-100 years. Therefore, they also require considering future climate changes and what the Swedish climate and coastal areas may look like in the future (Klimatanpassning.se, 3 November 2020). Future climate conditions, such as increased temperatures and changing precipitation patterns, require adaptation of future buildings and city or district planning, focusing on flexibility and sustainability (Klimatanpassning.se, 3 November 2020).

5.3 Climate Change Impact on Built environment in coastal regions- Spain

The Spanish Urban Agenda (Ministerio de Fomento, 2018) identifies climate impacts that currently affect Spanish cities. Including climate and risk forecasts into territorial and urban planning is essential to prevent climate-related risks. It will increase the resilience of urban environments and increase the capacity to anticipate and reduce uncertainties. Specifically, the Spanish Urban Agenda identifies several direct impacts on the built environment. One is the increase in urbanization. The reduction of soil permeability will increase the probability of flooding in urban systems. Then the changes in the rainfall regime and the drought will affect cities and can create dysfunctions. Heatwaves and increased temperatures will affect urban areas so much due to their urban characteristics and the heat island effect. Additionally, increased mortality and morbidity and increased temperatures can cause disease transmission through food and water (translated from Sanz, 2020).

In terms of economic impact, by the end of the century, the damage caused by permanent flooding in the Cantabrian coast could reach EUR 1 billion and EUR 8 billion, between 0.05% and 0.6% of each province's GDP (2008). Damages could double if extreme weather events are considered, and the most affected provinces would be Bizkaia and Gipuzkoa. However, Cantabria would be the most affected in relative terms. Infrastructures would be the most affected by coastal flooding, followed by land for industrial activities in terms of affected land uses. It is striking that on the Atlantic coast (A Coruña and Pontevedra), between 15% and 20% of the infrastructure surface area is located in areas at risk from coastal flooding (Losada 2014; Sanz, 2020).

5.4 Climate Change Impact on Built environment in coastal regions- Malta

Malta is densely populated, and from a land-use point of view, 22% of the total land area in Malta is built up. When considering other urban development such as airports, ports, industrial and commercial sites, mineral extraction sites, this value is almost 30% of the total area of the Maltese Islands (NSO, 2011). Agricultural land accounts for close to 50% of total land area, while naturally vegetated land accounts for the rest. As a small archipelagic state, all buildings and infrastructure are primarily exposed to coastal environments with increased vulnerability to climate change.

As a densely populated island state of around 1,400 persons per square kilometre, infrastructure and land use requirements have long been considered a major competing force against conserving natural habitats and eco systems. The impacts from climate change on the islands, including sea-level rise, changes in temperature, and extreme weather events, will strongly negatively impact the built environment, including infrastructure. A better understanding of these impacts and the associated risks is necessary to plan and develop better the built environment and its supporting infrastructure. Malta is densely populated, and land resources are scarce. Urban development, agriculture, industrial and commercial activities and quarrying are the primary land uses, adding significant pressures on the Maltese countryside. A significant percentage of Malta’s urban development also lies on the coast, covering 35% of the coastal zone in Malta and 19% of the coast of Gozo. The predicted sea-level rise and increase in extreme weather events pose a serious threat to the coastal population, particularly high-density ones. The impacts range from inundation, coastal erosion (including loss or movement of beaches), and damage caused by storm surges, waves, and high winds. Extreme weather events will also impact part of Malta's coast made up of fragile Blue Clay. Several vulnerabilities associated with sea-level rise, mainly related to coastal development, protected areas, ports, infrastructures and roads, have been identified. Climate change will impact Malta's land use in several ways, including flooding of coastal areas, drought stress on agriculture, extreme weather events (including flooding). These have impacts on structures and infrastructure, secondary impacts on property values and insurance, impact on plants, vegetation and subsequently on human health. The infrastructure of the Maltese Islands will not be immune to climate change, albeit at different levels depending on its development, resilience, and adaptability. With the current projections for the increase in temperature, changes in precipitation patterns and sea level, there is a threat to infrastructures which can impact other aspects of society. Damage from storms, increased energy demands due to extreme weather, as well as threats to low-lying infrastructure from sea level rise are amongst the more obvious vulnerabilities identified for infrastructure

5.5 Climate Change Impact on Built environment in coastal regions- Sri Lanka

The coastal areas of Sri Lanka, which are vulnerable to, are densely populated, with much of the urban cities, including Colombo's capital city, located there (Nianthi & Shaw, 2015). Infrastructure within the coastal belt in Sri Lanka significantly affects due to climate change and its associated hazards. Many infrastructures within the coastal belt zone are highly vulnerable to the SLR. For example, the study carried out by the ministry of environment (Ministry of Environment, Sri Lanka, 2011) maps out the vulnerabilities of the transport infrastructures (i.e., Figure 6.1 and Figure 6.2) to the SLR and floods. The report highlights that the main transportation infrastructures in Sri Lanka include roads, railways, airports, and seaports, are highly vulnerable to SLR. These vulnerabilities are highest in the island's Northern and South-western coastal region as infrastructures are not designed to accommodate climate change and its impacts. Vulnerabilities would be magnified as a substantial segment of transportation networks runs parallel to the coastline. Based on the study, 8 Divisional Secretariats Division (DSD) appear to be highly vulnerable. Within 500m of the coast, these DSDs have 117 km of main roads, 183 km of secondary roads, and 38 km of railroads. The 10 moderately vulnerable DSDs have 75 km of main roads, 143 km of secondary roads, and 24 km of railroads, all within 500 m of the coast. Jaffna District has 14 DSDs, 4 of which are highly vulnerable and 4 of which are moderately vulnerable, making it one of the most vulnerable districts in the country. Over the next few years, significant investments are planned in Jaffna. Sri Lanka has been experiencing impacts due to extreme events over the past years. Apart from the SLR, these infrastructures are highly vulnerable to floods induced by storms and extreme rainfalls. These events turned into disasters damaging lots of buildings. This increasing trend of disaster losses caused to the built environment is driven by the unprecedented rate of urbanisation, increasing dependence on complex infrastructure, outdated and poor-quality buildings and infrastructure(Amaratunga et al., 2017).

