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Disaster Risk Reduction in Mexico

Methodologies, Case Studies, and Prospective Views

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Synopsis

This book recognizes and describes the circumstances and challenges of Mexico in case of natural disaster offering empirical risk-reduction methods in critical cases in Mexico.

Mexico for its geological and geographical situation is tackled annually by different natural hazards, including severe rains, floods, volcanic eruptions, earthquakes, among others. These events are increasing over time in both frequency and impact (mainly socially and economically).

The proposals considered here include real and detailed analysis, a set of models, frameworks, strategies, and findings in the three stages of the disaster (before–during–after). During the stage "pre-disaster," this book proposes recommendations for specific communities to be resilient by using risk-reduction methods. For example, this book suggests how to find a convenient and safe location of the Regional Humanitarian Response Depot (RHRD). This position will be critical in order to keep safe and scatter all necessary goods among the victims after an emergency. This book proposes other recommendations such as location and creation of an export logistics cluster, analyses of inventory levels on humanitarian relief for vulnerable municipalities, forecasting medicines, or planning of evacuation routes, and so forth.

In the "disaster" stage, the documentation of what happened in the case of September 19 (19S) earthquake in Mexico is presented for knowing the help process from each one of the participants or actors that intervened in this stage. In this research, it was detected that the incorporation of information and communications technologies (ICTs) was a crucial factor for the flow of information that helps the volunteers in the decision making of humanitarian logistics. Also, in this stage, a framework of key performance indicators (KPIs) that can measure this process is proposed because it opens up possibilities to provide the necessary information for improvement. With both proposals were detected challenges and opportunities for better planning to support the victims of this disaster in the best way.

Finally, the `post-disaster' stage includes a case study that describes how the intervention of multidisciplinary volunteers led by a non-governmental organization implemented several recovery and reconstruction strategies, obtaining the solution

by diverse scientific methods with the objective of recovering the livelihoods of some particular communities of Mexico affected by the September 7 earthquake. Also, in this stage is proposed a theoretical mathematical model that would help allocation procedure of resources for restoring the affected community that takes into account the preferences of it.

Additionally, ways to create resilience in the main economic sectors of the country such as agriculture and industry are proposed. These proposals offer an evaluation framework, which will allow detecting disruption activities and their negative impacts. Then, the results will guide to elaborate a continuity business plan letting the farmers and companies be more resilient. Moreover, for last, the new trends for Mexico as a result of the climate change are described and made suggestions for mitigating the possible disasters.

We believe that this book can give support in the decision making of the society, national government, non-governmental organization, enterprises, and so, and protect the human life, the communities, and the livelihoods. Although the methodology of some of these proposals has been made at a regional level, they are highly replicable to other highly populated societies with similar socioeconomic structures.

Besides, this book can be the basis for generating more innovative proposals by researchers, graduate students, academics, professionals, and practitioner, since the creation of this antecedent is vital to obtain a better planning and a better collaboration between all the actors of the humanitarian chain, and in this way, minimize the risks and maximize the resilience of Mexico.

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Part I
Before the Disaster

Chapter 1
The Most Frequent Natural Disasters and Their Tendency in Mexico from a Perspective Based on Humanitarian Logistics

Hugo Romero-Montoya, Diana Sánchez-Partida, José-Luis Martínez-Flores, and Patricia Cano-Olivos

Abstract This paper presents a detailed analysis of humanitarian logistics and its components; the specification is to be able to identify and can be characterized once the disasters caused by natural phenomena are interconnected. From a qualitative methodology with an exploratory and non-experimental descriptive approach, analyze in detail three information bases referring to natural phenomena data and their implications. The first of these was the Center of research in epidemiology and disasters (EM-DAT), considered as an international database, second as a national level, the National Center for Disaster Prevention (CENAPRED), and the third also considered a national level the drought monitor in Mexico (CONAGUA). Besides, several articles related to the subject matter were reviewed. Among the identified components are the following; the humanitarian logistics cycle according to the reviewed literature, the phases of disaster management in Mexico, the areas of logistics decision, the types of natural phenomena, and future trends of natural phenomena that could affect Mexico in a period very close. Finally, it carries out a statistic of the behavior of the components analyzed, as well as a series of conclusions in this regard. This analysis will help to be able to characterize the components involved in disaster risk management as well as the response of humanitarian logistics to different conditions and unforeseen situations of risk of which is the next type of disaster with the most significant possibility of occurrence and repercussions in Mexico.

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1.1 Introduction

Currently, natural disasters are part of the global problems, and these cause suffering and havoc among those who come into direct contact with them (Zary et al., 2014). So it is necessary to be clear that the natural events they cause. These disasters differ from each other, acquiring relevance for specific groups of humans that are affected (Capacci & Mangano, 2015). Besides, that disasters of any type are generally events of great magnitude and that have a tremendous negative impact on society and the environment (Viera et al., 2012), thus impeding the development of countries, mainly from the poorest (CENAPRED, 2019), hence the importance of its analysis and monitoring.

Humanitarian logistics is a discipline that helps to mitigate the ravages of natural disasters. It refers to the process of planning, implementation, and control of the efficient and profitable flow and storage of goods and materials, including information related from the point of consumption with in order to meet the requirements of the final beneficiary (Ye & Liu, 2013). Although for others like (Costa et al., 2012) humanitarian logistics is also what happens:

> Immediately after the occurrence of disasters, humanitarian operations begin with the intention of providing rapid assistance to victims in different ways, such as rescuing the wounded and/or stranded, collecting and undoing corpses, resource allocation, provision of assistance food, shelter, medical care, and restore access to remote locations.

Recently, research on humanitarian logistics is becoming a critical factor in devising new ways of managing aid operations among multiple stakeholders (Ransikarbum & Mason, 2016). Its importance lies in the ability to mitigate the direct and indirect effects caused by the appearance of catastrophes within an unpredictable context.

