

Haiti – Five years after the 2010 earthquake

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ABSTRACT: The 2010, M_w 7.0 Haiti earthquake was one of the most devastating earthquakes in history. Tens of thousands of homes and buildings collapsed, killing an estimated 230,000 people. Most of these structures were of poor construction, mainly masonry blocks and reinforced concrete. Additionally, the Port-au-Prince seaport suffered catastrophic ground failures in calcareous-sand artificial fills, including liquefaction, lateral spreads, differential settlements, and collapse of the pile-supported wharf and pier. This paper provides an overview of current conditions in Haiti, five years after the earthquake, with particular focus on the Port-au-Prince seaport and debris removal from the Port-au-Prince. Although rebuilding after a devastating disaster is challenging for any country, the extreme poverty in Haiti and its lack of an effective government significantly hindered recovery efforts. At present the people of Haiti have little faith in their government and feel they are underrepresented and policies have showed little growth since the earthquake. To effectively move forward with the recovery effort, the Haitian Government needs to create policies that encourage development of public services to boost the economy and public infrastructure.

1 INTRODUCTION

On January 12, 2010 a moment magnitude, M_w , 7.0 earthquake occurred in Haiti, which is located on the west half of Hispaniola Island. The earthquake originated 13 km below the ground surface along the Enriquillo Fault system that runs just southwest of Port-au-Prince (Fig. 1). The epicenter of the earthquake was located only 15 km southwest of the densely populated city of Port-au-Prince (PAP). The Enriquillo Fault is the transform fault that marks the boundary between the North American Plate and the Caribbean Plate. The plates have an ~ 20 mm/yr convergence rate (Frankel et al. 2010), while the Enriquillo Fault has a slip rate of approximately 7 mm/yr. Although Haiti does have a history of seismic events, there were no strong motion seismograph stations in place at the time of the earthquake. The effects of the earthquake, however, were very evident.

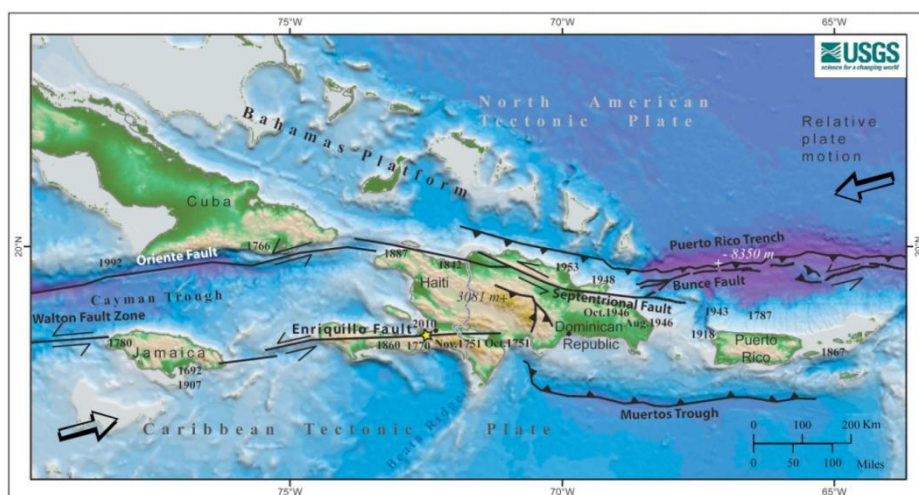


Figure 1. Fault locations and motions around Hispaniola Island (USGS, 2011)

The damage of the earthquake resonated across Haiti, severely damaging ~ 1.5 million homes and killing an estimated 230,000 people. Being the poorest nation in the Western Hemisphere, most homes

and small business buildings were of poor construction, mainly masonry blocks and lightly reinforced concrete. The ShakeMap below (Fig. 2) depicts the estimated shaking intensities, with the most severe shaking occurring just outside of Port-au-Prince, a city of nearly 900,000 residents. Much of the city was reduced to rubble and key structures were damaged, to include the National Palace, International Port of Port-au-Prince, Palace of Justice, National Assembly building, Supreme Court building, among other public administration buildings. In addition to structural damage, sources of food, power, water, and medical care were all disrupted, and the country came to a standstill. The earthquake resulted in soil liquefaction, landslides and rockslides in cut slopes, and road embankment failures.

