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Earthquake Risks in Haiti: An Analysis of Response and Preparedness Strategies for the Design of a New Mitigation Approach

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EARTHQUAKE RISKS IN HAITI: AN ANALYSIS OF RESPONSE AND PREPAREDNESS STRATEGIES FOR THE DESIGN OF A NEW MITIGATION APPROACH

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Abbreviations and Acronyms

ADRC	Asian Disaster Reduction Center
CRED	Centre for Research on the Epidemiology of Disasters (CRED)
DHS	Department of Homeland Security
FEMA	Federal Emergency Management Administration
GDP	Gross Domestic Product
GoH	Government of the Republic of Haiti
IEDC	International Economic Development Council
IFRC	International Federation of Red Cross
III	Insurance Information Institute
NAS	Nation Academy of Sciences
OCHA	Office for the Coordination of Humanitarian Affairs
PDNA	Post Disaster Needs Assessment
SWOT	Strength Weakness Opportunity Threat
UNISDR	United Nations International Strategy for Disaster Reduction
USAID	United States Agency for International Development
USGS	United States Geological Survey
WFP	World Food Program

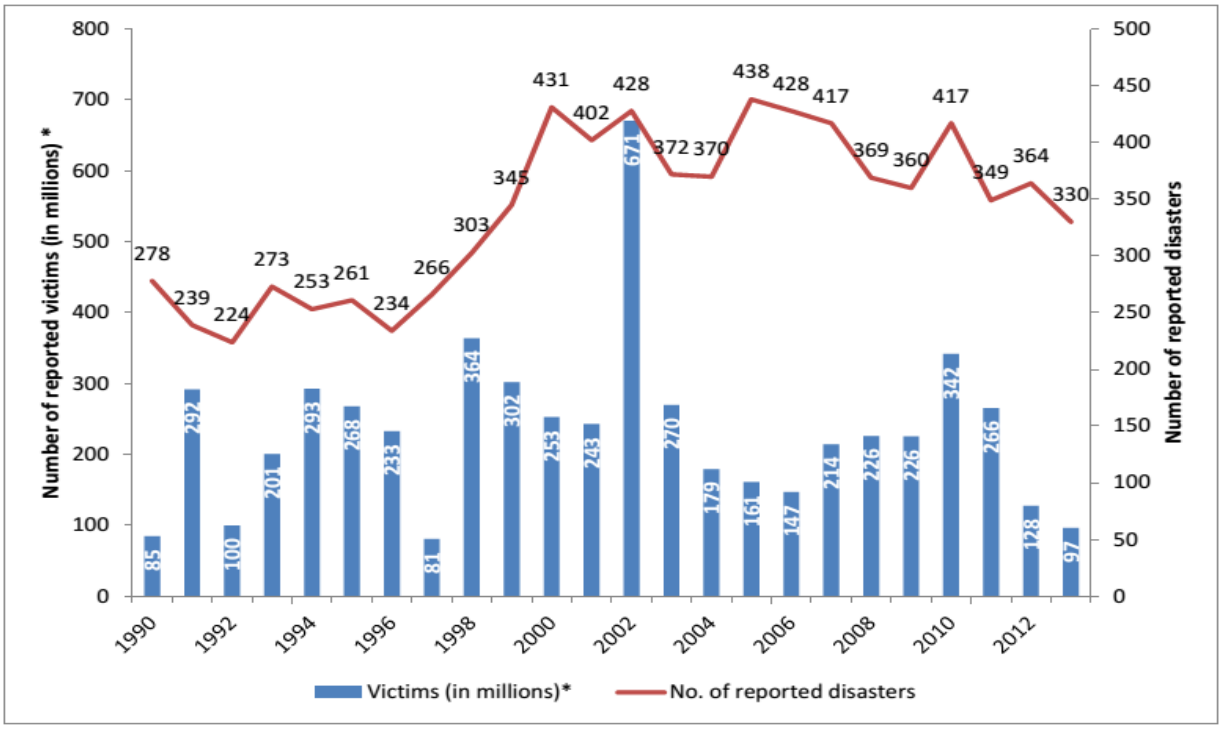
Abstract

Earthquakes can have enormous consequences on affected countries. To minimize these harsh consequences, an effective disaster management plan is necessary and a reasonable strategy is necessary to recover and get back to a normal life when they happen. Studies from scientists show that it is difficult to predict when an earthquake will occur. Because of this unpredictability, high-risk countries need to act continuously in order to deal with any sudden strike that may occur by stressing on the mitigation and preparedness activities and by designing appropriate response plans. In Haiti, a well-known earthquake-prone country, the preparedness and mitigation plans have always been critically deficient. Consequently, the 2010 earthquake has exposed the country's horrendous disaster management system. There was not a clear-cut strategy or measure to cope with any kind of major disaster even though it was well-known that the risk level is high and the threats are real. The response and recovery plans have been conceived promptly just after the earthquake hit with different international approaches that led to an astonishing inefficiency. The country is still under high-level seismic risk. Learning from the past mistakes can help to reduce potential disaster damage scope. Therefore, this thesis analyzes the effectiveness of the response plan by analyzing the strategies used by the different stakeholders after the earthquake and recalls the preparedness activities for potential major similar catastrophic events. To attain its objectives, a strategic management method, the hybrid SWOT-AHP analysis approach, is employed. Data needed to run the model are sourced from official reports, governmental websites and databases, and other scholarly sources. The results and analysis are used to make some recommendations with regard to the strategies needed to strengthen the country's mitigation, preparedness, and response capacity to earthquake risk and disaster threats.

CHAPTER 1. INTRODUCTION

1.1. Rationale

Natural disasters can have huge impacts on human life, infrastructures, and economies (Brown & Mike, 2009). Earthquakes are considered as one of the most destroying natural disasters. Unfortunately, there is not yet a well-understood method to predict them (Jordan, T. 2011). During the recent years, several countries have undergone the disastrous effects of cataclysms. The figure below shows the frequency of these events in the last two decades and the number of victims.



**Victims : Sum of deaths and total affected*

Figure 1. Trends in Occurrence of Natural Disasters and Victims (death and affected) (Source: CRED, 2013)

On January 12, 2010, Haiti was hit by a 7.0 earthquake that is considered as the most disastrous disaster in its history (Georges, Y. and Grunewald, F. 2010). Despite the country's

vulnerability, due to the fact it is located along two active faults in addition to its poor infrastructure, few efforts have been made to increase public awareness and prepare accordingly. As a result, this generation had limited knowledge about earthquakes and their consequences and was not powered to deal with the event. Even the rulers seemingly ignored the level of risk that the country was facing. They witnessed passively to the proliferation of non-standard buildings despite some warnings. The memories of the 1842 earthquake that destroyed, almost completely, the second most important city (Cap Haitien), were faded. There was no specific strategy or policy to deal with an eventual earthquake strike at any level of the society and the government. Therefore, the impacts of the 2010 disaster outstretched the country's capacity and capability.

The weakness of the national disaster management system and the passivity of the country to put in place a working mitigation plan drew attention of local experts and researchers who gave warnings to stop the spread of unregulated and unsound constructions and spur implementation of appropriate policy for a better preparedness as a life condition especially in the Capital where conditions for an unparalleled disaster in case of a major earthquake hit were met (Prepetit, C. 2004; Prepetit, C. 2002; Calais, E. 2002). Ignored, nothing has been changed to prepare for the unexpected. As a result, 260 000 houses were destroyed, more than 300 000 dead counted in less than 60 seconds (GoH, 2010). This latter number makes the catastrophic event one of the deadliest earthquakes recorded in the recent history of the world (I.I.I, 2016).The impoverished nation has to deal also with more than one million of homeless people and the challenge of reconstruction, an important stage, but a difficult one due to the country's economic, social, and political situation. However, the reconstruction process stakeholders unanimously agree that to reach their objective the country must learn from past mistakes and adopt the principles of a sustainable development. As usual, after the disaster the country could

count on support from all over the world for both the immediate response period to help its economically ruined survivors and to plan the recovery process that, obviously, required a longer period. From food to rubble clearance, the country was unable to count on his own capacity.

According to several seismic studies, the risk for a future major earthquake in Haiti and other neighboring countries is still high and obvious. After months of research about the causes of the 2010 earthquake, geoscientists discovered that the recent earthquake was not caused by the Enriquillo-Plantain Fault that they thought was the main culprit (Israel, B., 2010). In contrary, it was caused by an "unmapped fault that may be part of a whole fault system that was not known before" (Israel, B., 2010). This remains a controversial point that needs to be substantiated. However, the golden rule in the seismic field is "where there was an earthquake, there will be others" (Prepetit, C. 2012). So, Haiti needs to be prepared to face this hazard at any time. Moreover, research studies describe the *Septentrional Fault* that crosses the north region as very active. Prepetit C. (2012) argues that the energy accumulated along this fault since 1842 can be estimated to 900 atomic bombs and can trigger an earthquake with a magnitude between 8.0 and 8.3 on the Richter scale (np) [1]. Thus, the country must zoom in on effective preparedness strategies to lower the potential damages of an earthquake.

A widely known tenet in disaster management is that mitigation and preparedness can save life, property, and money. According to Shreve C.M. and Kelman I. (2014), the World Bank and the US Geological Survey have estimated that a 400 billion economic loss from a natural disaster in the 1990s could be decreased by 280 billion if an investment of 40 billion in prevention, mitigation, and preparedness was made (p.213). So, the country must conciliate its

[1] A M6 earthquake contains an energy equivalent to 1 atomic bomb (AB), a M7 earthquake 30 AB, a M8 900 AB.

development plan with the indisputable risks and embark into a well-designed blueprint to face this ever-present hazard. Research to identify the potential impacts, the best adaptive strategies and preparedness weaknesseses can help to attain this objective. It is from this perspective that this research study aims to scrutinize the post-earthquake response system led by the major international partners and the national disaster management system with regard to its weaknesses and potentials for a significant reduction of the constant earthquake risk in the country. Finally, some recommendations are formulated based on the analysis of the results in order to better confront any potential future earthquake disaster more efficiently.

Table 1-1. Summary of the main facts of the Haiti 2010 Earthquake

Haiti 2010 Earthquake Facts • January 12, 2010 , 16: 53 (EST) • Magnitude: 7.0 • Epicenter: 16 km • Area affected: 13 226 Sq Km		
Impacts	**Type**	**Damage (Number / Quantity)**
Infrastructure		
▪ Houses destroyed	-	105.000
▪ Houses badly damaged	-	188.383
▪ Schools destroyed or damaged	-	4.000
▪ Volume of Rubble	-	19 million m^3
Humans		
▪ Injuries	-	300 000
▪ Death	-	>220 000
▪ Displaced	-	500 000
▪ Homeless	-	1.3 million
▪ Affected	-	3.5 million
Economy		
▪ Economic flow variation	-	US $ 3.561 billion
▪ Damage and loss	private sector	US $ 5.722 billion
▪ Damage and loss (public sector)	Public sector	US $ 2.081 billion
▪ Country's GDP (2010)	-	US $ 6.623 billion

(Source: Author, combined data)

N.B: Controversial data exist in other sources for each of these numbers. The majority of these data presented are from the Government of Haiti and are included in the PDNA

1.2. History of earthquakes in Haiti

The Quisqueya Island (Haiti and Dominican Republic combined) is an earthquake-prone territory. It is located between the North American and the Caribbean plates, what makes it an island on permanent risk. Haiti, on its side, has known some destructive earthquakes in its history. The four well known are the 1751 earthquake, the 1770 earthquake along the Enriquillo fault that hit Port-au-Prince and destroyed the city, the 1842 earthquake along the Septentrional fault that destroyed completely the city of Cap Haitian, the 1860 earthquake in the south, and more recently the 2010 earthquake (Prentice, C.S, et al. 2010). The table 1-2 below shows the major earthquakes that hit the country and their places.