6 Discussion

The results relating to the key research questions have been analysed separately, and the discussion is presented under the four key research problems as follows.

6.1 Discussion on the evidence of climate change in coastal regions

The primary climate change evidence identified in the review are seal level rise, precipitation changes and changes in climatic conditions. In the global context, rising sea levels and the associated changing climatic conditions impose severe threats to coastal livelihoods and natural habitats. However, at the individual country levels, the risks vary locally depending on the geophysical characteristics. For example, in Sweden, the localised variations in the sea level rises are attributed to tectonic uplift due to being covered with thick layers of ice during recent ice ages. In the UK, the Southern part of Britain experiences higher sea level rises compared to the North area. When it comes to the Spanish coasts in estimating the local sea level rises, the subsidence effects, especially in the Ebro Delta and the mouth of the Guadalquivir River, need to be considered. Also, in Malta, a small island state, sea-level changes integrate several factors dictated by internal climatic influences and external signals like the North Atlantic Oscillation. However, the Sri Lankan case data shows that south and southwest coastal belts are primarily vulnerable to changing climatic conditions.

While in the UK, changing climatic conditions, coastal flooding is seen as the most frequent hazard in coastal regions. The changing precipitation patterns will lead to hotter, possibly drier summers and milder, wetter winters in the future. While in Sweden, warmer winters have already brought less snow falling, predictions for the future due to changes in precipitation. Cantabrian Sea experiences a significant wave of climate changes which affects the sediment transportation process in the coastal belts in Spain. However, storms and temperature extremes (heat and cold waves) are likely to become more frequent and severe across the Mediterranean coasts. Accordingly, the climate of the Maltese Islands is typically a Mediterranean climate with hot, dry summers and relatively mild winters in the years to come. Finally, Sri Lanka will experience rising air temperatures and rising intensity of sub-daily extreme rainfall events throughout the country as a tropical country.

6.2 Discussion on disaster risk and climate change

Climate change evidence in coastal regions creates natural hazards and induces the severity and frequency of the existing hazards. One of the main hazards induced by climate change impacts in coastal regions is coastal erosion.

According to Baba (2010), Sri Lanka, an island in the pacific Indian ocean, experiences coastal erosion at the rate of 0.30-0.35 meters a year, with the North and East region, highlighted as more vulnerable. Evidence of erosion in Sweden can moreover already be found along the southern coast of Skåne, wherein some places, the shoreline has shifted over 200 meters inland over the past 40 years (Malmberg Persson, Nyberg, Ising and Rodhe, 2016). In Malta, erosion has the highest hazard value depending on the specific coastal configuration (Micallef et al., 2018). About 45.7% of the Maltese coast has a low erosion hazard level, 12.1% with a moderate level of 12.1%, and a high and very high level of erosion hazard of 12.6% and 18.4%, respectively (Micallef et al. 2017). Along with coastal erosion, the following coastal hazard is the risk of inundation. The inundation will affect three main areas: coastal livelihoods, bare lands, and aquaculture ponds. For example, Malta predicted the sea-level rise and increasing extreme weather events as a considerable threat to the island's highly populated coastal areas due to the potential impacts of inundation.

On the other hand, in Sweden, an increased risk of inundation, erosion and landslides, heat waves, Shrinking Swedish glaciers are experienced due to changing climatic conditions. Furthermore, extreme climatic conditions will create hazardous situations in the coastal regions. Flooding is the most common hazard induced by climatic changes in coastal regions. There are different flood types such as coastal surge flooding, fluvial river flooding and pluvial surface flooding. One of the most dangerous challenges to UK settlements is flooding(Percival & Teeuw, 2019). For example, the 2007 summer floods affected 55,000 properties(Dale, 2021) and cost £3.2 billion. At the same time, the 2013–2014 floods cost approximately £1.3 billion in insurance claims in the UK(Smith, 2013). Also, severe winters, heavy downpours, cyclonic storms, hurricanes, tsunami situations, storm surges, and landslides are several other hazardous situations identified under the disaster risk review.