At the same time, the factors that are directly related to natural disasters such as the growth of the world population, the increase in the number and size of cities, the use of land, the stress of ecosystems, the global trend in urban planning and the gradual deterioration of the environment. They are currently considered as elements that make the world population more susceptible, exposing them to suffer the action of disasters in greater magnitude and aggressiveness (Huang et al., 2015; Zary et al., 2014) facilitating risk situations and the effects that cause the suffering of the population.

On the other hand, all this suggests, even more, the consequences of anthropic action as a determining factor for many catastrophic phenomena, especially those related to climate (Capacci & Mangano, 2015).

It should be mentioned that since the 1950s, the number of people affected due to their effect has increased in proportion to around 235 million people per year on

average since the 1990s (Boonmee et al., 2017). In parallel, the total insured and uninsured losses caused by natural disasters multiplied by seven between 1980 and 2015 (Jais et al., 2017).

On the other hand, those disasters that are related to the climate have also increased in number and magnitude, reversing development achievements. That is why for the last decade, the UN reported that more than 700,000 women, men, and children lost their lives, more than 1.4 million were injured, and around 23 million were left homeless as a result of disasters (Unidas, 2017) of this nature.

It must also be said that according to the data presented by the research center on disaster epidemiology (EM-DAT) of the Catholic University of Louvain, the trend that most impacts worldwide is led by hydrometeorological issues and their derivations (floods, landslides, and storms). Figure 1.1 specifies the composition in the distribution of the distress that occurred in the last 19 years.

Also, if the typology of natural phenomena is considered, the most significant impacts per continent are distributed according to their nature. For example, concerning hurricanes and tropical cyclones, America is the most affected; in Asia due to earthquakes and tsunamis; in Europe due to floods or other atmospheric phenomena, while in African countries, mainly in sub-Saharan Africa, deaths are due to droughts (Capacci & Mangano, 2015). It should be mentioned that in addition to these places, some specialists identify the Middle East as an area that could be highly vulnerable to natural hazards (especially drought) (Majewski & Heigh, 2010).

Meanwhile, at a national level, the tendency of natural disasters is very similar to that registered at a global level, the frequency of disasters in Mexico has increased in recent decades (mainly those of hydrometeorological origin), as well as their economic cost to from the eighties (Abeldaño Zúñiga & González Villoria, 2018).

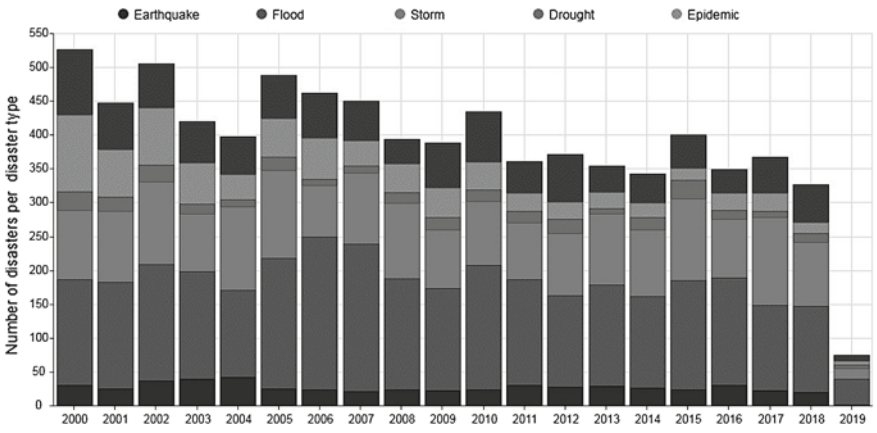

Fig. 1.1 Distribution of the types of natural disasters that have occurred in the world in the last 19 years extracted from the database of emergency and EM-DAT events Catholic University of Louvain (UCL) www.Emdat.be (Brussels Belgic)

All this is because Mexico is a country located in a place where it is frequently impacted by the formation of tropical cyclones in the Pacific coast and the Gulf of Mexico. Also, it is impacted by other types of disasters that are associated with instability of the soils (Abeldaño Zúñiga & González Villoria, 2018).

According to the National Institute of Statistics and Geography (INEGI), Mexico tends to be exposed to an intense rainy season, and about 90% of disasters are of the hydrometeorological type. These affect the southeast region of the country, so 75% National funds for disasters have been spent to alleviate this region (Cruz Benítez et al., 2015), all this shows that in Mexico catastrophic phenomena occur frequently and with results that They directly affect vulnerable populations (Abeldaño Zúñiga & González Villoria, 2018).

Although the evidence that exists about natural disasters in Mexico is closely related to hydrometeorological phenomena such as floods, landslides, heavy rains, and hurricanes, some claim the meteorological drought. That is, the climatic condition in which the accumulated rains in a season or years they are significantly below average, it constitutes one of the most significant climatic hazards for Mexico (Magaña-Rueda et al., 2018) due to its social, economic and food implications that it represents.

It should also be said that since the 1970s–1980s, desertification has been a topic of extensive media coverage and considered one of the most severe problems affecting the dry, semi-arid, and dry sub-humid regions of the planet due to its environmental and environmental implications. Socioeconomic (Diéguez et al., 2014).

At present, drought is one of the problems that is causing the most damage in Mexican society, mainly in the north of the country, where historically, this hydrometeorological phenomenon occurs (Esparza, 2014). While it is true that drought is not a spectacular phenomenon like other natural events (a hurricane or a tornado, for instance), its long-term impacts are often more substantial and more devastating (Ortega-Gaucin, 2013).

The effects of the drought, in economic and social terms, are a function of the impact on the various economic and productive sectors, associated with the supply and demand of goods and services they offer, and the imbalance due to natural and low conditions—humidity, which occurs when demand exceeds supply (Ortega-Gaucin, 2013).