Table 1-2. Earthquakes in Haiti, their dates, and places

Date	Location	Description
18 October 1751	Port-au-Prince	Port-au-Prince was hit by violent tremors which lasted around three minutes. Aftershocks continued for more than two months
3 June 1770	Port-au-Prince and southern regions	The capital was destroyed and the earth opened up in several places. Hundreds were killed by falling buildings
7 May 1842	Cap-Haitien and the rest of the extreme North	"[Le Cap], where all the houses were built in stone was reduced to a pile of rubble under which almost ten thousand people were buried" (Bellegarde, Dantès. La Nation Haïtienne, p. 110) in Haïti-Reference Désastres naturels en Haïti Tremblements de terres.mht
23 September 1887	Northern regions	Destruction of the church in Port-de-Paix, among other things
1904	The North of the country. Port-de-Paix and Cap-Haitien	Port-de-Paix and Cap-Haïtien were affected. • http://sciences.blogs.liberation.fr/home/2010/01/s%C3/A9isme-en-ha%C3%AFti-la-bonne-carte-tectonique.html • List of natural disasters in Haiti – Wikipedia, the free encyclopedia.mht

Table 1-2 (Continued)

Date	Location	Description
1946	Earthquake in the northeast of the Dominican Republic and a tidal wave in the Nagua region	Haiti was also affected. http://en.wikipedia.org/wiki/list_of_natural_disasters_in_Haiti
27 October 1952	Anse-à-Veau in the Grande Anse Department	6 people were killed and thousands were made homeless
24 June 1984		Magnitude 6.7 on the Richter Scale
12 January 2010	Northern part of the western department and certain parts of the southeastern department	Earthquake of magnitude 7.3 on the Richter scale. The most powerful earthquake to hit the country in more than two hundred years. The epicenter was near Template, 17 km from Port-au-Prince. A dozen secondary tremors between 5.0 and 5.9 were recorded in the subsequent hours. According to the report by the Haitian government, 222 500 Haitians were killed, 2 000 000 were affected, 300 000 were injured and 1.3 million lost their homes. In addition, around 500 000 people took refuge in provincial towns in, for example, Artibonite and Grand Anse after 12 January
20 January 2010	Western department and south-eastern department	Magnitude 6.1, it took place at 06:03 local time. Its epicentre was near Template, a neighbourhood in the western part of Port-au-Prince, and less than 10 kilometers below the surface.

(Source: Georges and Grunewald, 2010)

1.3. Background on the 2010 Haiti Earthquake

Haiti has undergone decades of poverty, political instability and environmental degradation before the earthquake. The social and economic indices available show that, even before the earthquake, the country has been one of the poorest in the region. With 9.6 million of inhabitants in 2001, 4 out 10 people were illiterate, half of the population was without healthcare access, and 80% were living without drinking water (Echevin, D. 2011). This situation has persisted for years. Therefore, the country ranked 145 out of 169 on the United Nations Human

Development Index in 2010, the year of the unexpected cataclysm (UNDP cited by Desroches, R. et al, 2010). In this specific year, it was "the only country in the Americas to be listed in the lower category of human development." (Edwards, F. 2011). Moreover, Haiti has scored 2.2 on a scale of 10 for transparency, which makes it the most corrupted country in the region (146 out of 178 worldwide) (Edwards, F. 2011).Corruption has always been a key obstacle to its development. The country's dire economic situation before the earthquake is also believed to play an important role in the degree to which it is impacted (Desroches, R. et. al., 2010). The figure below illustrates the main facts about the country's social and economic parameters, its risk profile as well as its priorities after the devastating earthquake.

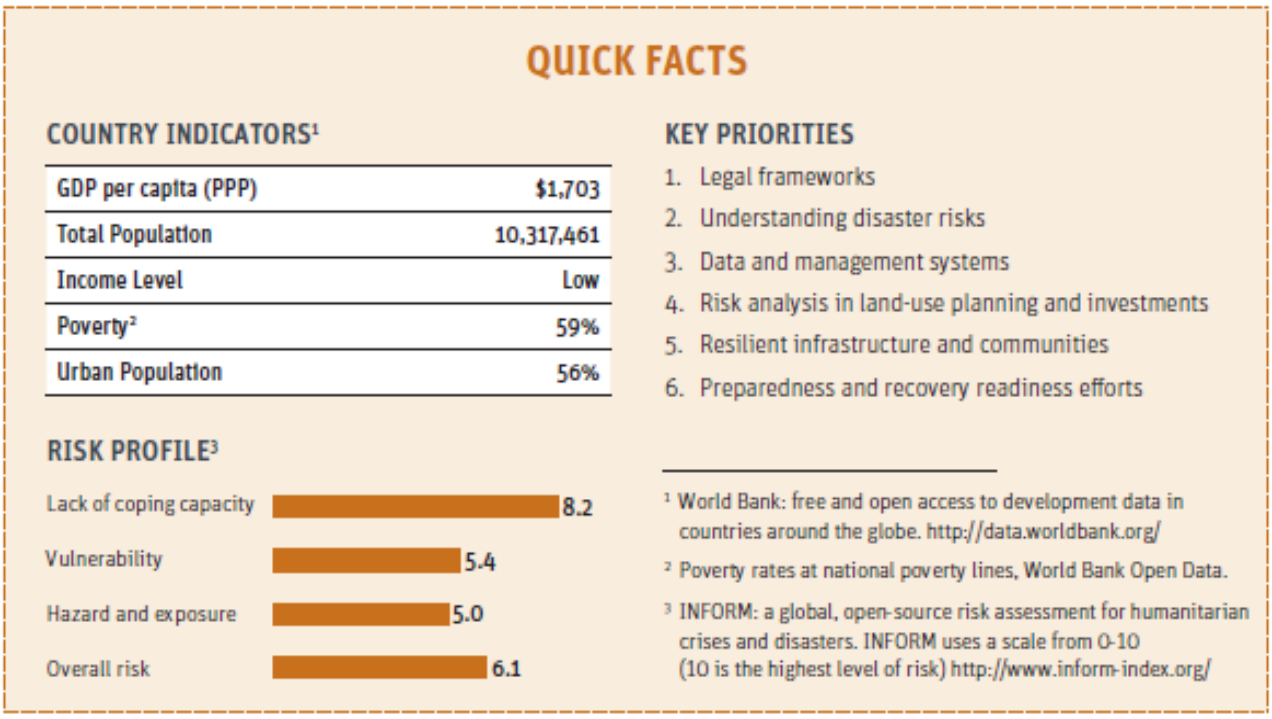


Figure 2. Key facts about Haiti's Economy and Risk Characteristics (GFDRR, 2010)

1.4. Purpose

The purpose of this research study is to analyze the effectiveness of the earthquake response and the national disaster management system and formulate some pertinent recommendations for improvement.

1.5. Research questions

Q 1: What are the factors that influenced positively or negatively the effectiveness of the 2010 Haiti earthquake response strategies?

Q2: What are the main nonstructural and structural measures that need to be taken to strengthen the national disaster management system for occurrence of an eventual strong earthquake?

CHAPTER 2. BACKGROUND AND REVIEW OF LITTERATURE

Disasters begin with human history (CBSE, 2006). The management of disasters is also very old. Various applications of disaster management techniques can be spotted throughout available historical records, books, and reports. Coppola (2015) points out that a great example of warning, preparedness, and mitigation is the story of Noah's ark in the Old Testament (p. 2). There is evidence of disaster management techniques and practices as early as 3800 B.C. (Coppola, D.P, 2015). Efforts of early civilizations to minimize the risks and increase their resilience are a significant foundation for the modern disaster management that applies a comprehensive approach where all or most of the hazard risks of a community are addressed. However, in the recent history the civil defense era has played an important role with instances of "Great Britain's disaster management that is rooted in the civil defense act of 1948, the Federal Emergency Management Agency (FEMA) with the civil defense act of 1950, France's civil protection that grew out of the nation's 1950 ordonnance and the 1965 civil defense decree, etc..." (Coppola, D.P, 2015). Understanding the terminologies of the natural disasters, their characteristics and particularities, the development of their management strategies, their phases and institutional aspects are among the main ingredients for an effective disaster management.

2.1. Natural Disaster Parameters and Related Definitions

The United Nations International Strategy for Disaster Reduction (UNISDR) describes the term disaster as "a sudden, calamitous event that seriously disrupts the functioning of a community or society and causes human, material, and economic or environmental losses that exceed the community's or society's ability to cope using its own resources." An equation that translates this idea is:

$$(\text{Vulnerability} + \text{Hazard}) / \text{Capacity} = \text{Disaster}$$

Ciurean (2013) argues that the vulnerability concept defines "the potential for loss to the elements at risk caused by the occurrence of a hazard, and depends on multiple aspects arising from physical, social, economic, and environmental factors, which are interacting in space and time." Vulnerability is always studied in function of a specific hazard, which is, in this particular case, seismic. This definition is more specific and gives a wider comprehension of the concept than the United Nations Environmental Program (UNEP)'s definition that states that the vulnerability is the "extent to which a community, structure, service or geographic area is likely to be damaged or disrupted by the impact of a particular hazard." However, they are also complementary as the first shows the factors that may contribute to this vulnerability and the second shows that vulnerability depends on to a certain level of exposure. Both of this is important when considering how to reduce the vulnerability for a specific threat.

As shown in the last-mentioned equation, a hazard is a component of the disaster equation. Its presence does not lead forcibly to a catastrophe. It can be natural or anthropogenic. The International Federation of Red Cross (IFRC) defines natural hazards as "naturally occurring physical phenomena caused either by rapid or slow onset events which can be geophysical, hydrological, climatological, meteorological, or biological." The most studied natural disasters are hurricanes, floods, droughts, tornadoes, wildfires, and earthquakes.

2.2. Natural disasters and their environmental impacts

Natural disasters are devastating events with enormous impacts on the region they hit (Hayward, D. 2011). These effects are even greater when the right decisions that should be part of a mitigation plan are missing. The United States and the World Bank highlight the importance of past decisions in minimizing the impacts of natural disasters by mentioning that disasters bring to light the aggregate consequences of previous decisions taken about land management,

poverty reduction, construction techniques, social inclusion, and sanitation, among others. (Lima, M.H. et al, 2013).

2.2.1. Waste management and sanitation

Waste management is one of the biggest environmental problems that the country is facing. Even in normal time, the country's institutions are impotent to manage daily-generated wastes and are replaced by spontaneous management by households (Durand M., Popescu, R., and D'Ercole Robert, 2015). The earthquake consequences contributed to worsening the situation. Food packages and medical products are two main types of waste that piled up and needed to be managed safely to prevent the risk of transmission of diseases. This situation confirmed the rule that sanitation is always a preoccupation in disaster time and needs to be well-planed at the preparedness stage. According to Tabish (2015), only food and medical supplies top sanitation and waste management in the list of priorities after a disaster (p.233). Living in camps, survivors of the Haiti earthquake faced incredibly bad sanitation issues.

The government of Haiti's official report points out that the earthquake increased the environmental vulnerability of the country. It mentions that "the earthquake added considerably to the pollution, nuisances, and risks that were already afflicting disaster zones, and increased pressure on the environment, natural resources, and the country's protected areas." (PDNA, 2010).

2.3. Environmental and natural ecosystem degradation

2.3.1. Landslides

One solace generally associated with the Haiti 2010 earthquake is there was not direct major environmental damage caused by the earthquake per se in the Port-au-Prince metropolitan area. Only a few landslides, one small oil spill from the coastal oil terminal, and some minor

warehouse fires were observed (Rastogi, 2010). Several environmental experts believe that lack of trees in hillside areas has favored the few landslides noticed (Ashton M. 2010; Stark C. 2010; cited by Than K. 2010). They also mention that the flatness of the land in Port-au-Prince and the still dry season in january are two factors that helped to minimize landslide environmental degradation in this area. However, the overall number of landslides in the entire country due to the earthquake was high. Harp, E.L., Jibson, R.W., and Schmitt, R.G.(2016) notice that the cataclysm triggered many landslides outside of Port-au-Prince. They inventoried 23,567 landslides from the north coast to the south coast of the southwestern peninsula region. Those landslides' category were shallow, disrupted rock falls, and rock slides. The geologic unit such as limestone, primarily basalt, andesite, and highly weathered volcanic rocks were the main geologic types affected. p.3. The authors also mention that some roads and dams were blocked by the landslides, and other infrastructures were threatened. A combination of topography, geologic factors, and local variation of ground shaking can relatively explain this type of environmental degradation due to the earthquake.