Additionally, global warming induces melting ice, water temperature increases, and hazardous situations such as heatwaves and forest fires. The type of hazards and the intensity and impact varies through the varying geophysical characteristics. For instance, in Malta, extreme weather events pose a considerable threat to the island's highly populated coastal areas due to the potential impacts of inundation, coastal erosion, and damage by storm surges, waves, and high winds (Micallef et al., 2018). In Spain, coastal flooding, continued erosion, increased drought and desertification risk and increased fire hazard can be seen in coastal regions. While in Sri Lanka, which is a tropical country, climate-related hazards, including droughts, heatwaves, and cyclones, are most experienced. Additionally, cyclones can result in flood and landslide situations afterwards.

6.3 Discussion on climate change impacts in coastal regions

6.3.1 Physical impacts

The physical impacts due to climate change evidence and associated disaster risks in the coastal regions mainly include the damages to the coastal infrastructure. The coastal infrastructure includes seaports, buildings, transport networks, water, and storm management infrastructure. For example, in the UK, an increase in the risk of riverine and coastal flooding and erosion has increased pressure on drainage systems with a potential increase in winter storm damage and summer water shortages increasing thermal discomfort in buildings and health problems in summer(Gawith, 2005). In Sweden, coastal regions are at risk for buildings, roads, railways, sewage systems, and drinking water sources (Naturvårdsverket, 22 June 2020).

The increase of mass movements is another significant physical impact due to climate change effects. This destabilises hillsides, sediment runs off, destabilises embankments, and has increased risk of subsidence in subsidence prone areas in the UK (Gawith, 2005). Norrlandskusten is prone to landslides in Sweden's case, as the soil primarily consists of mud (SOU 2007:60, p 135). More than 55 landslides of above one hectare in size have happened in Sweden over 100 years (SOU 2007:60, p 135).

During a hazardous situation, interruptions to emergency facilities, essential services, and critical infrastructure will be experienced. For example, in Malta, small islands are often poorly connectable to external economic markets, continental energy grids and other production and/or distribution systems due to their physical distinctiveness, remoteness and peripherality. In addition, it has been recorded that coastal flooding and flash floods from heavy rainstorms may indirectly affect health care services if it impacts infrastructure or access to hospitals, clinics, and pharmacies in Malta.

Another impact of the climate change-related saltwater intrusion and acid rains are their impact on building material. As an example, contamination of Pb and rising concentration of Cl will induce corrosion of plumbing systems. In addition, road salts cause corrosion in both the concrete and steel structures on bridges, roadways, and sidewalks leading to the risk of failure. In the UK, it has been recorded that mechanical and electrical systems such as Information Communication towers, flood gates, power generation turbines are sensitive to temperatures.

Furthermore, global warming results in urban overheating. It will induce more energy consumption due to heating and cooling needs in buildings. While in Sweden, costs related to pure maintenance of buildings caused by climate change (increased temperatures and humidity) amount to around 100 billion Swedish kronor up until 2080 (SOU 2007:60, p 485). In Spain also urban supply, hydroelectric production has been affected due to change in climatic conditions.

As a result of damaging conditions, the need for physical preventive structures arises. Structural changes to the built environment imply physical actions and engineering-based solutions building seawalls and breakwater arms, water recycling systems, water waste treatment plants, and beach nourishment sand pumping. There is a decreased reliability of coastal structures along the Spanish coast in Sweden, except in some areas of the Mediterranean façade due to wave climate trends. In Spain, coastal vegetation also contributes to coastal stability by influencing the coastal sediment balance and erosion. Since local vegetation land-cover is highly susceptible to climate change, the need for manmade preventive structures arises. In Malta, a small island state, environmental changes could restrict transportation linkages and hence accessibility unless substantial investments in permanent physical links, if possible, are made available. (Baldacchino, 2015).

Accordingly, there will be further physical implications such as governance and institutional changes coastal buffer zone or revising land-use plans. The loss of land undermines existing buildings and may cause damages to the buildings themselves. This has implications for the location of new buildings, investments, and risk analysis. For example, in Sweden, the responsibility lies with the municipality to investigate the appropriateness of the land and to show that the land is suitable for construction (Boverket, 22 December 2020). All of the physical implications will demand more environmentally friendly and adaptive built environment architecture in coastal regions. Impact of future climate, land-use change, and mitigation strategies on air temperature, heating and cooling energy needs to be incorporated into the Built environment design process. Build back better by integrating nature-based solutions, resilience-building, Eco-DRR, and wider greening initiatives into urban rebuilding will change the landscape of coastal regions' physical built environment.

6.3.2 Economic Impacts

The most significant economic impacts are mainly attributed to the losses due to damages in the coastal infrastructure. For example, in Spain, flood damage in the Cantabrian Sea could reach EUR 1 billion and 8 billion, between 0.05% and 0.6% of GDP (2008) for each province by the end of this century. While in Sweden, costs for reparation damages to roads and bridges caused by landslides, washed away roads or inundation is estimated at 80-200 million Swedish kronor per year and may amount to as much as 9-13 billion kronor by 2100 if risks increase successively. On the other hand, in developing countries like Sri Lanka, which already lacks infrastructure facilities, the destruction of existing infrastructure can be devastating.

