AN ANALYSIS ON DISASTER RESILIENCE

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ABSTRACT

The number of people made homeless due to natural disasters has been decreasing in the past years. However, given the urban population growth in vulnerable coastal areas, this number tends to increase around the globe over time. Hence, disaster resilience is vital, including built environment resilience, as there is a growing and urgent need to develop alternatives to increase the resilience of large urban centers and other denser areas. This study has studied data on natural disasters from different countries between 1990 and 2010 to understand how the countries were affected and how they have coped with different types of natural disasters. The study uses socio demographic variables of each country, namely, GDP per capita, urban percent, and density as leading indicators to investigate the countries' disaster resilience. The findings provide some insights that can help the architecture, engineering and construction (AEC) industry to increase disaster resilience in vulnerable areas, especially in large urban centers of developing countries.

Keywords: natural disaster, resilience, urban population, population density

1. INTRODUCTION

There is a tendency for people to believe that wealthier countries, less densely populated areas and less urbanized areas are more likely to have a lower number of homeless people when hit by disasters. While this assertion is true when analyzing the number of deaths caused by disasters, it is necessary to verify whether it can apply to the number of people homeless due to natural disasters (Ritchie & Roser, 2020). Indeed, wealthy countries are investing more in disaster resilience (Cutter et al., 2014; Esteban & Portugal-Pereira, 2014). Focusing on population density, one can affirm that a major disaster in the Siberian territory would cause fewer deaths and less material damage than a major disaster in central Europe. As for the large urban areas, large metropolises such as Mexico City or New York may be more drastically affected if hit by disasters than small cities located in the rural areas of Mexico and the United States, for example (McPhillips et al., 2018).

Over the years, disasters have affected regions and countries as distinct as Japan and Haiti (Guha-Sapir, 2020). Disaster data is inaccurate and often has a lot of missing data, but considering the effects of natural disasters on housing, data from reliable sources reveals that annually a large number of people have their houses destroyed or heavily damaged, needing shelter in the aftermath of the event (Ritchie & Roser, 2020).

Therefore, it is important to investigate the role of indicators such as country's wealth, population density and urban growth on the number of people made homeless by natural disasters.

The purpose of this study is to analyze whether and to what degree the disaster resilience of a region is dependent on the socio-demographic characteristics of the region. In other words, the study analyzes the relationship between people made homeless by natural disasters and factors such as percent of urban population, GDP per capita, and population density. Understanding the relationship between these factors and the number of homeless by disasters and how these factors affect and relate to each other will help the architecture, engineering, and construction (AEC) industry in developing alternative permanent and temporary housing projects to increase the disaster resilience of vulnerable areas, especially in large urban centers of developing countries. Vulnerable areas in this study include floodplains subject to floods, coastlines subject to storms (cyclones, typhons and hurricanes) and floods, areas prone to tectonic plate movement, and cliffs subject to landslides.

2. BACKGROUND

2.1. Resilience

Resilience, just like sustainability comprehends multiple dimensions and different systems, being the field of social-ecological resilience one of the most important, as it encompasses both social and ecological systems (social-ecological systems – SES), as well as all their interactions at different spatial and temporal scales (Biggs et al., 2012; Elmqvist et al., 2019; Walker et al., 2004). Hence, the concept of resilience should be aligned with system-based approaches, as a system comprehends interconnected parts of a whole. Walker et al. (Walker et al., 2004) defines resilience as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks" (Walker et al., 2004).

Walker (Walker et al., 2004) complements the definition by explaining four concepts essential to define resilience, which are:

1. Latitude: refers to the maximum limit of changes supported by a system from which its recovery capacity becomes difficult or impossible.
2. Resistance: refers to how resistant a system is to changes.
3. Precariousness: refers to the proximity of the current state of a system to its threshold.

4. Panarchy: refers to how cross-scale interactions (scales above and below) affect the resilience of a system at a particular focal scale.

Walker (Walker et al., 2004) emphasizes that strategies related to resilience must be context dependent and have to change over time, due to the changes in the SESs. Given the complexity of the interactions between system, all policies aimed at improving resilience need to clearly define what is desired to be resilient and to what (Biggs et al., 2012).

2.1.1. Resilient built environment and communities

History has shown that cities are quite resilient since we have cities that have existed for thousands of years, even in the midst of wars and natural and man-made disasters. However, under a broader approach, it is possible to realize that the context in changing and urban areas are facing multiple new risks and challenges (Elmqvist et al., 2019). Resilience is not only related to the built environment, but to the natural environment and to all living beings that inhabit these environments. Therefore, it is necessary to go beyond the principles of resilience engineering by also considering social-ecological system principles (McPhillips et al., 2018; Walker et al., 2004).

According to a study developed by Arup (2016) focused on cities resilience, resilience relates to four dimensions:

1. Health and well-being – comprehending (a) minimal human vulnerability; (b) diverse livelihoods and employment; and (c) effective safeguards to human health and life.
2. Economy and society – comprehending (a) collective identity and mutual support; (b) comprehensive security and rule of law; and (c) sustainable economy.
3. Infrastructure and environment – comprehending (a) reduced exposure and fragility; (b) effective provision of critical services; and (c) reliable mobility and communications.
4. Leadership and strategy – comprehending (a) effective leadership and management; (b) empowered stakeholders; and (c) integrated development planning.

When it comes to providing resilient housing, it relates mostly to minimizing human vulnerability (health and well-being dimension), but it also relates to the engagement of families and dwellers in active communities (economy and society dimension) and infrastructure requirements (infrastructure and environment dimension)

Some of the principles to enhance the construction of sustainable and resilient communities proposed above are related to the study of Biggs et al. (Biggs et al., 2012), worth mentioning:

- Maintain diversity and redundancy: variety and redundancy are important for resilience as they offer alternatives when disturbances occur in a system. Response diversity refers to multiple components with similar functions and different responses to disturbances, which provide protection to a system. Functional diversity refers to components with different functions within a system, which enhance the system performance. Redundancy is the result of combining functionally redundant components with response diversity to a disruption, increasing the resilience of a system (Arup, 2016; Biggs et al., 2012). It is important to emphasize that redundancies must be designed in an intentional and cost-effective way (Arup, 2016). A resilient and sustainable community should provide redundancy in terms of infrastructure, diversity in terms of services offered to the dwellers and in terms of people who live in this multifamily community.
- Manage connectivity: connectivity refers to all the links and connections between the socio-ecological system elements (natural environment, resources, species, etc.). Connectivity is important because it allows the system recovery after a disruption. However, connectivity may hinder resilience, by contributing to the spread of a disturbance (Biggs et al., 2012; Elmqvist et al., 2019). To achieve highly resilient socio-ecological systems it is necessary to balance connectivity and foster heterogeneity, for moderate connected and heterogeneous systems are more resilient (Biggs et al., 2012; Elmqvist et al., 2019). In social terms, a resilient and sustainable community should foster social connection between people in adequate levels. Focusing on the built environment, provision of common facilities and physical accessibility help to strengthen community connectivity (Arup, 2016).

2.2. Urban areas

Urban areas comprehend cities and the region surrounding the cities. When compared to rural areas, urban areas have a higher concentration of people, buildings and other human structures, as well as strongly interconnected infrastructure, which results in greater fatalities and economic losses when hit by natural disasters (Elmqvist et al., 2019). Therefore, urban planning must involve risk assessments and measures to reduce specific foreseeable risks associated with measures to increase cities' resilience (Arup, 2016; UN Office for Disaster Risk Reduction, 2019).

The United Nations study on urbanization (United Nations - Department of Economic and Social Affairs - Population Division, 2010) revealed that in 2009 the number of people living in urban areas (3.42 billion) surpassed the number living in rural areas (3.41 billion). Since then, the urban population kept a growth rate higher than the rural population growth rate, so that, in 2018, an estimated 55.3% the world's population was living in urban settlements (United Nations - Department of Economic and Social Affairs - Population Division, 2018).

Urban resilience is a topic that has attracted a lot of attention from industry and research due to the growing need to deal, in a sustainable way, with the social-ecological aspects of urban systems (Elmqvist et al., 2019). Considering the fast pace of growth of urban populations worldwide, which causes several megacities to proliferate globally, it is even more urgent to provide systems that are capable of absorbing disturbances and reorganizing while adapting to still retain essentially the same function, structure and identity (Wang et al., 2020). This is even more important when we focus on disaster resilience, since disasters not only destroy humans' lives but entire communities, including the social tissue and the built environment.