Studying factors that contribute to landslide susceptibility, Kamp. et al (2008) found that land cover plays a role. They found that the majority of landsliding occurs in grassland areas (<70%) and agricultural land (20%), while in forested areas landsliding have been rare (2%). While the relationship between the landslide cases registered during the Haiti earthquake and deforestation is not fully established, Than K. (2010) believes that it may play a role and is a threat in case of future earthquake. Thus, all other factors put aside, reforestation of Haiti's denuded hillsides can contribute to increase soil stability and decrease their likeliness to landslides during earthquakes.

2.3.2. The built environment degradation and impacts

The built environment has suffered enormously from the Haiti earthquake. The volume of debris generated is estimated to 20 million to 25 million cubic yards (Devarieux, J. 2010). This situation represented a challenge in the aftermath of the cataclysm. Scientists agree that a poor debris management can have huge environmental impacts. One of them is flooding of large area caused by the obstruction of the water outlets. The large amount of loose material is also a safety concern. Moreover, they can hinder rescue efforts and actions to reach survivors. They are also a risk to public and environmental health (Upadhhyay, S. 2015).

Another consequence not well-understood is the pollution of the air. The density of particulate matter in the atmosphere (particularly PM 2.5 or higher) may increase. With regard to the Haiti earthquake, a very high level of PM 2.5 has been recorded in several parts of the country (Cap Haitien, Port-au-Prince, Petion-Ville) two years after the earthquake (Davis, E.M, and Rappaport, A. 2014). However, the relationship between particulates from the earthquake and the level of atmospheric particulates observed could not be determined by the authors (Davis, E.M, and Rappaport, A. 2014). Nonetheless, they believe that the earthquake itself or subsequent consequences has contributed to degrade the air quality in the country. The USAID rapid environmental assessment report acknowledged that dust from rubble cleanup and the increase of waste disposal may contribute to air pollution in the country (Kelly, C. and Solberg, S, 2010).

2.3.3. Impacts on marine and costal ecosystems

The 2010 earthquake had extensive impacts on the coast along the affected area and on the marine ecosystems. Hayes, G.P. et al. point out that satellite data show some “uplifted coral

reefs, widened beach faces, extensive shaking-related lateral spreading, compaction and liquefaction along approximately 50 km of coastline" p4.

Another impact on the marine ecosystem is sedimentation. Using a geophysical and coring data, McHugh, C.M. et al. (2011) document the offshore sedimentation effect of the earthquake. They measured short-live radioisotopes *Th* and *Be* in the sediments by gamma counting and used tracers to differenciate sediments coming from land and those reworking from the marine environment. However, this information has been used to better understand the marine signature for a large earthquake. There was no environmental impact assessment associated to this observation. This is a weakness of the already-rare studies on the environmental consequences of the cataclysm.

2.4. Earthquake preparedness and impacts reduction

Disaster management strategies follow a specific pattern that is described as the cycle of disaster management. Cohen (2011) highlights that all disaster management has four main stages: mitigation, preparedness, response, and recovery. The first two are essentially implemented during the pre-disaster period and the last two during the post-disaster time. Each of these phases includes actions and strategies that help to reduce or face the seriousness of the catastrophic event. The figure 3 below illustrates the process of disaster management through these four phases.

Figure 3: Cycle of Disaster Management (Naghdi, K. et al, 2001)

2.4.1. Mitigation / Prevention

Reducing earthquake impacts through proactive measures is very often designed by a more general term: mitigation. The Federal Emergency Management Agency (FEMA) defines mitigation as "an effort to reduce the loss of life and property, which includes existing structures and future construction, by lessening the impact of disasters" (FEMA, 2016). According to Hayward (2011), it is the first step of the disaster risk management system because it aims the reduction or elimination of any kind of danger that people or properties may endure due to the presence of a hazard. Abramovitz (2001) acknowledges the importance of mitigation in natural disaster management by arguing this following strong sentences:

> *While we cannot do away with natural disasters, we can eliminate those that we cause, minimize those we exacerbate and reduce our vulnerability to most. Doing this requires healthy resilient communities and ecosystems. Viewed in this light, disaster mitigation is clearly part of a broader strategy of sustainable development-making communities and nations socially, economically, and ecologically sustainable (p.40).*

2.4.2. Preparedness

The US Department of Homeland Security (DHS) defines Preparedness as "a continuous cycle of planning, organizing, training, equipping, exercising, evaluating, and taking corrective action in an effort to ensure effective coordination during incident response" (DHS, 2016). Cohen (2011) mentions that in the case of Haiti, the vision and action plan from the government can be compared to "Preparedness versus Reactiveness" approach described by Hense, Wyler, and Kaufmann (Hense, K., Wyler, B., Kaufmann, G. 2010 cited by Cohen, S. 2011). The economic capacity of Haiti to engage in impact reduction of natural disasters is almost insignificant. Moreover, this situation is due to the weakness of the country's institutions to

implement an effective mitigation plan. According to Hayward (2011), the first two steps of disaster management (mitigation and preparedness) are the basis for a successful management of an earthquake. (p.3). They have a direct effect on the protection of life and properties. Failure of their implementation results in loss and costly impacts (Hayward, 2011).

2.4.3. Response

The Federal Emergency Management Agency (FEMA) describes the response period as "the moment that includes actions taken to save lives and prevent further property damage in an emergency situation" (FEMA, 1998). The International Economic Development Council (IEDC) points out that the response stage addresses the immediate threats and needs such as life-saving, humanitarian needs (food, shelter, clothing, public health), damage assessment, cleanup, etc..(n.p).This stage presents enormous challenges. An important challenge is the coordination and sharing of information between relief agencies (Bharosa, N., Lee, J., and Jansen, M. 2010). Manoj, B.S and Baker A. H (2007) argue that in emergency response "sharing and dissemination of information is both critical and problematic." The Haiti 2010 international relief effort underwent as well the coordination and information weaknesses described above. Vince Beiser a writer of Wired magazine mentions that "over 900 NGOs responded to the Haiti earthquake, each with its own priorities, suppliers, and work style" (Beiser, V., 2010). Further, he explains that those NGOs "compete with one another for resources, duplicate one another's efforts, and generally get in one another's way" and that the lack of coordination and capacity is doubtful. (Beiser, V., 2010). However, a well-defined preparedness plan can help to facilitate coordination in case of emergency.

2.4.4. Recovery/ Rehabilitation

Disaster recovery is defined as “the differential process of restoring, rebuilding, and reshaping the physical, social, economic, and natural environment through pre-event planning and post-event actions (Rodriguez, H., Quarantelli, E.L., Dynes, R. 2007). The IEDC (2016) defines it as the “restoration of all aspects of the disaster’s impacts on a community and the return of the local economy to some sense of normalcy.” For earthquakes, strategies used in the recovery step depend largely on the availability of funds. Thus, a planning of earthquake recovery must consider the type, amount, and source of funding for the implementation (Wojtarowicz, M. 1997).

2.4.5. Importance of the Disaster Management Components

Arya A.S. (2002) highlights that these steps of disaster management can be combined in two main parts: mitigation (that includes risk analysis, prevention, and preparedness) and response (that includes search and rescue, humanitarian assistance and rehabilitation, and reconstruction) p. 15. The importance of those strategical components of the disaster management has been discussed and tested. At the world conference on Natural Disaster Reduction in Yokohama (Japan) in May 1994, the United Nations have acknowledged that “disaster prevention, mitigation, and preparedness are better than disaster response in achieving the goal of a safer world” and that disaster response can only yield temporary results and at very high cost. (Coppola, D.P. 2015). The results from the Haiti earthquake response and the cost level confirm that theory. Thus, Haiti needs to emphasize on prevention to reduce loss of life, high response cost, and poor results.

2.5. Past earthquake experiences

2.5.1. The case of 1986 San Francisco earthquake, California (USA)

The west coast of the United States is an earthquake-prone region because it is subject to constant plate motion that can trigger destructive earthquakes. The most recent earthquake that hit the area is the M 7.1 Loma Prieta on 1989 October 18th. Data show that 62 died and 3,757 injuries have been reported (Kibler, C.T, and Kerber, J.L. 1990). One important lesson from this disaster has been the generality of the regional and local disaster preparedness plans that did not help to effectively face the challenge and issues generated by the catastrophe (Kibler, C.T, and Kerber, J.L. 1990). This lesson drove to continuously local actions to enhance the community resilience. The more recent resilience plan called *Loma Prieta 25 Symposium Policy Actions* (LP25) is currently being implemented by the Association of Bay Area Governments (ABAG). The generality issue has been addressed, experts expect a higher level of effectiveness of the plan in case of disaster and a lower level of damage in the risk-prone area.

2.5.2. The 2011 Tohoku-Oki earthquake (Japan)

Japan is known as an earthquake-prone country because of its geological formation and its location along the Pacific plate (ADRC, 2008). In March 2011 the country was stricken by an M9 earthquake, a magnitude that only the Jogan earthquake of 13 July 869 as documented disaster may equal (Simons, M.et al., 2011). This earthquake occurred “in the megathrust where the Pacific plate subducts below Japan at an average rate of about 8 to 8.5 cm/ year (Simons, M. et al., 2011). The consequences were detrimental. As april 2015, the number of confirmed deaths was 15,891, 230 000 people lost their homes (Oskin, B. 2015). Furthermore, a study from the National Institute for Environmental Studies (Japan) found that the earthquake had an impact on global warming as a significant amount of halocarbons have been emitted to the atmosphere. Chlorofluorocarbons (CFC-11), hydrochlorofluorocarbons (HCFC-22), hydrofluorocarbons

(HFCs), sulfur hexafluoride, were released abundantly accounting for 4% or less of global emission in 2011. (Saito, T. 2015).

2.5.3. The 2016 Ecuador earthquake (Muisne and Pedernales towns)

On April 16, 2016, a 7.8 magnitude earthquake struck the northern of Ecuador. More than 135 aftershocks followed within the next 24 hours (Nikolaou, S. et al, 2016). The consequences were disastrous. 660 people died, 4 605 people injured, 30.223 people displaced, 9,738 buildings damaged, and 720 000 were in need of humanitarian assistance (USAID, 2016).

The Muisne coastal Ecuador Earthquake is a result of shallow thrust faulting on the plate boundary (USGS, 2016). The oceanic plate, Nazca, slides under the lighter South American plate and the strains accumulated are released producing the earthquake (Fountain, H. 2016). At this time, very few studies exist and explain the geotectonic processes as well as the effectiveness of the mitigation, preparedness, and response strategies.

2.6. Analysis of two of the most effective earthquake response plans in the world: USA and Japan

With regards to earthquake risk, Japan and the United States have some similarities. Both have experienced numerous high magnitude earthquake and set up complex response strategies. However, the management approaches differ in several ways. The following paragraphs briefly present these two best earthquake preparedness and response system and their approaches.

2.6.1. The US Earthquake Preparedness and Response System

The United States adopts a shared government approach for earthquake risk management. The localities are responsible for preparedness, mitigation, recovery, and response plans (Greer, A. 2012). However, the disaster coordination is made at the federal level. Several federal agencies are responsible for the coordination of response actions. The Federal Emergency

Management Agency (FEMA) has the statutory authority under the Robert T. Stafford Disaster Relief Act of 1998 for disaster response activities. It also coordinates life-saving assistance, response efforts, resource and human capital, search and rescue operations, and the long-term community recovery. The Department of Transport is responsible for movement restrictions, the U.S Army Corps of Engineers ensures infrastructures protection and restoration. The Environmental Protection Agency (EPA) ensures environmental short and long-term cleanup as well as the management of oil and hazardous materials (Greer A., 2012). Other federal agencies such as the Department of Energy, Department of Homeland Security, Department of Justice, Department of Agriculture, Department of Health and Human Services, the National Communications System, and the US Forest Services play a crucial role in managing an earthquake disaster in the U.S.

