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# POLICIES AND TECHNICAL SOLUTIONS TO MITIGATE AND ADAPT THE CLIMATE CHANGE AND NATURAL HAZARDS RISKS IN THE BUILT ENVIRONMENT

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# Acknowledgement

*“When you want something, all the universe conspires in helping you to achieve it.”*

*Paulo Coelho, Alchemist*

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# Abstract

Nowadays, the people all around the world are vulnerable, also responsible for the changes in the climatic regime of the planet Earth. Added to the climate change impacts, natural hazards can impact the human life too.

Most of the activities which are done by human causes the increase to the Green House Gas emissions which in turn leads to other consequences like increasing the surface temperature, increase the rate of ice-melting, rising the sea level, and flooding, but from other way round other problems like drought. Also, there exist other kind of natural hazards which can have serious impacts on the people life and financial impacts, like earthquakes.

All of these events can impact the world in different fields like human health, food production, tourism industry, cultural heritages and so forth. One of the areas which has a great importance for the people is the built environment, since it is the place in which the people are living, working, and spending most of their time.

During the years, there were done a lot of efforts in global and national level in order to mitigate the risk of those events. Some of the solutions are in type of policies that all the countries all around the world have to follow, like the limits that were proposed in Paris Agreement that oblige the countries to decrease their GHG emissions up to a certain level in the next years. While, some other solutions are in national level in which, each country proposed some technical and engineering solutions to resist against the natural hazards, like construction of dams and

retention reservoirs to mitigate the risk of flooding, or trying to educate the people in order to know how to face the earthquake. Each of these solutions have some advantages and disadvantages.

This thesis tried to find some examples of using these different methods and their pros and cons, in order to have a general insight about these kind of climate-related events and natural hazards to decrease their consequences in the future. For this reason, the thesis is structured as follows:

- A general overview about the climate change and natural hazards and their consequences can affect the world in overall term and countries.
- Evaluate the different fields which were affected by the climate change and natural hazard. The more focus will be on the part of built environment and explain its importance on the human life.
- Assess the parameters related to the risks related to the climate change and natural hazards. For this reason, the ways to measure their impacts in qualitative and quantitative terms will be explained.
- Explain the ways in general term to reduce these risks, and focus more on two parts, first the policies (as the ways to reduce the risks in global term), and second the technical solutions (as the ways to reduce the risks in local term).
- Finally, in the conclusion, the comparison between those two methods will be done propose a practical strategy which is a combination of both of the methods, and there will be some suggestions.

# 1 Introduction

The human life is affected by various kind of positive or negative events that are called externalities. There is a wide variety of these events. The example of these externalities can be noise pollution, traffic congestion, and crime, also natural disasters and climate-related events like floods, fire, earthquake, tsunamis and so forth. One important point that should be taken into consideration is that the sources of these externalities are different. Some of those events are manmade like the crime and traffic congestion, while some others come from the sources that are out of human control, like the natural hazards. But, even in the case of natural hazards, there are some events that are related to the human activities and most of these natural disasters can be intensified by climate change which is an environmental crisis in this era. Moreover, some other natural hazards are not related to climate change or the relationship is still unclear. So, understanding the differences between natural hazards and climate change is an important subject.

According to the definition of Federal Emergency Management Agency (FEMA) on the natural hazards, they are the environmental events that have the potential to impact societies and human environment. This definition explains that natural hazards can be all the hazards related to the environmental events, whether they are related to the climate or not. One example of natural hazards can be the earthquake which is not related to the climate change, but as another example, flooding is a natural hazard and it can be due to climate change and its consequences like increasing the precipitation and rising the sea level, whereas, in

some cases the flooding hazard can be due to some events that are not climate related, like dam fault and extreme outflow of the dams which are human related.

But based on the definition of climate change by NASA, it is a long-term change in the average “weather” patterns. So, the climate related events are those events which are related to the changes in the weather in a long-term like the temperature, humidity and so forth. According to this definition, climate change can cause and intensify some sort of hazards like increasing the temperature, ice-melting, rising sea level and flooding. On the other hand, these changes in climate patterns does not impact some other kinds of natural hazards like earthquake.

The main source of the climate change is the Anthropogenic Green House Gas (GHG) emissions which are driven largely by economic, industrial and population growth. It is estimated that more than half of the observed increase in global average surface temperature in the last decades was due to the increase in the amount of GHG emissions.

In the last decades, climate change has resulted in changes in human and natural systems, like rising sea levels, increased precipitation, inland floods, more frequent and stronger cyclones and storms, and periods of more extreme heat and cold (UN-Habitat, 2022).

Added to the climate-related events, there exist also natural hazards which can be independent from climate-related events. For example, earthquake is one of the natural hazards that is not so related to climate change. This phenomena also causes the other events like landslide, tsunamis and so forth.

These phenomena have different impacts in various fields like economy, health, agriculture, tourism, cultural heritage and so forth. But, one of these fields which is very important for the people and is affected by climate related events is the built environment and real estate. It is because of the fact that this field is in a close relationship with people in terms of work space and living, so evaluation of the risks of climate related events is of a great importance.

In order to evaluate and analyze those risks, there are a lot of qualitative and quantitative ways to measure and mitigate the risk that each of them is very important. But in this thesis, the main focus is on the ways to reduce the risk and the ways to adapt with them, not on the ways to assess the risks. It is because that the source of those risks are more or less the same, but the intensity and severity is increasing during the time. Hence, find the practical solutions seems to be more important from this point of view.

As it was explained, there are a few methods to mitigate and adapt the climate-related events and natural hazard, like increasing the public awareness, using the insurance, using guideline for land-use planning, construction of more resilient buildings and construction of other structures and infrastructures, and other methods like those.

Since these methods include a vast variety of ways, it is better to divide them in two groups of methods which are policies and technical solution.

In this ways, the policies will be effective in the global scale and defines the general goals and scopes for the governments to follow and reach. The example of

these policies are the ones which are defined by the countries in Paris Agreement to reduce their GHG emissions in order to reach to a certain level and finally decrease the world temperature by 2°C in the next decades.

It should be taken into consideration that added to these policies, there should be some technical solutions to resist against climate-related and natural hazard events. For instance, building the infrastructures to resist against flooding (dams, reservoirs, wet lands, and so on), finding the prediction systems to avoid the negative results of those events, education of people especially from childhood and examples like these.

Since, each of the events depends on different factors like the geographic characteristics, level of education of people, level of income of the people, existing infrastructures in a country and so forth, every country has to opt the best solution based on its own characteristics. But, to have a better result, they can also benefit from the experience of other countries in using different methods to mitigate the risks or adapt themselves against the risks, especially the countries which are more similar in the above-mentioned characteristics.

Due to the fact that there are a lot of countries across the world which have different experience of using various methods, it is impossible to provide and evaluate all the cases in a thesis. For this reason, it is decided to choose examples among European countries, and non-European countries in order to make it more feasible to study the methods. Also it can be noticed that though the European

countries have differences in many terms, they can be considered more or less similar in their climatic regime in global scale.

According to the approach used in this thesis, it is possible to evaluate the methods in European countries and benefit from the experience of different countries in Europe, also in some cases it would be useful to see the examples and methods out of Europe to see how the other countries behave against these sort of events and benefit from their experience of using each of the methods which can be useful to mitigate or adapt the climate-related events and natural hazards that can impact the human life.

Moreover, considering the fact that there are a lot of climate related events and natural hazards all around the world, it is impossible to evaluate all of the events in this thesis. Some of those events could be rare, but very intense, while some others can be frequent, but does not have very intense consequences. According to this point, there are two cases of flooding and earthquake events will be considered in this thesis. It is because that those events are not so rare and happen time to time, and also they have intensive impacts on the human life, economy, assets, and infrastructures and so on.

## 1.1 Aim of the thesis

As a short expression of the aim of this thesis, it is possible to explain that getting a good understanding of climate change and natural hazards can have significant effect on the analyzing the risk of those events on the human life and to define and

design the best solutions to mitigate and adapt those risks. Among different aspects that are affected by the climate change and natural hazards, like the food production, human health, tourism industry, renewable energy and so forth, the built environment has a great importance, since it is mostly related with human beings in terms of place of living and working. Hence, the thesis aims to focus more on this aspect of the affected fields by climate related events and natural hazards.

During the analysis of the risks related to those events, it is necessary to understand and identify the sources of risk, assess the risks in qualitative and quantitative ways, find the ways to control the risk, and record and review the controls. Among these steps in risk analysis, this thesis focuses on the finding the ways to mitigate and control those risks, because the sources of happening the flooding and earthquake are more or less identified in previous researches, but the effort to find the best solutions to decrease the negative impacts is still continuing. Also, sharing the knowledge and ways to reduce those effects can enhance the ability of other countries with the same characteristics to resist better against those sort of events. Considering what is explained in this paragraph, finding the solutions to resist against the risks of climate related events and natural hazards is a vital action in order to save the human assets in terms of health and life, wealth, houses and built environment and land. For this reason, a good solution is to look for the previous experiences of countries in front of those kind of climate related events and natural hazards and to see the pros and cons of each activity which was done before.

Since the consequences of climate change and natural hazard depend on various factors like the geographical characteristics of an area, the behavior of people living in that area, the infrastructures, the government and its decisions, and so forth, the ways to reduce the risks could be different. This thesis has the aim to make it feasible to evaluate the solutions in a better way, so the solutions are divided in two groups of solutions:

- First, the solutions which can be applied in global scale and they are the policies which should be determined and followed by the governments, like the pledges in Paris Agreement to reduce the GHG emissions by each country.
- Second, technical solutions which are more related to local scale to reduce the impact of an event in an area like a city or region. These solutions can be the construction of a building, enhancement of the infrastructures, or education of people.

Hence, the aim of this thesis is to find the solutions against climate related events and natural hazards in terms of policies against climate change and its consequences, and the technical solutions which were done in different countries that can give a good insight to the other countries which have the same characteristics and they are vulnerable to the same kind of climate related events and natural hazards.

## 1.2 Scope of work

For the scope of work of thesis, among all the aspects which are affected by the climate change and natural hazards like the food production, manufacturing and trade, tourism industry and so forth, the impact of those events on the built environment are taken into consideration. It is because of the fact that this field is more related to the human activities like living and working. Also, most of the important assets are located in the built environment, like the cultural heritage, infrastructures, buildings, companies and so forth.

Hence, in order to decrease the risk of those events on the built environment, it is necessary to analyze those risks. Among all the steps during risk analysis, risk identification and finding the ways for risk reduction are of great importance. Since the sources of risk were evaluated in many papers, in this thesis this part is explained in a way to have an overall insight about that. But, for the ways to reduce the risks, since the solutions varies from region to region and event by event due to their different characteristics like the geography of the region, level of education of people, income level of people, government actions, and other parameters, the focus of the thesis is mostly on the ways to reduce those risks.

Also, because there are a lot of solutions to mitigate and adapt the risks related to climate change and natural hazards, this thesis tried to divide the solutions into two categories of policies (to act in global level) and technical solutions (to act in local level). In this way it will be easier to evaluate each of those groups.

In the technical solutions, there are considered the examples from European and non-European countries which can be helpful to have a comparison among them. Because, it is tried to consider the European countries more or less similar to each other in case of sources of risks and also the governmental policies, mostly because they are close to each other and a few of them are the part of European Union which have the overall proposals that should be translated in the regulations in each country. Moreover, as it is available in the tables of CarbonBrief (table 1), the EU countries are considered as on group.

Moreover, since the two climate related events and natural hazards of flooding and earthquake had the most levels of damages to the countries in terms of assets, financial, and human life, the focus of this paper is mostly on these two type of natural hazards. As it can be seen in the figure below, provided by PreventionWeb, it is possible to see that during the period of 1980 to 2008, the number of floods reported in the Europe is the first rank, and the earthquake is located in the $4^{th}$ rank.

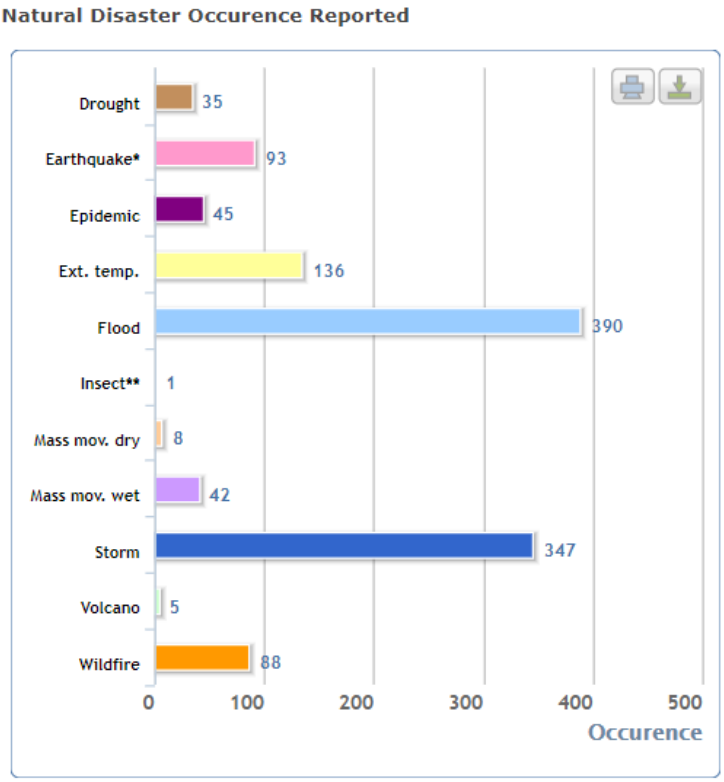


*Figure 1: Number of natural disasters reported across Europe in the period of 1980-2008*[1]

Also, other tables by the same website show that in the extreme number of killed people in the Europe due to natural hazards, the case of earthquake in 1988 resulted in death of 25,000 people and has the first rank in this field. For the case of Economic damage, the most of top rankings belong to Earthquake and Flooding, for example the Italy experienced the $20 billion due to earthquake in 1980, and Germany faced with loss of $11.6 billion due to flood in 2002.