2.3. Natural disasters

Natural disasters are inevitable. Every year we are witnessing numerous hurricanes, earthquakes, and tornados all around the world; incidents have been increasing in frequency through time, affecting more and more people (Bandyk, 2010; Wallemacq et al., 2015). According to the International Displacement Monitoring Centre (IDMC), 14 million people annually lose their homes due to natural disasters (Danan et al., 2015). Natural disasters are considered a test for the resiliency of the region as they create issues with societies. Therefore, coping with the catastrophic impacts of natural disasters by planning and implementing disaster resilience practices is critical, because such practices could strengthen the ability of a community to prepare for, absorb, adapt to, and recover from actual or potential natural disasters in a timely and efficient manner, including continuing or restoring vital services, basic functions, and structures (Wang et al., 2020).

Focusing on the effects of natural disasters on housing, data from reliable institutions reveals that annually a large number of people have their houses destroyed or heavily damaged, needing shelter in the aftermath of the event (Ritchie & Roser, 2020). As a response, different governmental and non-governmental agencies provide accommodations and sheltering to the affected regions as time plays a crucial role in post disaster construction (Hong, 2017). However, there have been many reports and incidents of these temporary houses not meeting the basic social and safety requirements of an acceptable lodging place, delayed, and being costly (El-Anwar et al., 2009; Patel & Hastak, 2013). Meeting shelter needs remains a major challenge for governments, humanitarian agencies, and, most important of all, survivors (Bashawri et al., 2014). In addition, in the last century, two major factors have contributed to the importance of temporary housing:

1. The increase of natural disasters both in destruction and occurrence – according to diverse studies, the frequency of natural disasters are increasing in a way that they are becoming more of a standard than a rare occurrence (Banholzer et al., 2014; Hayles, 2010; Susman et al., 2019)
2. The population growth, especially in urban areas – with the population growth in the modern time, people tend to live in cities more than ever, especially the coastal lines where some cities are experiencing extremely high populational densities (Sweet et al., 2017). This would result in more complex building scenarios (Wang et al., 2020) which contributes to a potentially higher degree of destruction in these areas (Ahmed & Charleswort h, 2010; Platt et al., 2016)

Considering the above factors, it is possible to identify developing countries as more vulnerable to disasters, because in addition to having extremely populated cities close to disaster risk regions and that continue to grow at a dizzying pace, such countries live with chronic problems of poverty, inequality, environmental degradation, prosperity, and peace and justice (UN Office for Disaster Risk Reduction, 2019). In addition, the built environment of many of these countries is more fragile and was not designed and built to withstand natural disasters such as earthquakes, hurricanes and floods. Therefore (UN Office for Disaster Risk Reduction, 2019).

In this sense, the built environment including housing buildings, in developing countries is more vulnerable to natural disasters. A mixture of poorly, unequipped development with the high rise of population and increase in urban rate accelerate the negative impact of natural disasters. The physical built environment is an integral part of a resilient community (Taeby & Zhang, 2019) as the fatalities and consequences of a disaster shows a to be have a stronger relation to level of preparedness of that country rather than the magnitude of the disaster (Keraminiyage, 2011). this "preparedness" is often insufficient and even sometimes non-existence (especially in the case of developing world) and post disaster decisions are often made in a rush and in situations of almost total chaos

Considering the classification of natural disaster provided by the Emergency Events Database (Guha-Sapir, 2020), and analyzing data related to the effects of natural disasters, it is possible to grasp that floods, storms and earthquakes are the types of natural disasters that most negatively impact the built environment, destroying or damaging a large number of homes and causing many people to become homeless. The Emergency Events Database provides important definitions for these types of disasters and people involved in disasters:

- Earthquake: "sudden movement of a block of the Earth's crust along a geological fault and associated ground shaking".
- Storms: extra-tropical storms, tropical storms and convective storms, including hurricanes, tornados, cyclones, sandstorms, etc.
- Flood: refers to an "overflow of water from a stream channel onto normally dry land in the floodplain (riverine flooding), higher-than- normal levels along the coast and in lakes or reservoirs (coastal flooding) as well as ponding of water at or near the point where the rain fell (flash floods)".
- Landslide: refers to any kind of moderate to rapid soil movement which can be superficial or deep, but the materials have to make up a mass that is a portion of the slope or the slope itself.
- Affected: "People requiring immediate assistance during a period of emergency, i.e. requiring basic survival needs such as food, water, shelter, sanitation and immediate medical assistance."
- Homeless: "Number of people whose house is destroyed or heavily damaged and therefore need shelter after an event."

3. METHODOLOGY

To gather general information on natural disasters, including disaster type, frequency, magnitude and general number of people affected and made homeless, the researchers analyzed data on disasters available for all countries from 1990 to 2019. To deeper investigate the impact of natural disasters on different countries, the researchers analyzed socio-demographic and economic indicators associated to data on disasters for each country between 1990-2010. The data used was gathered from:

1. EM-DAT: The Emergency Events Database - Université Catholique de Louvain (UCL) - CRED, www.emdat.be – data on disasters including:

    - Number of people made homeless by natural disasters in the world disaggregated by year.
    - Number of people affected by natural disasters in the world disaggregated by year.
    - Occurrence of different types of natural disasters in the world disaggregated by year

    The researchers analyzed the data for the period between 1990 and 2019.

2. The Humanitarian Data Exchange (HDX - (License: CC BY 4.0) – https://data.humdata.org/ – an open humanitarian data sharing platform managed by the United Nations Office for the Coordination of Humanitarian Affairs – data on disasters including:

    - Number of people made homeless by natural disasters disaggregated by country and year.
    - Number of people affected by natural disasters disaggregated by country and year.

    Only countries hit by disasters between 1990 and 2010 were considered. Some countries were not considered due to two factors: (1) complete lack of data; and (2) extremely low number of occurrences combined with reduced number of people affected in those occurrences ($<$ 2,500 people affected/ occurrence). The researchers aggregated the data for every 5 years, i.e., 1990-1995 (6 years)/ 1996-2000/ 2001-2005/ 2006-2010.

3. World Bank national accounts data, and OECD National Accounts data files (License: CC BY 4.0) – https://data.worldbank.org/indicator/ – demographics and economic indicators for different countries:

    - Population density (people per sq. km of land area): midyear population (all residents in the country) divided by land area in square kilometers (country's total area) disaggregated by country and year.
    - Percentage urban (urban population as a percentage of the total population) disaggregated by country and year
    - Total population disaggregated by country and year.

      The researchers aggregated the data, by calculating the average value of each indicator for every 5 years, i.e., 1990-1995 (6 years)/ 1996-2000/ 2001-2005/ 2006-2010.

4. DATA ANALYSIS

4.1. Cities and disasters

Between 1990 and 2010 the urban population of most countries increased considerably and only in Oceania the percent of urban population slightly decreased. Asia was the continent whose percentage of urban population increased most significantly (Figure 1).