The climate change impact on marine-based industries such as tourism, fisheries, aquaculture is also very much of a concern in the coastal regions. There will be damages to the coastal industry capital and vital national economic assets like seaports. In countries like Sri Lanka, tourism is a primary national income source. Tourist infrastructure and natural coastal tourism assets, such as beaches and coral reefs, will be the most vulnerable to climate-induced shoreline change (Philips & Jones, 2006; Scott et al., 2012, as cited in Tam, 2019). It has been recorded in Malta that changes in water availability, biodiversity loss, reduced landscape aesthetic, altered agricultural production (for example, food and wine tourism), increased natural hazards, coastal erosion, inundation, damage to infrastructure, and the increasing incidence of vector-borne diseases, will all impact tourism to varying degrees. Also, other sectors of the economy will be affected by increased occupational health and safety concerns, such as construction workers and those working in the primary industries (agriculture, fisheries) and exposed to high temperatures, rainfall, and extreme weather events. In Sweden, the fishing industry is also heavily impacted by changing conditions in the Baltic Sea. The Swedish fishing fleet has already decreased significantly as decreasing fish populations means decreasing livelihood resources for many fishers.

Loss of coastal income and economic depression, and unemployment will result in reduced tax bases, and impact credit ratings increased borrowing during reconstruction. One-third of the EU population lives within 50 km of the coast. The GDP generated by the coastal sector of the population amounts to over 30% of the total EU GPD. In the EU, the economic value of coastal areas within 500 metres from the European sea's totals between €500-1,000 billion and the costs of doing nothing against the effects of climate change in coastal areas are estimated to be higher than the annual costs of taking actions, which is estimated at around €6 billion by 2020. On the other hand, the net benefits of adaptation are up to €4.2 billion (EC, 2021). For example, due to rising sea levels, there will be a decrease in the time adequate for port operation in all Spanish harbours. Furthermore, due to changes observed in wave climate, port operation downtimes are expected in ports on the Atlantic coast, southeast Canary Islands, and north Mallorca if no adaptation measures are implemented.

Accordingly, there will be an economic impact due to the cost of adaptation and reconstruction. Adaptive measures taken to decrease the risks with regards to climate change impacts on railroads include, among other things, education of workers, mapping of risk areas, increased maintenance, change of drainage systems and protection against erosion, an examination of current requirements for dimensioning, as well as maintenance of forests to prevent power failures. While in Sweden, costs related to such adaptive measures are estimated at 100 million kronor, with another 20 million kronor per year aimed at increased maintenance (SOU 2007:60, p 481). Also, as the Sri Lankan case records, cleaning up land and water bodies after coastal hazards can incur additional costs that the farmers may not be able to bear. In these instances, the government may need to step in to compensate and support the local farmers, who will be an extra burden to the national economy.

6.3.3 Social Impacts

One of the most harmful impacts of climate change and the associated disaster risks is the threat to human life in terms of casualties and mortalities. In Malta, it is recorded that temperature increases will undoubtedly impact the number of heat-related deaths and respiratory and cardiovascular diseases. The most vulnerable are the elderly, and one cannot ignore that the percentage of older people in Malta is increasing due to the increase in life expectancy (MRA, 2017). Also, in the same manner, in Sweden, human health is affected by the increased frequency of periods with extreme temperatures. Periods with extreme temperatures are increasing in Sweden, which can cause increased fatalities, especially amongst already vulnerable groups such as the elderly (SOU 2007:60, p 439). Thus, another major challenge the coastal communities are facing is the increased threat to human health.

Along with global warming, the warmer summers will increase outdoor activity and exposure to UV radiation in the UK. In Spain and Malta, it has been recorded that human health has also been affected through air pollution and aeroallergens. These conditions create allergenic diseases or respiratory conditions. Furthermore, Sri Lanka has increased human health concerns due to shifts in vector and water-borne diseases like Dengue. Furthermore, decreased nutrition and food security, reduced availability and increased disruption of health services, reduced water quality and availability and the difficulty maintaining sanitation and practices significantly during emergencies worsen the predicament.

Agriculture is a key industry in many districts along the UK coast. Climate changes, including increased temperature and precipitation variability, could negatively affect UK agriculture (DEFRA, 2005b). For hotspot areas such as Yorkshire and Lincolnshire, and East Anglia, where there is a predicted rise in temperature and lower precipitation levels, this could put additional pressure on freshwater availability. It can affect local farmers, creating a compounding effect that could have severe consequences for sustained agricultural production in these areas (Mary Zsamboky et al., 2011). With the expected sea-level rise in Malta, the aquifer's saltwater will also rise, limiting the freshwater lens (Hartfiel et al., 2020). In Sri Lanka, storm surges result in an agricultural loss (S. K. Dube et al., 2009). On the other hand, fishers would be heavily affected due to a lack of fish resources. For example, Barange et al. (2014) project a potential decline in fish catch due to climate change to be around twenty per cent by the 2050s (World Bank Group & the Asian Development Bank, 2020).

Due to life dangers and loss of livelihoods and coastal income sources, there will be Voluntary and involuntary human migration. In Sri Lanka, sudden onset disasters such as floods and landslides make people lose their land, homes, and properties and move out of affected areas into temporary shelters. While some may return to their original settings, many will have to permanently relocate (SLYCAN Trust, 2020). These circumstances pose pressure on urban infrastructure and impact planning human livelihoods as well. In addition to the cost of relocation and reconstruction, psychological and socio-economic stresses will impact people forced to relocate from their homes and communities. The lack of well-planned shelters can cause harm or difficulties to shelters' residents, especially women and children live (Rathnayake et al., 2019).