[1] Source: Website of PreventionWeb - https://www.preventionweb.net/

*Table 1: The number of killed people and amount of economic damage in Europe due to climate-related events and natural disasters*[2]

**Killed People**

| Country | Disaster | Date | Killed |
|---|---|---|---|
| Soviet Union | Earthquake* | 1988 | 25,000 |
| Italy | Extreme temp. | 2003 | 20,089 |
| France | Extreme temp. | 2003 | 19,490 |
| Spain | Extreme temp. | 2003 | 15,090 |
| Germany | Extreme temp. | 2003 | 9,355 |
| Italy | Earthquake* | 1980 | 4,689 |
| Portugal | Extreme temp. | 2003 | 2,696 |
| Russia | Earthquake** | 1995 | 1,989 |
| France | Extreme temp. | 2006 | 1,388 |
| Belgium | Extreme temp. | 2003 | 1,175 |

**Economic Damages**

| Country | Disaster | Date | Cost (US$ X 1000) |
|---|---|---|---|
| Italy | Earthquake* | 1980 | 20,000,000 |
| Soviet Union | Earthquake* | 1988 | 14,000,000 |
| Germany | Flood | 2002 | 11,600,000 |
| Italy | Flood | 1994 | 9,300,000 |
| France | Storm | 1999 | 8,000,000 |
| Italy | Flood | 2000 | 8,000,000 |
| United Kingdom | Flood | 2000 | 5,900,000 |
| Germany | Storm | 1990 | 5,500,000 |
| Italy | Earthquake* | 1997 | 4,524,900 |
| Spain | Drought | 1990 | 4,500,000 |

Added to the solutions for these two types of natural disaster, in this thesis also for the other kind of natural hazards there are provided some examples and solutions.

[2] Source: Website of PreventionWeb - https://www.preventionweb.net/

# 2 State of the art

## 2.1 Climate change and natural hazard

In order to define the climate, first of all, it is helpful to notice to the difference between weather and climate. Weather is an atmospheric condition which occurs locally in a short period of time (from minutes to days) like rain, snow, wind and so forth. On the other hand, climate refers to the long-term regional or global average in the temperature, humidity, and rainfall patterns over seasons, years or even decades.

By the definition of NASA on global climate change, “the climate change is a long-term change in the average weather patterns that have come to define Earth’s local, regional and global climates.”

In another definition for climate change which was proposed by Australian Academy of Science, “climate change is a change in the statistical properties of the climate system that persists for several decades or longer—usually at least 30 years.” Added to this definition, this academy explains that it is possible to forecast the weather up to about a week, using the considerable skills; also, some short term fluctuations in climate can be predicted from season to season, like droughts. But, the long-term changes in climate events can be predicted if they are caused by long-term influences which are known or predictable.

Most of the changes in observed in Earth's climate since the mid-20$^{th}$ century are due to the human activities, especially in terms of burning the fossil fuels, which causes the increase in heat-trapping Green House Gas levels in Earth's atmosphere, that in turn raises the average surface temperature (Global climate change, NASA, 2022).

According to the report by the website of European Commission, the main driver of the climate change is the greenhouse effect. In order to explain it in more detail, it is worth noticing that some gases in the Earth's atmosphere act like a glass in the greenhouse, and they cause the sun's heat to be trapped and it cannot be go beyond the atmosphere which finally leads to global warming. There are a lot of these gases which exist naturally, but the point is that the human activities are increasing the concentration of some of them in the atmosphere, especially carbon dioxide ($CO_2$), methane, nitrous oxide, and fluorinated gases.

Bases on the report by European Commission, there are other human activities (rather than burning fuel) which increases the emissions:

1- Cutting down the forests (deforestation): In this way, there exist lower number of trees to absorb the $CO_2$ from the atmosphere. Also, when the trees are cut down, the stored carbon (C) in the trees will be released into the atmosphere.
2- Increasing the livestock farming: It causes the increase in the amount of methane due to the digestion process by cows and sheep.
3- Fertilizers containing nitrogen

4- Fluorinated gases: The emission of this kind of gases is very stronger warming effect which is 23,000 times greater than $CO_2$.

Since 1850, the Earth's surface has observed its warmer temperature for the last three successive decades. The period between 1983 and 2012 was the warmest 30-year period in the last 1400 years in the Northern Hemisphere. In average, the global data for combination of land and ocean surface temperature shows a 0.85°C of warming as a trend over the period from 1880 to 2012 (IPCC, 2014).

In the other report by NASA, from the pre-industrial, it is estimated that the human activities caused an increase about 1°C in Earth's global average temperature. As it can be seen in the figure below, the global surface temperature in 2016 and 2020 was 1°C above the 1951-1980 baseline.

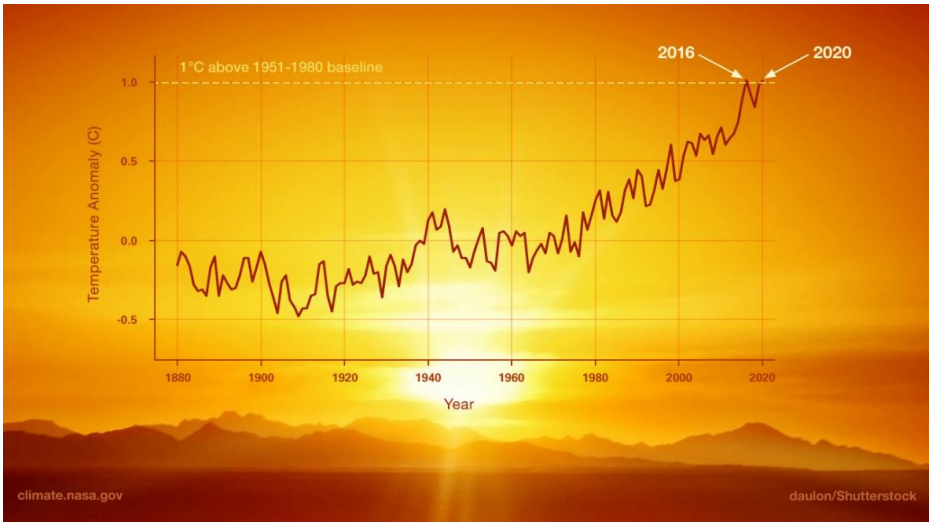


*Figure 2: Changes in global surface temperature relative to 1951-1980 average temperatures*[3]

[3] Source: Website of NASA (Global Climate Change) - https://climate.nasa.gov/global-warming-vs-climate-change/

Human activities are not always the reason for climate change, but sometimes the natural processes may contribute to climate change, including the internal variability (e.g., cyclical ocean patterns like El Niño), and external forcing (e.g., changes in sun's energy output or variations in Earth's orbit).

In order to study the climate change in its past, presence, and future situation, there are some key indicators like the increase in the temperature of global land and ocean, rising sea levels, ice loss in the pols and glaciers, frequency and intensity of extreme weather events such as hurricanes, droughts, flood, heat waves, cloud and vegetation cover changes, and so forth.

Added to the climate related events, there are also another type of events which cause a huge amount of damages every year to the human which are called "Natural Hazards".

Based on the definition of natural hazards by the Federal Emergency Management Agency (FEMA), "Natural hazards are defined as environmental phenomena that have the potential to impact societies and the human environment." In the definition of these phenomena, it is necessary to take into consideration that they should not be confused with other types of hazards, like the manmade ones. For example, the flooding due to the changes in river flow is a natural hazard, while the flooding which is caused by the dam failure is considered a manmade hazard. Moreover, natural hazards can cause the secondary natural hazards, for example, the Volcanic activity creates other hazards like ash and lava spread.

According to another definition which was provided by World Meteorological Organization, “Natural hazards are severe and extreme weather and climate events. Although they occur in all parts of the world, some regions are more vulnerable to certain hazards than others. Natural hazards become disasters when people’s lives and livelihoods are destroyed.”

By this definition, if a country wants to have a sustainable development, the human and material losses caused by such disasters can be a major obstacle. In order to solve this problem, it is necessary to find the solutions to resist against them. For example, issuing the accurate forecasts, warning in a proper way, and educating the people about how to prepare against such hazards can avoid a hazard to be a disaster. The most important goal should be on prevention, as it was expressed that one dollar which is spent for disaster preparedness can prevent seven dollars of disaster-related losses.

Considering this introduction and definition of climate change and natural hazard, in the next sections there will be explained some examples of natural hazards and climate related events.

## 2.2 Examples of climate related events and natural hazards

### 2.2.1 High temperature

One of the consequences of high temperature is that they will result in heat stress which can cause respiratory and cardiovascular illness and even premature

death. During the heat wave in 2009 in Melbourne and Adelaide, there were recorded more than 500 deaths and over 3000 reports for heat-related illness. Also some other forms of damages to Australian infrastructures like power supply, train, and highways transportation were recorded and it is estimated that the direct financial losses from that period of heat wave were around $800 million. In addition, it is estimated that around $17 billion will be required between 2015 and 2050 to rebuild critical infrastructures which will be damaged due to natural disasters (Steffen et al., 2019).

### 2.2.2 Ice melting

Due to increase in the earth's temperature, during the period of 1992 to 2011, the Greenland and Antarctic ice sheets have lost their mass, and the rate has been increased over 2002 to 2011. Also, since 1901 the precipitation in the mid-latitude land areas of the Northern Hemisphere has increased. Moreover, the annual mean Arctic sea-ice extent decreased over the period 1979 to 2012, and this phenomenon happened in every successive decade since 1979. As a result, the global mean sea level rose about 0.19m with an increasing rate since the mid-19$^{th}$ century regarding the previous two millennia (IPCC, 2014).

During the extreme rainfall in Mina Gerais (Brazil) in January 2020, more than 90,000 people affected in terms of being homeless, temporary displaced, or sick or injured. Also, that event caused over $240 million of monetary losses consisting material damage, public, and private economic losses. It was estimated that

human-induced climate change resulted in 71% of increase in likelihood of this event (Dalagnol et al., 2021).

### 2.2.3 Flooding

Another example of climate change impact is the case of flooding. Flooding itself is a natural phenomenon that can be translated as the overflow of rivers, lakes and streams from their natural banks. The lands near to the flood areas can be attractive for human settlement due to their characteristics like attractive view, ease of transportation, water supply and rich agricultural soil; but it can be considered as a natural disaster in the presence of people and property in the flood prone areas and its damages. So this is a catastrophic natural event all around the world which is especially occurring mostly frequent in Canada. Floods are the most costly natural disaster in Canada and causes the average loss of 1-2 billion Canadian dollars each year (Belanger et al., 2018).

Since the flooding is an exogenous event, it has consequences related to some parameters like geographical and hydrological characteristics, resistance of buildings against water, existence of flooding insurance and so forth. However, the most important factor affecting the house price is the awareness of households about the risk of flooding (Troy and Romm, 2004).

### 2.2.4 Earthquake

Another type of natural disaster which causes a huge cost every year for the countries is the earthquake. For instance, in Italy the earthquake is the most costly natural disaster each year and it did cost the average of $9772.86 million as of 2015. The earthquake on 2012 in Po river plain in northern part of Italy was estimated to cause the overall cost of 5 billion euros (Ronchetti, 2012). It is worth-noticing the difference between the costs due to earthquake and that of flood which is in the second rank and is equal to $777.37 million (STATISTA, 2020).