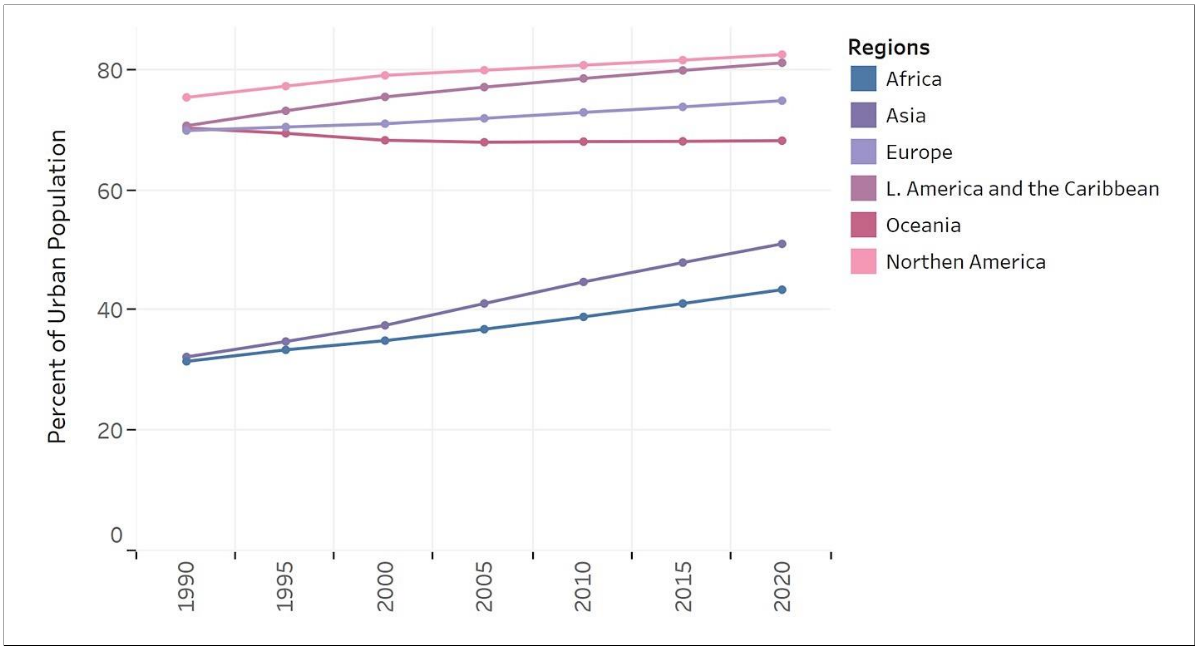

Figure 1. Variation of percent of urban population between 1990 and 2010 by region.

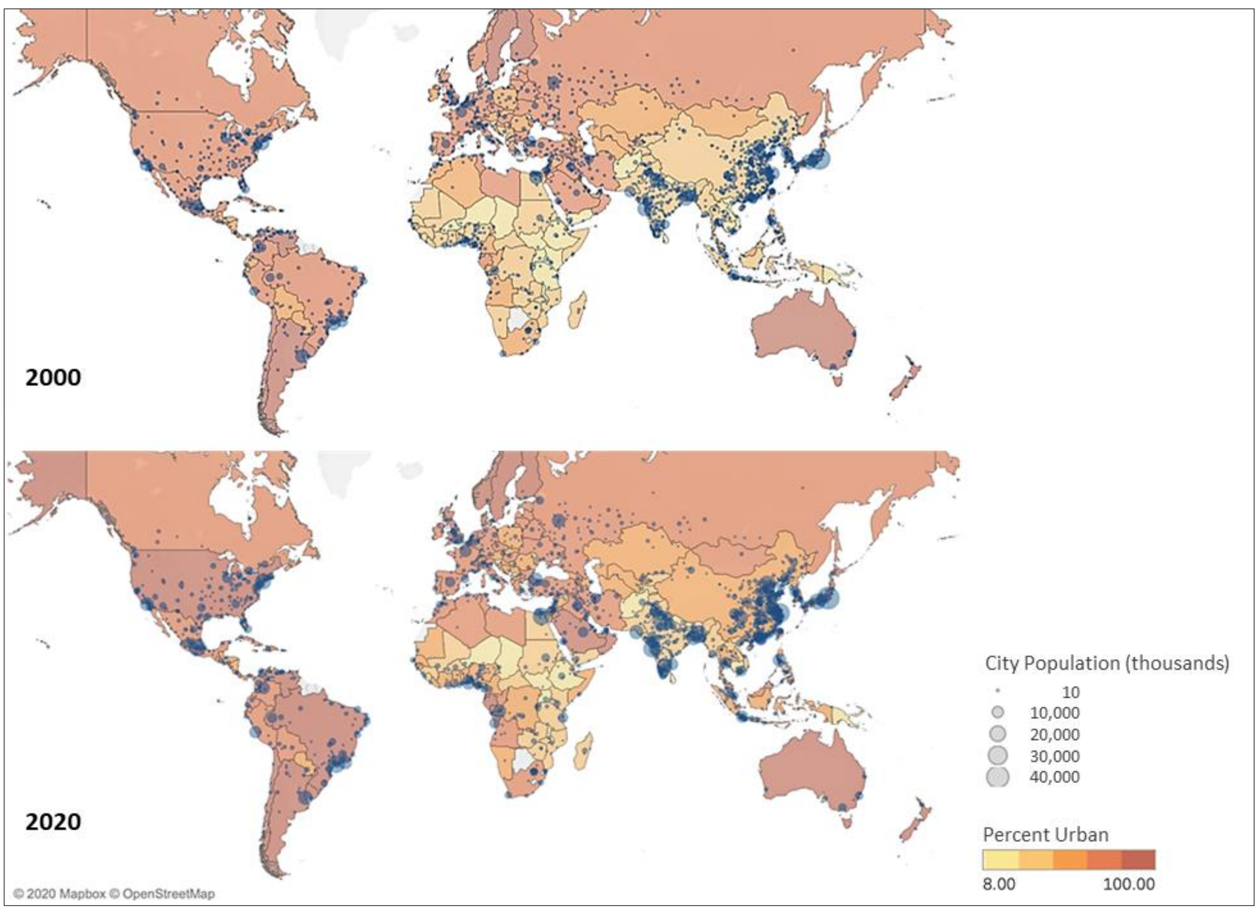

Figure 2. Percentage of urban population by country and city population by size class in 2000/ 2020.

Figure 2 shows the percentage of urban population in different countries and cities with a population of over 300 thousand inhabitants worldwide in 2020. The map color in the background shows the urban rate of each country. The population for each city in this figure is depicted by circle on the map graph, where the size of the circle increases with bigger populations. It reveals a greater population growth of many coastal cities, which are the most vulnerable to natural disasters, especially floods and storm related disasters. In addition, many of the cities with the highest population growth are cities located in developing countries, which further increases their vulnerability, given the lack of financial capacity of developing countries to deal with disaster resilience.

4.2. Floods, storms, earthquakes and homelessness

Earthquakes, storms and floods are among the disasters that have the greatest destructive power over the built environment, including housing, therefore will focus on these types of disasters. Figure 3 shows the number of occurrences of floods, storms, earthquakes and landslides between 1990 and 2019, highlighting 2005 as the year with most records. The records of natural disasters show that between 1990 and 2019 (Guha-Sapir, 2020) most of the homeless resulted from floods and storms (Figure 4).

Figure 4 shows that there is a huge spike in number of homeless people in 1998. In fact, the years 1991, 1994, 1998 and 2005 stand out in terms of people made homeless due to natural disasters. Although 1998 was not the year with the highest number of occurrences of floods and storms (see Figure 3), an enormous number of people lost their homes due to these events. As for 2005, this was the year with the greatest number of disasters in the last few decades, and despite the enormous amount of floods and storms, the greatest number of people were made homeless by earthquakes. Data also reveals that while there has been an increasing number of natural disasters occurrences, the trend in the last twenty years shows a decrease in number of people made homeless.