Groundwater is the only natural source of water in Malta. In such circumstances, these threats will pose food and freshwater insecurities within the affected and host communities. In summary, the social changes due to climate change and associated disaster risks will impose culture, heritage and identity values, governance, population distribution in the territory, social cohesion, conflict associated with natural resources, social inequality, and gender inequality, etc.

6.3.4 Environmental Impacts

One of the leading environmental threats in coastal regions associated with climate change is damage to coastal ecosystems, salt marshes, mangrove forests, seagrass beds, soft sediments, kelp forests, coral reefs, and oyster reefs. Significant saltmarsh losses have been widely reported in parts of Britain over the last few decades, including North Kent and Essex (Nicholls et al., 2021). The sea-level rise appears to threaten saltmarshes in East Anglia more than those in the Northwest. While in Sweden, increased temperatures and heat waves have caused a change in the habitat of several species of fish, which have migrated northwards. Cold-water species have been particularly vulnerable to warm-ups, which has had spill-over effects on the fishing industry, which largely depends on these species (Boverket, 1 April 2021). Accordingly, the effect on the coastal ecosystems have impacts on the biodiversity as well. In the sea, biodiversity is affected by increasing temperatures, eutrophication, and changes in salinity and the fact that the ice in the Baltic Sea is shrinking. Therefore, in the Erupoean regions, species affected by these changes are cod, as its reproduction areas, dependent on salinity and oxygen levels, are shrinking (SOU 2007:60, p 386).

Another impact on the coastal ecosystems is the alteration of forests' composition, wildlife habitats in coastal regions. Furthermore, recent measurements have demonstrated acidification of Swedish waters, caused by increasing carbon dioxide levels in the atmosphere dissolving into the seawater. This further stress the already delicate ecosystems existing in the Baltic Sea, as sea acidification increases the solubility of lime (a type of stone which is abundant in Swedish coastal areas such as Skåne, Gotland and Öland [Svenska Kalkföreningen, 2020]). It poses difficulties for marine organisms in building up shells and skeletons (Boverket, 1 April 2020a). In Malta, it has been recorded that the increase in temperature may lead to the shift of terrestrial and marine species and change their life cycles.

Impacts on surface, ground and aquatic, and terrestrial ecosystem function affect the water resource quality majorly. In Malta, climate change influences the physical dynamics and the hydrological structure of the Mediterranean basin (EEA, 2017). This is related to the acidification of seawater, rising water levels and changes in the currents. Sea temperatures are increasing even in deep waters (PAP/RAC, 2005). These climate changes have different ecological consequences such as freshwater Salinization Syndrome, acid rains, saltwater intrusion are also results of climate change impacts. For example, in Spain, saltwater intrusion is reported, especially in the Ebro delta, due to the combination of sea-level rise and river flow decrease.

Further in Sri Lanka, it is reported that coastal hazards can cause coastal water bodies to fill up with debris, beach erosion, uprooted vegetation, and salinization of drinking water and agricultural fields (IUCN, 2005; UNEP & MENR, 2005, as cited in Satyanarayana et al., 2017). Furthermore, environmental pollution occurs due to the dispersal of toxic substances and Off-site mobilization of wastes, contaminating rivers, groundwater, soil, and crops. Therefore, environmental restoration after a disaster is much needed after hazardous situations.

6.4 Discussion on climate change impacts and links to the coastal built environment

The built environment undoubtedly significantly impacts the climate change impact and the associated disaster risks in the coastal regions. In the individual country scenarios, it can be seen that all the countries in different manners have a considerable impact on the coastal built environment due to climate change impacts. For instance, increased precipitation, melting ice and rising sea levels entail those cities, districts and buildings close to the coast and shorelines risk inundation and landslides. This both requires adaptation of the existing built environment, as well as it is a risk factor to take into account in the future planning of cities and districts.

Over the last decade, the UK has experienced several severe natural hazard events with significant economic and human impacts on communities, properties, and infrastructure networks. If action is not taken, especially in the coastal and low-lying areas vulnerable to flooding could be completely submerged in water in thirty years. As a result, coastal regions, popular holiday destinations and vital roads in North Wales and eastern England could be wiped out by floods due to climate change. Around 40% of the Swedish population lives within five kilometres of the coastline. Many buildings are similarly located close to the Swedish coast. Critical infrastructure such as roads and railways are often located close to watercourses, which means they are vulnerable to increasing precipitation, inundation, flooding, and landslides. Increased precipitation may contribute to elevated groundwater levels and change the soil's pressure, affecting slope stability. High levels of water in watercourses similarly contribute to an increased risk of erosion. Roads, banks, and bridges may, as a consequence, be flushed away or damaged by landslides. In Spain, where the infrastructure is mainly at risk due to landslides and erosion. Additionally, flooding also severely attack urban network infrastructure and other constructions.