In particular, Mexico is especially vulnerable to natural disasters due to the existence of areas that will be impacted by droughts (Northwest); by floods (Southeast) due to extreme weather events on both coastlines. Whose intensity could increase depending on the economic and social structure, especially the states that are most affected (Ochoa Lupián & Ayvar Campos, 2015) or also because of climatic variability that consists of those changes on the climate that depend on atmospheric conditions extremes that far exceed the standard averages (Serrano Vincenti et al., 2017). If climate change is creating different problems that go beyond the immediacy of a natural disaster, for example, the most significant

impact it is producing is and will be on the population. One of its consequences will be involuntary and compulsive mobility, which, in turn, influences and will influence territorial planning (Rua, 2013).

Mexico is a developing country where irrigation and seasonal agriculture is an essential source of employment and economic income. The problem of drought, according to Ortega-Gaucin (2013), must also be considered as a significant disaster and, therefore, evaluated from the perspective of humanitarian logistics, since this seems to be a problem that has not been analyzed with sufficient depth and importance.

It is vital to consider that humanitarian logistics operations should be planned accordingly to the nature of natural disasters to obtain the maximum response and a minimum loss of resources (Safeer et al., 2014). They were carefully distinguishing each one of the factors that characterize them and, thus, be able to establish concrete and practical conditions before their appearance.

This research aims to define and identify: What are the natural disasters with the most significant impact at the national level? What factors are involved in this type of natural disaster? What is the trend regarding the type of natural disasters that will impact Mexico in the coming years? Moreover, what types of impact do disasters have in the country?

The answers to these questions will help to be able to characterize the main factors involved in natural disasters in Mexico, which would help strengthen risk management not only based on known natural phenomena but also concerning those that very likely occur in the future.

1.2 Literature Review

1.2.1 Natural Disasters

The need to explain the origin of disasters as well as the effects of climate on society and ecosystems have often led to the naturalist paradigm suggesting that disasters are caused by "atypical" weather and climate conditions, without repairing in the high vulnerability of society and its economy to variations in the climate (Rueda & Neri, 2012).

The World Health Organization (WHO) defines a "disaster" as any event that causes damage, destruction, ecological disturbance, loss of human lives, human suffering, deterioration of health, and health services on a sufficient scale to ensure a response extraordinary from outside the affected community or area. For example, earthquakes, hurricanes, tornadoes, volcanic eruptions, fires, floods, blizzards, drought, terrorism, chemical spills, nuclear accidents are included among the causes of disasters, and all have devastating effects in terms of personal injuries and property damage (Safeer et al., 2014) which in turn have different characteristics in

the management of risks and problem solving during the performance of humanitarian aid.

On the other hand, (Scarpin & De Oliveira Silva, 2014) argue that disasters can be classified into four types:

1. Sudden natural appearance: such as earthquakes, tornadoes, hurricanes;
2. Naturally slow onset, such as hunger, drought, and poverty;
3. The result of a sudden start caused by men, such as the terrorist attack, the coup d'etat and the escape of chemical substances;
4. The slow result of human origin, such as political crises and the refugee crisis.

The perception of gravity is often associated with the rapidity of events that, as in the case of earthquakes, landslides or hurricanes, concentrate their effects in a limited period. And they are characterized by manifesting themselves unexpectedly and with consequences that persist for a long time. The phenomena due to in large measure, to human activities, such as air pollution, desertification processes, among others, do not have tangible territorial, economic, or social in the short-term and are perceived as less dangerous (Capacci & Mangano, 2015), but this does not mean that they are not harmful.

The greenhouse effect and climate change have been present for a few years at the center of scientific discussions and are phenomena that develop very slowly. For what is in the background, concerning those who, as we have seen, have tangible economic and social consequences immediately (Capacci & Mangano, 2015), but in recent times its effects are becoming devastating problems for society, which makes them red foci for disaster analysis.

1.2.2 Humanitarian Logistics and Natural Disasters

Large-scale disasters can lead to a massive loss of lives and the means for it, as already mentioned above. In such disasters, humans perish due to multiple causes such as drowning, fire, and lack of food and medicine (Chakravarty, 2014). Most of these occur unexpectedly concerning time, place, and intensity (Safeer et al., 2014).

Due to this enormous escalation of disasters, more attention has been paid to the need for management (Bozorgi-Amiri & Khorsi, 2016). That is capable of reducing complications due to the increase in the number of scenarios and the complexity of the development of activities and humanitarian logistics processes.

That is why, in order to organize humanitarian logistics effectively, it has become a significant economic challenge (Chandes & Paché, 2009), which to date involves the search for new forms of action and not only from Conventional means, it is a new situation. For a long time, the priority concern was to collect donations to have sufficient financial resources and thus face the effects of a natural earthquake or famine catastrophe or a human-made catastrophe, war or coup d'etat (Chandes & Paché, 2009). According to Beamon and Kotleba (2006) the picture is currently

different, and the logistical needs of humanitarian organizations are often exceeding the capabilities of current emergency.

Due to the nature of disaster-related activities, humanitarian logistics is carried out in a complex environment, characterized by the pressure of time and filled with various sources of uncertainty (Gómez et al., 2017). It is not possible to predict natural disasters, but measures can be taken to deal with such complex crises and reduce the impact of natural disasters on people and society (Chiappetta Jabbour et al., 2017).

1.2.3 The Cycle of Humanitarian Logistics and the Phases for the Disaster in Mexico

Today the world faces increasingly complex and interrelated challenges, which require sustained responses (United, 2017), the management of humanitarian logistics implies a systematic approach to deal with natural disasters and human-made disasters (Ahmadi et al., 2015). The disaster management cycle has been used to define response and recovery logistics (David Swanson & Smith, 2013). The life cycle of humanitarian operations is linked to the timing of such events. There are pre-disaster decisions/operations made before the occurrence of the disaster and post-disaster decisions/operations made after the onset of the disaster (Moreno et al., 2017; Boonmee et al., 2017).