2.6.2. Japan Earthquake Preparedness and Response System

The Japan Disaster Management System is composed of three stages and addresses all of the disaster phases (mitigation, preparedness, response, and recovery). The First stage is at the national level. At this stage, a council (Central Disaster Management Council) formulates and promotes the implementation of the basic disaster management plans (BMP) and some designated government organizations and public corporations ensure the implementation and formulation of the Disaster Management Operation Plans (Sekimov, A., 2012). This first stage is coordinated by the Prime Minister. At prefectural level, the same system is set up and is coordinated by the governor. A prefectural disaster management council formulates and implement local disaster management plans with the participation of designated local government organizations and local public corporations. At the municipal level, mayors of cities,

towns, and villages coordinate the municipal disaster management council, which formulate and promote the implementation of the local disaster management plans.

2.7. Summary of some results of research studies on the Caribbean faults

There is an abundant literature about the seismic activities in the Caribbean region. Before and after the Haiti's recent earthquake, efforts have been multiplied in the scientific world to understand seismic hazards of the Caribbean region. These efforts depend on the understanding of the current motion of the existing microplates between the Caribbean and North American plates (Benford, B., DeMets, C., and Calais, E. 2012). The Caribbean plate is located between the Cocos, Panama, North Andes, South America, and North America plates. The northern part of the Caribbean plate is more seismically active and object of several studies.

Parsons, T. and Geist, E.L. (2009) calculated the probability of tsunamis at coastal sites throughout the Caribbean region. As a result, they identify the areas that may be most affected by and more exposed to tsunamis generated by an earthquake and produced a tsunami probability map of the region. Hayes, G.P. et al (2013) quantifies the seismic hazard in the Lesser Antilles subduction zone in the Caribbean. They show that a significant national or potentially international disaster may occur following an earthquake shaking effect in the region (p.9). Dolan, J.F. and Mann, P. (1998) present and describe the results of the fist marine geophysical investigations of the northern Caribbean plate (the 250 km-wide zone located between the Caribbean and North America Plate in the north-central Caribbean region). They describe the seismicity of the region and present a model explaining the tectonic evolution of the north-central region during the late Cenozoic time.

2.8. Risks, Vulnerability, and Disasters in Haiti

The United Nations Disaster Relief Organization (UNDRO) defines the notion risk as "the expected physical damage and the connected losses that are computed from the convolution of the probability of occurrence of hazardous events and the vulnerability of the exposed elements to a certain hazard." Haiti's vulnerability to risks and disasters is obvious. The country is highly exposed to natural disasters and possesses one of the highest city urbanization rate in the Caribbean region (third behind Cuba and the Dominican Republic with 49.6 % in 2010 and 78.9% projected for 2050) (USAID, 2010)

Besides the vulnerability related to densely populated areas and critically inappropriate dwellings, the fault lines crossing the country are highly active. Paultre (2012) indicates that Haiti is located between two major tectonic plates, the Caribbean and the North American plates that slide at a 20 mm/year speed (Paultre, P. 2012). This economic, social, structural situation makes of Haiti a high-risk country to the ever-present earthquake hazard. The figure 4 below shows the two faults and the earthquakes generated over time.

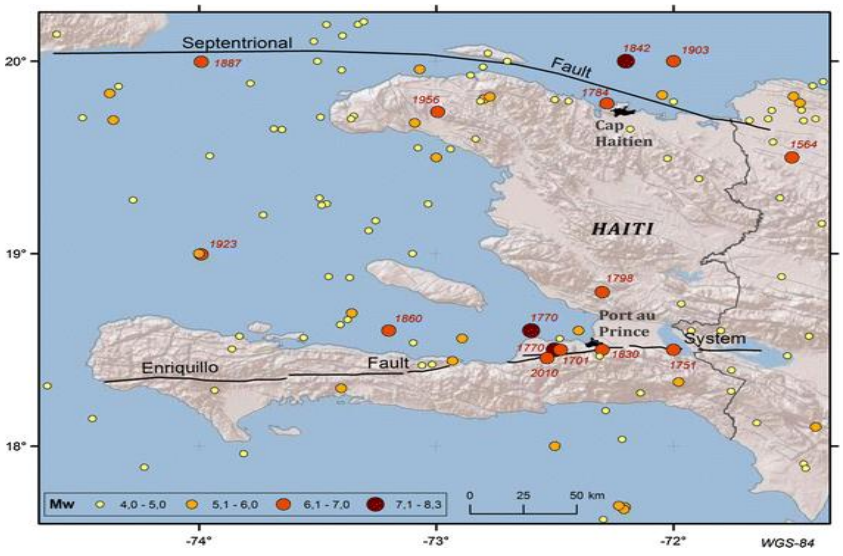


Figure 4. Seismicity of Haiti (SISMO-Haiti Project, 2012)

2.9. The Caribbean Disaster Emergency Management Agency

At regional level, efforts for a faster response have been made. Therefore, a regional intergovernmental agency was created in 1991 and is called Caribbean Disaster Emergency Management Agency (CDEMA). It comprises 18 states in the Caribbean Common Market (CARICOM) and is also open to non-CARICOM states. (CDMA, 2016). Its objective is to better manage disaster response in the region. To attain this purpose, they group the state-members in four (4) sub-groups with a leading operative unit dubbed sub-region focal point (SRFP). The following table shows the sub-regional operation units and the states pertaining to the groups.

Table 2-1. Focal Points and the Participating States of the Caribbean Disaster Emergency Agency

Sub-Regional Focal Point	Responsible for			
Antigua	Anguilla	Virgin Islands	Montserrat	St. Kitts/Nevis
Barbados	Dominica	Saint Lucia	St. Vincent & the Grenadines	-
Jamaica	Bahamas	Belize	Haiti	Turks & Caicos Islands
Trinidad &Tobago	Grenada	Guyana	Suriname	-

Source: CDEMA, 2015

A look at the table above shows that Haiti is in the third sub-regional group with the Bahamas, Belize, Turks and Caicos Islands, as well as Jamaica as the focal point. This structure has also played an important role in the 2010 earthquake response. Haiti can learn from their intervention strategies to strentghten its own disaster preparedness and response system.

2.10. The Haitian National System for Risks and Disasters Management

The World Bank defines a national disaster system as “a system that is comprised of formal and informal interactions of policies, institutions, financial mechanisms, and regulations.”

Considering the components of this definition some analysts argue that even before the 2010 earthquake, Haiti had an ill-functioned disaster management system. The Haitian national disaster system is managed by the Directorate of Civil Protection (DPC: in French) (analogous to the FEMA in the U.S). This directorate is part of the ministry of Interior and functionally composed of representatives of the main ministries and components of the government. Their sphere of activity is centered on awareness and intervention especially in case of hurricanes. With a limited budget, they rather cooperate with international organizations. Looking at this situation, Hayward (2011) points out that: "The January 2010 earthquake in Haiti illustrates how devastating an earthquake can be in a place where mitigation and preparation policies have gone unattended." The figure below shows the actors/ organizations composing the national disastersystem.

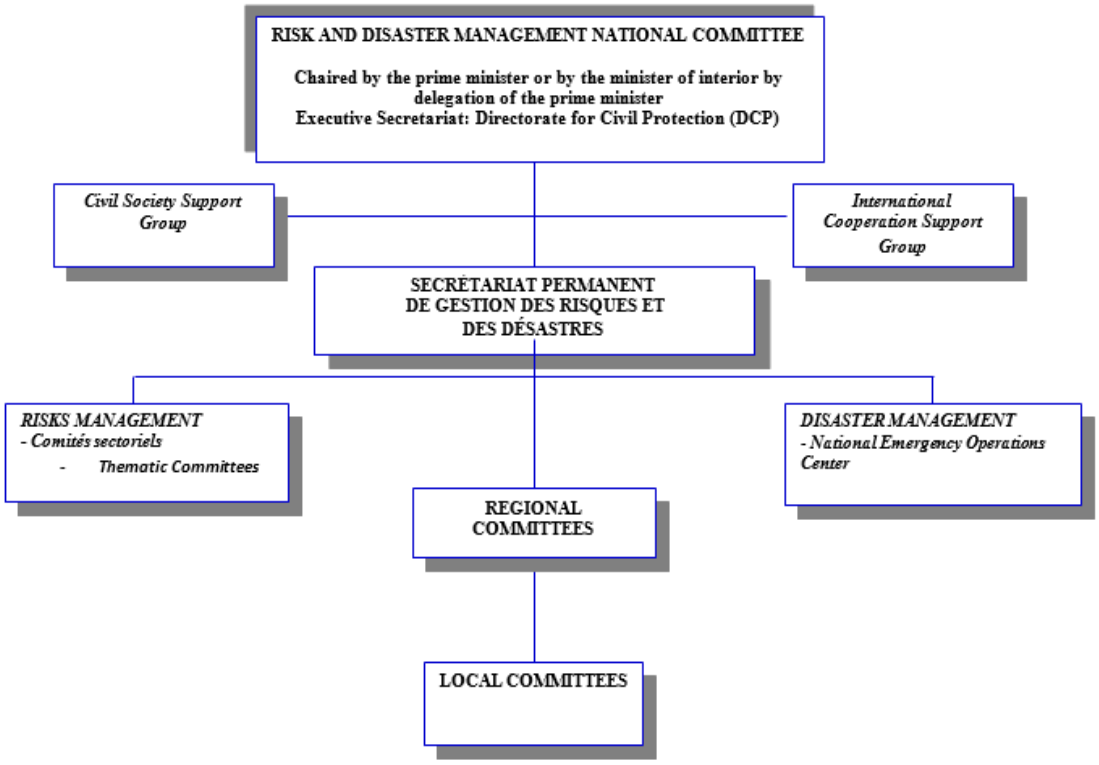


Figure 5. Organizational Chart of the Haiti's Directorate of Civil Protection (DPC/Internews, 2010

CHAPTER 3. METHODOLOGY

3.1. Study area

The disastrous earthquake that hit Haiti at the beginning of 2010 had its epicenter approximately 17 miles from Port-au-Prince, the Capital. Other cities relatively close to the capital such as Leogane, Petit-Goave, and Jacmel have been also struck (GoH/PDNA, 2010). The map below shows the populated areas affected by the earthquake and its intensity in each of these areas.