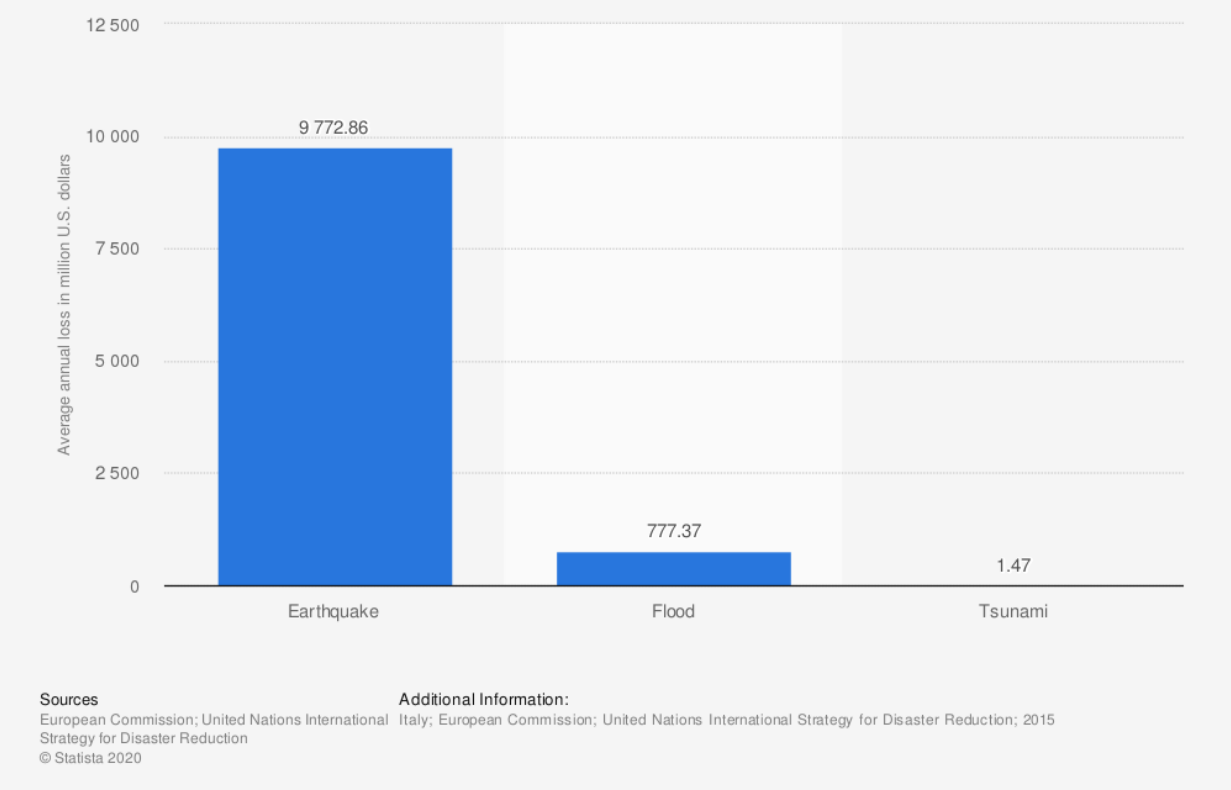


*Figure 3: Average annual loss related to disaster risks estimate in Italy as of 2015, by hazard (in million US dollars)*[4]

[4] Source: Website of STATISTA - https://www.statista.com/

After the earthquakes in 2009, 2012 and 2016, the awareness about its risk has increased in Italy. Since there is a huge concentration of urban assets in big cities, it is necessary to consider the seismic risk and its related economic consequences. For this reason, civil protection agencies and insurance companies require the detailed and documented seismic risk analysis information.

While the seismic hazard is well-known itself, the consequences are more difficult to assess and it can trigger the secondary effects like landslides, dam breaks, liquefaction and so forth. Since these consequences can vary among various areas due to different characteristics of soil and structures and seismic zones, the local knowledge is very important during the assessment. In EU, the Joint Research Center (JRC) has been involved in the risk assessment of the earthquake through various actions like definition of the risk by two elements of percentile of the population exceeding 50000 people and percentile of peak ground acceleration (pga) value which was resulted in making the earthquake risk map (European Commission, 2013).

Climate change exposes people, societies, economic sectors and ecosystems to risk. This kind of risk arise from interaction among hazard (happened due to an event related to climate change), vulnerability and exposure. In this case, risk will be defined as the multiplication of the probability of occurrence of a hazardous event and the magnitude of the consequences if these events occur. Therefore, the risk won't be high only due to the high probability of an event, but also it may be because of the high magnitude of such events. It shows the importance of

evaluating all range of possible outcomes, even those with low probability (IPCC, 2014).

### 2.2.5 Tsunamis

Tsunamis are one of the events that can happen not only due to earthquakes occur under the sea, but also large landslides which sometimes induced by collapsing volcano domes that occur near the coast. This phenomenon becomes more important when the superposition of tsunami wave with other phenomena happens, like tides and storm surges. The risk of this phenomenon will increase by infrastructures at risk (like nuclear plants), seasonal tourist activity (beaches), and local coastal amplification (typical in ports). But this risk can be reduced by steep coastal geometry, coastal protective infrastructure or warning mechanisms, moreover, the JRC prepared the risk maps for this kind of phenomenon (European Commission, 2013).

### 2.2.6 Drought

Drought is one of the kind of natural hazard which affect the people directly, and it was reported in a few papers as the first rank among all other natural hazards in term of the number of people directly affected.

What is important to consider for the case of drought is that this kind of natural hazard differs from other types of climate-related events in various aspects:

First of all, drought is a slow-onset hazard which is difficult to determine when it was started.

Secondly, there is no universal agreed definition for droughts. So, it causes a sort of confusion about whether a drought exists and its severity. The definition of this phenomenon is highly dependent on the region and kind of activity, but from a hazard perspective, drought is often defined as a below-normal hydro-meteorological anomaly. As it was mentioned before, the normal situation depends on other factors like space and time.

Third, notwithstanding this phenomenon does not destroy physically and rapidly like most of other hazards, it can affect wide range of areas in terms of economic, environmental, and social.

As it was reported by Federal Emergency Management Agency (FEMA) in 1995, the annual estimated loss from drought was around $6-8 billion (Hayes et al., 2004).

In Europe, the central and northern drought and heat wave had a great spatiotemporal footprint on different aspects. It is estimated and expected that in future there will happen at least similar or even worse events, since the demand for atmospheric water and human pressure on freshwater resources are increasing (Tijdeman et al., 2022).

## 2.3 Impacted fields by climate change and natural hazards

### 2.3.1 Food production

There are different fields which can be affected by climate change. One of these fields is the food security including food production, access, use and price stability (IPCC, 2014). For example during the Millennium Drought in 2000 in Australia, the agricultural income reduced by 42% and employment by 70,000 people (about 15% of reduction). Also this drought and the same ones happened in 1980s and 1990s caused 1% of national GDP decrease in the years they occurred, and it is estimated that future droughts will have the same lowering of GDP by 1% every year (Steffen et al., 2019).

### 2.3.2 Human health

Another impact of climate change is on the human health which is mostly due to exacerbating health problems that already exist. This effect can increase the ill-health in different regions, especially in developing countries with low level of income. For example, the intense heat waves and diseases due to foodborne and waterborne can reduce the labor productivity which can have negative effects especially in poor regions (IPCC, 2014).

### 2.3.3 Supply shocks

Extreme weather events create supply shocks which can reduce output, increase unemployment, and inflation. For example, the agriculture sector is totally sensitive to the climate related changes. Hence, notwithstanding this is a relatively small sector (about 2-3% of 1GDP), the impact of drought through this sector is apparent on the GDP. This supply shock also can cause to push up the commodity prices, and exhaust the productivity capacity of the economy. For example, instead of investing funds in new technologies or machines or researches, this fund should be applied to recovery the economy (Steffen et al., 2019).

### 2.3.4 Cultural Heritage

Cultural heritage sites are one of other vulnerable areas affected by climate change. In this case, climate change can have three areas of effect on the cultural heritage which are the (i) gradual change on the outdoor heritages, (ii) gradual changes on the indoor heritage, and (iii) sudden changes due to climatic stressors. The gradual changes can be due to some factors like change in temperature (which in turn causes freeze-thaw cycles), change in precipitation (which in turn causes corrosion, biological degradation, and salt crystallization cycles), change in wind, mechanical degradation, and chemical degradation. As an example of this effect it is possible to mention the pollution soiling and biological colonization on the stones of Edinburgh Castle, Scotland, in which it is possible to see this kind of gradual changes in the figure below.


*Figure 4: The example of pollution soiling and biological colonization on the stones in Edinburgh Castle.*[5]

For the sudden changes, there are some sources like flooding, slope instability, sea level rise, permafrost thawing, drought and extreme heat (Sesana et al., 2021).

### 2.3.5 Renewable energy

Since the renewable energy sources mostly depend on the climate, they can be affected by the climate change. Nowadays, renewable energy sources supply 15% of global primary energy and they will play more important role in the future as it is estimated that theoretically it is possible to move toward a completely renewable

[5] Source: Article by Sesana et al., 2021

energy system by 2050 (World Energy Outlook, 2017). However the changes in climate can impact the renewable energy sources negatively, it is not always the case for all the kind of them. For example, climate change under a baseline warming scenario will have negative impact on bioenergy, but it will cause to increase the Concentrated Solar Power (CSP) (Gernaat et al., 2021).

### 2.3.6 Manufacturing and trade

There is another sector which is relatively high climatic sensitive, Manufacturing and Trade, since it depends on climatic sensitive raw materials and intermediary inputs like agricultural products, timber and energy. Also, the production processes and productivity of workers might be influenced by some climatic parameters like temperature and humidity which in turn can cause serious damages to companies. The level of this damage varies according to the climatic development and the degree of adaptation (Urban, H. and Steininger, K., 2015).

### 2.3.7 Tourism industry

The tourism industry is one of others sectors which is impacted by climate change and it is highly climatic sensitive, because most of tourism activities have a strong link to the environment. These effects can be positive, for example the extraordinary sunny and warm summers like 2003 in Austria which resulted in above-average tourism demand increases in lake regions. From other way round, the impact could be negative, like the snow-poor winters during 1989/90 and 2006/7 in Austrian regions which were faced with noticeable drops in tourism

demand. But in overall, the net impact of climate change on tourism industry would be considered negative (Koberl et al., 2015).

### 2.3.8 Built Environment

Climate change and environmental degradation can cause physical damages which in turn affect the built environment and financial system significantly (European Central Bank guideline, 2020).

In some cases, the climate change can have positive effects on built environment, for example in the case of heating and cooling of the buildings. Maintaining the building temperature within a comfort range is important, also is sensitive to climate change. Because the higher temperature in winter leads to reduction of heating energy demand, and in summer leads to increase in cooling demand. But, the researches show that the energy reduction in heating is much higher than the increased energy demand for cooling (for example the energy demand for cooling in Austria in 2008 was only 0.4-0.5% of energy demand for heating). For the case of Austria, it is estimated that the net saving from this fact would be around €230 million per year in 2050 (Kranzl et al., 2015).

As an example of the negative impacts of climate change on built environment it is possible to mention its effects on transport. Since the most of transport activities occur on the roads, it is important to consider the damages resulted from climate change on the roads. Most of these weather-related damages are from precipitation events and their consequences like flooding and mass movement.

These damages require the upcoming maintenance activities which consist 30 to 50% of total maintenance costs of roads in Europe (Bednar-Friedl et al., 2015).

## 2.4 Importance of built environment

During the last years, urbanization became an influential trend. In the report of the United Nations about World Urbanization Prospects in 2014, it was mentioned that in 2007, for the first time in history, the global urban population exceeded the global rural population. It is estimated that this trend will be projected until 2050 and the percentage of people living in the cities and urban areas will be increased up to +66% at world level and +80% at EU level. According to the United Nations Environment Program (UNEP), cities generate up to 80% of the GDP of a country, but from other way round, they also consume 75% of natural resources. Moreover, they are responsible for 60-80% of GHG emissions (Rome et al., 2019).

In the past, the extreme events were mostly cyclical around a stable average, allowing enough recovery time between events; now the situation is changed, both in frequency and severity of the events. Also the probability of simultaneous events in different locations has been increased. Moreover, the possibility of coincidence of two or more extreme weather events which can produce even worse impacts increased (Steffen et al., 2019).

The coincidence of urbanization and climate change effects is going to result in serious dangers. Based on the current national government commitments, global warming seems to reach 1.5°C between 2030 and 2052, and near to 3°C in 2100.

Urban areas affect the climate change with 71-76 percent of CO2 emissions from global energy use, also they can be affected by climate change, since the high vulnerability of infrastructures, human assets and activities (UN-Habitat, 2022).

Although the climate change causes the several risks, there are many cities in which the climate change is not addressed yet. Because, in some cases there is no relevant city policies and action plans, and the existing regulations on urban planning and environment are not adjusted to manage climate change. Moreover, in some cases, due to lack of capacity and resources, response to climate disasters is very slow. The last but not the least, lack of public awareness about the climate and environment/related risks is another factor which can intensify the consequences of the climate change risk (UN-Habitat, 2022).

Coastal cities on the U.S. East Coast are emerging hotspots of global sea level rise as well as increasingly attractive real estate markets. In a changing climate, more severe storms, more intense precipitation, and sea level rise magnify the risk of flooding in these same cities. By 2030, average annual losses from storm damage along the Eastern Seaboard and Gulf of Mexico could reach $35 billion.

In New York and New Orleans, federal, state, and local agencies have made post-disaster investments in large (though potentially still inadequate) flood infrastructure projects.

Firms that perceive flood risk as a financial risk seek to transform that risk into an opportunity. When cities encourage, incentivize and institutionalize competitive

resilience they tend to prioritize the needs of privileged populations and properties over the needs of the people and built environments most exposed to risk (Teicher, H., 2018).

Many of the nation's most beautiful and productive cities are located along oceans and rivers like New York City, Miami, Seattle, Washington DC, San Francisco and Los Angeles. As sea level rise takes place, urban economies and the value of their real estate capital could be impacted. Forward-looking real estate investors face choices over constructing new housing and investing in maintaining the existing real estate stock. In order to face the climate change, we have to choose whether to keep the real estate capital in its current location or move it to higher ground. But there are more empirical solution when facing the flooding like building sea walls, raising foundations, and mitigating the risk of sea-level rise. Another solution is to build the coastal houses and make them as natural wet land to reduce the flood risk (Bunten, D., and Kahn, M., 2017).