The disaster management cycle consists of four main phases: mitigation, preparedness, response, and recovery. The mitigation phase involves long-term efforts to prevent the occurrence of disasters or reduce their effects (Ahmadi et al., 2015) while the focus of preparedness is the response before a disaster occurs (Ransikarbum & Mason, 2016). These operations carried out before a disaster occurs called pre-disaster operations and play an instrumental role in strategic planning (location of facilities and pre-stock positioning) or disaster mitigation (evacuation) (Caunhye et al., 2012).

In the response phase, immediate relief operations are carried out after a disaster. These include the location of alternative care facilities, distribution of relief items, mass evacuation and transportation, and treatment of wounded (Caunhye et al., 2016). Finally, the recovery phase refers to the restoration of disaster-affected systems through activities such as infrastructure repair and reconstruction and debris management (Caunhye et al., 2016).

Most authors agree on these four phases to identify the disaster cycle, although some change their terms a bit. For example, (Awan & Shafiq, 2015) refer to the phases as mitigation, preparation, response, rehabilitation, and development, while (David Swanson & Smith, 2013) determine that the immediate response operation is divided into demand management, supply management, and compliance. However, in the end, all the authors focus on the four elements of Fig. 1.2.

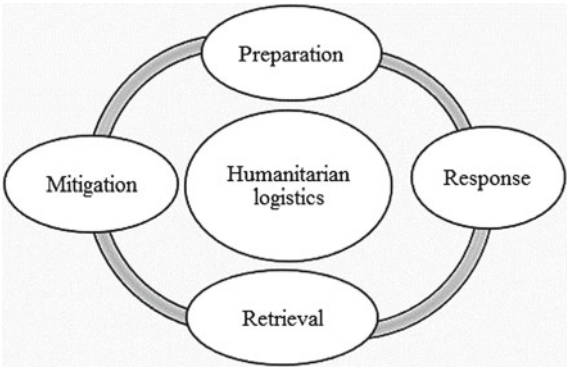

Fig. 1.2 The cycle of humanitarian logistics based on the phases of the own elaboration catastrophe

The phases of humanitarian logistics constitute a spiral that guides the use of resources from the supply chain resulting in a kind of task execution cycle that entails not only the comprehensive approach to the incident but also a way to provide for the use of elements keys. As well as the most suitable strategy, locating the incident in different stages, times, and circumstances of progress, which deliberately becomes a guide facilitating the choice of strategies in the face of the different problems that could happen again.

In Mexico, the cycle of humanitarian logistics is configured from a series of phases very similar to those mentioned above. However, in which case its main objective is to strengthen the integral management of risks in the country through a series of actions and efforts that the government carries out from institutional means such as the law of the national civil protection system, which stipulates within its content the phases of the disaster such as (CENAPRED, 2019):

> A set of actions aimed at the identification, analysis, evaluation, control, and reduction of risks, considering them for their multifactorial origin and in a permanent construction process, which involves the three levels of government, as well as the sectors of society. These facilitate the realization of actions aimed at the creation and implementation of public policies, strategies, and procedures integrated to the achievement of sustainable development guidelines. It fights the structural causes of disasters and strengthens the resilience or resilience capacities of society.

This set of actions can be summarized in three moments; the first moment Before, the second moment During and the third moment After each moment, in turn, are subdivided into phases, this classification is summarized in the information presented in Tables 1.1, 1.2 and 1.3.

The details presented in Table 1.1 establish a clear picture of all the joint actions that the government develops to establish actions preceding the overwhelming impact of a disaster on the population, which causes significant effects and alterations between it. The first moment is the phase with the most stages; there are five approaches oriented to the prevention of risks and the possibilities that these entails.

Table 1.1 The definition and the actors established in the first moment (BEFORE), according to data contained in the material of the Mexico X platform comprehensive risk management course (CENAPRED, 2019)

Moment	Phase	Definition	Actors
First moment: BEFORE	Identification	It is the first step to establish comprehensive risk management, and it is defined as a set of actions and procedures that are carried out in a specific town or geographic area to obtain information about natural or technological hazards and conditions of vulnerability	Three government levels
	Foresight	The foresight is to become aware of the risks that may be caused and the need to face them through the stages of risk identification, prevention, mitigation, preparedness, emergency care, recovery, and reconstruction	The foresight is to become aware of the risks that may be caused and the need to face them through the stages of risk identification, prevention, mitigation, preparedness, emergency care, recovery, and reconstruction
	Prevention	Set of actions and mechanisms implemented in advance of the occurrence of the disturbing agents, in order to know the dangers or risks, identify them, eliminate them or reduce them; avoid or mitigate its destructive impact on people, goods, infrastructure, as well as anticipate the social processes of their construction	The actors that have an impact on prevention are many, including the transport, agricultural, construction, and other sectors. It constitutes a much more extensive range than the forecast since it involves the authorities and the general population
	Mitigation	Mitigation is any action aimed at reducing the impact or damage in the presence of a disturbing agent on an affectible agent. Mitigating means are taking actions to reduce the effects of disasters before they occur	The actors involved in the mitigation stage are diverse, ranging from experts and scholars on the different aspects of risk to the authorities involved in the construction of infrastructure, health services, education
	Preparation	Preparation is the last preventive stage in comprehensive risk management. It constitutes those activities and measures taken in advance to ensure an effective response to the impact of a disturbing phenomenon in the short, medium, and long term. The preparation, unlike prevention, is made up of measures taken when the impact of the disturbing agent is imminent	Disaster preparedness is a permanent multisectoral activity involving institutional actors, both from the private sector and the public and social sector. The affected population and voluntary groups also participate

Table 1.2 The definition and the actors that the second moment establishes (DURING), according to data contained in the material of the Mexico X platform comprehensive risk management course (CENAPRED, 2019)

Moment	Phase	Definition	Actors
Second moment: DURING THE EVENT	Assistance	The aid is the response to help people at risk or victims of an accident, emergency or disaster by public or private specialized groups, or by internal civil protection units, as well as actions to safeguard the other agents Affectable	Municipal bodies, government instances, the participation of society, the Secretary of the Navy, and the Secretariat of National Defense (Sedena)

1.3 Discussion and Findings

By consulting the disaster records at the base of EM-DAT Center, contingency reports issued by part of the CENAPRED, the CONAGUA records collected by the drought monitor in Mexico and various publications related to the subject, it was possible to carry out a descriptive exploratory analysis of the conditions that currently prevail concerning natural disasters and their implications in Mexico.