The earthquake resulted in a mobilization of international resources. The recovery will be a continuous effort by local government, international non-government organizations, non-profit organizations, and local and international engineering contractors. Addressed in this paper are the social impacts, an essay by the second author who experienced the earthquake firsthand, some of the challenges that Haiti has faced, the current state of the International Port of Port-au-Prince (PPAP) and the debris removal, and what needs to be done going forward.

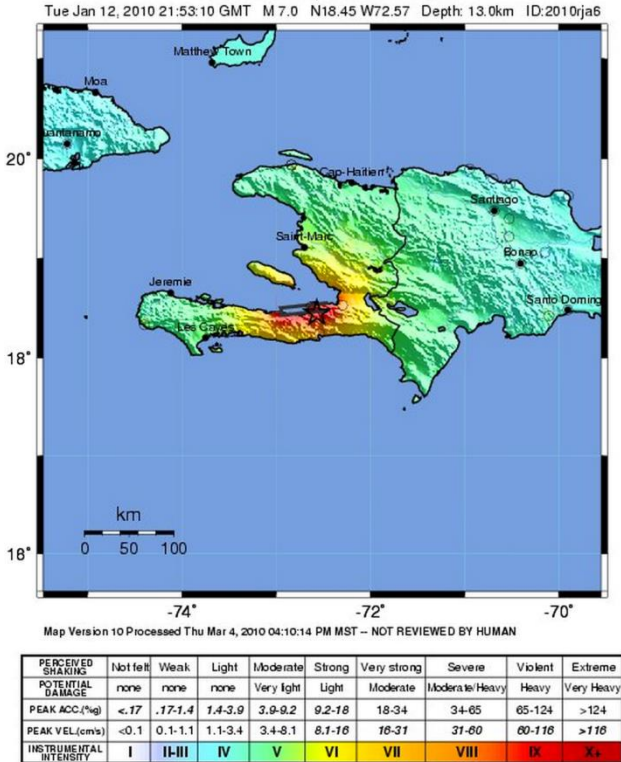


Figure 2. ShakeMap of Haiti during 2011 earthquake (USGS, 2011)

2 A PERSONAL TAKE

The following are personal reflections about the earthquake as experienced by the second author, Christina Beauboeuf, who is a second year undergraduate Civil Engineering student at Virginia Tech. Christina grew up in Port-au-Prince, Haiti and recalls her experience of the 2010 earthquake.

As the aftershocks and bugs kept me awake, calls came in proclaiming that family and friends were not found or that amputations were critical to their survival; I was overwhelmed, speechless, and distraught. Haiti was ravaged in thirty seconds, at 4:53 pm, on January 12, 2010.

People were panicked, they needed help; some were covered in blood and dust. Many large houses and structures were reduced to rubble. Thousands of people lost their lives; it was heart wrenching. Haiti was devastated. It felt like the end of the world.

It took me nearly 10 hours to get home that first day. I burst into tears when I learned that fourteen of my friends and neighbors were trapped under the rubble, dead. My house was still standing and less damaged than most. The toxic smell of lifeless bodies and the melancholic echo of people crying resonated in the chaotic atmosphere. My grandmother's Limoges collection, which meant the world to her, was now a pile of shards. For the next fifteen days, I shared my food, clothes, underwear, sanitation products and water with my neighbors. We slept in the middle of the streets, shivering in the cold while rats and abandoned dogs wandered among us, feeling equally as lost as we were.

My family and neighbors were able to receive food and clean water from the Dominican Republic, which did a great job helping the Haitian population during this rough period. There was no local organized emergency response crew or personnel available. The Haitian Government, itself, was greatly affected and could not play any role in the immediate recovery. Foreign Aid and Jesus were the only relief the Haitian population had to turn to. From what I remember, medical care was provided anarchically because of the colossal amount of injured people and the lack of resources available. As a result, thousands of people had amputations, many of the cases may not have been necessary had adequate care been provided immediately.