In the World Bank Report about Country Risk Profiles for Floods and Earthquakes which was published in 2016, it was explained that the Europe and Central Asia region experiences a variety of natural hazards, including floods, earthquakes, droughts, landslides, and wildfires. The frequency and impact of such events can be considerable.

Even if catastrophic events are not as frequent as in other regions, the region has experienced close to 500 significant floods and earthquakes in the last three decades alone – causing a total of 50,000 fatalities, affecting nearly 25 million

people, and resulting in over US$80 billion in damage. Over time, close to 30 percent of the capitals of countries in the region have been at one time or another devastated by earthquakes and floods.

*Table 2: Annual average affected population and GDP for flood and earthquake*[6]

| | FLOOD | | EARTHQUAKE | |
|---|---|---|---|---|
| | Annual average affected population | Annual average affected GDP (million US$) | Annual average affected population | Annual average affected GDP (million US$) |
| **Baltic States** | 800,000 | 9,000 | 50,000 | 600 |
| **Caucasus States** | 300,000 | 800 | 600,000 | 2,000 |
| **Central Asian States** | 1,000,000 | 4,000 | 2,000,000 | 5,000 |
| **European Union States** | 2,000,000 | 20,000 | 1,000,000 | 20,000 |
| **Russian Federation** | 2,000,000 | 20,000 | 200,000 | 1,000 |
| **South East European States** | 1,000,000 | 9,000 | 2,000,000 | 20,000 |

[6] Source: World Bank Report (Country Risk Profile for Floods and Earthquakes), 2016

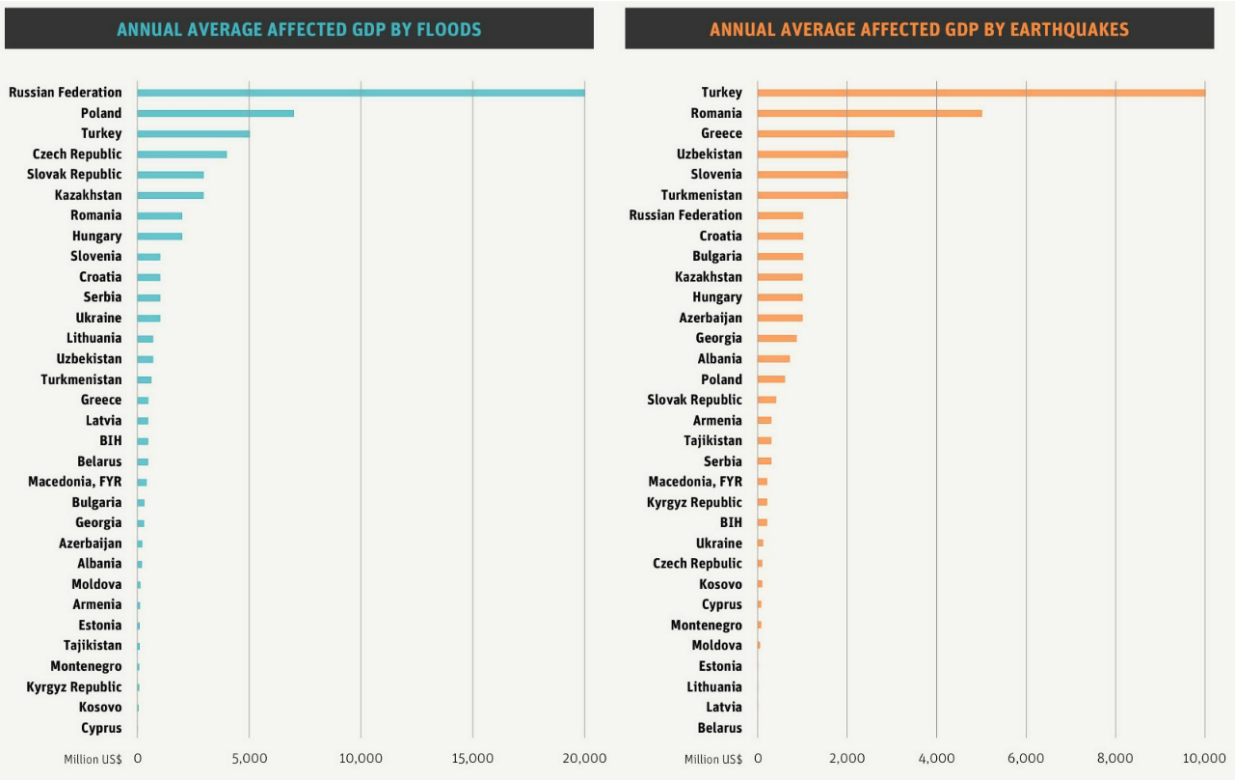


*Figure 5: Annual average GDP affected by floods and earthquake*[7]

As it was explained before, the continuous emission of green-house gases will cause further warming and long-lasting changes in climate system. So, the adaptation and mitigation are complementary strategies to reduce and manage the risks of climate change. There are some Representative Concentration Pathways (RCPs) which have the aim to reduce or at least keep the cumulative amount of GHG emission in a specific amount, for example keep the global warming below 2°C above pre-industrial temperatures (IPCC, 2014).

[7] Source: World Bank Report (Country Risk Profile for Floods and Earthquakes), 2016

## 2.5 Impacts of climate change on property value

There are many studies tried to evaluate the impact of climate related events on the property value.

In general, for two equivalent homes, the one which is more exposed to the climate related hazards and extreme weather events is anticipated to have less value than the house which is less vulnerable to those kind of events (Steffen et al., 2019).

As an example, the earthquake is one of the events that can have this impact. In a study which was done on the Tehran, capital of Iran, it seemed that this city has a high population (around 6.5 million people in 1991), and it is facing the risk of earthquake. This risk can have significant impacts on the economy and built environment in Tehran (Willis, K., and Asgary, A., 1997).

For example in the case of flooding, there are different reports about the values of discount price assigned for the property value, like 2% of average discount price for houses located near to floodplains in U.K. which was reported by Belanger and Bordeau-Brien in 2018 reported, also Luechinger and Raschky in 2009 and Beltran et al. in 2018 reported the average discount price of 4%-5% in United States.

Also another study which was done on the case of Dougherty County in Georgia in 2013 showed that the prices of properties for 100-year floodplain fell significantly (Atreya et al., 2013).

It should be taken into consideration that some researchers like Bialaszewski and Newsome in 1990 reported no price discount, and seen from other way round there are some papers which reported higher values for the discount price in excess of 10% (MacDonald et al., 1990).

In another research done by Beltran et al. in 2019 they analyzed the change in price of properties affected by the flooding in England between 1995 and 2014. The results showed that there is about 21.1% to 24.9% of lowering in the price was happened immediately after the flood event in the properties entirely inundated by flooding. Also, it was found that this discount is short-lived and won't be statistically significant after 5 years. The magnitude of this effect generally depends on some factors like characteristics of the properties, characteristics of flood and existence of flood protection assets.

The natural hazards like flooding can also affect the rent price in the cities and built environment. But a study in US showed that the house prices do not drop much. So, the final rent to price ratio will increase. This impact will be beneficial for high-wealth households, since they can increase their rent and earn more money (Dillon-Merrill et al., 2018).

As it was seen in the case of flood in Canada, the effect of natural hazards on the housing market is to reduce the housing prices (Baade et al., 2017). There are theoretical reasons for this effect, for example Brookshire et al. in 1985 explained that households are ready to pay more for locations with lower possibility of loss.

The main mechanism for price reduction after extreme events is unclear, but it is related to the possible behavioral scenarios (Booth and Tranter, 2018).

First of all, for example once a new seismic event happens, there will be a new risk assessment which is more accurate and affects the housing prices (Beron et al., 1997).

Added to this, the behavior of households in land pricing before and after a seismic event is also important. Gu et al. in 2018 found that there is no relation between the land price and proximity to the fault line before an earthquake, but they were negatively correlated with geographic proximity after the seismic event.

Finally, the main assumption for these reasons is that the housing price is affected by the assessed risk which is done by individuals on the intrinsic and extrinsic characteristics of the building against seismic events (Votsis and Perrels, 2016). It roots from psychological mechanisms. These mechanisms leads people to assess the risks according to their social and cultural learnings (Crescimbene et al., 2014). Also Logan in 2017 identified that there are important aspects which affect the seismic risk perception, like experiencing the hazard before and individual characteristics (e.g. gender, level of education, religion, age and so forth). For example, it was found by Armas in 2006 that females, young people and non-highly educated people perceive higher seismic risk like it has been found before by Slovic et al. in 1977. This risk perception depends on individual expected damages which is related to the probability and cost of suffering from damage.

In order to be more focused on residential properties, Razali et al. in 2018 investigated that the growth in the population caused to explore new areas for housing development including the areas prone to flooding. But the results revealed that residential price in case study areas in Langat River area in Malaysia had only little impact. One reason for this fact was related to national conditions which was related to the high demand for the houses and limited supply which resulted in increasing the prices even in the flood prone areas.

## 2.6 Ways to measure the damages

In order to understand and manage the risks, it is not necessary to only evaluate them quantitatively, but the qualitative assessment can be useful, since there are a wide range of formal and informal tools and approaches exist. These approaches evaluate the qualitative goals and priorities based on ethical, psychological, cultural or social factors (IPCC, 2014).

In the quantitative approach, what is important is that how to measure these damages, considering that the measures are mostly proxies, like location in a particular area, distance from fault and occurrence probability, and simulation of earthquake scenarios.

Modica et al. in 2021 used an approach so-called macro-seismic approach to assess the damage to residential buildings according to the scale from D1 (almost no damage) to D5 (collapse) which is based on the EMS-98 intensity scale (European Macroseismic scale, Grunthal, 1998). They used the difference-in-

difference method to evaluate the market response to the earthquake and the market was obtained from the OMI (Osservatorio del Mercato Immobiliare-Observatory of the Housing Market). The results showed that the price in the areas affected by the earthquake was significantly lower than that of the undamaged areas. Also this price is not so much related to the quality of building itself, but it is more related to the external factors. There is also another side effect of this phenomenon which is 'wealth effect'. It explains that this phenomenon can impact the price of other places that are not affected by the earthquake directly, since lowering the value of the affected houses can lower the value of houses in the near areas. Moreover, if restoration of the houses cannot fully recover the pre-event real estate value, the opportunity cost of assigning a portion of incomes or savings to restore can be very high. In this way, households accept that their property value has been decreased.

There is another result which explains that the lower the quality of the houses, the higher the level of drop in their value. Therefore, it will be inferred that the historical disparities in the socio-demographic structure not only shape the vulnerability of residents to the hazard, but they also increase the social inequalities.

Finally, evaluating the long-run effect of the earthquake on housing price seems to be necessary, especially the persistence of property value reduction.

In another research done by Bin, O., and Landry, C., in 2013, it was also shown that the property risk can affect the sales price, for example properties facing lower

risk of flood sell at premium. In the Pitt County, North Carolina, there were no risk before Hurricane Fran in 1996, but after the Hurricane Fran it was found the price differential of 5.7% decrease and after Hurricane Floyd it was 8.8%. In average, this amount is between 6.0% and 20.2%, but is diminishing over time about 5 or 6 years.

There are different ways to determine which kind of climate-related and environmental risks impact the business strategy, like Scenario (Stress) Analysis. This tool has used a set of plausible scenarios to test the resilience of the business model in the short or medium-term (three to five years) and long term (more than five years). These scenarios include some quantitative and qualitative assumptions regarding the impact of climate-related and environmental risks and their related time horizon. To do so, institutions are expected to set and monitor the Key Performance Indicators (KPIs) as the proxies. For example, it is possible to assign the rating to either assets or risks which can be done by due diligence for the significant institutions. Also, critical exposures to such risks should be highlighted in order to ensure that an appropriate risk mitigation measure can be introduced.

It is expected that institutions include climate-related and environmental risks in their Risk Appetite Framework (RAF) which could be helpful to increase their resilience. The RAF is fed and formulated by the Risk Inventory which is the result of the Risk Identification process based on Risk Taxonomy (the categorization of different risk types and factors) (ECB guideline, 2020).

## 2.7 Ways to reduce the risk on built environment

### 2.7.1 Public awareness

As explained in Paris Agreement (2015), it is important to enhance climate change education, training, public awareness, public participation and public access to the information related to the climate change.

Among all the people living in the cities, the poor people are the most negatively affected ones, because generally they are living close to river banks, in the slopes with the risk of landslide, near to polluted areas, in unstable structures more vulnerable to the risk of earthquake, and they are less educated and has lower level of awareness about the climate related risks (UN-Habitat, 2022).

Pryce et al. in 2011 created a model to estimate the discount price over time regarding the risk awareness and stated that the level of awareness increases by flood events, but it will be affected by amnesia or myopia.

### 2.7.2 Insurance

In different researches, there are different solutions proposed to face with the risk of climate-related event, but the main solution is using the full insurance, for this reason, Congress of US created the National Flood Insurance Program (NFIP) in 1968.

Availability of overland flood insurance causes the information to be disseminated about flood risk and informs households about the expected cost and likelihood of a flood (Blenger et al., 2013).

In the case of insurance, a case study among residents in Metro Vancouver showed the willingness to pay for flood insurance and how the attitudes about insurance relate to other factors which determine the vulnerability to flood hazards. Findings of that research showed some expected results, such as the willingness to pay for flood insurance is positively related to risk perception (Oulahen, G., 2015).