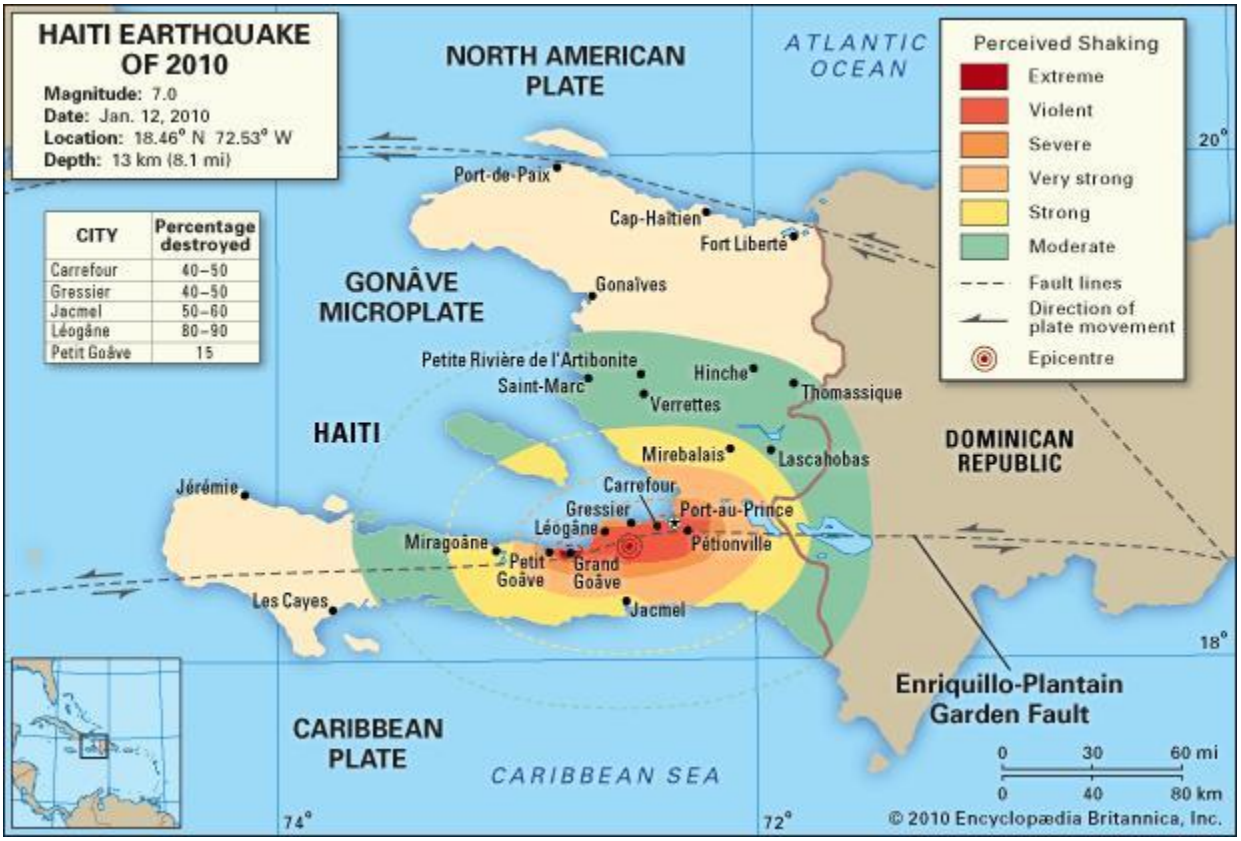


Figure 6. Haiti Earthquake Intensity Distribution and Populated Areas Affected (EB, 2010)

The country itself is located in a high-risk region and is crossed by two active plates: the Septentrional fault and the Enriquillo Plantain Garden fault. The map below shows the location of these two (2) faults in the Caribbean region in the areas they may affect in Haiti.

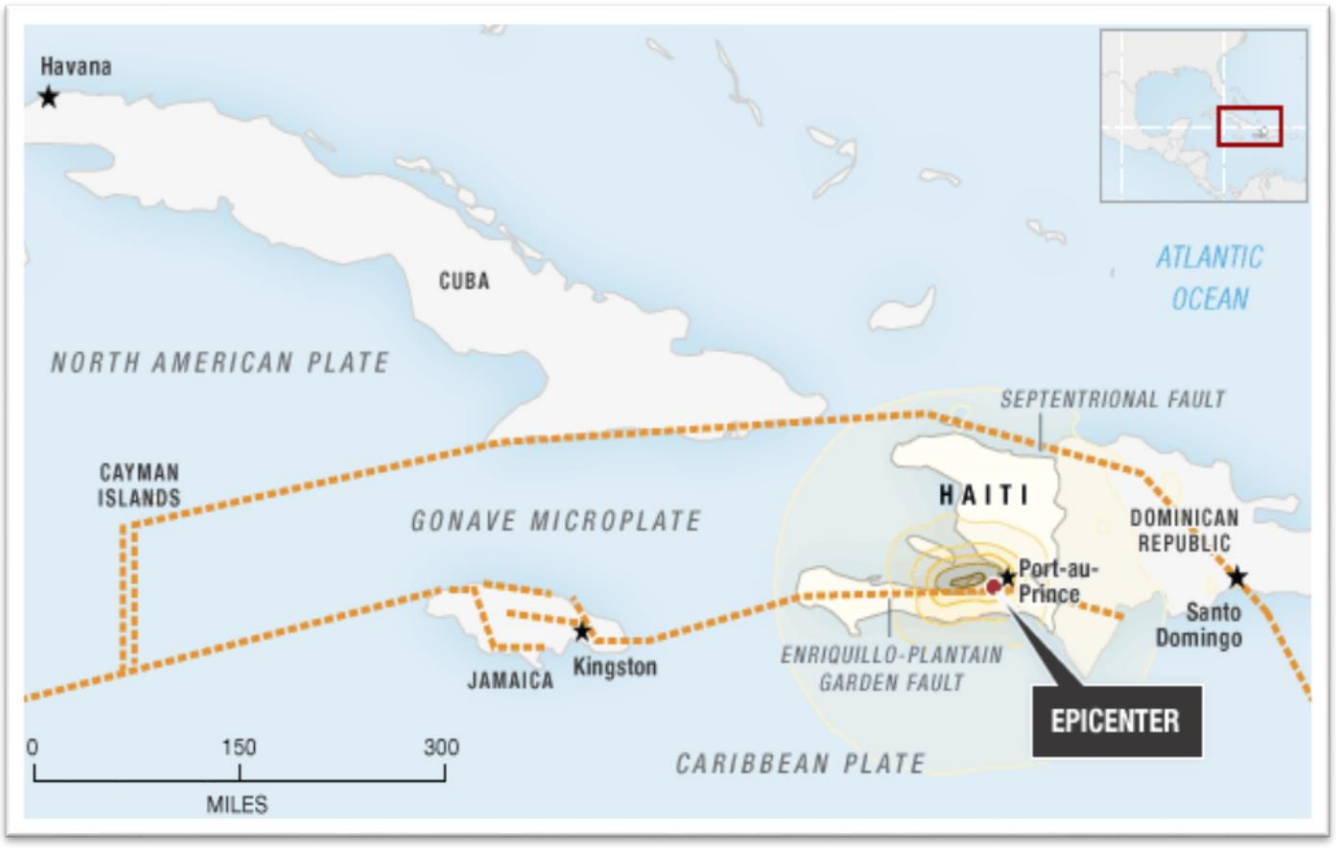


Figure 7. Haiti Location and the Seismic Plates in the Caribbean Region (Harris Richard, 2010)

3.2. Approach

3.2.1. SWOT-AHP Analysis

Various approaches are used in the analysis of an institution or country's policies and strategies. Among them, the SWOT analysis is known as a straightforward method. The acronym SWOT stands for Strengths-Weaknesses-Opportunities-Threats. This strategic management method is used for analyzing the effectiveness of strategies and for situational analysis in management. It is also used as a tool for decision-making in order to analyze the internal and

external factors that may impact a process, an institutional decision or a project. It has been successfully used for the development of environmental management system and environmental impact assessment (Hai, H.L, 2011). Harrisson, J.P. (2010) defines it as "an examination of an organization's internal strengths and weaknesses, its opportunities for growth and improvement and the threats the external environment presents to its survival."

The analytic hierarchy process (AHP) is used to determine the weight of internal and external factors. It is a method used to choose the factors that are important in decision-making (Katz, J.M. 1990). Shapira & Simcha mention that "the fundamental approach of AHP is to break down a big problem into several small problems; while the solution of these small problems is relatively simple, it is conducted with a view to the overall solution of the big problem." p.308. This method combines expert's judgment and appropriate mathematical model to determine the factors' weight (Xie, L. 2014). It also helps to simplify a complex decision problem by structuring it, identifying the decision factors and measuring their importance (Zhang, H & Chen, M. 2013).

The combination of SWOT and Analytic Hierarchy Process is a successful way to remove the imperfections of the traditional SWOT method, which display a strong subjectivity (Kong, H. 2012). The SWOT-AHP is a hybrid method that helps to use the SWOT more efficiently by combining qualitative and quantitative criteria. Moreover, it helps to compare the criteria used for the results.

3.2.1.1. Implementing the SWOT-AHP Analysis

In this study, the inputs (decision factors) necessary for preparing the advanced SWOT-AHP method are literature-derived. They were identified, classified, and collected from exploring

data and facts from three main reports about "Lessons learned from the Haiti Earthquake" [2]. These reports are available from organizations and institutions that involved in the response and recovery process and were written at least 6 months after the earthquake and were based on surveys, interviews, and poll results on the field.

To evaluate the importance of critical decision factors of the management system put in place as part of the earthquake response, we weight each factor. Because the number of pairwise matrices increases with the number of factors, 4 or 5 factors were chosen for each component of the SWOT matrix. The choice of the weight values was made according to the importance of each of these factors. The prioritization techniques that evaluate the internal factors according to their importance, priority, and score and the external factors, according to the importance, probability, and score were applied. Two matrices were used to facilitate this prioritization: the Internal factors Evaluation (IFE) matrix and the External Factors Evaluation (EFE) Matrix (Rafee, N et al, 2007).

3.2.2. External Factor Evaluation and the Internal Factor Evaluation Matrices

3.2.2.1. The External Factor Evaluation (EFE) Matrix

The External Factor Evaluation of a firm/organization is a tool used in strategic management to prioritize the opportunities and threats that it is facing. In other words, it evaluates the external environment. This tool is also used in fields other than business, policy analysis, and strategic planning to analyze the factors that are helpful or harmful to attain an objective. This matrix focuses on the opportunities and threats to this stated objective.

[2] (1-Haiti Earthquake Response: Emerging Evaluation Lessons (2011) written by Jonathan Patrick and commissioned by Haiti Evaluation Task Force, 2- Inter-Agency Real-Time evaluation of the humanitarian response to the earthquake in Haiti (2011) written by Silvia Hidalgo, 3- Haiti's 2010 earthquake and the US response: Lessons for Asia-Pacific Disasters (2015) written by James A. Schear

In this research, the opportunities and threats identified are weighted in order to measure their importance. A total weight is determined by the addition of weights associated with the opportunities and threats. David F.R. (2001), mentions that scores greater than 2.5 indicate that a firm/organization external environment is healthy.

3.2.2.2. The Internal Factor Evaluation (IFE) Matrix

As the EFE, the IFE matrix is a tool that helps to reveal an organization's weaknesses and strengths (Jurevicius, O. 2013). It can be broken down into strengths factors and weaknesses factors. Like the external factors, we weight the strengths and weaknesses factors identified to measure their importance and how they impact the effectiveness of the strategies used during the response time. A total weight is also determined by the addition of each individual value.

3.2.3. Steps of elaboration of the SWOT-AHP methodology

A four-step process helps to deal with the complexity of the problems.

a) A situational Assessment (SWOT Analysis). In this step, factors are selected and a hierarchy is made by taking into account the importance or influence of each factor on the operational environment of a policy, strategy or industry. In other words, a relative priority is assigned to each factor considering their respective category.

b) A pairwise comparison matrix. After establishing the hierarchy between factors, a judgement matrix is constructed (by pair). In this matrix, comparisons between each pair are made. It is judged which factor is preferred or has a greater importance or whether the two factors are identical or not. Single-digit numbers are used to indicate the importance of an element of the matrix a_{ij} , where the value of a_{ij} is decided based on the relative importance between targets i and j. The pairwise comparison matrix or judgement matrix obtained can be written as:

$$A = \begin{vmatrix} a11 & \ldots\ldots & a1n \\ . & . & . \\ an1 & \ldots\ldots & ann \end{vmatrix} \quad (1)$$

a_{ij} can be considered as approximately the rate ratio of i and j, with $a_{ij}=w_i/w_j$. The reciprocal of each a_{ij} element is expressed as $1/a_{ij}$. When i=j, then $a_{ij} = 1$. So, the value of the pairwise comparison matrix A can be expressed as:

$$A = \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{pmatrix} = \begin{pmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_n \\ \cdots & \cdots\cdots & \cdots & \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_1 \end{pmatrix} \quad (2)$$

Rows in the matrix express the ratio of weights of each individual factor with regard to the others. The Saaty scale is used to express how many times more dominant or more important an element is than another. The table 3-1 below shows the Saaty rating scale indicating the values of a_{ij} elements and their meaning and implications.