The first data analyzed were those obtained from the international base of the Santé Publique de l'Université Catholique de Louvain, Belgium (EM-DAT), the data extracted from this base covered from 1985 to date, the result of this was a projection of 34 years of disasters in Mexico as well as its trends.

On the other hand, verified records also include factors such as; the frequency of disasters per year, the costs of the disaster, the number of deaths, the number of people affected, the total number of people affected (which is equivalent to the sum of the number of deaths plus that of the people affected), homeless and total injured.

Figure 1.3 shows the frequency bars assigned to each type of disaster observed according to the records obtained from EM-DAT in it. It can be seen in detail that the hydrometeorological phenomena lead to natural disasters in Mexico, which corroborates in some way what already was thought about the type of disasters that most impact the country.

Now, concerning the information observed in Fig. 1.3, the storms are the first to position themselves in the graph followed by the floods, later the earthquakes, and finally, the extreme temperature. It is necessary to consider that this group of natural disasters frames 80% of the observations collected in the 34 years analyzed, which already is considered as regards the volume of data analyzed.

Table 1.3 The definition and the actors established in the third moment (AFTER), according to data contained in the material of the comprehensive risk management course of the Mexico X platform (CENAPRED, 2019)

Moment	Phase	Definition	Actors
Third moment: AFTER	Retrieval	Retrieval is defined as the process that begins during the emergency, consisting of actions aimed at returning to the normality of the affected community It is a transition period between the time of onset and the end of the emergency. At this stage of comprehensive risk management, the essential public services, such as the supply of electricity, access to drinking water, urban drainage and communication and transport roads, must be restored. Likewise, the repair of damages in housing must be initiated with temporary solutions or relocations	When natural phenomena impact the country, local and state governments coordinate to support recovery efforts. If the damages exceed national capacities, international support can be requested. In this case, the World Bank is one of the international organizations that support countries through assessments of subsequent needs and planning recovery and reconstruction tasks
	Reconstruction	Finally, reconstruction is the transitory action aimed at reaching the environment of social and economic normality that prevailed among the population before suffering the effects produced by a disturbing agent in a given space or jurisdiction. This process should seek, as far as possible, the reduction of existing risks, ensuring the non-generation of new risks, and improving pre-existing conditions	The reconstruction phase can have a very variable duration according to the type of disturbing phenomenon presented, and the magnitude of its impact. Coordination between political actors and society is essential successfully to carry out reconstruction work so that there is a fair use of human and material resources. Similarly, professionals, scientists, and planners from the urban, economic, environmental, and civil protection development sectors must participate

After obtaining a perspective of the main disasters from an international database, the same evaluation process was carried out with the information, but now in the records that CENAPRED reports at the national level from two databases of records of disasters. The first so-called socioeconomic impact and the second

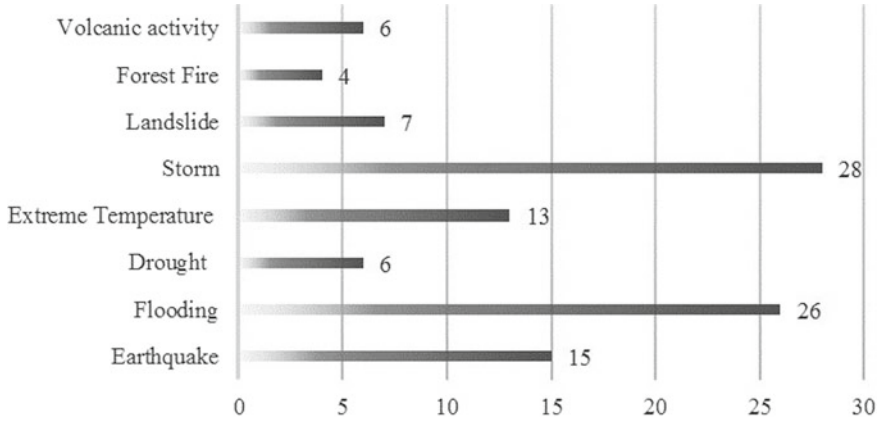

Fig. 1.3 Frequency of occurrence of natural distress in Mexico from 1985 to date. Own elaboration based on the data obtained from the EM-DAT base Centre de Recherche sur l'Epidémiologie des Desastres (CRED), L'École de Santé Publique de l'Université Catholique de Louvain, Bélgica

declarations of disasters, unlike previous data, CENAPRED records only cover an analysis horizon of 18 years (2000–2018).

In the same way as in EM-DAT, the CENAPRED base weights hydrometeorological disasters as those with the highest frequency above all others, this is evident if Fig. 1.4 is observed where the bar with the highest height corresponds to this type of event.

Although Fig. 1.4 shows a general classification of the types of disasters that are registered at the base of CENAPRED, within each item, there is another detailed division concerning the events that arise from this context. For example, for hydrometeorological contingencies, there is a division that distributes the different types of disasters; this classification is contained in Table 1.4.

Besides, it was also possible to identify which of the different types of disasters have the most significant impact according to the information obtained, and Table 1.5 shows the different classifications and their frequencies.