Of the guidelines that aim to enhance the awareness about managing climate-related and environmental risks, one is European Central Bank (ECB) Guideline. As it can be understood from its name, it is not substitutable with applicable laws, but it should be read in conjunction with other ECB guides, especially the ECB guide to the Internal Capital Adequacy Assessment Process (ICAAP). This guide was applied from early 2021 on the significant institutions.

### 2.7.3 Land-use planning guidelines

One of the adoption ways is providing risk-appropriate national land-use planning guidelines which do not allow the construction of new infrastructures and buildings in the areas which are or will be highly exposed to climate change hazards (Steffen et al., 2019).

Not only the buildings and infrastructures should be constructed in a way to resist against future climate hazards, but they also should be able to facilitate the transition into the more circular and low-carbon economy which is a proper solution to avoid the consequences of climate change (European Central Bank guideline, 2020).

### 2.7.4 More resilient buildings

Nowadays, there are 139 cities in 27 countries have measured and strengthened their resilience to climate change impacts, with the adaptation fund financed projects which worth more than $49 million to support the community-level adaptation of infrastructures in south-eastern Africa, Cambodia, Jordan, Lebanon, Pakistan and Vietnam (UN-Habitat, 2022).

Real estate developers and land owners have strong incentives to consider the risk of climatic events when investing in the real estate. They choose in a joint decision among different options of durability, upkeep of an existing piece of capital and the decision of whether to keep the real estate capital in its current location or to move it to higher ground. The more the risk of climate change increases, the more the willingness of choosing the last option for the owners of coastal properties. For example, if the land owners be aware that they cannot move their assets to higher ground, they will build less durable capital and maintain it less. Some other owners build sea walls and raising foundations (Bunten, D., Kahn, M., 2017).

### 2.7.5 Risk sharing

Risk sharing is another way to face the climate-related issues. For example in a study which was done on the cities of Toronto and Calgary in Canada, it was confirmed that municipalities can use a range of risk-sharing policy instruments that engage different partners, like municipal departments, provincial governments, regional watershed management agencies, and the private sector. These instruments include flood maps, land use planning, flood warning system, insurance and so forth. This kind of risk-based approach will be more useful during the definition of design standards in these cities, especially in more important parts of cities like downtowns which contain more economically important and politically sensitive assets (Henstra, D., and Thistlethwaite, J., 2017).

# 3 Methodology

In order to achieve the main goals of this thesis, it is considered a top down approach in which it is tried to move from a general overview to a more focused subject. For this reason, in the previous chapters, it was seen that what is the climate change and natural hazard in general definition and the impacts of their examples on different fields of human life like the health, trade, tourism, food production and so forth.

The way chosen in this thesis to evaluate different fields was that the thesis tried to evaluate the fields not all in one sector and in one aspect. For example, some of the affected areas are economical like manufacturing and trade, and tourism industry, but some others related directly to the human like the human health and food production. Also, some others did not directly affect the human activities or the economic activities, and they were related the heritage and history of the nations and countries. To explain each of those affected fields, it was tried to find the expressions in global level which could be common for all the countries, also tried to provide example from papers which evaluated a case study in a specific country and in this step, the thesis tried to provide the examples not only from the Europe, but also from other parts of the world to see how different countries facing with this problem.

Among all those affected fields, this thesis focused more on the field of built environment which has a great importance for the human life and the government;

since as it was explained, the human activities are more related with the built environment in terms of living and working space. For this part, different published were provided that each of them explained one aspect of importance of built environment, for example the guideline by European Central Bank that aimed to do the evaluation in more financial terms, but other research papers which explained the importance of the cities as the place for living in US and Europe and other parts of the world.

After understanding the importance of the built environment and the types of impacts that climate related events and natural hazards can have on this field, it was tried to analyze the risks related to those events. Since the risk analysis has different steps consisting of, identify the hazard, assess the risk, control the risk, and record and review the findings, it was necessary to focus on a step which is important from one hand, and more ignored by the previous research on the other hand. Moreover, the climate related events and natural hazards were occurring from many years ago and they are tied with the human life, so the sources of their risk are almost clear for the nations and people and scientists. Whereas those risks are clear for the scientists and people, every year there are a lot of people who die due to those kind of events.

The reason for this unpleasant truth is that there exist a lot of policies, instructions, ideas, and proposals to mitigate those risks. But, in reality, the efficiency and performance of the solutions are insufficient and each of them has some shortcomings. Hence, this thesis focused on the evaluation of the solutions

and to find their shortcomings and defects in order to avoid the repetition of their problem in the similar cases in the future.

It is crystal clear that the number of climate related events and naturals, and the solutions for each of them are too much and they have different characteristics. So, if one wants to evaluate them, the first step should be grouping them and do some simplifications. Since it was seen that the solutions have differences in the ways that some of them are the policies for the country level, some others are the proposals to avoid the risks, some others try to mitigate the risk, some other focus on the assets or on the human life, and also they can be differentiate in the way that if they want to construct a structure (physically) or increase the knowledge (mentally).

In order to make it possible to evaluate the solutions in a better way, this thesis have the top down approach also for this part. It means that the solutions are divided in two groups of solutions, first the policies which have the aim and scope in global and country level, and second the technical solutions which are useful more specifically in local level and some of them are the instruments to reach the goals of first group.

To achieve this goal and go in more detail in the bottom of the approach, in this thesis it was tried to evaluate the papers and guidelines and agreements all around the world, see if they had efficiency in their scope and what are their shortcomings. To choose the papers, it was followed a criteria which looked for the papers in two

areas, in the European countries, also outside of Europe. It is because of some reasons:

- Since in the Europe, there exist the European Union that publishes the general approaches for its members, and these approaches will be transformed and used in the national rules for each country, the policies for the European countries can be more or less the same as it can be seen also by the report of CarbonBrief in which they considered the EU as one part.
- Since the characteristics of the countries and events vary significantly across the world, like the geographical and meteorological characteristic of an area, the level of education and income of people, the general approaches of governments and rules, and other parameters; it is necessary to make a simplification in the assumptions in order to be able to evaluate and make the comparison. Hence, this thesis assumed to consider the Europe as one part in order to evaluate and compare it with respect to other countries.
- Those different characteristics can cause the fact that each country across the world tries to adjust the solutions according to its own characteristics. So, by evaluation of countries in other parts of the world, this paper tried to find the pros of different solutions that can be helpful for European countries to adjust for their own case.

Another part of specification in this thesis is that although there are provided different examples for the events and the solutions, the focus of the thesis is more on two events of flooding and earthquake. In this way, different papers were

evaluated in order to find the technical solutions for each of the cases. In each paper, there are common parameters which are evaluated including:

- The amount of damage that happened for that case study due to the flooding or earthquake,
- The technical solution that country proposed and implemented to mitigate the risk of that event,
- The efficiency of the method they used in terms of the decrease in the number of victims or decrease in the financial loss or other parameters,
- And the possible defects for that solution which should be considered in implementation of that method for other cases in the future.

Finally the thesis concluded the differences among those methods and tried to find the best proposal to resist against those kind of climate related events and natural hazards, and proposed the future possible works which should be done to improve this subject.

## 3.1 Policies

In order to evaluate the policies which were considered for climate change mitigation, there is provided a database by Grantham Research Institute on Climate Change and the Environment and the Sabin Center on Climate Change Law. This database contains more than 1200 relevant policies across 164 countries which are responsible for about 95% of GHG emissions at global level.

As it can be seen in the figure below, the number of climate laws is increasing in a rapid way, in which in 1997 there were just 60 laws in place, but nowadays this amount is around 1260 which have risen 20-fold.

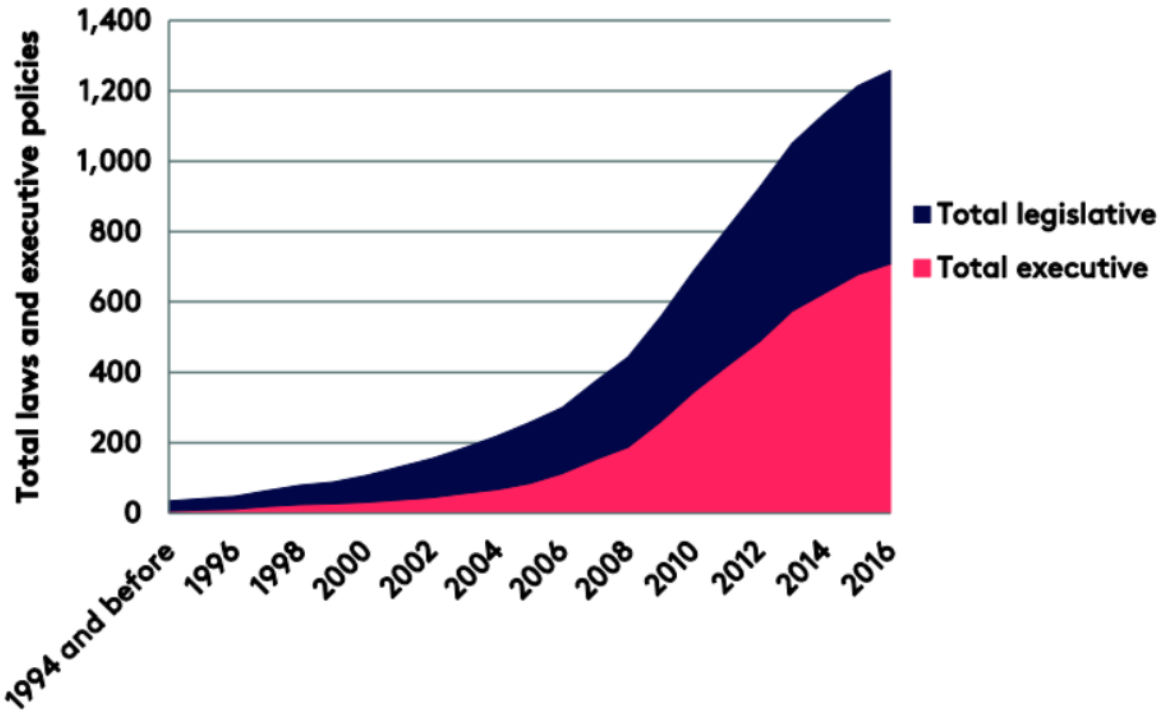


*Figure 6: Climate change laws around the world. Parliaments pass the legislative laws, though executive laws or policies are enacted by governments.*[8]

As it can be seen from the figure above, after a pick around 2009, the rate of increase in climate laws has slowed, it is because that according to the report of the institute in 2017, nowadays, most of the countries have at least the outlines of their climate policies in place. Also, it was announced by Grantham Institute that since the Paris Agreement was sealed in December 2015, another 47 climate laws have been passed.

[8] Source: Website of CarbonBrief - https://www.carbonbrief.org/mapped-climate-change-laws-around-world/

Also this database explained an important point which is that the Least Developed Counties (LDCs), which include 48 nations which are more vulnerable to climate change, are increasing their activity in the field of definition and implementation of climate change policies.

What is important in the results of this report, is the difference between the type of activities done by Developing and Developed countries. Because, notwithstanding the developed countries are trying to focus on policies to cut the emissions, the developing countries have paid more attention to adaptation to the climate related events and their consequences.

These policies by each of the countries all around the world have been submitted to the UN and it was explained in each of the pledges of countries the level of reduction they intend to have in their greenhouse gas emission. These promises are called “Intended Nationally Determined Contributions” or INDCs that determine the success level of the deal in Paris agreement.

In the figure below, it is possible to find the information about the countries who have proposed their pledges and the percentage of emissions covered in the world so far. As a summary of this figure, there are 192 parties among total 196 parties have submitted and INDC which can cover the 87.6% of global emissions.