The earthquake broke bodies, houses, Limoges collections and plans, showing no mercy. The backlash of this natural disaster motivated me to become a Civil Engineer. My parents had no option but to send me to the United States in order to seek a better education and heal my trauma. I became determined to be culturally aware of the world around me. I am committed to restoring people's hopes as I help Haiti recover from the most significant disaster the country has seen. I cannot fix the past, nor prearrange the future, but I can, without doubt, make the moments we have been granted worth living for my destroyed country, my desolated countrymen, and me.

Christina has since spent her summers back in Port-au-Prince helping to rebuild her home town with CEEPCO contracting. CEEPCO is an US-based firm providing engineering, environmental, and construction expertise in Haiti primarily based on USAID funded projects.

3 CHALLENGES FACED

Haiti has a long history of social and political unrest; it has been a nation overwhelmed by poverty and corruption for centuries. Despite approximately \$5.2 billion in foreign aid, nearly one million Haiti's remain homeless, political riots sweep the nation over the delayed recovery, and Haitians faced a cholera epidemic. The 2010 earthquake was so devastating and the recovery is slow for a number of reasons: poor construction methods and materials, preexisting political instability and poverty, and difficulty in determining the most effective method of foreign aid.

Haiti's political history is colored with corruption from gang coups to fraudulent leaders. The consecutive corrupt leaders led the nation into poverty and overcrowding in cities like PAP, making the consequences of the earthquake that much more devastating. Haiti has been subject to international trade sanctions as a result of their uncooperative government. Past presidents and military-run governments stole government money and foreign aid that was meant for natural disaster remediation. Businessmen and professionals were driven out by the political and economic instability. Given these crises the main question is what is the most effective way to deliver foreign aid and contributions? Given that the local government of Haiti (GOH) had a history of irresponsible and disorganized leadership, do we work with it or work around it? Nations remained reluctant to give money to the GOH during UN conferences.

Immediately after the earthquake, Haiti was flooded with international aid, including from non-government organizations (NGOs), the International Red Cross, Doctors without Borders, Islamic Relief Worldwide UK, etc. The president of Haiti at the time of the earthquake was President René Préval; he advocated for international aid to work with the GOH rather than giving money to NGOs and foreign and private contractors. The methods of contributions are discussed later in this paper.

President Préval recognized that Haiti could not recover and rebuild until political stability was established. The immediate emergency relief response was led by international organizations, with ~\$2.21 billion being pledged by foreign governments and ~\$3 billion being pledged by private donors (Katz 2013). Figure 3 summarizes the how recovery aid was distributed from 2010 to December 2013. While some money has been dispersed to organizations like the Haiti Reconstruction Fund, some funds still sit in the banks waiting for projects to be executed. Another issue that arose was how the money should be spent. Former US president Bill Clinton advocated the “build back better” mantra, focusing on both short term and long term recovery, but the vastness of tasks made it an idealistic mission. Clinton’s Interim Haiti Recovery Commission was a prime example of good intentions that were dismantled by the lack of support from the Haitian government and the overwhelming number of proposed projects without an understanding of what was crucial to rebuild a crumbled nation.