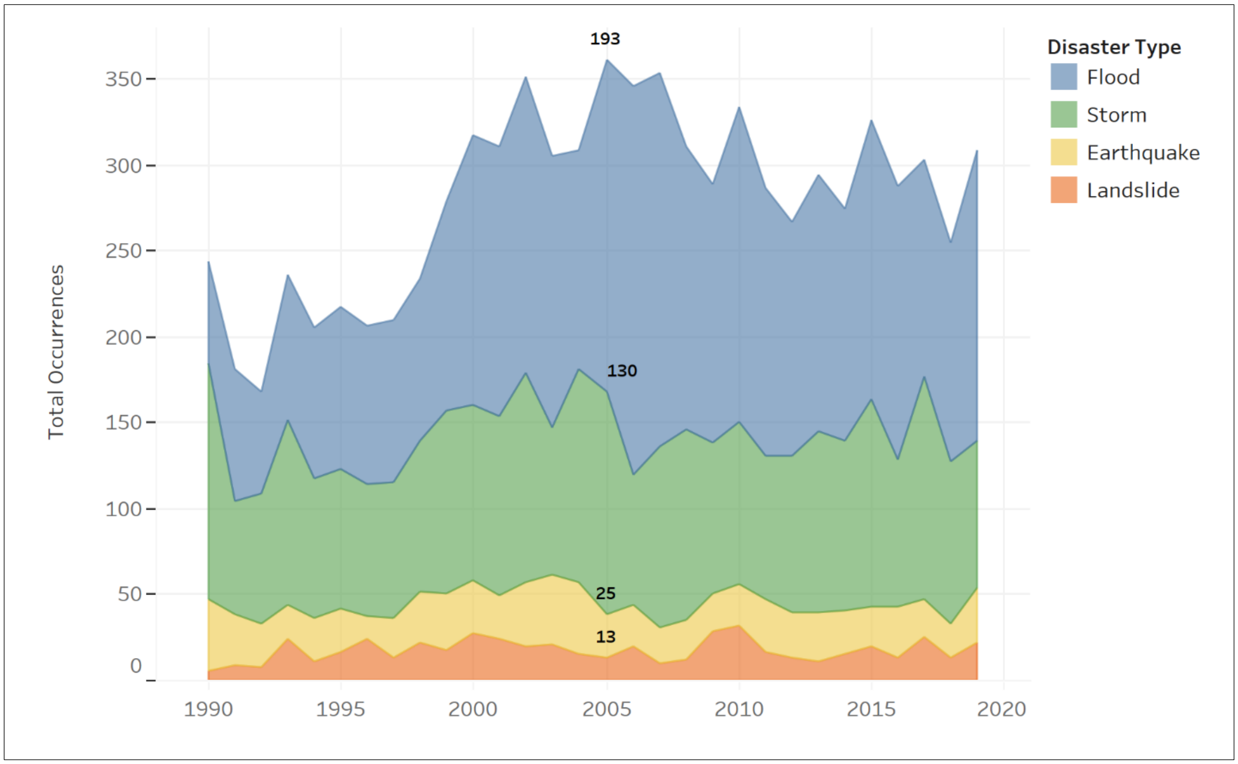

Figure 3. Number of occurrences of natural disaster by type between 1990-2019 in the world (Guha-Sapir, 2020).

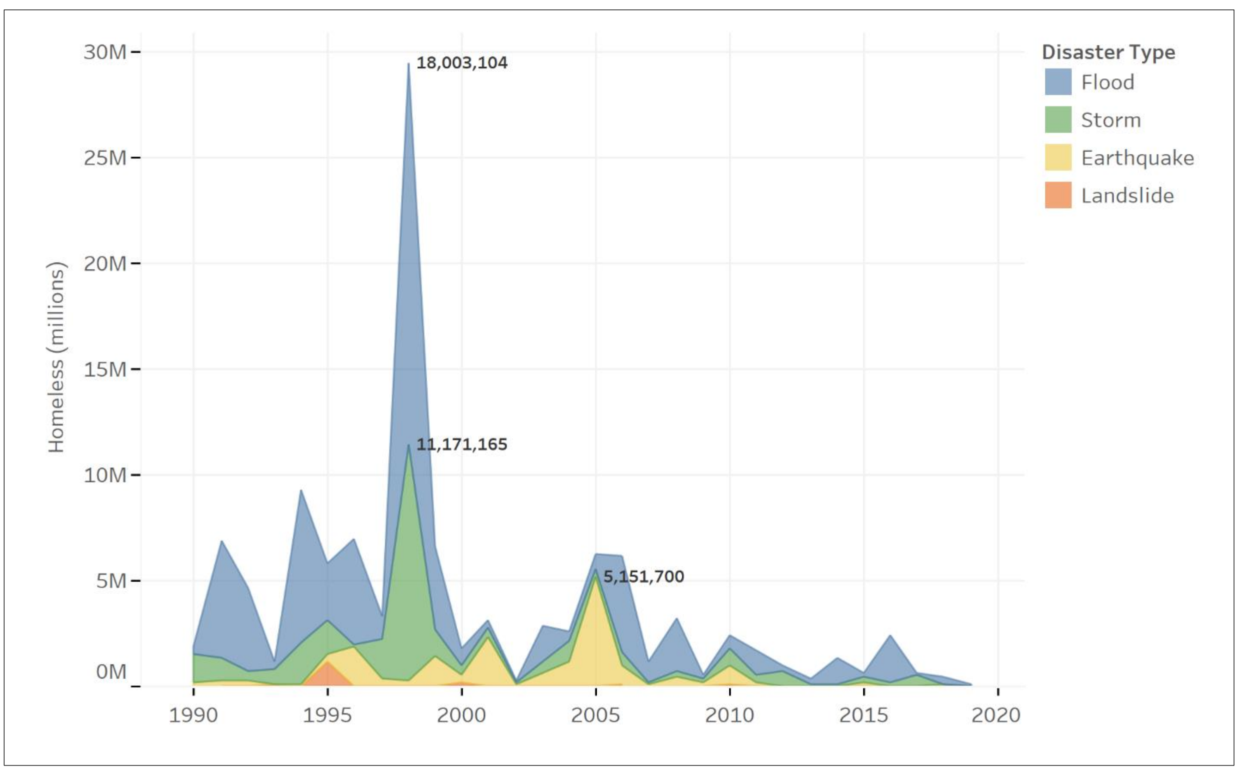

Figure 4. Number of homeless by different natural disaster types between 1990-2019 in the world (Guha-Sapir, 2020).

Figure 5 compares the number of people affected and people made homeless by natural disasters between 1990 and 2019. The data confirms that in 1998 there was a huge spike in the number of homeless by disasters but also shows a peak in the proportion between people made homeless and people affected by natural disasters.

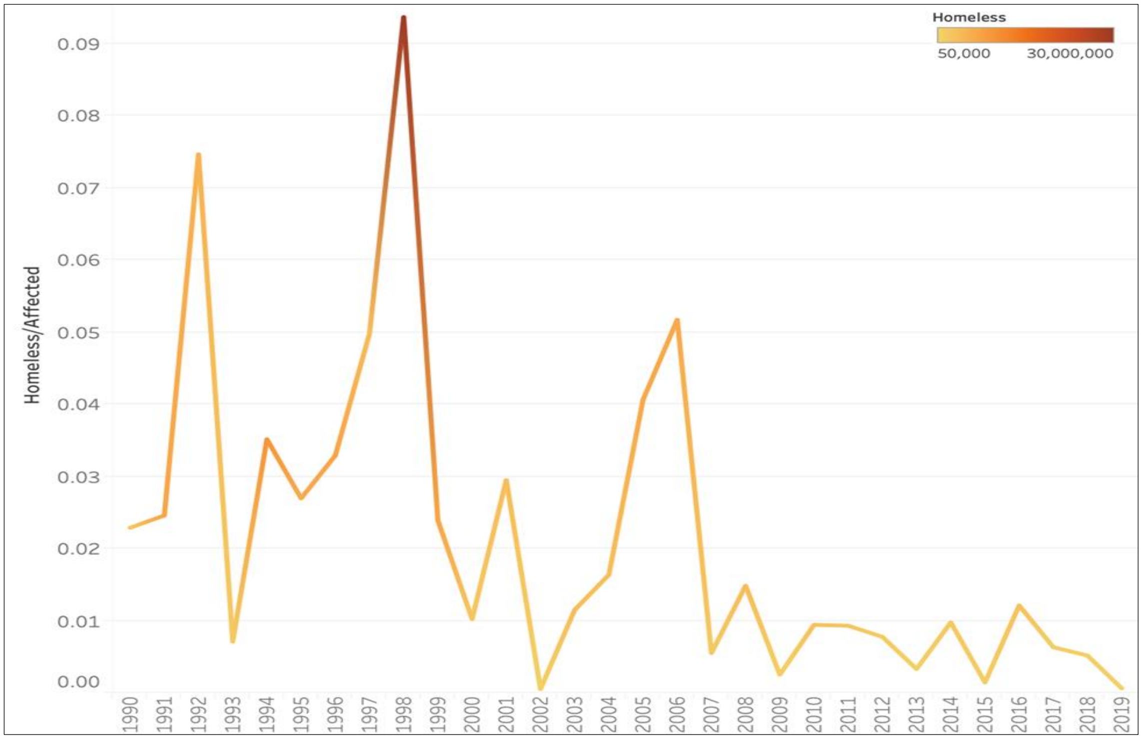

Figure 5. Ratio of people made homeless and affected by natural disasters between 1990-2019 in the world (Guha-Sapir, 2020).