Another significant impact on the coastal built environment is the damage to port infrastructure and increased risk of failure of coastal protection structures. This is a significant fact in countries like Malta which are small island developing states. Some of the primary link roads in the network have been constructed in low lying areas (valleys), which are naturally prone to flooding and will be impacted by sea-level rise. A significant percentage of Malta's urban development also lies on the coast, covering 35% of the coastal zone in Malta and 19% of the coast of Gozo. As a densely populated island state of around 1,400 persons per square kilometre, infrastructure and land use requirements have long been considered a major competing force against conserving natural habitats and ecosystems. The impacts from climate change on the islands, including sea level rise, changes in temperature, and extreme weather events, will have a strong negative impact on the built environment, including infrastructure.

Similarly, in Sri Lanka, the coastal areas are vulnerable and densely populated, with much of the urban cities, including Colombo's capital city, located there. The urban poor in urban slums in Sri Lanka are the most vulnerable as they lack the strength to withstand extreme conditions and cannot afford preventive measures. The main transportation infrastructures in Sri Lanka include roads, railways, airports, and seaports that are highly vulnerable to rising sea levels. Apart from those, vulnerabilities would be magnified as a substantial segment of transportation networks runs parallel to the coastline. These vulnerabilities are highest in the island's Northern and South-western coastal region as infrastructures are not designed to accommodate climate change and its impacts.

The analysis of the individual country cases and the global level review depicts that there will be differential impacts on the various elements of the built environment. Therefore, as per the original definitions provided in section 5 of this report, the climate change impacts to the built environment could develop. Accordingly, the built environment is most generally defined as the part of the physical environment constructed by human activity. It mainly includes roads, utility systems, schools, subdivisions, housing, hospitals, playgrounds, public spaces, open spaces, green areas, well-built street layouts, and accompanying physical features. Based on these definitions, the links of the physical, economic, social, and environmental impacts to the different elements of the built environment are illustrated using theoretical frameworks.

7 Theoretical framework

The thematic analysis has developed two frameworks from the study findings. Figure 2 presents the first theoretical framework developed. It presents the summarised climate change impacts in the coastal regions under four main themes physical, economic, social, and environmental. Figure 3, the second framework, includes the thematic analysis in which the links to the built environment in coastal regions are identified.

In figure 2, the first layer summarises the climate change impacts and associated disaster risks in the coastal areas. The primary climate change evidence visible in the coastal regions identified are sea-level rise, change in climatic conditions and precipitation changes. Then the next level of the framework identifies the coastal hazardous situations induced due to the highlighted climate change evidence.

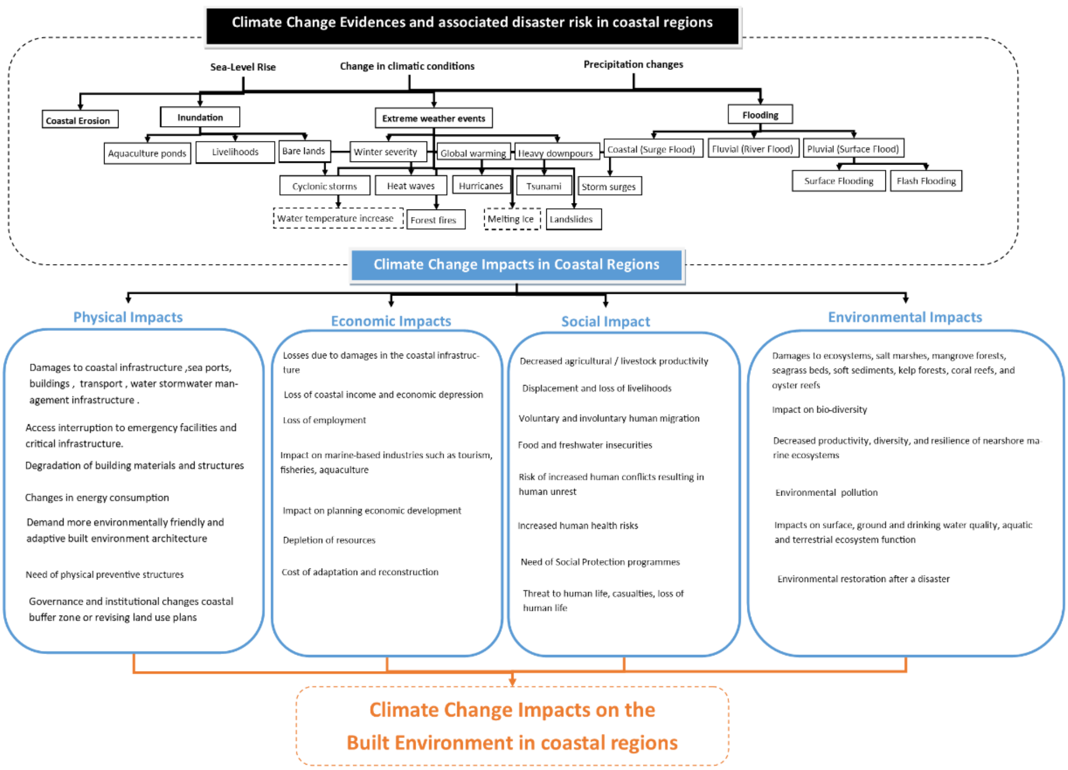

Figure 2: Conceptual framework on climate change impact on the built environment in coastal regions

Finally, at level 3, due to the identified climate change evidence and the associated disaster risks, the impacts on the coastal regions identified through the study are synthesized under four main categories: physical, economic, social, and environmental, with their links to the built environment in coastal regions.