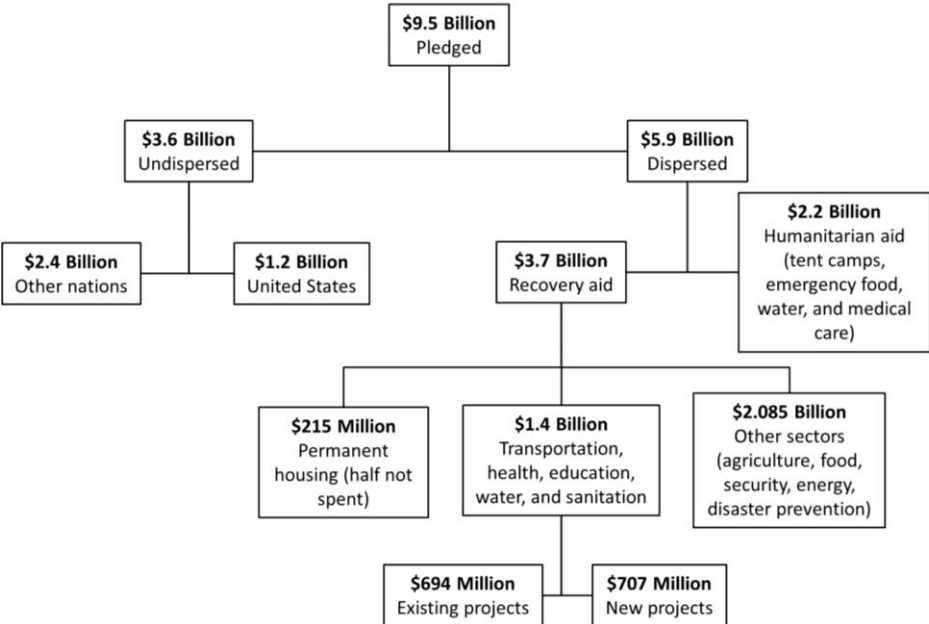


Figure 3. Money pledged by public donors and distribution as of December 2012 (United Nations Office of the Special Envoy for Haiti, 2012)

Haiti’s disorganized government was not only reflected in their finances, but also in the lack of regulation in the development and construction industry. As the agricultural industry collapsed in the 1950s, people migrated to the cities. The nation’s capital, Port-au-Prince, was overcrowded and underdeveloped. Houses were built haphazardly typically by the homeowner using masonry block and concrete with no inspection process. Despite Haiti’s history with natural disasters such as hurricanes and tropical storms, buildings were typically non-engineered. Concrete was the primary element used in construction and typically “lacked sufficient cement, had poor-quality aggregates, and were heterogeneously mixed” (Marshall et al. 2011). Buildings were lightly reinforced with improperly sized rebar, hollow rebar, and/or non-deformed rebar and voids were present in the concrete due to poor quality materials and little or no vibration upon placement (Joint Task Force-Haiti, unpublished document, 2010). When the 2010 earthquake struck it is not surprising that the city was reduced to rubble. After the earthquake, American reporter and author, Jonathan Katz, asked President Préval why there is not a building or construction code in Haiti, and Préval’s replied, “there is a code already, but they don’t follow it...what we need is *political stability*” (Katz, 2013).

4 WHERE IS HAITI TODAY?

4.1 Port de Port-au-Prince progress

The original north wharf was a ~460-m long by ~4.6-m wide pile-supported structure that was

supported by ~0.5 m square pre-stressed concrete piles. The wharf failed as a result of liquefaction-induced lateral spreading. The soil underlying the wharf consisted of loose-to-medium-dense sands, silty sands and gravel (Green et al. 2011). The entire north wharf collapsed seaward along with two cranes located on the structure. The deck failed by means of two mechanisms: separation of deck segments at the expansion joints and separation from pile supports due to pile settlement and pile deterioration prior to the earthquake. Lateral spreading occurred in soils up to ~50 m inland of the north wharf (Rathje et al. 2010). Figure 4 shows aerial images of the PPAP taken before and after the earthquake, to include the north wharf and the south pier.

The south pier was supported by pile bents spaced at ~6.1 m on center with each bent supported by two vertical piles and two interior pairs of 0.5-m square pre-stressed concrete battered piles. The two causeways connecting a small island to the south pier (Figure 4) were pile-supported, one of which collapsed after the earthquake along with ~122 m of the western end of the pier. The pier collapsed as a result of liquefaction-induced lateral spreading resulting in lateral movement of the pile supported bridge and abutments. Only a few days after the earthquake, Naval Facilities Engineering Command (NAVFAC) Dive Team and the Military Task Force (MTF) was on site to assess the damage and current state of the remaining ~260 m of the south pier. The dive inspectors observed “significant corrosion of the reinforcing steel and deterioration of concrete” (Werner et al. 2011). Further exploration “showed that 143 of the 156 battered piles along 39 of the pier’s 45 bents were categorized as moderately or severely damaged” (Werner et al. 2011).