Table 3-1. The Saaty Rating Scale

The value of a_{ij}	Implications
1	i and j have the same importance
3	j is more important than i
5	j is obviously more important than i
7	j is strongly more important than i
9	j is extremely more important than i
2,4,6,8	median value to above-mentioned value
Reciprocal	if the ratio of importance in the elements i and j is aij, then the ratio of importance of the element j and i is $a_{ji} = 1/a_{ij}$

Source: Hongshen, Z. and C. Ming. 2013

Determining the importance of each criterion can be challenging. It is necessary to assign a relative ranking to each criterion to indicate their relative degree of importance. This weighting strategy of the criteria considers the relations between each of them simultaneously. Therefore, the

pairwise matrix is a method that allows to evaluate alternatives and provide a means to rank decision-making criteria (Masur, A. & Salustri, F. A. 2007).

c) Key factor weight is calculated

After obtaining the pairwise comparison matrix, the weight (w) is calculated. Several methods are usually used to determine it. Some of them are the eigenvalue method, the minimized square method, and the root method. In this study, the root method is used. It is expressed by the following formula:

$$w_i = \frac{\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}}{\sum_{k=1}^{n}\left(\prod_{j=1}^{n} a_{kj}\right)^{1/n}}, i = 1, 2, \cdots, n \quad (3)$$

d) The overall impact/priority score

The internal factors (strengths and weaknesses) and external factors (opportunities and threats) do not have the same impact on the effectiveness of an organization, company or policy. Strengths are considered as beneficial, thus, relatively more important than weaknesses in many instances. Theoretically, the internal factors are attributed an overall priority score and the external factors an overall impact score. Theses scores indicate whether the factor is a major (4) or a minor (1) for the response strategy.

CHAPTER 4. ANALYSIS OF FACTS AND KEY FINDINGS

4.1. SWOT-AHP Analysis

To analyze the scope of the effectiveness of the response time, five (5) generally accepted elements of strength, four (4) weaknesses, four (4) factors of opportunity, and four (4) threats are compiled and used in the mathematical advanced SWOT model (see table 4.1). Bhattacharjee, A. & Lossio, R. (2011) defines effectiveness as the measure of the "extent to which an activity achieves its purpose, or whether this can be expected to happen on the basis of the outputs." In the case of the Haiti earthquake response, some objectives have been met while others were not fully accomplished. We point out the internal and external factors that contributed to success or failure in this case. Woods (1997) argues that the SWOT analysis method gives a systematic examination of the factors listed and helps to select the most suitable strategies by knowing how the threats and weaknesses, as well as the strengths and opportunities, influence the final result. The figure 8 below shows the hierarchical structure of the SWOT matrix.

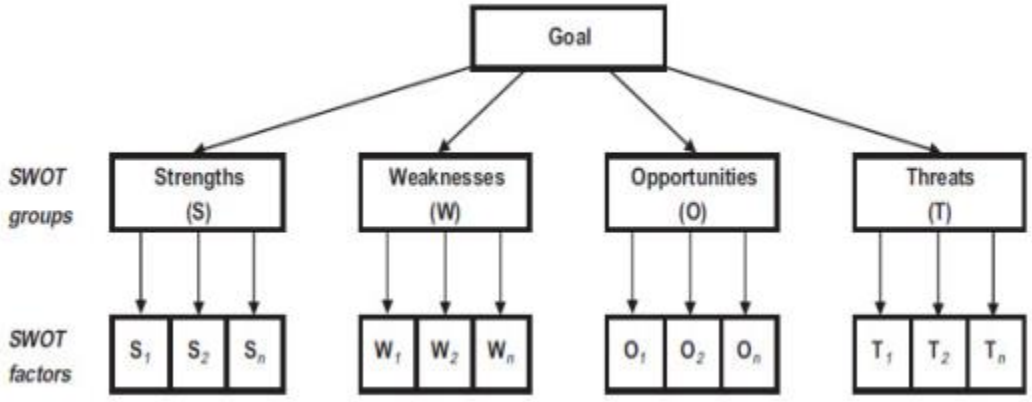


Figure 8. Hierarchical structure of the SWOT matrix (Gorener A, Toker K, and Ulucay, K. 2012)

Table 4-1. S-W-O-T Factors Influencing the Response Time of the 2010 Haiti Earthquake

Strengths	***Weaknesses***
S1. Promptitude and mobilization of search aid and rescue S2. Response fund mobilization efficacy S3. Adequate response to the critical needs (food, water, medicines, etc...) S4. No major epidemics have been struck immediately as a consequence of the disaster S5. Presence of a functional government as a legitimate interlocutor	W1. Lack of coordination and leadership among stakeholders W2. Absence early on of a unified and integrated logistics command and control structure W3. Inexperience of the local government and the civil society in managing earthquake disasters W4. Incomplete situational awareness in the early time after the earthquake that made it difficult to determine requirements and priorities
Opportunities	***Threats / Challenges***
O1. Possibility to redefine the failed structure of the country in several sectors (infrastructure, regulations, economy, etc…) O2. Possibility to promote the country's potentiality, increase its visibility and open it to the global market for prosperity and stability O3. Potential for collaboration and sharing of knowledge between nationals and international experts O4. Potential for using a large number of jobless young people for response activities	T1. Unavailability of funds pledged or reduction of the amount expected T2. Triggering of other disasters such as flood, hurricanes, epidemics requiring that the response fund is reoriented T3. Political instability due to the national election period T4. Lack of trust and feeling of marginalization of civil society organizations

4.2. Evaluation of external and internal elements

4.2.1- Evaluation of internal factors

As the EFE, the internal factor evaluation matrix is a strategic management tool for assessing the major strengths and weaknesses of a policy, an industry or an organization. It shows the capacity of taking advantages of the evident strengths and minimizing weaknesses that prevent the full success of the given strategy. The table 4-2 below presents the strengths and weaknesses selected in the case of the Haiti earthquake response strategy.

Table 4-2. Internal Factors of the Haiti Earthquake Response Effort

Strengths (E1)	S1 Promptitude and mobilization of search aid and rescue
	S2 Response fund mobilization efficacy
	S3 Adequate response to the critical needs (food, water, medicines, etc...)
	S4 No major epidemics have been struck immediately as a consequence of the disaster
	S5 Presence of a functional government as a legitimate interlocutor
Weaknesses (E2)	W1 Lack of coordination and leadership among stakeholders
	W2 Absence early on of a unified and integrated logistics command and control structure
	W3 Inexperience of the local government and the civil society in managing earthquake disasters
	W4 Incomplete situational awareness in the early time after the earthquake that made it difficult to determine requirements and priorities

An important step of the SWOT-AHP hybrid method is to make comparisons between factors. However, in order to make these comparisons, two questions must be answered. The first is which factor is greater and the second to what extent (Kurttila, M. et al. 2000). Table 4-3 below shows the judgment matrix for strengths (E1) and weaknesses (E2) of the response strategies after the Haiti 2010 earthquake. Next, the factors are compared between themselves through the tables 4-4 and 4-5.

Table 4-3. Pairwise Comparison Matrix of Strengths and Weaknesses

A2	E1	E2	Weight (1)
E1	E1/E1 = 1	E1/E2 =2	0.67
E2	E2/E1 = 1/2	E2/E2 = 1	0.33

E1: Strengths E2: Weaknesses

A2: Strengths and Weaknesses judgment matrix

As previously mentioned, the inputs of E1 and E2 are compared to each other to quantify their relative importance through detailed judgment matrices by considering the Saaty scale described in the previous chapter. The table 4.4 below represents the comparison of the strength factors and the table 4.5, the weaknesses factors.

Table 4-4. Pairwise Comparison Matrix for Strengths

E1	S1	S2	S3	S4	S5	$\sqrt[n]{(\prod_{j=1}^{n} aij)}$	weight (2)
S1	1	2	5	4	3	2.6051	0.4053
S2	1/2	1	3	4	5	1.9743	0.3072
S3	1/5	1/3	1	1/3	3	0.5818	0.0905
S4	1/4	1/4	3	1	3	0.8913	0.1387
S5	1/3	1/5	1/3	1/3	1	0.3748	0.0583

S = strength factors (with i= j = 1, 2, 3, 4, 5)

Table 4-5. Pairwise Comparison Matrix for Weaknesses

E2	W1	W2	W3	W4	$\sqrt[n]{(\prod_{j=1}^{n} aij)}$	weight (2)
W1	1	5	3	5	2.5900	0.5292
W2	1/5	1	1/3	1/3	0.3860	0.0789
W3	1/3	3	1	1/3	0.7598	0.1552
W4	1/5	3	3	1	1.1583	0.2367

W = weakness factors (with i=j= 1, 2, 3, 4)

4.2.2.1. Weight of internal factors

For strength factors, the *promptitude and mobilization of search aid and rescue (S1)* has received the highest score because of its importance in saving survivor's life. The order of the other factors is: *Response fund mobilization efficacy (S2)* because of its importance in aid

mobilization for the neediest. It receives a slightly equal score to S1. Then, *adequate response to critical needs (S3)* and *absence of epidemics in the first days as a consequence of the disaster (S4)* have received respectively the average scores and are considered less important than the first two factors. *Presence of a functional government as a legitimate interlocutor (S3)* has received a lower priority compared to the other factors. For weakness factors, the strict order is W1>W2>W3>W4.

Table 4-6. Score of Strengths and Weaknesses

	Key internal factors	Score
Strengths (E1)	**S1** Promptitude and mobilization of search aid and rescue	5
	S2 Response fund mobilization efficacy	3
	S3 Adequate response to the critical needs (food, water, medicines, etc...)	3
	S4 No major epidemics have been struck immediately as a consequence of the disaster	2
	S5 Presence of a functional government as a legitimate interlocutor	1
Weaknesses (E2)	**W1** Lack of coordination and leadership among stakeholders	5
	W2 Absence early on of a unified and integrated logistics command and control structure	3
	W3 Inexperience of the local government and the civil society in managing earthquake disasters	2
	W4 Incomplete situational awareness in the early time after the earthquake that made it difficult to determine requirements and priorities	1

After assigning an overall priority score to the internal factors, the weighted score is calculated. The table 4-7 below shows the calculation and values of the weighted score for the individual factors and the total weighted score for the strengths and weaknesses.

4-7. IFE Matrix of the Effectiveness of Response Time

	Key Internal factors	*Weight (W1)*	*Weight (W2)*	*Actual Weight W1xW2*	*Score*	*Weighted Score*
Strengths (E1)	**S1** Promptitude and mobilization of aid and rescue	0.6700	0.4053	0.2716	5	1.3580
	S2 Response fund mobilization efficacy		0.3072	0.2058	3	0.6174
	S3 Adequate response to the critical needs (food, water, medicines, etc…)		0.0905	0.0606	3	0.1819
	S4 No major epidemics have been struck immediately as a consequence of the disaster		0.1387	0.0930	2	0.1860
	S5 Presence of a functional government as a legitimate interlocutor		0.0583	0.0391	1	0.0391
Weaknesses (E2)	**W1** Lack of coordination and leadership among stakeholders	0.3300	0.5292	0.1746	5	0.8730
	W2 Absence early on of a unified and integrated logistics command and control structure		0.0789	0.0260	3	0.0780
	W3 Inexperience of the local government and the civil society in managing earthquake disasters		0.1552	0.0512	2	0.1024
	W4 Incomplete situational awareness in the early time after the earthquake that made it difficult to determine requirements and priorities		0.2367	0.0781	1	0.0781
Total				1.0000		3.5139

4.2.2. Evaluation of External Elements

The external factor evaluation is a strategic tool that helps to determine the capacity to take advantage of existing opportunities adequately while minimizing threats (Hongshen, Z. and Ming, C. 2013). Table 4.2 presents the main opportunity and threat factors selected to analyze the effectiveness of the response time of the Haiti 2010 earthquake.