The physical impacts are summarised under seven themes as; damages to coastal infrastructure, seaports, buildings, transport, water stormwater management infrastructure; access interruption to emergency facilities and critical infrastructure, degradation of building materials and structures; increased energy consumption, demand more environmentally friendly and adaptive built environment architecture; need of physical preventive structures and governance and institutional changes coastal buffer zone or revising land-use plans. Then the analysis under the economic impacts derived another seven themes as; losses due to damages in the coastal infrastructure; loss of coastal income and economic depression; loss of employment; impact on marine-based industries such as tourism, fisheries, aquaculture; impact on planning economic development; depletion of resources and cost of adaptation and reconstruction. The social impact category included eight different themes; decreased agricultural / livestock productivity; displacement and loss of livelihoods; voluntary and involuntary human migration; food and freshwater insecurities; risk of increased human conflicts resulting in human unrest; increased human health risks; the need for social protection programmes and threat to human life, casualties, loss of human life. Finally, the environmental category includes damages to ecosystems, salt marshes, mangrove forests, seagrass beds, soft sediments, kelp forests, coral reefs, and oyster reefs; impact on biodiversity; environmental pollution; impacts on surface, ground and drinking water quality, aquatic and terrestrial ecosystem function and environmental restoration after a disaster.

The climate change impacts in the coastal regions identified in the above framework is presented in the diagram below.

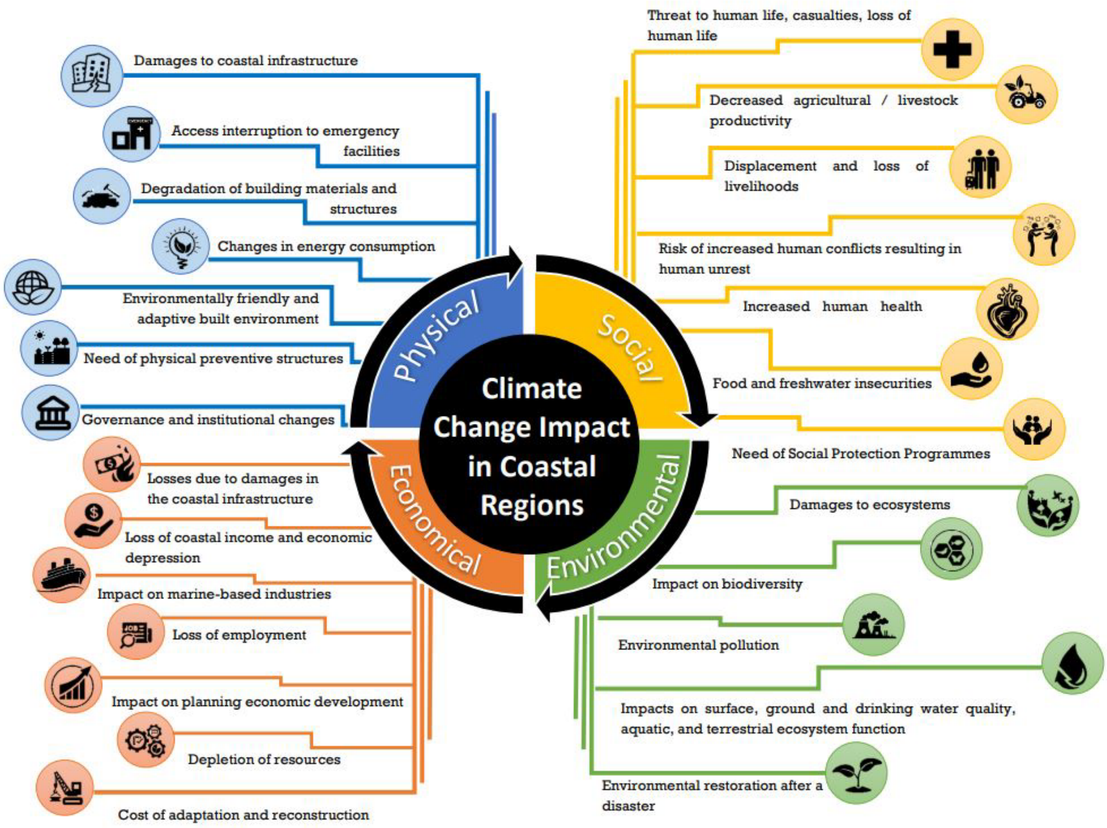

Figure 3: Climate Change Impacts in the coastal regions

The following section demonstrates the links of the identified climate change impacts to components of the built environment. Figure 4 presents the framework illustrating the links of the Climate change impacts to the built environment in coastal regions. The different impacts identified under the physical, social, economic, and environmental categories will affect the built environment and its functions in various manners. Therefore, the points were carefully scrutinized through the study and the impacts were linked through the diagram. For example, the coastal infrastructure damages impose threats on the buildings and structures, telecommunications services, road and rail networks, seaport structures and disruption to service supplies in the coastal regions. Then these consequences could be further elaborated to the next level as wastewater contamination, pipe float due to increased groundwater levels, groundwater ingress, etc. Accordingly, the climate change impacts and their links to the built environment identified through the review have been illustrated in the following framework.