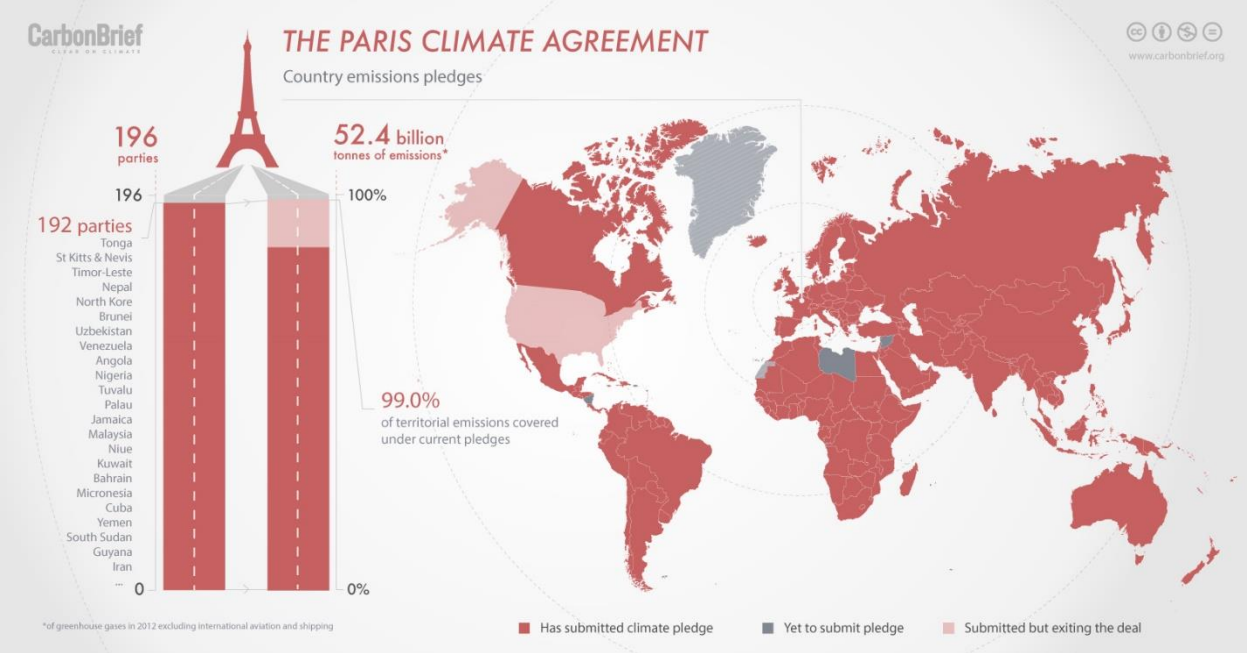


*Figure 7: Info graphic: Who has pledged an INDC so far, and what percentage of the world's emissions are covered.*[9]

In order to have this information in more focused way, there is also published another table in which the summary of the INDC and share of GHG for each of the countries are provided in details. As an example of this table, it is decided to choose the countries across different part of the world to have an insight and to make it possible to have a sort of comparison among them as it can be seen in the table below:

[9] Source: Website of CarbonBrief: https://www.carbonbrief.org/paris-2015-tracking-country-climate-pledges/

*Table 3: Some of the countries and their INDC and share of GHG*[10]

| Country | Date | Summary of the I/NDC | Share of 2012 GHG |
|---|---|---|---|
| **China** | 30/06/2015 | A peak in carbon dioxide emissions by 2030, with best efforts to peak earlier. China has also pledged to source 20% of its energy from low-carbon sources by 2030 and to cut emissions per unit of GDP by 60-65% of 2005 levels by 2030, potentially putting it on course to peak by 2027. | 23.75% |
| **USA** | 31/03/2015 | [The US plans to withdraw from Paris and not meet this pledge] 26-28% domestic reduction in greenhouse gases by 2025 compared to 2005, making its best effort to reach the 28% target. This includes the land sector and excludes international credits at this time. Carbon Brief has a more detailed article on the US INDC. | 12.10% |
| **EU** | 06/03/2015 | At least a 40% domestic reduction in greenhouse gases by 2030 compared to 1990 levels. Carbon Brief has a more detailed article on the EU INDC. | 8.97% |
| **Russia** | 31/03/2015 | 25-30% domestic reduction in greenhouse gases by 2030 compared to 1990 levels. The Russian pledge | 5.35% |

[10] Source: Website of CarbonBrief - https://www.carbonbrief.org/paris-2015-tracking-country-climate-pledges/

| | | | |
|---|---|---|---|
| | | includes maximum possible account of the land sector. Carbon Brief has looked at the details. | |
| **Japan** | 17/05/2015 | A 26% reduction in emissions on 2013 levels by 2030. Includes precise information on how it will generate its power by 2030. | 2.82% |
| **Canada** | 15/05/2015 | A 30% reduction on 2005 greenhouse gas emissions, by 2030. This includes possible use of international emissions credits. It also includes the land sector and forestry. | 1.96% |
| **Iran** | 21/11/2015 | A 4% cut in emissions by 2030 relative to business as usual, or a 12% cut conditional on international support of $35bn. Both elements are conditional on an end to sanctions. Includes section on adaptation. | 1.05% |

One of the important points which can be understood from this table is that there is a leading group of countries which are using the policies in a strict way to resist against the consequences of climate change. This leading group includes the UK as the leader in the tackling the climate change, also its main partners in the field of trading.

Also, this table shows that the reduction target defined by China about its greenhouse gas emissions associated with each unit of wealth (emissions intensity) is more or less as the same level with the one of UK, even it can be said that it is slightly more ambitious.

In order to have a better insight about the general comparison of the adequacy of the policies in different countries, there are some indices produced by various institutions like Climate Action Tracker and PWC. For example, for the case of China and UK, the aim to cut the carbon intensity by 2030 is 3.5% and 3.1% per year, respectively.

Though there are a lot of works were done in order to mitigate the GHG emission and its related policies, it is necessary to notice about one of its shortcoming. It is the fact that the current policies fail the final expectation about avoiding the warming of 2°C or more. To solve this shortcoming, one proposed solution is to ask for stronger laws, not more laws. Because, most of the evaluated countries have at least a framework to deal with climate change problem, but they are weak and it is required to strengthen and empower those frameworks, implement stronger policies, have less exemptions, higher price for carbon produced, pay more attention to support the energy efficiency, and better ways of prohibition and land use. Hence, the laws should be strict enough, also against the governments and corporations who failed to be prepared for the climate change events (Website of CarbonBrief, 2017).

### 3.1.1 Flood legislation and land policy framework

As the risk of flooding is increasing due to climate change, there is a pressure on the governments to enhance the flood protection measures. For this reason, there are several policy frameworks which have been developed to mitigate the flood

risk at European Union (EU) and global level. These policies should be followed by governments, institutions, and households to reduce the risks.

In order to have an integrated management of floods in Europe, the European Commission (EC) published the Flood Directive 2007/06/EC (FD) which had the aim of reducing the flood risk on health, environment, cultural heritage, and economic activities. It is obligatory for each of European Union member State to implement the FD at national scale. According to this directive, all the member States in EU must do preliminary flood risk assessment for river basins and coastal zones to identify the possible areas and zones for future floods. Moreover, it is necessary for them to provide flood hazard and risk maps, and establish flood risk management plans which have focus on prevention and protection.

According to the study which was done on two EU countries (Portugal and Slovenia) and two other non-EU countries (Serbia, and Bosnia and Herzegovina), it was resulted that EU countries benefited from implementation of FD mostly in flood adaptation and mitigation on the country level. But, the level of benefit depends on the date of joining the countries to EU and other parameters like economic and political situation. For the case of non-EU countries, there are some barriers for flood resilience enhancement like weak economy and complex land governance administration. As a result, in these countries, floods are considered mostly as secondary importance (Solomun et al., 2021).

### 3.1.2 Flooding Insurance

Nowadays, most of the international existing systems for catastrophic insurance have been developed with some sort of governmental involvement. This participation could be through private markets or through providing a sort of compensation by public reinsurance or a state guarantee. In most of the cases, Public-Private (PP) partnership sets up those systems with the participation of private insurance companies that have different degrees of roles and responsibilities.

PP system in this field means the system in which there is the cooperation of the government and private sector with the goal of sharing the risk or selling the insurance policies to make the optimal use of the experts and capacities to carry the risk to both sectors.

In a study by Paudel, Y. in 2012, characteristics of PP flood insurance systems in the U.S., France, and Belgium were collected and compared from various aspects. First of all, the general characteristics will be argued and later, the funding sources will be evaluated.

In the United States, the PP flood insurance system has a long history and frequency of flood events with a large amount of damage is relatively high. In 1968, the National Federal Insurance Program (NFIP) was published by U.S. congress which is administrated by Federal Emergency Agency (FEMA) with the goal of covering the risks. Added to the NFIP compensation, U.S. president can issue an official disaster declaration after large floods which is an assistance for federal

programs. The number of this Presidential declarations has increased in a significant way over past 50 years. For example, after Hurricane Katrina in 2005, three emergency supplemental appropriations bills were issued by congress which were about $88.4 billion.

One of the first countries in Europe which set up a mandatory PP catastrophe risk insurance was France. In 1982, after major floods in the Saône and Rhôn valleys in the south-west part of the country, the French natural catastrophic insurance *Catastrophes Naturelles*, CatNat, was founded. This is a mandatory arrangement which should be followed by private insurers who are responsible for covering flood risk, but the main role of the government is to provide reinsurance and establish the plans to prevent and mitigate the natural hazards. The main challenge of insurance in France is that there is required an official natural disaster declaration in order for insurance to be taken effect. This sort of official trigger is not based on a pre-defined damage level and causes a level of uncertainty for the victims of floods about whether they can receive the compensation or not.

Belgium is another European country which established a sort of flood insurance system which utilized an interesting combination of private insurance instruments together with public reinsurance. The arrangement of *Waarborg Natuurrampen (WN)* for natural disaster coverage which also covers the flooding, was established in 2005. Though this new form was established recently, it is inspired by the French and Spanish systems. In this system, the private insurers

cover the risks and the government is responsible for flood protection and state guarantee for insurers.

In order to make a comparison in terms of ways of funding the insurance coverage in each of these countries, first of all the case of NFIP in US will be explained.

There are provided optional insurance coverage by NFIP which considers the maximum for damages to the buildings with the exception of damage caused by landslides, direct rain, snow, hail and storm. The main sources of funding for the NFIP are the premiums and loans from the federal government. In order to determine the amount of the premiums, there are different factors which play role, such as physical characteristics of flood hazard, the location, age, type of occupancy, and the design of buildings. These NFIP premiums for standalone flood insurance are about three times of French CatNat and the Belgium WN. In the case that the premiums are not sufficient, it would be possible for FEMA to borrow from U.S. Treasury with the maximum limit of $20.75 billion which must be swift and risk-free interest rate.

In the case of CatNat, most of the natural hazards are covered consisting of floods, with the exception for wind, storm, hail, weight of snow, and damage to unsorted harvest and crops. Here the amount of premiums are set by the governmental institute “The Central Tariffs Office” in which the private insurers collect these premiums, process and manage the claims with respect to the limits defined in the insurance policy. Choosing the type of insurance between Public

reinsurance or the Private insurance is allowed in the French system. It will result in risk selection in a way that the good risks are privately insured, while the bad risks are publicly reinsured. This is a problem that does not exist in a fully public system like Spanish Consorcio in which all the bad and good risks are covered by public system.

The coverage of Belgian WN is provided under a common risk insurance policy for buildings. The maximum overall coverage by WN is too low to cover extreme damages and it is only about $352 million. Also for this case, the amount of premiums for flooding depends on some factors such as flooding history, flood probability, and the location of insured property.

### 3.1.3 Drought Policies and risk analysis

Although the climate change causes the rising sea level and flooding in some parts of the world, the other side of the coin is the other sort of natural hazard which is drought. Despite a lot of improvements in systems of weather forecasting and warning, government policies and programs, public education and development of new tools and technologies, the costs resulted from these events are still high and unfortunately increasing. For instance, in the United States, from fall 1995 into the summer of 1996, parts of Southwestern US experienced severe drought. Also, parts of Florida, Georgia, Texas and Hawaii experienced four consecutive years of drought from 1998 through 2001. So, it seems to be necessary to find solutions to resist against this sort of natural hazard.

In order to mitigate and manage the risk of drought, one cannot exempt it from other natural hazards and the best situation to resist against this sort of climate related event is again the prevention. For example, in the United States, the Natural Hazards Caucus was established in 2000 by the US Congress in response to the rising cost of natural hazard with the aim of understanding the reason of why the nation is increasingly vulnerable to natural hazards. In this context, mitigation is considered as all the actions taken before happening a natural hazard in order reduce its negative impacts.

For the case of drought, National Drought Mitigation Center (NDMC) conducted the drought planning in which one step is doing the risk analysis in order to identify the proper mitigation action against drought.

In this case, risk analysis is defined as the process of identifying and understanding the relevant components of drought risk and try to find the strategies to manage it. During facing the event, it is important to know that the different people have different attitude about the risk and this fact depends on their awareness, previous experiences and other factors. Anyway, the risk analysis process should be user-friendly as much as possible, because it will help the decision makers and policy designers to get help from other stakeholders during the critical situations.

In order to put these aspects into effect, a user guide was developed by the NDMC and members of the Western Drought Coordination Council which is called ‘How to Reduce Drought Risk’. It had aim to assist states, communities, and tribes

in performing their own drought risk analysis, and tried to transform theory into a relatively simple and practical process to understand better the drought in a specific region and find the proper actions to mitigate its effects.

In the United States, the planning was used the first time in 1998 at New Mexico and later followed by Texas, Hawaii, Georgia, Nebraska and Colorado, also by some tribal governments such as Navajo, Zuni, and Hopi nations in the southwestern parts of US.

For instance, Nebraska benefited from public participation into its risk analysis process and progressed in its mitigation actions. The Hopi Nation also completed a comprehensive analysis for hazards and vulnerabilities which was helpful to identify the short- and long-term mitigation actions that are necessary for the tribes to reduce their drought risk.

One important point which should be taken into consideration is that the drought risk analysis must remain nonpolitical as much as possible. For this reason, public participation is an important step which can be helpful to keep the process nonpolitical, if done correctly.

Another important point is that since the drought and other hazards affect the national, community, and individual sustainability especially in the regions with vulnerable societies, the drought risk analysis should be incorporated into a larger process which involves other hazards, or into a larger process of water resource planning. This sort of overall goal can help also the states or federal governments (Hayes et al., 2004).

## 3.2 Technical Solutions

### 3.2.1 Flood

Floods are a widespread natural hazard which affect the human activities and assets all around the world. Resisting against the floods is always a great challenge for governments. Since the flood risk is a function of three components of hazard, exposure, and vulnerability, the ways to resist against this kind of natural hazard and to mitigate and manage its consequences should be focused on one or mix of these parameters.