As previously stated, extreme rains continue to be the disasters that most impact the national territory, as well as those derived from them. Although on the other hand, it is evident to highlight that the frequencies observed by droughts and extreme temperatures also register a significant Weighting in Table 1.5, which establishes a condition for this type of hydrometeorological conditions.

There is no doubt that hydrometeorological disasters are the ones that cause the most considerable amount of affectations within the national territory, their effects are distributed nationally, and they establish a specific type of parameters regarding the type of hydrometeorological disturbances and the geographical location of the

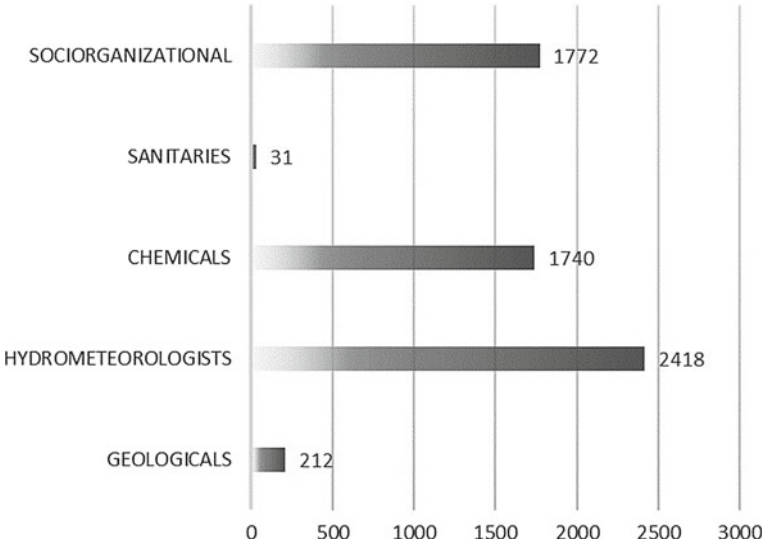

Fig. 1.4 Frequencies observed according to the types of distress that are recorded in the contingency base of the national destination center. Own elaboration based on data from the CENAPRED 2000–2015 base

Table 1.4 Classification of disasters, according to CENAPRED

HYDROMETEOROLOGISTS	HIDRO (ID)	Low temperatures
		Tropical cyclone
		Strong winds
		Severe storm or hailstorm, twister
		Flood
		Showers (EXTREME RAIN)
		Storm surge
		Drought
		Frost
		Extreme (high) temperature

affected state. So, in general, there are states of the republic that record a more considerable amount of hydrometeorological incidents, and these initiations were also determined to be able to establish a distribution of frequencies. These go from the state with the lowest record of them to the highest. Figure 1.5 shows this distribution of frequencies in ascending form for a bar graph to be able to appreciate in more detail this condition.

On the other hand, the records from the extreme rains and their derivations were finalized individually. It helped to identify which states of the republic have a more significant impact on this type of phenomenon. Figure 1.6 contains an ascending

Table 1.5 Frequencies recorded according to the type of hydrometeorological disaster with the data obtained from the socio-economic impact bases and declarations of emergency CENAPRED 2000–2018

Classification of disasters HIDRO	Frequency
Showers (EXTREME RAIN)	1444
Low temperatures	228
Severe or hailstorm, tornado	214
Tropical cyclone	174
Drought	145
Flood	141
Strong winds	93
Extreme temperature (high)	79
Frost	37
Storm surge	5

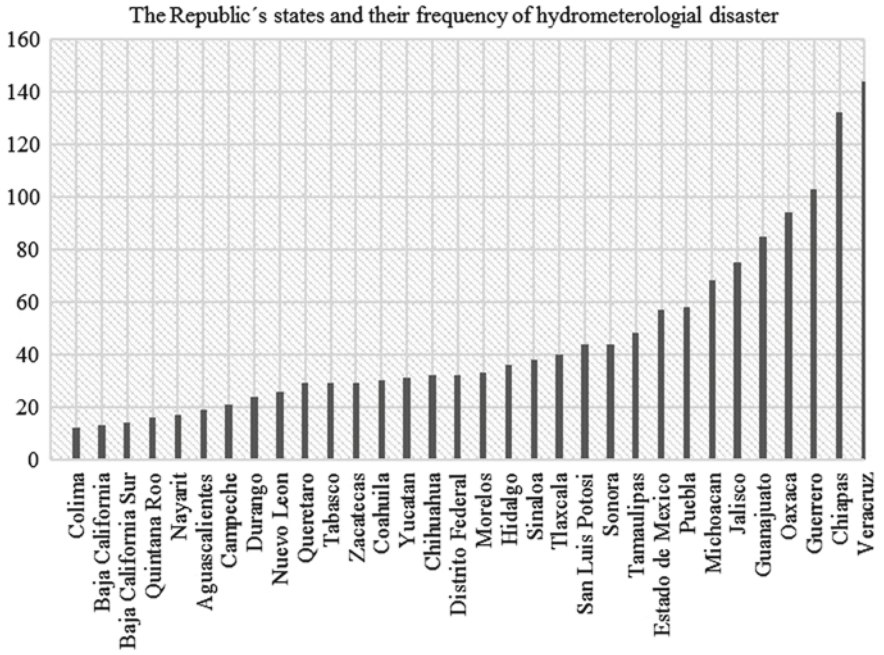

Fig. 1.5 Frequencies prioritized for the number of hydrometeorological disasters produced in the states of the Republic between 2000 and 2018 according to the records obtained from CENAPRED

graph that identifies the states of the Mexican republic that have a higher incidence of rains, winds, floods, and storms.