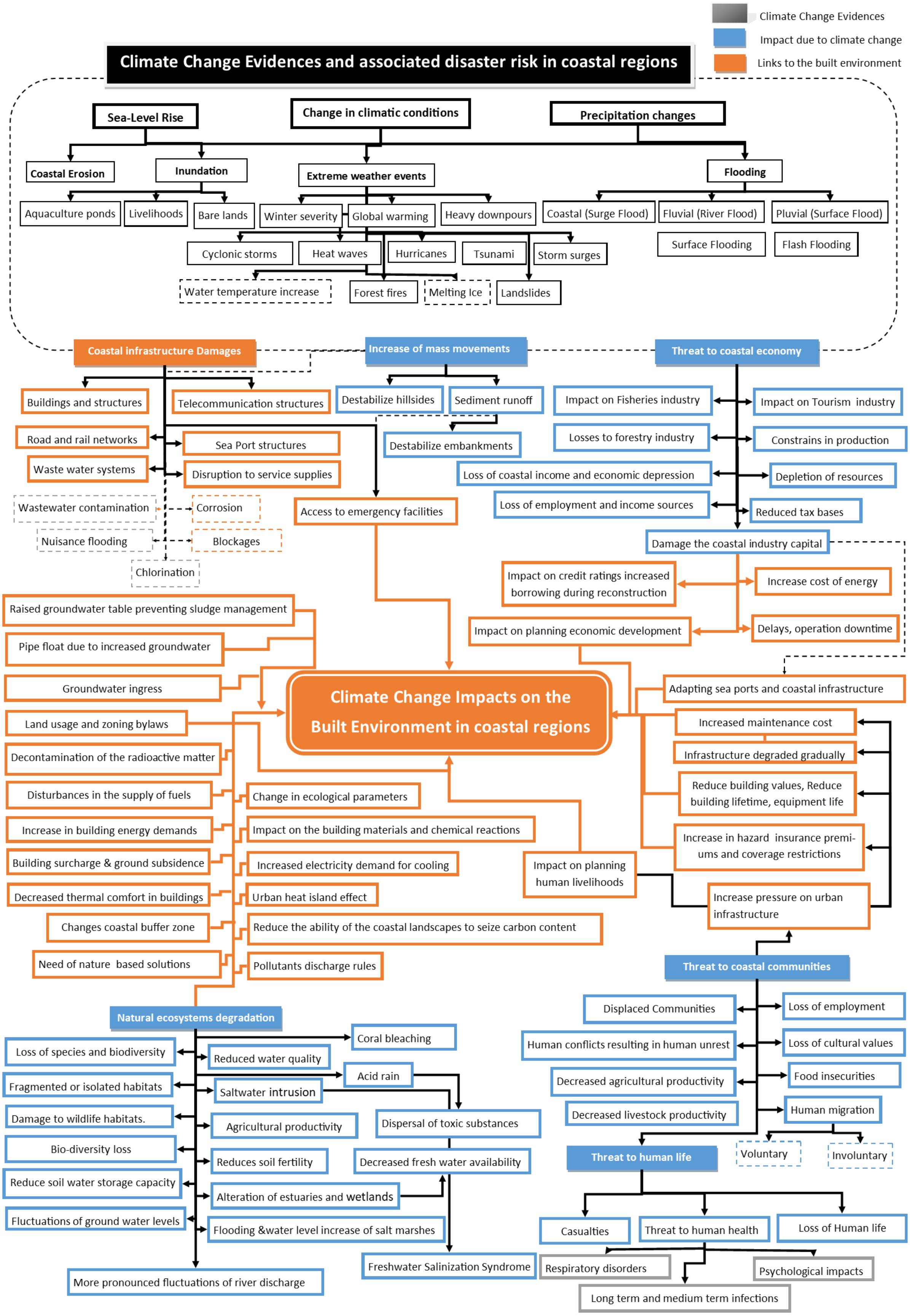

Figure 4: Climate change impacts to built environment in coastal regions

8 Conclusion

Disasters and disaster risks are on the rise worldwide. The trend is expected to continue as climate change increases the frequency and severity of extreme weather events. The study was conducted at two different levels. A global review was conducted based on a systematic literature review, and parallelly induvial country-level studies were conducted based on the partner countries. The study was farmed around four primary research questions; the evidence of climate change in coastal regions, the disaster risks associated with climate change in coastal regions, the impact of climate change in coastal regions and the impact of climate change on the built environment in coastal regions. The primary climate change evidence in the coastal regions is the sea-level rise, changing weather conditions and precipitation changes. Then the associated natural hazards due to this climate change evidence were highlighted as coastal erosion, inundation, extreme weather events and flooding. Under each of these hazard categories, their impact on the coastal regions was summarised through the findings.

This systemic review of climate change risk and associated disaster risks and individual country-level studies has been brought together in the frameworks. The results concluded that the physical impacts of climate change are most directly linked to the built environment. However, the non-physical elements of economic, social, and environmental impacts due to climate change have been identified. Still, their links to the built environment in coastal regions are yet to be discovered. This will be very useful for local actors to understand the current risks and expand the future research in the subject area. The developed framework can be adapted to develop tangible climate change adaptation measures for the built environment in coastal regions, subsequent steps of the BEACON project process.

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