Table 4-8. External Factors of the Haiti Earthquake Response Effort

Opportunities (B1)	**O1** Possibility to redefine the country failed structure in several sectors (infrastructure, regulations, economy, etc...) **O2** Possibility to promote the country's potentialities, increase its visibility and open it to the global market for prosperity and stability **O3** Potential for collaboration and sharing of knowledge between nationals and international experts **O4** Potential for using a large number of jobless young people for response activities
Threats (B2)	**T1** Unavailability of funds pledged or reduction of the amount expected **T2** Triggering of other disasters such as flood, hurricanes, epidemics, requiring that the respond fund is reoriented **T3** Political instability due to the national election period **T4** Lack of trust and feeling of marginalization of civil society organizations

As previously done for the internal factors, a comparison between the external factors through a judgment matrix is made (table 4-9). B1 represents the opportunities and B2 the threats/limitations. Moreover, individual factors are compared to each other (tables 4-10 and 4-11) to point out their relative priority.

Table 4-9. Pairwise Comparison Matrix of Opportunities and Threats

A	B1	B2	Weight (3)
B1	B1/B1 = 1	B1/B2 =2	0.67
B2	B2/B1 = 1/2	B2/B2 =1	0.33

B1: Opportunities B2: Threats/limitations

A: Threats and opportunities judgment matrix

The table 4-9 (above) shows the relationship between the opportunities and the threats for the Internal Factor Evaluation. Opportunities weight , on a gross basis, 67% of the total of the external factors that may affect the effectiveness of the response strategies. To better analyze each component, we will split the above pairwise comparison matrix and analyze its components.

Table 4-10. Pairwise Comparison Matrix for Opportunities

B1	O1	O2	O3	O4	$\sqrt[n]{(\prod_{j=1}^{n} aij)}$	weight (4)
O1	1	3	5	4	2.783	0.5245
O2	1/3	1	3	5	1.495	0.2818
O3	1/5	1/3	1	3	0.667	0.1257
O4	1/4	1/5	1/3	1	0.361	0.0680

O = Opportunity factors (with i= j = 1, 2, 3, 4)

Table 4-11. Pairwise Comparison Matrix for Threats

B2	T1	T2	T3	T4	$\sqrt[n]{(\prod_{j=1}^{n} aij)}$	weight (4)
T1	1	5	5	7	3.6171	0.6116
T2	1/ 5	1	3	5	1.3161	0.2225
T3	1/5	1/ 3	1	3	0.6687	0.1131
T4	1/7	1/ 5	1/3	1	0.3124	0.0528

T = Threat factors (with i=j= 1, 2, 3, 4)

4.2.1.1 – Weight of external factors

The assessment of factors depends on their efficiency with regard to the final result. In the case of the opportunity factors, the *possibility to redefine the country failed structure in several sectors* (O1) has received the highest weight, followed by the *potentiality to promote the country's potentiality and open it to the global market* (O2), *the possibility for collaboration and knowledge sharing between national experts and expats* (O3), *and the potential to use the large number of jobless citizens to rebuild the country* (O4). For threat factors, the order of importance is as follows: the *unavailability of funds pledged by the international community* (T1) is the greatest threat, the *triggering of other disasters such as flood, hurricanes, and epidemics* (T2) is the second threat, the *political instability due to the elections in the country* (T3) is the third threat, and finally, the *lack of trust and feeling of marginalization of the civil society organizations* (T4) is the fourth threat. The table 4-12 below shows the score of each of these factors for their computation into the total weighted matrix.

Table 4-12. Score of Opportunities and Threats

	Key external factors	Score
Opportunities	**O1** Possibility to redefine the country failed structure	4
	O4 Possibility to promote the country's potentialities, increase its visibi lity and open it to the global market	3
	O2 Potential for collaboration and sharing of knowledge between nationals and international experts	2
	O1 Potential for using a large number of jobless young people for response activities	1
Threats (B2)	**T1** Unavailability of funds pledged or reduction of the amount expected	4
	T2 Triggering of other disasters such as flood, hurricanes, epidemics, requiring that the respond fund is reoriented	3
	T3 Political instability due to the national election period	2
	T4 Lack of trust and feeling of marginalization of civil society organizations	1

As previously decided for the internal factors, after assigning an overall impact score to the external factor (opportunities and threats), a weighted score is calculated. The table 4-13 below shows the values of the individual weighted scores and the total weighted score for both the opportunity and the threat factors.

4-13. EFE Matrix of the Effectiveness of the Response Time

	Key Internal factors	*Weight (W3)*	*Weight (W4)*	*Actual Weight W3xW4*	*Score*	*Weighted Score*
Opportunities (B1)	**O1** Possibility to redefine the country failed structure	0.67	0.5245	0.3514	3	1.0542
	O2 Possibility to promote the country's potentialities, increase its visibility and open it to the global market		0.2818	0.1888	2	0.3776
	O3 Potential for collaboration and sharing of knowledge between nationals and international experts		0.1257	0.0842	2	0.1684
	O4 Potential for using a large number of jobless young people for response activities		0.0680	0.0456	1	0.0456
Threats (B2)	**T1** Unavailability of funds pledged or reduction of the amount expected	0.33	0.6116	0.2018	4	0.8072
	T2 Triggering of other disasters such as flood, hurricanes, epidemics, requiring that the respond fund is reoriented		0.2225	0.0734	3	0.2202
	T3 Political instability due to the national election period		0.1131	0.0373	2	0.0746
	T4 Lack of trust and feeling of marginalization of civil society organizations		0.0528	0.0174	1	0.0174
Total				1.0000		2.7652

4.3. Interpretation

The internal factors play a leading role in the effectiveness of the Haiti earthquake response (score 3.5139 compared to 2.7652 for external factors). The weaknesses and strengths can be easily identified and outnumber the opportunities and threats/limitations. The country and its partners need to emphasize on the strengths to prepare any eventual similar disaster. The country's proximity to the United States (without underestimating the role of the other stakeholders) favors the majority of the strengths observed such as immediate response for rescue, food, and medicines. The weaknesses are also important in designing a preparedness

plan. They are the barriers that prevented a totally effective response. Emphasis on coordination, logistics, determination of priorities, and local sensitization and disaster education are the main strategies that can be addressed. For opportunities, collaboration with disaster scientists, professionals and institutes for sharing and improvement of knowledge can integrate the preparedness plan for a better result. Finally, minimizing potential threats such as potential for epidemics in a fragile environment needs to be considered. The figure 9 below shows the strategies for a better effectiveness base on the SWOT-AHP method applied. It shows that in the case of the Haiti earthquake response system, two strategies can be implemented for a better result based on the past experience. The first is the weakness-Opportunity strategy (WO Strategy) and the second is the Strength-Opportunity (SO) strategy. WO means minimize the weaknesses by taking advantage of opportunities and SO means emphasize on strengths to maximize opportunities.

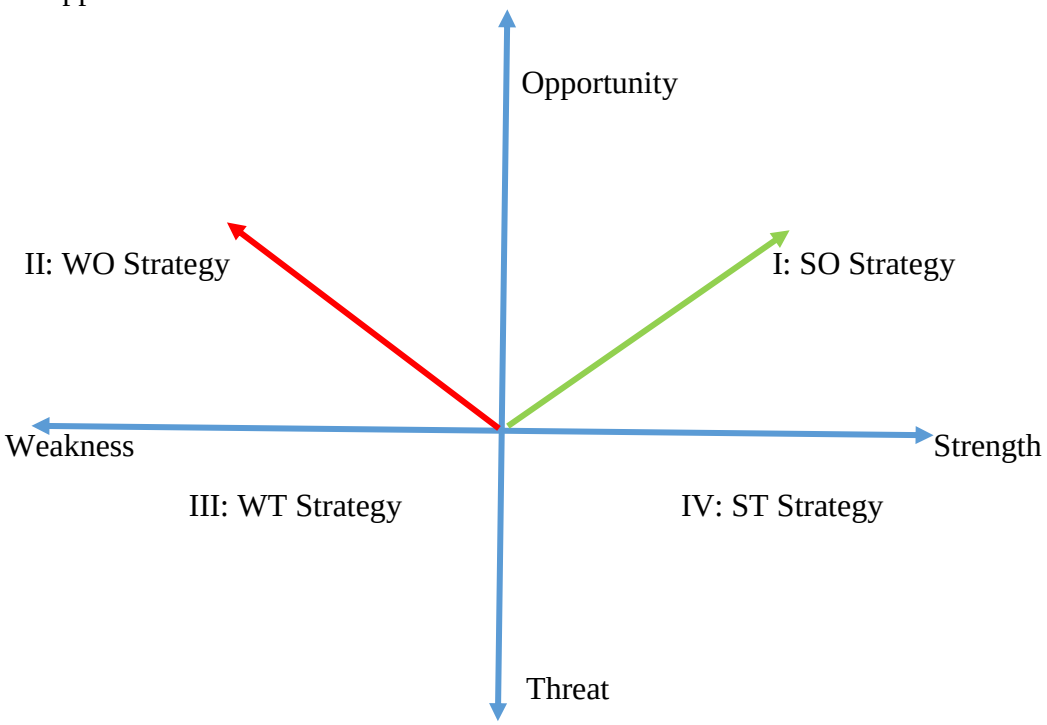


Figure 9. Haiti Earthquake Response Evaluation Diagram

CHAPTER 5. CONCLUDING COMMENTS AND RECOMMENDATIONS

5.1. Conclusion

Understanding the effectiveness of the Haiti Earthquake response is an essential step for better preparing any eventual similar disaster. Application of the SWOT-AHP model gives an idea of the extent to which the combination of the internal and external factors played a role in the controversial poor result of the disaster response despite its high financial cost. As there is a necessity to reinforce the country's preparedness capacity in order to deal with its ever-present hazard, the application of the model shows that the weighted score of the internal factors was more important than the weight of the external factors with a weighted of 3.5139 for the first one compared to 2.7652 for the second. Moreover, the model shows that weakness factors have contributed significantly to limiting a full effectiveness of the massive effort unfolded to help the country to cope with the consequences of the disaster. Thus, it is concluded that strategies for a better response preparation should include a weakness- opportunity (WO) strategy to reduce the internal weakness factors and take advantage of the opportunities and a Strength-Opportunity (SO) strategy to emphasize on the importance of strengths and enhance their impacts while taking advantage of the opportunities. These considerations can be integrated in a mitigation and preparedness plan to improve the national disaster management system.

5.2. Recommendations

Haiti is still struggling to ameliorate the socioeconomic situation of its population and increase the government's financial capability, two conditions necessary for the mitigation of the risk of natural disasters. Meanwhile, in the event of an unexpected cataclysm, the international humanitarian support remains critical. The identification of the weaknesses and strengths of the past earthquakes is essential for a better result. The SWOT analysis brings out the importance of

strengths, weaknesses, opportunities and threats on the effectiveness of the response strategies to ensure that the scope of the disaster itself and its secondary threats are contained. In order to avoid that the same factors limit the success and effectiveness of response strategies in the future, the recommendations made are based on preparedness strategies and their corollaries.

5.2.1. Preparedness

Haiti prioritizes reaction over preparation in its policy. A group of quake experts underlined that Haiti is still not prepared for earthquakes. They mention that the country's lack of earthquake risk reduction effort is a major gap in its development efforts (Cohen, S. 2011). Banerjee and Gillepsie (1994) point out that disaster preparedness is the most effective way to lower their damage potentiality and the number of people affected. Then, to confront the earthquake risk and its probable destructive consequences, Haiti and its partners need to repair the ongoing flawed disaster management policy though efficacious preparedness strategies. Therefore, Haiti needs to invest more in disaster preparedness.

5.2.1.1. Coordination and leadership

It is fundamental that Haiti puts in place a post-disaster scenario plan where the objectives and goals of earthquake management strategies are clearly defined and roles of probable actors are identified according to their possible response time. This scenario-based preparedness plan can detail the roles of each stakeholder and their different geographic responsibility. The intervention and coordination capacity of the national disaster management system needs to be improved specifically for short-term emergencies.