Generally, the southern states of the country like; Veracruz, Guerrero, Chiapas, and Oaxaca concentrate the highest number of incidents. However, as discussed

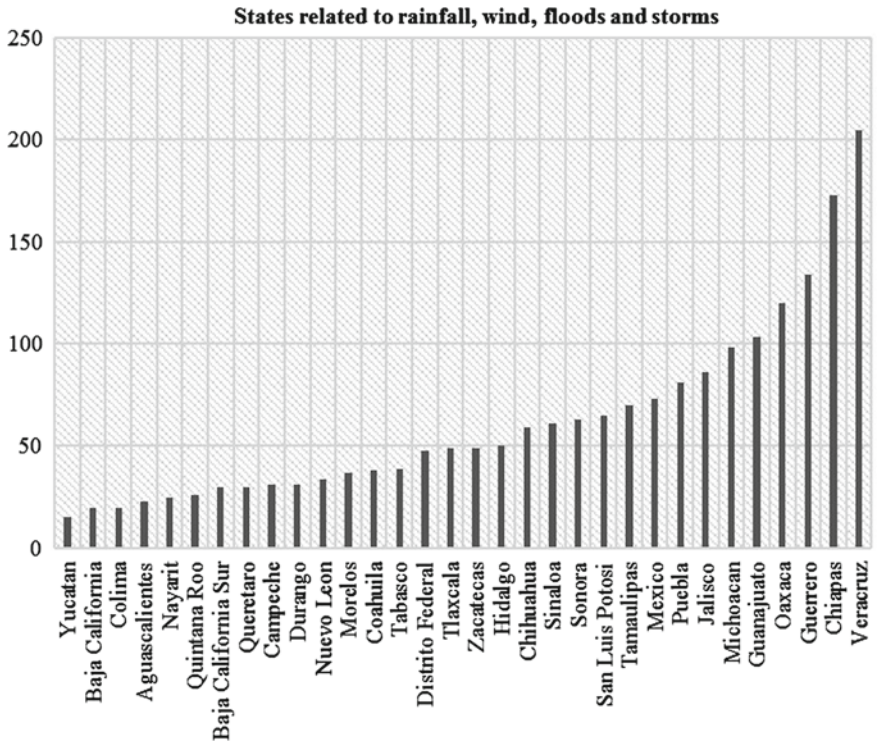

Fig. 1.6 States of the republic with the highest incidence of extreme rains and their derivations ordered of lesser number of incidents

below, these states not only participate in this type of hydrometeorological phenomena.

At the same time, droughts and extreme temperatures tend to occur in the north-central states of the republic as Chihuahua, San Luis Potosi, Michoacan, Durango, and Sonora. This behavior is very natural if we take into account that Mexico has a large part of its territory in the high-pressure strip of North latitude, so it has arid and semi-arid areas that coincide in Latitude with the regions of the great African, Asian and Australian deserts. Also, due to its orographic characteristics, these types of areas are located in the central highlands of the Mexican Republic (Ortega-Gaucin, 2013).

Nevertheless, although the behavior of the data obtained in Fig. 1.7 is similar to that established in the previous paragraph, the presence of droughts in states such as Puebla, Veracruz, Campeche Chiapas, and Tabasco is striking, since these republic states are characterized by be places cataloged with the presence of phenomena related to extreme rains, floods, and storms.

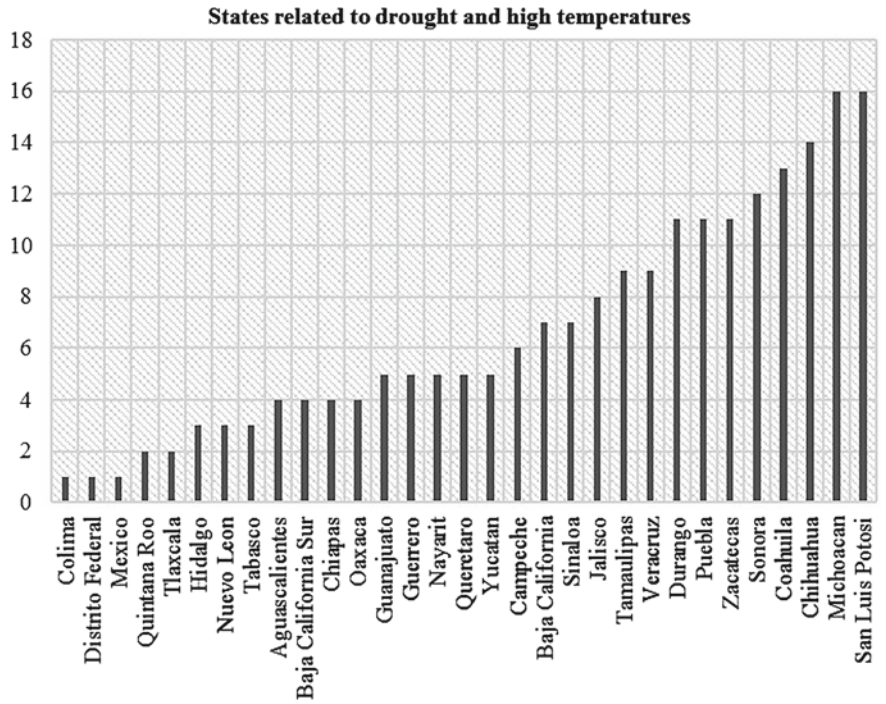

Fig. 1.7 States of the republic with more significant initiation of droughts and high temperatures accommodated from lowest to highest

The evaluation of the data obtained in the information base of CENAPRED concerning droughts and high temperatures seems to give a new pattern that could become a trend within the occurrence of hydrometeorological phenomena related to drought.

According to the last report issued on August 15th of the current year by CONAGUA through the drought monitor in Mexico, the state of the republic such as Veracruz, Yucatan, Chiapas, and Hidalgo among others are indicated as entities that present more than 40% from its affected territory (municipalities) due to some drought condition that ranges from abnormally dry—to exceptional drought. Figure 1.8 is a map of the conditions related to the percentage of areas with droughts in the federal entities of the Mexican Republic. It was published on August 21st, 2019, and shows the hydrometeorological conditions that currently prevail in the national territory for the drought phenomenon.

