ACCELERATING POST-DISASTER RESPONSE: THE HAITI (2021) EXPERIENCE

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Abstract: *In the aftermath of a destructive event, such as large earthquakes, several immediate actions need to be put in place to reduce the impacts to the affected population. In spite of the best engineering efforts, large earthquakes still cause a great deal of material and human losses; more so when they occur in vulnerable areas, or when they get superimposed to the effects of other natural or human induced disasters. Immediately following the search and rescue including associated medical support, and restarting the supply chain for primary necessities, it is of paramount importance to assess the state of the building stock in order to facilitate the development of a mid to long term shelter approach. Identifying shelter needs and selecting suited shelter approach(es) can have significant impact on the pace and quality of recovery. Relocation is often seen as a solution, however it can cripple communities and social structures, particularly when applied out-of-context, by severely impacting quality of life since it disrupts consolidated human relations and can delay and extend reconstruction times. The assessment of a large building stock to identify buildings still suitable for shelter use poses several challenges, among them is the time needed as well as the record keeping related to an orderly scan of the damage in the population of buildings affected by the event (earthquake). In this regard, digital tools can play an important role and are increasingly used by humanitarian operators in disaster responses to increase efficiency, reduce lag times for data availability, and increase consistency. This paper first introduces the approach that was implemented after the 2021 M7.2 Haiti seismic event to accelerate the assessment of the building stock and disaster response, then it compares it to current practice in Italy. The approach adopted for Haiti allowed to reach more than 600,000 beneficiaries during the relatively short time period of 5 months, and allowed to create a database of the state and damages of the scrutinized buildings that permitted real-time reviews and analyses by remote experts, further enhancing the quality of the assessments and, in the end, the safety of the survivors.*

1. Introduction

At 8:29am of the 14th August 2021, a magnitude 7.2 earthquake hits the south-west regions of Haiti (Okuwaki and Fan, 2022; USGS, 2021). More than 2,300 people are reported dead or missing (European Civil Protection and Humanitarian Aid Operations, 2021), making Haiti 2021 earthquake the deadliest of the year. Considering the Covid-19 pandemic, the assassination of the president Moïse on the 7th July 2021 and the impact of the tropical depression Grace only two days after the earthquake (UN-OCHA, 2021), the emergency that Haitian people were facing was multi-faceted and extraordinarily complex.

In the aftermath of the quake, the goal of MTPTC (Ministère des Travaux Publics, Transports et Communications of Haiti), supported by the World Bank, UNOPS (United Nations Office for Project Services) and Miyamoto International, was to assess the damage and reparability of 120,000 buildings in 3 months. The challenge was to accelerate the speed of the assessment and ensure adequate support to the affected building owners. Eventually, 179,800 buildings have been assessed between October 2021 and February 2022.

This achievement is aligned with the 2015-2030 Sendai Framework, that encourages innovative approaches in the disaster response (UNISDR, 2015). Digital tools and ICT (Information and Communication Technologies) already stood out for their adaptability and outreach in the DRR (Disaster Risk Reduction) sector (Aitsi-Selmi *et al.*, 2016), but their potential is still not fully expressed (Stute *et al.*, 2020). Developing countries are becoming more and more digitalized (Garg *et al.*, 2021; World Bank Group, 2016). However, the current literature is lacking of large scale tests of digital tools in disaster response programs.

The scope of this paper is to share the experience and the lessons learnt, highlighting the advantages of the peculiar digital approach that was followed, as well as the challenges that were faced.

2. Use of digital tools in disaster response

The use of digital tools in disaster response programs is variegate and increasing. A first, broad, classification can be done on the base of their accessibility. Widely accessible Social Media, which are generally acquiring a new role in knowledge sharing and risk communication (Alexander, 2014; Jayasekara et al., 2021; Kavota et al., 2020). are prone to inconsistencies and diffusion of fake news (Eismann et al., 2016; Wyche, 2015) as the quality of the information shared is not controlled. Big data, drones, satellite images, artificial intelligence and social media already proved to have an interesting role in crisis and emergencies management (Alexander, 2014; Kavota *et al.*, 2020; Madianou, 2019; Nagendra *et al.*, 2020). Remote sensors and satellite images, typically of more restricted access, are useful for early warning systems and post-disaster damage evaluations (e.g. comparing satellite photos before and after an earthquake and calculating the permanent movement of the earth surface) (Delvaux et al., 2017; Nagendra et al., 2020. Artificial intelligence and machine learning can be used to speed up the processes in the damage, repair and vulnerability assessments (e.g. a smartphone application that evaluates the quality of a masonry wall from a photo) (Abello et al., 2020; Harirchian et al., 2021).