5.2.1.2. Disaster scale analysis

An important element of preparedness is the measure of probable disaster scale. In the US, the west coast states that are exposed to earthquake risk permanently, have adopted a

foundational exercise scenario document to deal with the complexity of an earthquake response and improve their operational readiness. They estimate the impact of a 9.0 magnitude earthquake in the region and the possible damages to infrastructures (lifelines, public safety facilities, fire stations, hospitals, schools, water and wastewater treatment facilities, hazardous material facilities, etc…) and at different levels (low, medium, high) (Cascadia Raising, 2015). Facing a similar risk, Haiti can partner with the experimented institutions on the west coast such as the Western Washington University Resilience Institute, the Homeland Infrastructure Threat and Risk Analysis Center (HITRAC), the Federal Emergency Management Agency (FEMA/region 10) to design a locally-adapted functional response document. For example, Haiti needs a well-trained team in the Hazus software designed and used by FEMA to simulate disaster loss and impacts as its risk parameters are changing with its constant population increase rate.

5.2.1.3. Education, training, and research

In mitigation of natural disasters one of the main tenets of any effective, comprehensive disaster management strategy is education. It can be subdivided in school education, community communication, family education, and self-education. Education enhances community awareness, which is necessary to reduce loss of life, injuries, and damages. To prepare for the ever-present risk, Haiti needs to incorporate a specific disaster education policy in its national disaster management system. Cooperation with schools, universities, research centers, and the social community groups is necessary to enhance public awareness. Currently, no policy exists and gives responsibility for earthquake disaster preparedness and awareness in schools and communities.

5.2.1.4. Law and disaster prevention in Haiti

In a report, the International Federation of Red Cross and Red Crescent Societies (IFRC) mentions that “Haiti lacks any dedicated legislation that provides a formal, legal backing for the institutional structure, obligations and responsibilities of the national system for the disaster risk management” (IFRC, 2015). To improve this situation the report made three pertinent recommendations that we restate here: establish a cross-sectoral committee, revise and update policies on disaster risk reduction, and consolidate the existing laws and also develop new ones on disaster risk management.

5.2.1.5. Institutional reinforcement

The National System for Disaster Risk Management System [SNGRD in French] is a multi-sector entity that needs to be re-evaluated. Lead by the government structure called DPC which stops at communal (counties) level, it is ineffective and non-operational at local level. It counts on NGOs to empower communities. Moreover, even at the regional level, an insufficient fund is allocated for disaster response and not for preparedness. The country needs to work with authorities at local level to allocate not only disaster response fund but also a disaster preparedness fund to empower their communities specifically in most disaster-prone areas.

Proposed Steps for the Design of a new Disaster Mitigation Plan

Implementation of a robust and earthquake-centered mitigation strategy is a critical step for a good disaster preparedness in Haiti. This mitigation approach needs to be inclusive and considered the complexity of the Haitian vulnerability parameters. The figure 10 below highlights the elements that should be included in the plan in order to strengthen the existing weak Haitian national disaster management system and ensure its maturity.

Figure 10. Suggested Steps in Implementation of a Mitigation Strategy (Ralph, J.P & Patrick, A. 2017)

Education/ outreach is a core component of disaster preparedness. In a study realized in Japan, Rajib Shaw (2004) shows education is more important than even earthquake experience. However, in the case of our proposed new Haitian mitigation plan, other steps such as an appropriate legislative package, urban and rural adapted interventions, communication strategies, an inclusive Hispaniola blueprint, and some Caribbean-Atlantic disaster management

aspects should come before or along with its implementation because we consider education as a cross-cutting strategy for the success of the plan.

The legislative package would include laws that help to eliminate the potential hazards such as the proliferation of unsound constructions, the establishment of measures for progressively having institutions for continuing preparedness actions, negotiations, and cooperation. It should also give authority to the Haitian National Disaster Management System for enforcement of the law.

Urban strategies should be implemented separately due to the differences and specificities of cities. We propose that some Earthquake Information Center (EIC) offices be established in cities to collect risk data, invest in research, and archive earthquake information. They can be put under the National Disaster Management System control with a separated budget. With structural and non-structural components for disaster reduction, development of cities needs to be regulated. We propose that a game plan is designed for densely populated cities such as Port-au-Prince, Cap Haitian, Port-de-Paix, Fort-Liberté, Jacmel, and their surroundings. Municipalities's capability need to be reinforced in order that they can play a central role in activities and projects aiming to strengthen cities's preparedness and reponse capacity. They can also involve in preparing evacuation routes by considering local behavioral and environmental factors.

The rural initiative can include food, water, transport assessment, and public health and hospitals. Rural areas face challenges such as remoteness, communication issues, and resource availability for development. In other words, their coping capacity is low, increasing their vulnerability to earthquake hazards. Therefore, our new mitigation plan proposes a rural-integrated approach instead of an urban-focused plan.

Effective communication strategy is very important during disaster response. However, communication strategies need to be included first in the preparedness plan, meaning that building of a strong communication capacity is important before the occurrence of the disaster. In the case of our proposed mitigation plan, a specific strategic communication blueprint needs to be designed.

The entire island Hispaniola is at risk of devastating earthquakes. An inclusive (considering the entire island) Haitian preparedness and mitigation plan may yield a better result. A partnership and cooperation with the Dominican Republic for disaster response strategies (mutually committed) is suggested.

Geographically, Haiti is located in a disaster-prone area (the Caribbean) with countries implementing different mitigation and preparedness plans according to their level of risks. However, our proposed plan takes into consideration the possibility to put in place a successful partnership and cooperation with neighboring countries for the design of a Caribbean/Atlantic preparedness and response strategy. In this regard, an earthquake-hurricane game plan that includes the possibility of a double disaster Earthquake-Hurricane situation can be designed.

Lastly, we propose that education be the core strategy for the implementation of the new disaster mitigation, response, and preparedness plan. With a community-approach, disaster awareness can be improved. Moreover, it is important to introduce geo-hazard curriculum in schools and universities -in both Haiti and Dominican Republic-to create a generational hazard-awareness and readiness culture.

The specific pathways

Theoretically, the Haiti Response and Preparedness strategy can be subdivided into two main components: the national oversight with urban and rural initiatives, and the international outreach. The figure 11 below shows the specific pathways for the Haiti response and reparedness strategy.

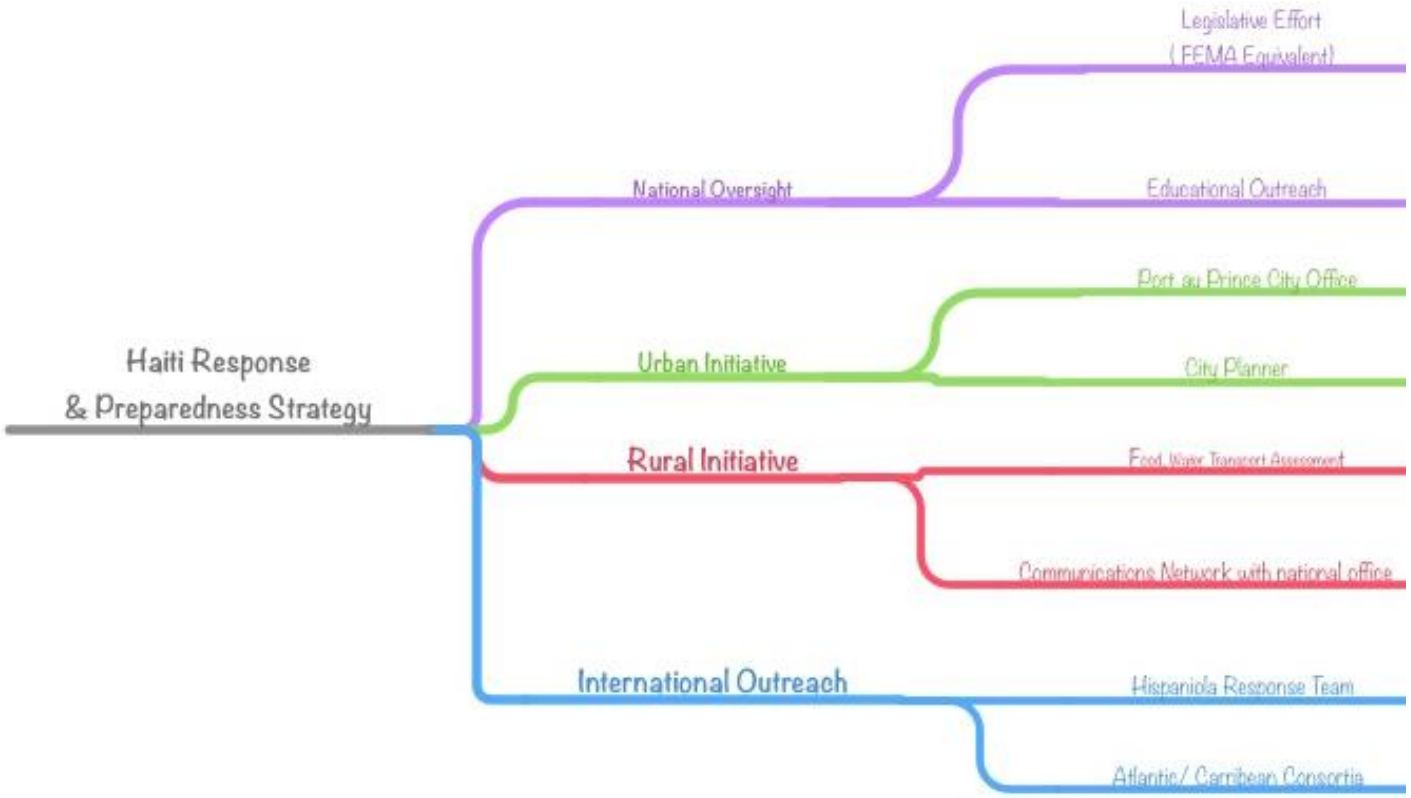


Figure 11. Specific Pathways for the Haiti Response and Preparedness Strategy (Ralph, J. P & Patrick, A. 2017)

The graph above shows an effective Haiti Response and Preparedness Strategy should include a national oversight component, an urban initiative, a rural initiative, and an international outreach aspect.

The urban initiative would emphasize on the risk on major cities, particularly Port-au-Prince and Cap Haitian. Each city would include a planning strategy that take into account the aspect of the earthquake risk and also a combination earthquake-hurricane risk that is high possibility in Haiti. An inter-city preparation plan needs to be designed and may include analysis of subsequent impacts in non-affected areas. Strategic capabilities for urban areas can be managed jointly by regional disaster comittees to ensure their availability if a specific city is hit and its local capability damaged.

The rural initiative would provide capabilities necessary to rural towns to cope with a disaster in case of deterioration of lifeline and communication structures that would prevent them to receive help and rescue immediately from bigger cities. It includes a food, water, and transport assessment. A communication network and strategy with the regional offices needs to be incorporated in order to ensure that pieces of information needed for localized response are successfully shared with other offices. Emergency response game plan for disaster-prone rural areas needs to designed and popularized.

The international pathway foresee the implementation of an island-wide response team that would be activated in case of major disaster. Development of a disaster-related curriculum in Universities in both Haiti and Dominican Republic is suggested. Drills and scenario efficiency need to be implemented and studied in both side of the island. Sharing of disaster response game plans can also help to yield efficiency in case of a major earthquake hit response.

The disaster response strategy can be extended to the larger Caribbean/Atlantic area with a strategy that seeks a fruitful cooperation with other regional countries with better and bigger response capabilities. Disaster research, geoscience and geological studies, scholar exchange, and sharing of information and innovation are some benefits that can be resulted from this cooperation.

In a nutshell, the response and preparedness strategy for Haiti needs to be inclusive with pathways that include a strong national disaster mitigation and management plan and an international strategy that take advantange of the possible cooperation with its better-prepared neighbors and beyond.

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