Figure 6 shows the scatterplot of the distribution for homeless and people affected. The horizontal axis is showing the number of affected people as a result of a disaster and the vertical axis represents the number of people made homeless. Each data point represents a specific country. The color of the data points represents the density of that country in a logarithmic scale. In order to respond to skewness towards large values, i.e., cases in which one or a few points (outliers) are much larger than the majority of other data points, the researchers used logarithmic scales of data in charts and graphs. Log scales show relative values instead of absolute ones. Therefore, the distance between 0.1 and 1 is as big as the distance between 1 and 10 and 100,000 and 1,000,000.

The total GDP (average for every five years) for each country is represented by the size of the data input. The model suggests a linear correlation between the number of homeless people and affected people. However, this cannot be said regarding the population density and/or the wealth of the countries, represented by each country's GDP. According to this figure, there is no clear relationship between the population density of the countries and the number of homeless people. Same deduction applies to the GDP of the countries. Therefore, while the developing and poor countries usually suffer more from natural disasters (Smets & van Lindert, 2016), the resiliency of countries to natural disasters does not necessarily rely to the wealth of the countries.

Figure 6. Distribution of homeless and affected people for each country for every five years: 1995, 2000, 2005 and 2010.

Table 1. Regression Results

Data	Line Equation	R Squared	P value
1990-1995	Homeless = 0.0188305 * Affected	0.910798	<0.0001
1996-2000	Homeless = 0.0565095 * Affected	0.891996	<0.0001
2001-2005	Homeless = 0.0056100 * Affected	0.451491	<0.0001
2006-2010	Homeless = 0.0037612 * Affected	0.10345	0.0022453

The objective of the analysis performed here is to find the most destructive occurrences in terms of number of homeless and / or affected people based on the type of the natural disaster. This information will be important to identify the countries most affected and with the greatest homelessness due to a disaster.

4.2.1. 1998 Floods, storms and homelessness

Figure 7 shows the number of people affected and made homeless by natural disasters in 1998. It is remarkable that floods and storms were the most striking disasters in term of homelessness (Guha-Sapir, 2020).

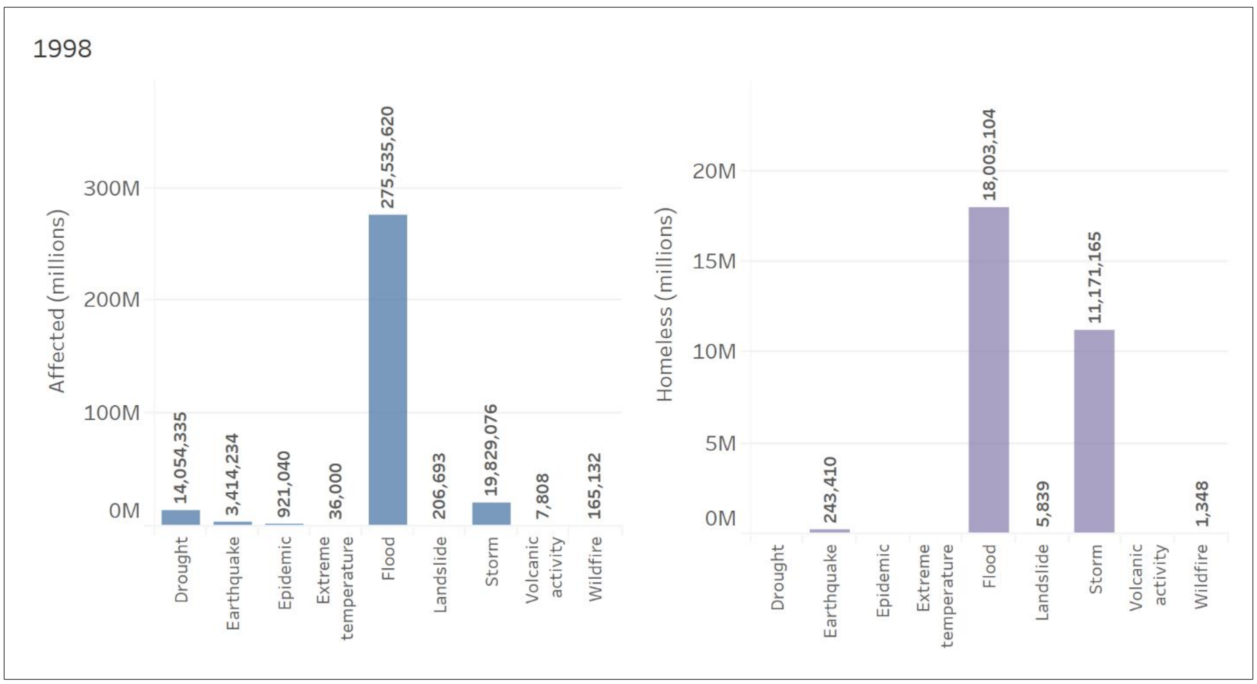

Figure 7. People affected and made homeless by natural disasters in the world – 1998 (Guha-Sapir, 2020).

In 1998 a huge numbers of countries suffered from severe flooding (Guha-Sapir, 2020). Table 3 shows the numbers of the top three countries most affected by floods in 1998 (based on the number of people affected).

Table 2. Top three countries most affected by floods in 1998

Country	Occurrences	Affected	Homeless	Homeless / Affected	Type of Flood
China [(1)]	5	225,241,300	17,350,000	7.7%	Riverine and flash flood
India	3	74,324,539	No data	-	Riverine and flash flood
Bangladesh	1	15,000,000	No data	-	Riverine flood

Source: EM-DAT – CRED (Guha-Sapir, 2020). [(1)] Missing data for homeless.

Table 3 shows the socio-demographic and disasters indicators for the period from 1996 to 2000, which provides some insights into the situation of these countries. Comparing the indicators, apparently China was the country with the highest proportion of homeless people per people affected, but this analysis is compromised by the fact that many data are missing with numbers of homeless people in India and Bangladesh. Therefore, it is likely that the Bangladesh's proportion of homeless people per affected was the highest both in 1998 and in the period 1996-2000. Bangladesh's population density is much higher than that of India and China, which makes the country very vulnerable to disasters and compromises its ability to deal with major disasters like the 1998 flood.

Table 3. Top three countries most affected by floods – disasters and socio-demographic indicators 1996-2000

Country	Affected	Homeless	Urban Percent	GDP per capita	Density	Homeless/ Affected
China	602,864,772	38,610,873	33.88	831.55	132.19	6.4%
India	223,875,306	1,189,500	27.24	423.22	342.89	0.5%
Bangladesh	29,589,407	1,324,500	22.82	406.48	942.37	4.5%

Sources: Humanitarian Data Exchange (HDX, 2015), The World Bank (2019).

Bangladesh is a densely populated country with an extensive coastal area in which 28% of its population lives, which makes the country super vulnerable to disasters related to floods and storms. In fact, the country has a long history of floods. In 1998, a combination of heavy rainfall (monsoon season) within and outside the country flooded over 75% of the total area of Bangladesh, including the greater Chittagong area, one of the most populous in the country. This event contributed to the homelessness of millions of people, but the exact numbers of homeless is still unknown. It is very difficult to build resilient communities in countries that deal with extreme floods, like Bangladesh, but important actions are being taken. In the case of Bangladesh, with the help of the World Bank, since 2013 the country has provided improved resilience to some coastal areas by protecting them from tidal flooding and frequent storm surges.

As for the storms, Table 5 shows the countries most affected by storms in 1998. Data shows that three of the most affected countries are from Southern Asia, which is home of some of the most densely populated areas in the world.

Table 4. Top four countries most affected by storms in 1998

Country	Occurrences	Affected	Homeless	Homeless / Affected (%)	Type of Flood
India	4	4,658,000	No data	-	Tropical cyclone and convective storm
Philippines	4	7,322,133	No data	-	Tropical cyclone
Vietnam	3	2,481,635	43,510	1.8%	Tropical cyclone and convective storm
Honduras [(1)]	1	2,100,000	1,000,000	47.6%	Tropical cyclone

Sources: EM-DAT – CRED (Guha-Sapir, 2020), [(1)] Aid (1999).