Various organizations that work in the humanitarian field have already understood the potential that digital tools have and integrated them in their work: such as Build Change retrofitting program in Colombia (Abello *et al.*, 2020) or mHS City Lab micro-credit app in India (Mehra *et al.*, 2017).

Overall, digitalisation is changing the humanitarian world: various organisations are capitalising on digital tools' versatility to expedite the workflow in an emergency setting (e.g. by simply using tablets to collect data on the field) (Abello et al., 2020). More specifically, a recent study (Stute et al., 2020) found that automated reporting produced thanks to data collection through smartphones and tablets could expedite the emergency response and reduce the errors due to manual reporting, while Geographic Information Systems (GIS) and databases can make disaster response faster and more transparent (Shuvo et al., 2022).

On a larger geographic scale a mention should be due to the new web-based tools, which also allow for the collection and processing of disaster response data using crowdsourcing and crowd-mapping platforms (Mejri et al., 2017). While networks of digital volunteers, formed by citizens around the world, can be activated to aggregate and visualize data linked to a disaster and provide open-source support to organizations (Park and Johnston, 2019). In an emergency setting, Disruption-Tolerant Networks become critical, and have also been studied with the purpose of allowing continuity of operations in case of major events that affect communication networks (Schmittner et al., 2017).

The case study presented herein leverages on these concepts, and can be the first one to present the advantages and challenges faced by digital data collection, GIS integration and database analysis, in response to an earthquake that struck a low-income country.

3. Haitian digital infrastructure and seismic risk

Haiti is one of the poorest countries of the world (The World Bank, 2020). Nonetheless, the penetration of digital tools in Haiti is considerable: 41.4% of the total Haitian population has access to internet, and this percentage is rapidly increasing (Kemp, 2022). Nonetheless,Haiti internet bandwidth is one of the lowest in the Caribbean area, and affordability of internet services is a barrier to connectivity (The World Bank, 2020).

Haiti, also, has a significant level of seismic hazard throughout all the country (Frankel et al., 2011). The construction quality is generally poor, and a large portion of the built environment is prone to seismic damage (Torres et al., 2016).

High seismic hazard combined with the informal settlements' high vulnerability results in high seismic risk. In 2010, a M7 earthquake caused 300,000 victims and more than a million displaced people (DesRoches et al., 2011). Most of the damage was concentrated in Port-au-Prince, where MTPTC, UNOPS and Miyamoto International already had successfully worked together for the damage and repair assessments, and the reconstruction (Miyamoto et al., 2011).

The Magnitude M7.2 earthquake, object of this study, occurred at 8:29am local time on Saturday, 14th August 2021. The epicentre was in the Nippes region, 13km southeast of Petit Troup de Nippes and around 125km west of the capital Port-au-Prince (USGS, 2021). The earthquake, which had an hypocentre located at a depth of 10km, broke a blind thrust fault, that subsequently stressed a network of already fragmented faults (Okuwaki and Fan, 2022; Panuntun, 2021). The estimated Peak Ground Acceleration, close to the epicentre, is of 0.78g and the modified Mercalli intensity index reached the level of IX (violent) (USGS, 2021) (see Figure 1).