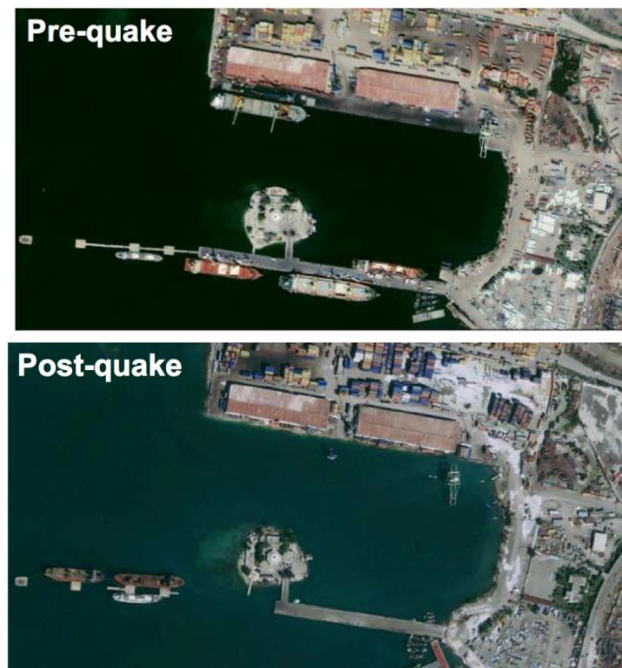


Figure 4. Before and after photos of the North Wharf of the Port de Port-au-Prince (SOUTHCOM, 2011)

The damage to PPAP impeded the delivery of relief supplies such as food, water, and construction equipment. In order to accommodate the delivery of relief supplies in the short term, the MTF focused their efforts on construction of a temporary port along the shoreline. The south pier was temporarily repaired by the Navy’s Underground Construction Team One (UCT-1) and restored to the load-bearing capacity prior to the earthquake. The restoration of the pier involved the placement of epoxy mortar for piles that were still in contact with the deck to provide reinforcement of the pile and the construction of a cast-in-place reinforced concrete pile cap to restore the connections of piles that were no longer in contact with the deck (Werner et al. 2011).

In February 2012 the Haitian Government and the Autorite Portuaire National (APN) reached an agreement on funding and management for reconstruction of the port facilities of the PPAP. The project is being managed by Director Generals Evens Jean Charles (2011 to 2012) and Alix Celestin (2012 to present). Mr. Celestin is a civil engineer with more than thirty years of experience, and his

goal is to make the APN the “reference of the Caribbean” as it was in the 1980s. Celestin opened bids for reconstruction of the PPAP shortly after taking lead on the project. The summary of a few of the items the bids were to include pertaining to the PPAP is listed below.

- Construction of the new North Wharf that is ~460-m long to a water depth of roughly 11.6 m in order to accommodate the rails and equipment needed to operate the cranes
- Reconstruction of the south pier’s RO-RO bridge. It is to have a ramp roughly 30-m wide to a water depth of ~11.6 m
- A portion of the basin and ~100 m navigation channel are to be dredged to 11.6 m to access the dock
- The north wharf is to be completed 18 months after the contract has been signed

Figure 5 depicts the APN final design of the PPAP including a complete rehabilitation of the north wharf and south pier and docking area that suffered extensive lateral spreading.

In May 2013, the contract was signed by Minister Wilson Leau, Alix Celestin, and Fransisco Senis, the Chief Executive Office of the Italian-American firm GLF Construction Corporation, headquartered in Miami, Florida, with a completion deadline of November 2014. GLF has done many international heavy civil and marine works projects accumulating over 100 years of experience in roughly 20 countries. Little has been published on the progress of the rebuilding of the port. However, GLF performed vibro-compaction at 1440 compaction points, demolished the remainder of the north wharf, and removed ocean debris. On 3 July 2014 the Director General of the APN visited the site for inspection and updates on the progress of the north wharf. The Director met with GLF engineers and concluded that construction was on schedule (APN, 2014). At the time of the meeting, piles were being driven and vibro-compaction was ongoing. In September 2014, it was released to the press that construction was progressing at a reasonable rate, with 118 1-m piles and 4 ~0.9-m piles driven and 199 reinforcement bar cages for the pre-slabs assembled (HaitiLibre, 2014). While the inland grounds have been remediated, the reconstruction of the wharf and pier is still ongoing.