The analysis of the socio-demographic and economic indicators and data referring to disasters in the period from 1996 to 2000 help to understand the dimensions of the tragedies that have befallen these countries (Table 5). Honduras reached a proportion of homeless by affected people of more than 47%, very different from what was verified in the period of 1996-2000 (0.1%). Unfortunately, due to the lack of data on disasters, especially regarding the number of people made homeless, it is difficult to

Table 5. Top four countries most affected by storms – disasters and socio-demographic indicators 1996-2000

Country	Affected	Homeless	Urban Percent	GDP per capita	Density	Homeless/ Affected
India	191,643,418	1,702,285	26.08	335.01	308.92	0.5%
Philippines	20,459,323	231,031	46.31	1,074.98	250.48	1.1%
Vietnam	19,921,577	583,440	23.42	355.06	242.08	2.9%
Honduras	2,693,578	3,000	44.45	991.13	55.61	0.1%

Sources: Humanitarian Data Exchange (HDX, 2015), The World Bank (2019).

Honduras is one of the poorest countries in the Western hemisphere and has been suffering with poverty, corruption and natural disasters for many years. In 1998 Honduras and other countries in Central America were devastated by Hurricane Mitch. According to Aid (1999), “What turned Mitch from a natural hazard into a human disaster was a chain reaction of social vulnerabilities created by long-term climate change, environmental degradation, poverty, social inequality, population pressure, rapid urbanisation and international debt” (p.1). One million people was made homeless, almost 15,000 people died and entire communities, bridges, factories were swept away, since 70 per cent of the country's productive infrastructure was damaged or destroyed. Honduras had a population of six million and nearly one third was affected. In the case of Honduras, vulnerability to natural disasters such as Mitch is closely related to poverty, which is amplified with each new disaster, since the country has been unable to increase its resilience to disasters.

4.2.2. 2005 Earthquakes and homelessness

2005 was a dramatic year in terms of disasters that impacted on the built environment (see Figure 3). Data analysis shows the number of people made homeless by earthquakes in the last three decades was the highest in 2005 (see Figure 4). Figure 8 shows the number of homeless and affected people by different disasters in 2005. It is important to notice that unlike floods and storms, earthquake has a high ratio of homeless per affected people, meaning that because of the type of the disasters, people who are hit by the disaster will usually end up losing their homes as it is destroyed.

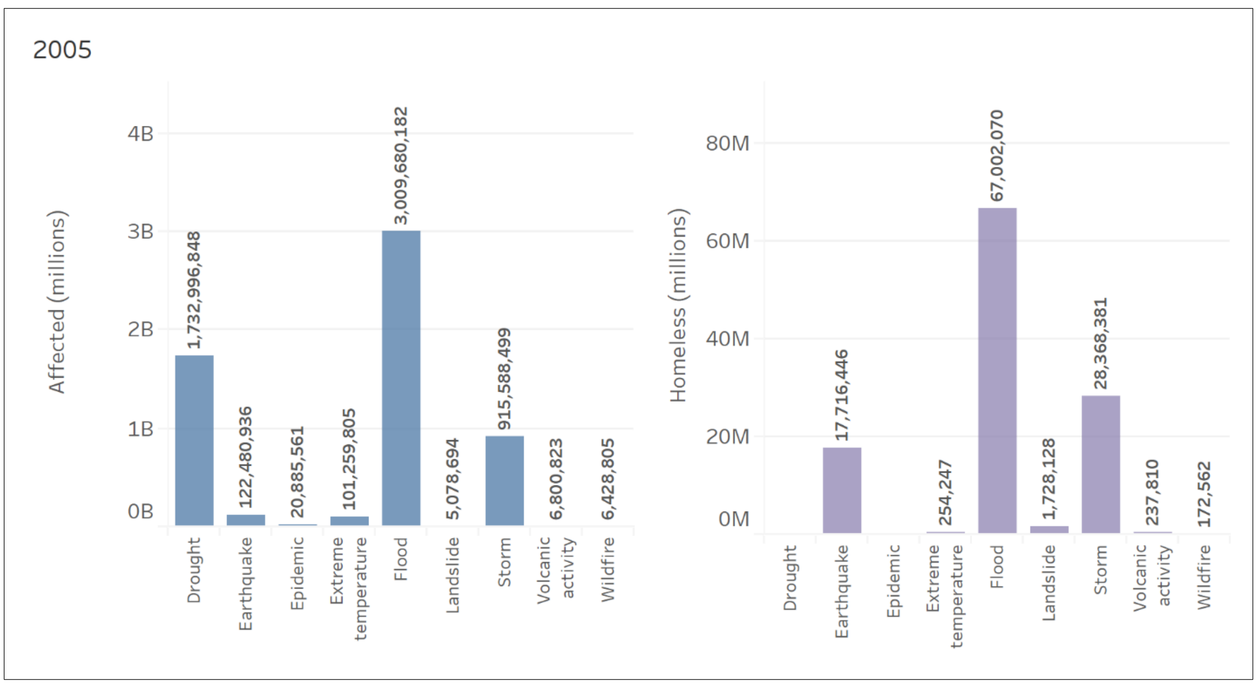

Figure 8. People affected and made homeless by earthquakes in the world – 2005

Table 6 shows the countries most affected by storms in 1998. Data shows that three of the most affected countries are from Southern Asia, which is home of some of the most densely populated areas in the world.

Table 6. Top three countries most affected by earthquakes in 2005

Country	Occurrences	Affected	Homeless	Homeless / Affected	Disaster Magnitude
Pakistan	1	5,128,309	5,000,000	97.5%	8 Richter
China	2	634,009	No data	-	5 Richter
India	1	156,622	150,000	95.8%	8 Richter

Source: EM-DAT – CRED (Guha-Sapir, 2020).

The indicators from Table 7 shows that Pakistan is by far the country with the highest ratio of homeless by people affected between 2001 and 2005. However, in 2005, both India and Pakistan had high proportions of homeless by people affected. This is mainly due to the magnitude of the earthquake (Mw = 7.6) that struck both countries, being one of the most devastating earthquakes that occurred between 1900 and 2019.

Table 7. Top three countries most affected by earthquakes – disasters and socio-demographic indicators 2001-2005

Country	Affected	Homeless	Urban Percent	GDP per capita	Density	Homeless/ Affected
Pakistan	15,417,612	5,013,820	33.58	568.63	198.63	32.5%
China	682,106,929	3,629,573	39.79	1,352.63	137.20	0.5%
India	439,672,766	2,602,545	28.57	564.62	373.81	0.6%

Sources: Humanitarian Data Exchange (HDX, 2015), The World Bank (2019).

Pakistan is an underdeveloped country, with a retrospective of many earthquakes: a total of 23 earthquakes between 1990-2019, nine of great and major magnitude (Guha-Sapir, 2020). In October of 2005 a high magnitude earthquake struck the Himalayan region of northern Pakistan and Kashmir (part in Pakistan and part in India). More than 780,000 buildings were destroyed, or severely damaged and innumerous roads and bridges were affected (Earthquake Engineering Research Institute, 2006). Muzaffarabad and Balakot, two cities located in the Pakistan-administered territory of Kashmir, had most of their buildings destroyed. Measures must be taken to increase earthquake resilience of buildings, but the country's economic situation prevents advances in this direction. Considering the history of the country, with a large proportion of homeless by people affected, resilience preparedness for future earthquakes should include temporary housing strategies.

4.3. Factors affecting disaster resilience

Analysis of the previous cases, and more specifically the cases of Honduras, Bangladesh, and Pakistan, suggests that the geographic location of the country is one of the crucial factors affecting the number of homeless people due to disasters. This is because it is known that some countries are located in highly vulnerable areas to natural disasters that have great destructive power over the built environment, namely: floods, storms, earthquakes, and landslides. Countries or regions located in areas prone to tectonic plate movement, in coastal regions subject to storm seasons (typhoons, cyclones, and hurricanes) or in river valleys and coastal areas subject to floods, will invariably have to face very destructive disasters that will occur with certain frequency over the years.