Here there are provided some possible solutions to manage and decrease the flood risk.

#### 3.2.1.1 Flood warning system

One of the solutions that can be useful to mitigate the flood risk is the flood warning systems which contain of Flood Forecasting, Warning and Response Systems (FFWRS). This systems include continuous monitoring and forecasting of precipitation and water levels, and the detection of possible dangerous situations. These information should be linked to the defined thresholds and rules about how, when and whom to warn in case of heavy precipitation or rising water levels.

This system has been improved over the past 20 years in Germany and in a study which was done in Germany about the warning systems, the capacity and responsibility of forecasting, warning and response are divided between the

federal, state and local level. The warning during the critical situation will be announced through different ways, like media operators, warning apps, sirens, loudspeakers and so forth.

During this study, it was shown that this system had good overall performance in the areas of Elbe and Danube, but regarding the pluvial and fast-onset flash floods survey data, it was understood that there are still crucial weaknesses in the system. In this case, about 30 to 40% of the affected residents were not warned by the system. This shortcoming had fatal results during the flood in July 2021.

Also, this study showed that it is important to enhance the knowledge of people about how to behave properly when a flood event happens. Hence, they should be well educated and aware of how to protect themselves, their families and their properties. It was revealed from this study that during the flood in July 2021, up to 50% of the warned people did not know what to do (Thieken et al., 2022).

According to the research by Smith et al., in 2017 which was done on the case study of Nepal, there is also another type of warning systems which are called Community-Based Early Warning Systems (CBEWSs). These systems are people centric which help the communities to use local resources and capacities in order to respond to flood events. In this way, the communities are active participants that are not only playing role in the design phase, but also they are active in monitoring and management.

One of Non-EU countries which face the flooding is Nepal which is surrounded by Himalayas in the north and Indian plain in the south. The rivers in this country

are divided in two types of snow-fed and rain-fed rivers. One of the important river basins from this aspect is the Karnali River basin which is located in the west of Nepal. The climatic regime of this basin is affected mostly by the monsoon and westerly circulation systems. The analysis of Nepal Department of Hydrology and Meteorology (DHM) showed that around 70-80% of the annual precipitation and river flow occurs due to the monsoons. Since there is a high variability in magnitude, duration and intensity of precipitation in macro- and micro-scales, forecasting the occurrence of flooding is still challenging.

There are significant flood events which was occurred in this basin in 1983, 2009, 2013 and 2014 which had impacts on livelihoods, agriculture, livestock, food production and infrastructure development.

In 2002, the first CBEWS was piloted for the East Rapti River by the International Non-Governmental Organizations (INGOs) practical action. This pilot was improved and expanded in the next 10 years to cover eight river basins across Nepal which were Karnali, West Rapti, Babai, East Rapti, Narayani, Bagmati, Kankai, and Koshi basins.

Among the result of using this pilot, the most important one was that for the case of Karnali River basin, the lead time at which the warnings are issued can be increased potentially from the current 2-3 hours to up to 7-8 hours. Also the results showed that this level of increase is more or less the same in other basins across the country. As the pros of this system, it is possible to mention the following ones just as examples:

- The cost is near to zero due to open free licensing, and simple means of interfacing with existing warning systems infrastructures.
- It does not require for very detailed information like detailed topography, land use and soil property

#### 3.2.1.2 Floodplain retention

As it was explained before, flood forecasting and warning systems can be one of the solutions, but this solution has some defects like that an efficient flood forecasting needs good input data to setup the model. So, in the cases that this system cannot work sufficiently, an additional prevention measure could be useful to decrease the negative impacts of flooding.

In a case study which was done on the Glinščcica River catchment (Slovenia), there are three forms of these prevention methods were evaluated. These solutions are afforestation, implementation of permeable concrete, and dry and wet retention reservoirs which also a comparison among them were carried out.

Afforestation is one of the solutions to reduce peak flow and it has different eco-system benefits. In the research was done by Bezak et al. in 2021 on the Glinščcica River basin, the Cost-Benefit Analysis (CBA) was considered for the periods of 2, 10 and 25 years and they considered the parameters of biodiversity, carbon capture, recreational value, and water quality. In the results, it was shown that the peak discharge reduction due to afforestation was less than 15% and it can be proposed

as a supplementary measure to reduce the risk of flooding in a basin for the built environment.

Using the permeable concrete is a hypothetical option for flood risk management which can reduce the storm-water runoff. The costs of this approach are mainly due to the cost of construction and maintenance which are tangible costs, but the benefits are mostly difficult to be expressed in economic value like reduction of surface temperature, protection of streams, watersheds, and ecosystem. The problem of this hypothesis is mostly related to the fact that it cannot be applied in large scale and needs soils with good infiltration capacity. The results showed that the peak discharge capacity of this solution is higher than the afforestation.

As the other solution, the paper suggested using the wet and dry retention reservoirs which are frequently used in Slovenia and after the reconstruction of them, their maximum retention volume was estimated around 450,000 $m^3$. The flooding area will cover around 42 ha of the lands and the land use for this area is considered as extensive agriculture. The results showed that the efficiency of this solution is higher than the previous ones which decreases the peak flow discharge for the 25-year return period events about 45%, and for the 2-year return period events about 32%. Also it causes a lag of around 2h and 1h for the cases of 25-years and 2-years, respectively. In the figures below, it is possible to see the reservoir and the outlet structure which were designed and implemented.

*Figure 8: Upstream reservoir in Glinščcica River basin*[11]

*Figure 9: Outflow structure and downstream of the Glinščcica River basin*[12]

[11] Source: Article by Bezak et al., 2021
[12] Source: Article by Bezak et al., 2021

As a summary, the result of this paper showed that for the cases of afforestation and permeable concrete implementation, there are required relatively large areas to obtain a notable peak discharge reduction. It will result in relatively high costs to implement such measures which can be even higher than the potential benefits that can be achieved by doing such solutions. From other way round, the peak discharge reduction can be more significant when the dry and wet reservoirs are implemented. But, it should be noticed that such reservoirs can have only significant local effects, and their impact at larger scales will be a minor one (Bezak et al., 2021).

The city of Jakarta in Indonesia is one of the cities with very high flood risk all around the world. In 2007, there were at least 56 deaths in the history of this city due to flooding and over 340,000 people were obliged to evacuate their homes and more than 74,000 houses were flooded. The economic damage of that event was estimated around $560 million. Also there were happened other heavy flooding in 2013, 2014 and 2015. The flooding in this city is mostly because of change in river discharges and increasingly sea level rise which seems to be intensified in the future, due to the continues trend in these terms. So, design and implementation of large-scale risk reduction and adaptation measures are of great importance.

Beside all the policies proposed for mitigate the risk of flooding, there is more focus on engineering solutions. One of the solutions was the refurbishment and expansion of flood reservoirs, especially in the northern part of the city as it can be seen in the figure below.

*Figure 10: Water retention reservoir refurbishment and expansion in northern part of Jakarta.* [13]

Also in Jakarta, like other cases of flooding across the world, the vast majority of affected dwellings belong to low-income households. After implementation of the technical and engineering solutions for this city, it cause the resettlement of 15,000 people in five years. This defensive strategy has been revised and expanded since 2011 and resulted in publishing the National Capital Integrated Coastal Development Masterplan (NCICD) in 2014 (Garschagen et al., 2018).

#### 3.2.1.3 Wetlands

Ecosystem plays a key role in supporting human life through different ways. One type of its function which is related to the topic of this paper is wetlands, Wetlands have different ecosystem functions, but one of the most important functions of

[13] Source: Article by Garschagen et al., 2018)

wetlands is flood reduction which some of them are called to ‘act like a sponge’, because their function is to absorb and store the water during the wet periods and to release it in the dry periods.

Wetlands have different types of land, like wet woodlands, reed beds, peat bogs, fens, wet grassland and salt marshes. Each of these types of wetlands behaves and operates in a different hydrological way from other types.

About the general function of wetlands, different papers have different results. Many of them reported that wetlands reduce the floods, some concluded that there is no impact from wetlands, and some others found evidences that wetlands even increase the flooding. This variation in results comes from the fact which was explained before about their different hydrological behavior of different types of wetlands. Moreover, there are some other characteristics related to the river basins which influence the magnitude of flood on a river, like rainfall, drainage area, soil type, vegetation cover and slope. The figure below explains in a simple way how the different characteristics of wetlands can affect its behavior in different water supply mechanisms, ***a*** stands for precipitation-fed, ***b*** for river-fed and ***c*** for groundwater-fed). In this figure, *P* is precipitation, *E* evaporation, *R* runoff, *GD* groundwater discharge, *GR* groundwater recharge, *OF* outflow, *OB* overbank flooding, *D* drainage, *L* lateral inflow and *S* spring flow.

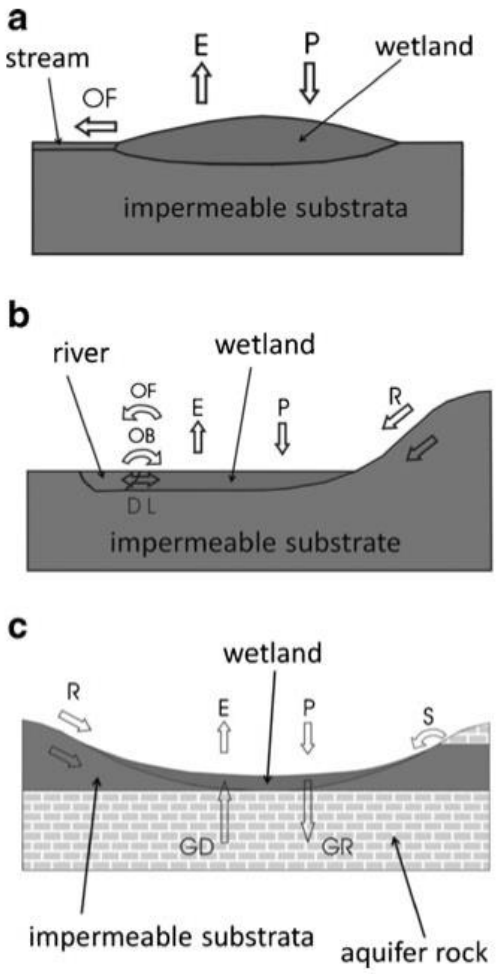


*Figure 11: Different mechanisms of wetlands*[14]

Anyway, it should be noticed that the wetlands only cover a small percentage of a river basin, hence, during the catastrophic floods, the whole area of the basin will be saturated. In this case, the other parameters like the rainfall intensity will prevail over the parameter of existence or lack of wetlands (Acreman, M., and Holden, J., 2013).

[14] Source: Article by Acreman and Holden, 2013

#### 3.2.1.4 Dams

One of the most common infrastructures in water control is the dams which have different functions and provide valuable benefits for human like irrigation, hydropower and flood protection.

In a great number of researches, it is agreed that the dams can significantly modify the hydrology of the river in downstream. One of the consequences of this modification is the changes in high flow events, like flood peaks and annual maximum daily discharge. For example, in a case study in Spain on the Ebro River, it was concluded that there is a reduction in the magnitude of floods in most of the rivers. Also, in another study which was done on the Sacramento-San Joaquin River system in California, it was shown that 2-year flows decreased by 53% in Sacramento basin and 81% in San Joaquin River basin.

In another research in the US, there is collected the data from 38 rivers distributed all over the US with the records of pre- and post-dam annual peak discharge records in order to study the overall behavior of floods at national scale. The results showed that there is a significant reduction in flood magnitude for nearly all of the sites. The amount of decrease varied from 7.4% to 95.14%, except the case of Dead River in which it decreased the peak discharge about 1.46%.

The percentage of this decrease depends on some characteristics like geographic location and function of dam, the ratio of the storage capacity of the dam to the mean annual runoff of the river, and the ratio of reservoir storage capacity to the area of its drainage (Mei et al., 2017).

#### 3.2.1.5 Dry-proofing and Wet-proofing measures

In recent years, there has been done a lot of researches which showed the abilities of some measures to decrease the costs of flooding for the households. These measures include two kind of mitigation strategies which are called Dry-proofing and Wet-proofing strategies which can be defined as follows:

- Dry-proofing

  Dry-proofing strategies are all the strategies like sandbags, coffer dams, or panels on doors and windows to stop entering the flood water. These kind if strategies are estimated to decrease the damage of flooding between 60% to even 100% in some cases.

  The result of researches showed that the effectiveness of these strategies mostly depends on the height of water and it was mentioned that for the water height above 1m, the reduction percentage would be zero which means that it has no reduction impact for the case of flooding. Some examples of dry-proofing strategies are shown as figures below.


*Figure 12: Use of sandbags during the flooding in Prague, 2013*[15]

*Figure 13: Use of temporary cofferdam implemented by PORTADAM Company*[16]

[15] Source: Website of Wikimedia Commons - https://commons.wikimedia.org/wiki/File:Flood_in_Prague_2013,_Ko%C5%BEelu%C5%BEsk%C3%A1_street_with_sand_bags.JPG

[16] Source: Website of PORTADAM - https://portadam.com/flood-protection-overview/

- Wet-proofing

This strategy contains all the semi-structural and non-structural measures that can be used to exterior, interior, and use of the house, with the goal of decreasing the flood damages, if the water enters to the building.