On the other hand, CONAGUA, through its drought monitor in Mexico, establishes an index of water vulnerability formed from:

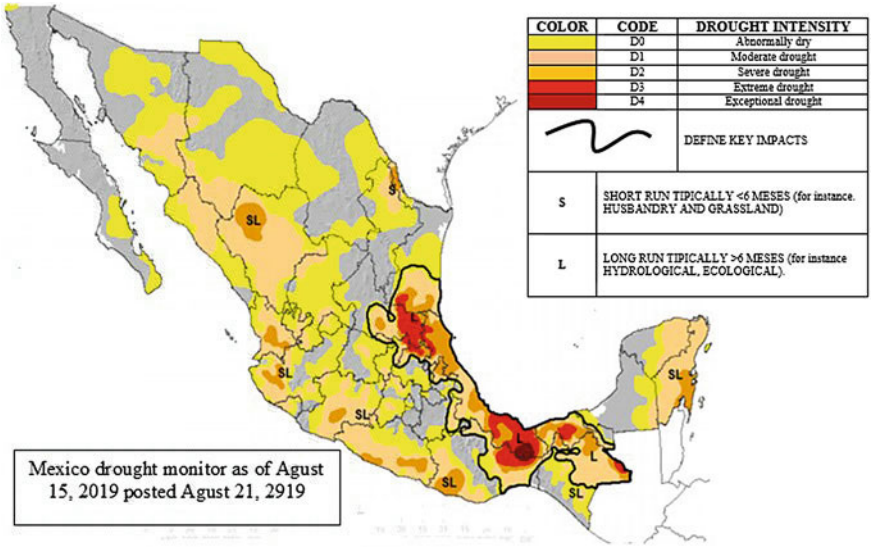

Fig. 1.8 Map issued from the data of the drought monitor in Mexico until August 15 of the year, in turn, the possible results range from abnormally dry to exceptional drought, where the yellow color is the lowest valuation and the crimson red higher (CONAGUA, 2019)

Table 1.6 Classification of drought indices according to their intensity and periods of appearance, according to CONAGUA, from the sub-management of climatology and climatological services (CONAGUA, 2019)

COLOR	CODE	INTENSITY OF DROUGHT
	D0	Abnormally dry
	D1	Moderate drought
	D2	Severe drought
	D3	Extreme drought
	D4	Exceptional drought
		DEFINE KEY IMPACTS
S	SHORT-RUN TYPICALLY <6 MESES (for instance. HUSBANDRY AND GRASSLAND)	
L	LONG RUN TYPICALLY >6 MESES (for instance, HYDROLOGICAL, ECOLOGICAL)).	

Obtaining and interpreting various indices or indicators of drought such as the Standardized Precipitation Index (SPI) that quantifies the conditions of deficit or excess rainfall (30, 90, 180, 365 days), Rain Abnormality in Percentage of Normal (30, 90, 180, 365 days), Satellite Vegetation. Health Index (VHI) that measures the degree of vegetation stress through the observed radiance, the Leaky Bucket CPC-NOAA Soil Moisture Model that estimates soil moisture through a single layer hydrological model, the Normalized Index of Vegetation Difference (NDVI), the Average Temperature Anomaly, the Percentage of Water Availability in the dams of the country and the contribution of local experts (CONAGUA, 2019).

This index stipulates the percentages of affectations according to abnormally dry (D0), moderate drought (D1), severe drought (D2), extreme drought (D3) until exceptional drought (D4). Table 1.6 shows in more detail the conditions mentioned above, which are also considered in the map of Fig. 1.8.

In the same way, as with the EM-DAT and CENAPERD records, an exhaustive review was carried out on the data obtained from the CONAGUA drought monitor that covers from January 2003 to August 2019, except for August 2003 and February 2004 dates in which it is reported that there was no drought monitoring due to external factors, so the record was not prepared.

These data address a more realistic perspective on the behavior of droughts in the different states of the republic. Figure 1.9 prioritizes from minor to major the states of the Mexican Republic about the number of municipalities affected by drought. It means that the frequency observed corresponds to the number of municipalities affected in that state. Thus in the case of Oaxaca that It has the highest frequency, equal to 570 equivalents to the 570 municipalities that have been registered with drought during the specified time, and so on for each of the frequencies observed.

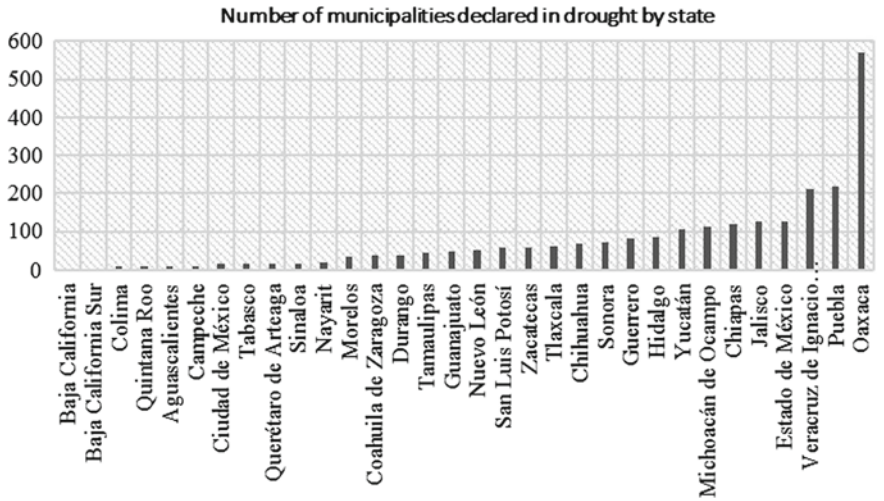

Fig. 1.9 Ascending distribution of the number of municipalities by states considered to have drought problems