However, other factors might be relevant in contributing to higher proportions of people made homeless by disasters in some countries. This study will analyze the relationship between people made homeless by natural disasters and (1) GDP per capita, (2) population density, and (3) percent of urban population. The following graphs, based on data from 1990 to 2010, provide a visual analysis of the relation between the number of homeless and these three variables, including two other variables: GDP and people affected. The color of each data input represents the logarithmic scale of people affected by natural disasters and the size of the data points represents the total GDP for each country. The vertical axis represents the ratio of homeless on affected people, which cannot be higher than one, therefore, as the logarithmic scale is in base on ten, the vertical axis for this graph will have negative range with a maximum of zero (log 10 = 0). The variables in the horizontal X represents:

- the GDP per capita for each country (Figure 9)
- the logarithmic scale of population density for each country (Figure 10)
- the percentage of urban population (Figure 11).

The three set of graphs suggest that there is not a strong relation between people made homeless by natural disasters and the GDP per capita, the population density and the percentage of urban population of each country.

Figure 9 shows that while some countries have a high GDP per capita, depending on the type and magnitude of the disaster, their built environment are as vulnerable as the built environment of countries with much lower GDP per capita. For example, according to the graphs, between 1990-1995, the proportion of homeless/affected in the United States and Japan was the same as the proportion of homeless/affected in Mexico, and the number of affected was also at a similar level. Japan and the United States are countries considered relatively resilient to disasters, with strict buildings codes that regulate construction, aiming to obtain buildings more resilient to earthquakes and hurricanes / cyclones of certain magnitudes, but even so, we can see that these two countries float by the charts, assuming different positions over the years, according to the types and magnitudes of the disasters that hit them.

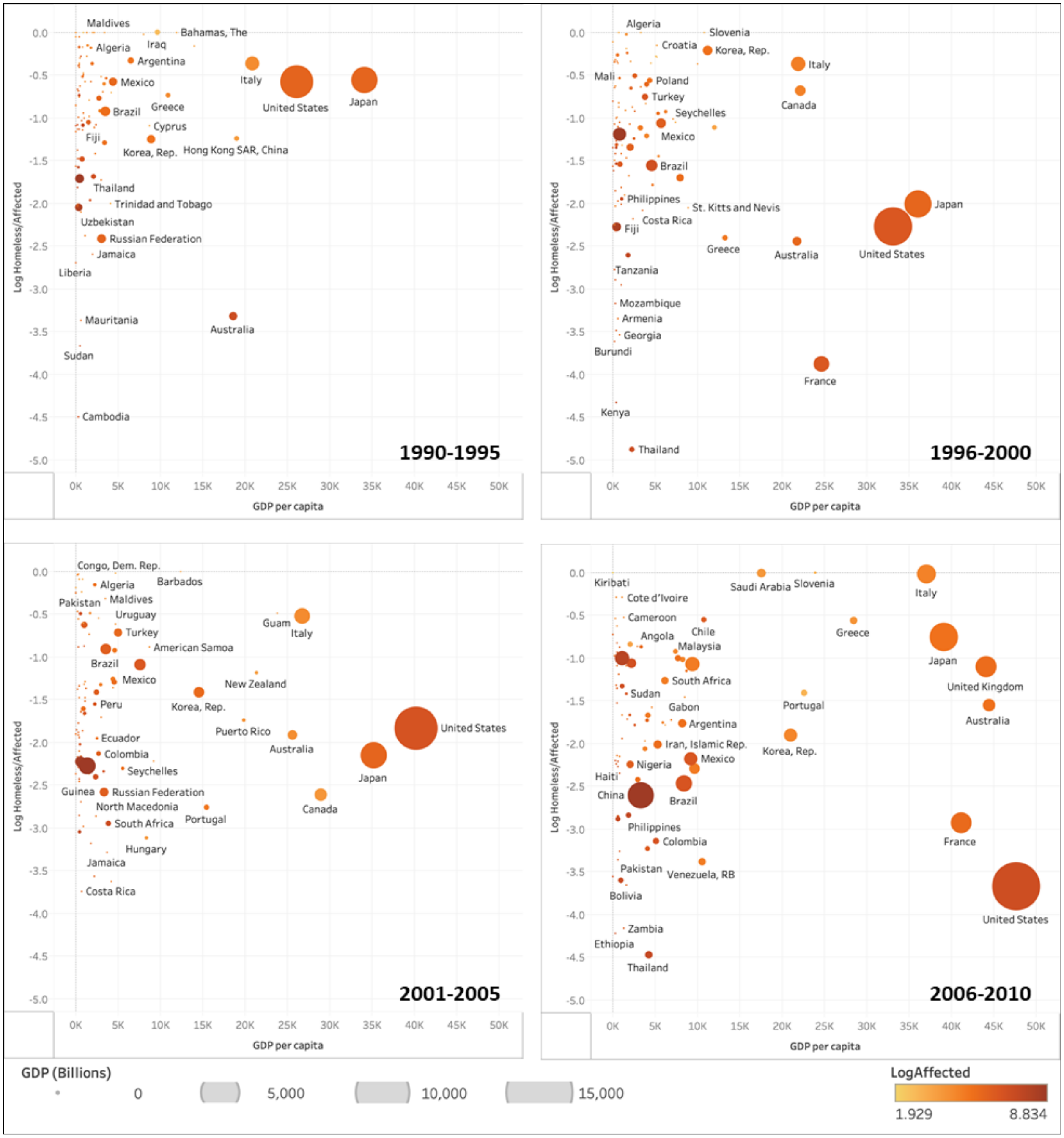

Figure 9. Relation between homeless/affected and GDP per capita, considering the GDP and people affected for each country – 1990-2010.

The graphs in Figure 10 show that there is no clear relationship between the proportion of homeless/affected and the population density of each country. For example, the position in the graph of India and Russia between 2006-2010 shows that although the levels of population density in these two countries are very different, the proportion of homeless/affected of both is close, even with India having a much higher number of people affected by natural disasters in that period.