These measures include a vast range of activities like increase the strength of walls against water pressure, use water proof materials to adapt the flood-prone areas of the house, avoid to keep the non-waterproof objects in the areas which are flood-prone, move the sensitive and vulnerable appliance to upper floors, storing the chemical and dangerous materials in the upper part of house, using one-way valves on water evacuation pipes in order to avoid the outside waters from entering the house via these pipes, and other solutions like those.

Different studies were done in order to estimate the impacts of such measures to decrease the flood damage, but generally it is possible to consider a range of 35% to 50% of damage reduction for the floods up to 2m of height. Above 2m flooding height, the efficiency of these sort of measures strongly decreases.

In order to evaluate the impact of such measures on the built environment, it was done a research on 2012 by Poussin et al. which studied the Meuse river basin in Netherland. The Meuse basin is one of the most densely-populated areas of Western Europe which is inhabited by about 9 million people.

They studied this zone for the period between 2000 and 2030 and their result suggested that the risk of flooding will increase up to 185% in 2030 compared with

2000. During their study, they evaluated the impact of measures to reduce the negative impact of flooding in this area and found that using dry-proofing and wet-proofing measures can have the risk-reduction capacity of between 21% and 40% which depends on some factors like their rate of implementation.

Between these two kinds of measures, the dry-proofing measures seem more interesting. It is because the fact that they are easier to implement and less expensive with respect to wet-proofing measures.

### 3.2.2 Earthquake

As it was explained before, every year, earthquakes cause a lot of problems all around the world in terms of money loss, human injury and death, damage to infrastructures and buildings and so forth. As well as the case of flooding, here there are many ways to resist against the earthquakes and decrease their negative consequences. In this chapter, some of the ways which were used in the previous years by different countries are explained.

#### 3.2.2.1 Education of people

During the evaluation of the consequences of seismic hazard, there are two factors which play the role, one is frequency and intensity of the event, and the other one is the vulnerability of the elements of the affected area. So, in order to decrease and manage the final consequences, it is necessary to manage these parameters.

Since some of the natural hazards are unpredictable, especially for the case of earthquake, it is very difficult to modify and manage the first parameter which was frequency and intensity. Hence, in this case, it is essential to focus on the second parameter and to reduce the vulnerability of people and infrastructures and all the other elements which can be affected by the earthquake.

The most important step to decrease the vulnerability and increase the resilience of the assets is the prevention. For this reason, there are five priority actions defined as the Hyogo Framework for the period of 2005-2015 which one of those is to use the knowledge, innovation and education to build a culture of security and resilience at all levels.

There exist a lot of studies in which it was shown that the more the level of awareness among the members of community, the less the number of victims and injured persons during the natural disasters. The importance of this fact will be more evident, if the education process starts from the childhood. It will have the further consequences since the children pass their knowledge to their parents.

During a study which was done in the city of Kraljevo in Serbia, it was seen that only 12% of the pupils responded correctly at the time of earthquake, and 60% of the pupils have not realized that their behavior was incorrect. But, as another result, it was seen that about 61% of the pupils thought about the earthquake or expected that it will happen again and this fact showed that having the experience of previous earthquakes will have the impression on the people to be more ready for the next occurrences. This paper finally concluded that it is necessary to have a

proper training for the people, especially for the children, to have the correct behavior before, during and after an earthquake (Panic et al., 2013).

#### 3.2.2.2 Inspections and prediction

As it was explained before, the prevention is the best option to mitigate the risk of climate related hazards. But, it will be the case for some events that are easier to predict. For the case of earthquake, it was always a great challenge to make a prediction about the exact time and intensity of an earthquake. However, during the years there were done a lot of researches which tried to have a sort of prediction about earthquake.

Operational Earthquake Forecasts (OEFs) are one of these sort of predictions which can be defined as time-dependent probabilities of future earthquake hazard and risk. These kind of probabilities can be announced in various formats such as tables, maps, and text-based scenarios.

In some countries like New Zealand, United States, and Japan, scientific organizations have released these kind of OEFs to the agencies and public which have the intention of providing the information for them to have a better decision making. According to this kind of information, decision makers can opt to choose different solutions and scenarios for the assets like safe access into the buildings, cordoning, safely demolition, timing about the repair and maintenance of the infrastructures, insurance, post event land-use planning and so forth.

In a study which was done in New Zealand following the 2016 $M_W$ 7.8 Kaikōura earthquake, it was found that the agencies have utilized OEFs in many of the ways mentioned above (Becker et al., 2020). SLAT is also another framework which was used in New Zealand which had the aim to estimation of seismic losses and it was developed by the University of Canterbury in New Zealand (Bradely, B., 2009).

Of the researches were done on the prediction of earthquake, one was the research by Angelier et al. in 2000 in which they evaluated the active faulting in the Chihshang Fault in Taiwan.

In Taiwan, it is possible to observe the main boundary between Eurasia and the Philippine Sea Plate on land. By using the repeated observations in this field, it will be possible to measure the displacement across the fault zone and to record its changes during time which will be resulted to have parameters like velocity of this displacement. These data can be useful and significant to assess the earthquake hazard.

As the result of this paper, in the present, fault creeping behavior prevails on this fault zone, in which no large earthquake has occurred since 1951 and earthquake activity remains minor. The earthquake crisis in 1951 closed the stage of fault locking and compressional stress accumulation. Also, it seems that the 1951 earthquake started the creeping period which we have nowadays.

During the annual surveying of the zone from 1990 to 1997, it was understood that the variations in the slip velocity were quite small. Analyzing the fault slope velocity showed that there is a major decrease in this parameter which would

probably announce a new stage of fault locking and accumulation of compressive stress which in turn causes the increase in the earthquake hazard (Angelier et al., 2000).

# 4 Results and Conclusion

Evaluating the papers which were provided in this thesis, it is possible to see that the climate change is a phenomenon which its effects and also its triggers are long-term (as it was explained by the definition of climate change, its changes covers a period of at least 30 years). Also for the case of natural hazards, they can have the consequences that last for the years, even decades to compensate their effects.

Also it can be seen that the existing situation in the emission of GHG and global temperature has an increasing trend in overall. It means that the activities in the past were done in a way that show their impacts now in this increasing trend, and the methods to decrease it effect were not enough. As it can be seen from different references, it is expected that the global temperature increase in the next years.

Added to this, every year the number of important assets all around the world in increasing and the population growth is another phenomenon which needs more infrastructures, resources, space to live and work, food to eat and other requirements. So, this increasing trend causes that every year there will be more assets and people vulnerable against the climate related events and natural hazards, also it has another effect that increase the GHG emission which in turn intensifies the climate change and global warming.

The positive aspect is that as it was seen in the report by CarbonBrief, the global awareness about the climate related events and natural hazards is increasing. This

is approved by the fact that nowadays there exist 164 countries who participate in decreasing the GHG emission in the future and they are responsible for 95% of emission. Also, the number of policies in the recent years increased a lot. So, if these countries succeed in their approach, the general trend will have a significant change.

Another positive aspect in the policies is that in the last years, the countries paid attention more on the quality and intensity of the policies, instead of just increasing them in a quantitative way. Moreover, the developing countries are trying to participate more and it can be seen that the number of developing countries joining in this approach is increasing.

What is important to take into consideration is that there is a difference between the approach by the developed and developing countries, in which, the developed countries try to cut the emission, but the developing countries are going to adaptation approaches. Among all the countries responsible for the GHG emission, about 41% of total emission are because of the activities of only three countries of China, USA, and Russia. These countries pledge to decrease their emission by different ways, for example China pledges to source 20% of its energy from low-carbon sources by 2030.

These policies are in global scale to decrease the GHG emission to prevent the consequences, but there exist other policies which are related to the specific events like flooding and they are also in European level and global level. In the case of this

specific policy, the positive aspect is that these policies are preventive in terms of assessment of the river basins.

The problem of these policies as it can be seen in the papers is that there are different actions which could be done like providing flood hazard maps and risk maps, but these tools need huge amount of financial support. This amount of financial support make a difference between benefiting from the policies in a way that in non-EU countries, there are some barriers for enhancement like weak economy, complex land governance administration.

In order to solve this problem of financing, there is composed the cooperation of public and private (PP) partners in terms of providing the insurance coverage. One point in this topic is that the insurance has longer history in US rather and Europe. It caused some shortcomings in the flood insurance in Europe, for example, in France it is required and official trigger which is not based on a pre-defined damage level which in turn leads to uncertainty about if the victims can receive the compensation or not. Another effect of this leading action of insurance in US is that the premiums offered by the insurance is three times of European cases like France and Belgium. What is common among the countries inside and outside of Europe is that the insurances have some exemptions in some events, like storm and hail.

Even in the case of technical solutions, the results showed that the prevention methods are the methods which are more efficient and also more desirable by the countries. Also the prevention methods can be more proper in term of cost-benefit

analysis. Since the results showed that spending a specific amount of money in preventing an event will cause the significant decrease in the later costs.

As an example of the prevention methods, the warning systems was evaluated in this thesis and the results showed that this system can have the efficiency in terms of increasing the lead time from 2-3 hours to 7-8 hours and also decreased the number of victims. The Work of this system is the same in the case studies of Europe and Asia, and the common problem was that these methods should be done in a way that all the people become aware of the risk of events, also they had to be educated about how to behave against the events.

Though the prevention systems are exist and also evaluated in this thesis, it should be noticed that after happening the event, it is required to find the solutions to resist against the events. For the case of retention, two cases of Slovenia and Indonesia were evaluated in this paper. The results showed that among all the possible solutions of retention, afforestation has the less efficiency with only 15% of discharge reduction. Using the permeable concrete is the next option which worked better; but, the best solution was using the wet and dry retention reservoirs which caused the discharge reduction of about 45%. Also for the case of Indonesia, the best solution was using the water retention reservoirs. There are also some shortcoming of these solutions which are as follows:

- They need a relatively high amount of money that are sometimes even higher than the potential benefits achievable,

- These kind of solutions can work in local scale, so their effect on larger scales will be minor.

The thesis proposed another kind of technical solution which requires less money to provide, which is the wetlands. But this solution also has the previous shortcoming of that it can be efficient only in small scales, but during the catastrophic events, it won't have significant result.

Among all the possible solutions, the results showed that construction of dams can be a proper solution. As the results showed, in the case of Spain, the dams caused the flow reduction of at least 53% and at most 81%. However, in the case of US, the results had wider range which were from 7.4% to 95.14%. The reason for this difference is that the efficiency of a dam depends on various parameters that should be taken into account. So, it is possible to see that this solution can have good efficiency regardless of Europe or other countries, and each country should consider its own characteristics during the decision about if they want to use this solution or not. Moreover, it should be noticed that the dams have the potential damage to be a manmade hazards due to its structural fail.

In the case that a city is facing the flood, using some other solutions are proposed. These solutions are wet- and dry-proofing solutions which can have efficiency even about 100%, but it should be taken into consideration that these solutions are proper for the small amount of water up to 1 or 2m of height. Different studies showed that in a real world, these solution can work in combination of each other to reach about 21% or maximum 40% of damage

reduction when the flood is large enough. The positive aspect of these solution is that they can be easily economic affordable and they can be even temporarily implemented.

During the studies of the thesis about the other kind of natural hazard which is earthquake, it seems that also for this case, the preventions methods are better solutions. The papers tell that since the earthquake is more or less unpredictable, so the frequency and intensity are out of control. So, it is only possible to decrease the vulnerability of people. The first solution evaluated was the education of people. This solution is more efficient when starts from the childhood. As a summary, the more the level of knowledge among people, the less the consequences of the earthquake.

Although the earthquake seems to be unpredictable, the studies showed that in some countries like US, New Zealand, and Japan, there were done many studies to find a sort of Operational Earthquake Forecasts (OEFs) and they are provided again to increase the knowledge of people. Specifically, the research in Taiwan showed that annual surveying and analyzing the slope velocity of faults is a useful tools to forecast the earthquake.

As a conclusion of what has been explained as the results of the thesis, it is important to consider the followings:

- Since the triggers for the climate change and global warming are increasing and cooperate with together, there is a requirement for more intensified policies which are stricter and oblige the countries to reach to the overall

goals. Also it is required to have a better monitoring systems to monitor the behavior of the countries and make some rewards and punishments for the countries according to their works which were done to decrease the GHG emissions.

- The great part of emissions are due to developed countries, so if it is possible to decrease their emissions, the final impact would be significant. But also the developing countries should be taken into consideration, because they are more vulnerable and have less capacity to afford the financial aspects. Especially for the cases of natural hazards, there is no difference between developing and developed countries in terms of their responsibilities, but it seems that the developing countries are even more vulnerable in this kind of events.
- There is a difference between policies and technical solutions in such a way that, since the technical solutions are more based on technological aspects, it can be easily spread around the world and there is no significant problem in using different technical solutions, the only problem is affording the financial aspects for the developing countries. But for the case of policies, it can be seen that as a country has longer history in providing the policies in a specific subject, it will be more successful to resist against the risks. Because, this sort of solutions need the managerial and governmental experiences which cannot be obtained in a short time.
- About the technical solutions, it should be noticed that those solutions depend on the characteristics of each country, so evaluation of those

solutions should be done in more depth which is suggested by this thesis for the next researches on this field.

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