Figure 5. Final design of the Port de Port-au-Prince (APN, 2014)

4.2 Debris removal

Much of Port-au-Prince and surrounding areas were reduced to rubble after the 2011 earthquake. Most construction in Haiti was done by home owners using masonry block reinforced concrete with no quality or construction inspection. As a result, roughly 30% of buildings in Port-au-Prince collapsed. Moving outwards from the epicenter of the earthquake towards Leogane, roughly 62% of buildings were partially to completely collapsed (Marshall et al. 2011). The massive amounts of rubble blocking roadways greatly retarded the distribution of relief supplies and efforts. With the amount of debris covering streets and communities, implementation of a debris removal program was crucial to the immediate recovery efforts. There was no comprehensive plan put into place, which made it difficult

for efforts to be effective. The United States funded a significant portion of the debris removal efforts, which are discussed in the following.

Immediately after the earthquake, the Obama administration assigned the Department of Defense (DoD) to oversee rescue and recovery operations in Haiti. The United States Army Corps of Engineers (USACE) Debris Planning Cell took charge in developing a debris plan in February 2010. In the management plan the goal identified was “to provide structure, guidance, and standards for debris clearance, processing, and disposal, identify methods to resolve debris removal in an environmentally responsible manner, identify private and non-governmental organizations to participate in the management of debris, expedite debris removal, recycling, and disposal, efforts that provide visible signs of recovery, and maximize opportunities for employment of the Haitian people and Haitian contractors” (United States Southern Command, 2010). The volume of debris was estimated to be 15-20 million cubic meters. Some of the challenges faced in this plan were the limited landfill capacity, and limited financial resources and equipment. Following the efforts by the USACE, the Obama administration transferred the responsibility of all US efforts to the United States Agency for International Development (USAID). For these efforts, the US pledged over \$100 million for rubble removal (USAID 2014). The USAID provided grants and contracts to four NGO partners, the International Organization for Migration, Cooperative Housing Foundation, Development Alternatives Incorporated, and Chemonics International Incorporated, to use Cash-for-Work (CFW) programs to remove earthquake debris. While 60,000 short-term jobs were created through the CFW programs, the efforts proved neither efficient nor cost effective on a large scale, as determined by the audit initiated by the Office of Inspector General (OIG) (Trujillo 2010). Following these efforts, the USAID issued an 8(a) contractor, PSH Group, to manage earthquake debris at the Verraux Terminal (private port) and the Port-au-Prince Landfill, Truitier in March 2010 and June 2010 respectively. The PSH Group established the Construction & Demolition debris site management by means of providing management, labor and equipment. The debris was taken to a controlled 2.8-hectare lot waste disposal site. In June 2010, the USAID issued a task order to Parsons Global Services to monitor and track the progress on the debris removal efforts by deploying staff members to assess the daily progress and prepare monthly and daily updates. This organizational effort was made with hopes to turn over to the GOH.

In 2011, the GOH issued the first large debris contract through the Prime Minister’s office to the Haiti Recovery Group, a US-Haitian joint venture. Haiti’s Ministry of Public Works, Transportation, and Communication (MTPTC) was directed to oversee project and assess the structural damage of PAP and surrounding areas, organize preparations for reconstruction and debris removal efforts, and ensure coordination of the GOH and the municipality. The MTPTC later became head of a Debris Working Group under the Interim Haiti Recovery Commission (IHRC), an organization that operated as a forum for NGOs, Government, and contractors to coordinate debris efforts. The role of IHRC was to evaluate projects for consideration that were in line with the GOH’s action plan for recovery. After a project is granted approval, the Haiti Recovery Fund (HRF) was responsible for the appropriate dispersion of project funds. Approved funds and projects were allocated by the World Bank, United Nations, or Inter-American Development Bank (Rouzier 2014). As discussed above, the effectiveness of the IHRC was limited. In January 2011 the USAID awarded a contract to CHF International to remove debris in the heavily populated PAP neighborhood of Nazon. CHF removed over 480,000 cubic meters of debris and employed nearly 15,000 Haitians in CFW programs. CHF partnered with the local Caterpillar-Haytrac dealership in Haiti to train local operators to remove rubble from roads, canals, and public centers. The mission was to get Haitians back into their homes by demolishing those that were destroyed or unrecoverable and to build up to 6,000 shelters (Global Communities 2011).