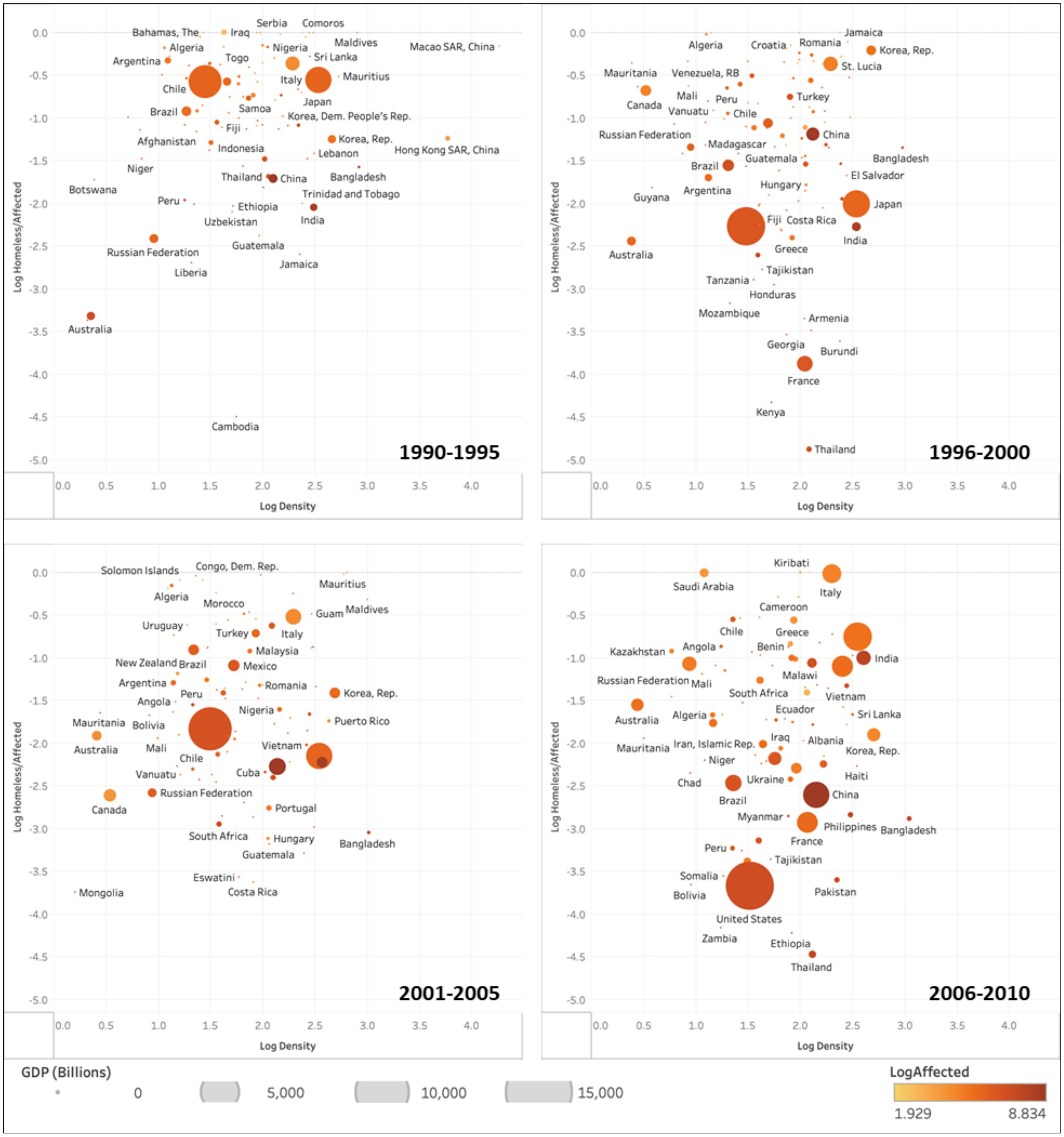

Figure 10. Relation between homeless/affected and population density, considering the GDP and people affected for each country – 1990-2010.

The graphs in Figure 11 also shows no clear relationship between the proportion of homeless/affected and the percentage of urban population in each country. For example, between 2006-2010, France and Bangladesh had practically the same proportion of homeless/affected, with France having an urban population percentage of almost 80% while in Bangladesh the urban population is less than 30%.

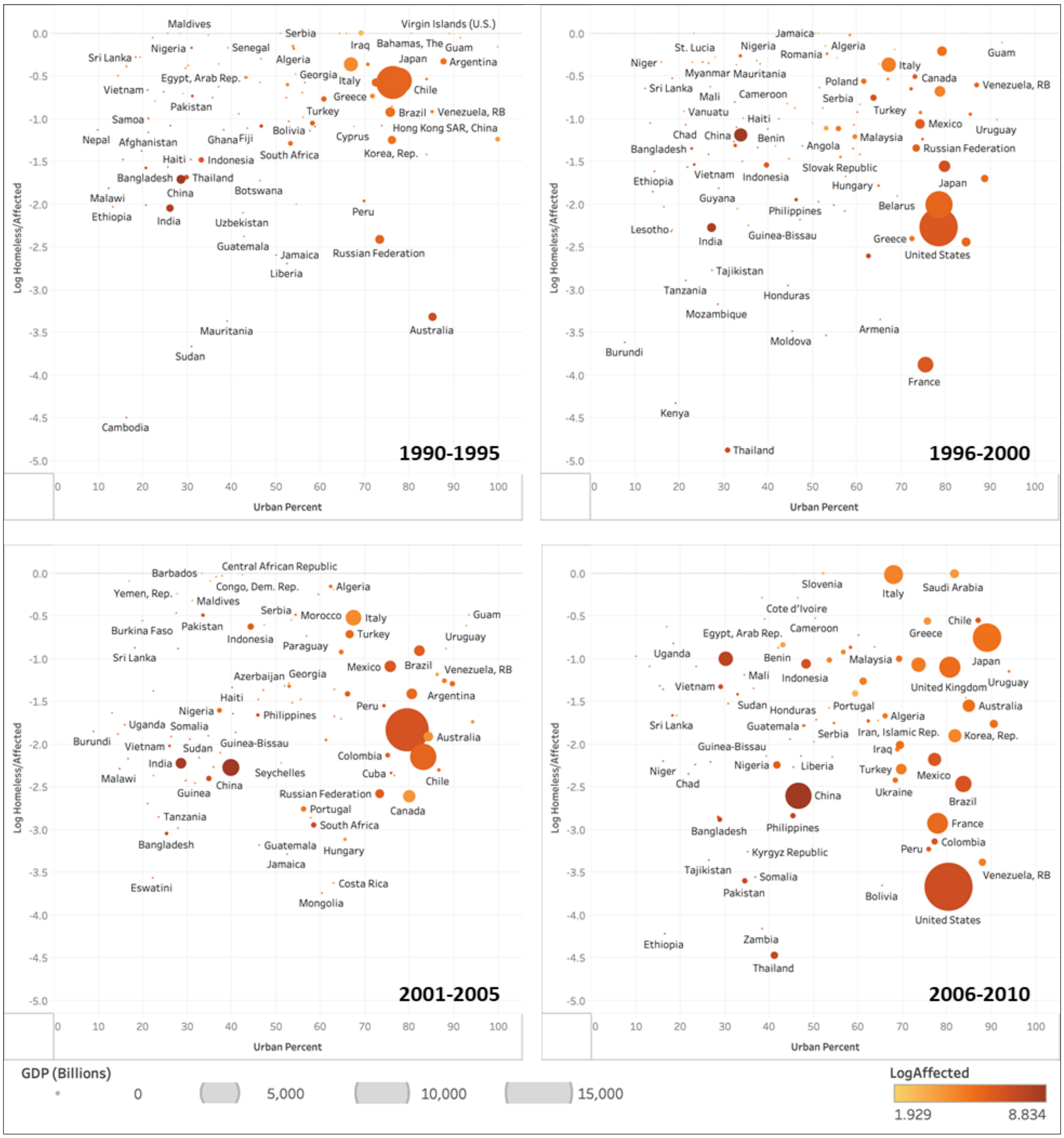

Figure 11. Relation between homeless/affected and the percent of urban population, considering the GDP and people affected for each country – 1990-2010.

Some other observations can be made from the above lists:

- The proportion of homeless/affected has decreased over the years, with a large number of countries migrating to the bottom of the charts between 2006-2010.
- The GDP per capita of most countries increased between 1990-2010 (Figure 9).
- In general, the population density of most countries did not change much between 1990 and 2019. But this indicator can be misleading, since the population of most countries is not evenly distributed across their territories (Figure 10).
- As the GDP of many countries increased, the percentage of urban population in these countries also increased, with many larger circles migrating to the right side of the graphs (Figure 11).

5. DISCUSSION AND CONCLUSIONS

Urban population is increasing exponentially in the coastal lines, making a huge number of residents and their homes vulnerable to floods. Data from the past three decades shows that floods are the major cause of homelessness in natural disasters events. Because of this, it is important for the architecture, engineering, and construction (AEC) industry to develop strategies to increase the resilience of the built environment of vulnerable areas.

This study analyzed whether the disaster resilience of a region is dependent on the socio-demographic characteristics of the region. The study shows that through time, the number of homeless people from natural disasters deviates from being a simple linear function of the population of the number of the affected people. Data suggests that the resilience of an area is not a merely function of a single variate of GDP, urban percent, or population density, but it involves many other factors. Some of these factors are manageable, like sustainability, social equity, public policy. Other factors are unpredictable, such as the magnitude of disasters and the precise definition of the regions to be affected by a disaster occurrence.

The study identified, through analysis of reliable data, the most vulnerable areas to natural disasters and the most frequent types of disasters in such areas. This information will help the AEC industry to increase disaster resilience in vulnerable areas, especially in large urban centers in developing countries, with a view to two main aspects:

- Increase the resilience and sustainability of the built environment, especially housing, focusing on specific conditions and vulnerabilities to disasters in each region;

- Develop alternative temporary housing projects tailored to each region and each type of disaster, to shelter people displaced by natural disasters in an efficient and economically viable way.

The main limitation of this research is the huge amount of missing data, especially for the number of homeless people by disaster, which relates to the focus of the study. Another limitation is the lack of data in the scale of each state and providence for the countries, because while factors like density and urban percent are important indicators, they can be misleading if taken as an absolute value for the whole country. The urban pattern and population configuration are not evenly dispersed in a country; thus, additional consideration needs to be applied when using these indicators for a whole country.

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