By October 2010 the USAID had \$17 million set aside to spend on debris removal, but rather than contract it out directly, the money was transferred to the United Nations Development Programme (UNDP). The agency essentially created its own debris removal company to compete with professional contractors. By December 2010 an additional \$25 million was received and was put towards an 18 month debris management program scheduled to start May 2011. The UNDP, UN-Habitat, International Labor Organization (ILO), and the United Nations Office for Project Services

(UNOPS) partnered together in collaboration with the MTPTC and NGOs to begin the recovery phase of urban areas of PAP. The UN-Habitat was responsible for organizing and mobilizing community efforts, the UNDP was responsible for demolishing the unstable structures as identified by the MTPTC and organizing the rubble removal process, and the ILO was responsible for creating a network of employment opportunities by developing small enterprises. The primary targeted areas in PAP, as identified by the MTPTC, included Bolosse, Turgeau, Gros Morne, and Nerette. As outlined by the Haiti Reconstruction Fund Project Document, the expected results were:

1. Community participation, social cohesion and capacity development of local institutions.
2. More than 7,000 structurally damaged building (tagged as red houses) will be safely demolished.
3. Over 625,000 m³ of debris will be removed and managed.
4. At least 300,000 m³ of debris will be recycled.
5. A minimum of 3,000 people will be benefit from the income generating activities (HIMO) and support to small and micro-enterprises
6. Local economies will be revitalized thanks the direct and indirect benefits of the project (UNDP, unpublished report, 2010)

All initiatives from UN-Habitat, UNDP, and the ILO were highly dependent on the GOH's ability to organize the communities and lead the ongoing process. The project was completed in October 2012 with ~2.1 million cubic meters of rubble removed and 13,000 short-term jobs created.

Also launched in 2011, the UNOPS, UNDP, and ILO jointly implemented the 16/6 Project with funding from the HRF under the leadership of the GOH. The objective of the project was to help Haiti transfer from the recovery and rubble removal phase to the development phase by relocating the displaced from 6 shelter camps to 16 neighborhoods. The project had two primary components, housing and community infrastructure. The housing component ensured that unsafe homes were demolished and safely rebuilt while the infrastructure component ensured that basic services were provided to the populations of each of the 16 communities (such as road and drainage paths, environmental and sanitation remedies, and education and health opportunities). Local labor and products were used in collaboration with the ILO in an effort to train the local community. The mission of UNOPS was to advise the government on the strategy involved in creating an effective and organized plan and ultimately transfer effective know-how (UNOPS 2013). After more than \$100 million of funding from USAID and the DoD, the project was completed in October 2012 with a total of 7.4 million cubic meters removed and more than 350,000 short-term jobs created (HRF, 2012). The debris removal phase was critical in order to proceed to the reconstruction phase, but due to the absence of a nation-wide plan, individual agencies and the GOH essentially operated separately making the debris removal process a sluggish operation.

5 GOING FORWARD

In order for Haiti to become a developed nation, the GOH must find a means of transitioning from short-term to long-term recovery. The short-term recovery addresses the immediate relief needs of the people like medical care, food supplies, debris removal, shelters, etc. The long-term recovery is much more crucial and has several moving pieces associated with it, all dependent on a stable government. The GOH must learn from the recovery efforts and methods used by foreign aid organizations and become capable of developing a long-term plan for Haiti. Before tackling a project, the GOH and its foreign contractors need to develop realistic timeframes, be proactive in establishing a contract, and be thorough and realistic in setting the scope of the project. In going from recovery to development the GOH must focus on road infrastructure, waste management, enforcement of the building code (including a standard of materials), enforcement of security, and port infrastructure while maintaining practical observations of the needs of the people. In order for Haiti to continue to receive foreign aid, the GOH needs to establish stable and reliable leadership that is supported by the public. The redevelopment of Haiti will create jobs and boost the economy and reinstall the public's confidence in

their government. A nation cannot escape underdevelopment and poverty solely by means of foreign donations. The people of Haiti have little faith in their government and feel they are underrepresented and policies have showed little growth since the earthquake. The GOH Haiti needs to create policies that encourage development of public services to boost the economy and public infrastructure.

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