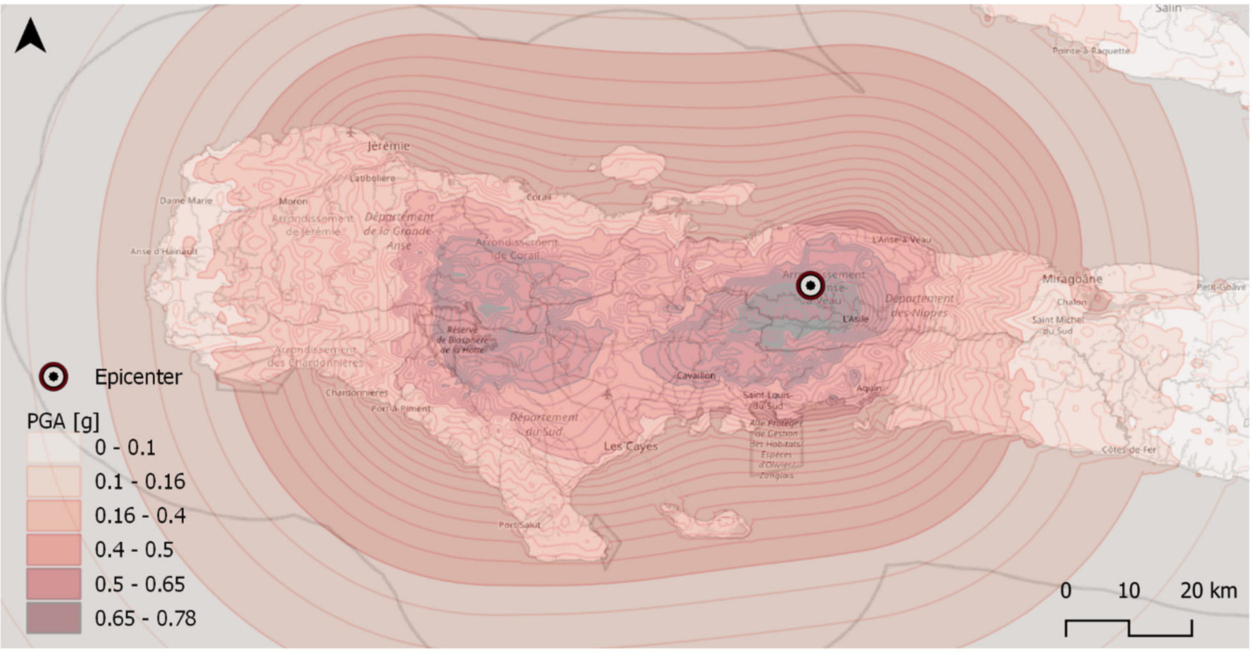

Figure 1. Peak Ground Acceleration (PGA) and quake epicenter (data retrieved from USGS (USGS, 2021)).

The areas impacted are in the Nippes, Grand'Anse and Sud regions; an estimated number of 800,000 people have been affected (European Civil Protection And Humanitarian Aid Operations, 2021; UN-OCHA, 2021). Two days later, on the 16th August 2021, the tropical depression Grace hit the southern coast of Haiti: strong winds and rainfalls caused landslides, isolated villages and disrupted relief activities (UN-OCHA, 2021).

4. Methodology implemented in Haiti

Building on the previous experience of the 2010 seismic emergency response, in the aftermath of the 14th August seismic event MTPTC, in collaboration with the World Bank, UNOPS and Miyamoto International, launched the damage and repair assessment. The initial goal was to assess 120,000 buildings in 3 months. To achieve this objective, a multi-disciplinary team that included civil and structural engineers, IT (Information Technology) specialists, GIS experts and social workers from the different organizations was formed. An international collaboration started, with members on the field located in the Sud, Grand'Anse and Nippes regions of Haiti, and in the capital city of Port-au-Prince, supported by experts located in the United States, India, Nepal and Italy.

The main difference from the 2010 quake is that in 2021 the area affected was more extended and mostly rural. Due to the broad geographic zone impacted and the need to provide as much information as possible in each single on-site visit by an engineer, MTPTC determined a need for repair assessment in conjunction with a rapid damage assessment. As a result, a digital approach was developed to reach as many beneficiaries as possible, as soon as possible.

The data collection campaign started in October 2021 and finished in February 2022, covering the regions of Sud, Grand'Anse and Nippes that suffered the most damage. A total number of 179,800 buildings were evaluated, reaching approximately 600,000 local stakeholders. Despite the ongoing Covid-19 pandemic, the development of the project was not affected. The field work was only suspended for almost three weeks in November, due to civil turmoil and gasoline shortage in the country. The data were collected with KoBoToolbox ("KoBoToolbox", n.d.) and analysed with ArcGIS ("ArcGIS", n.d.) and Microsoft PowerBI ("Microsoft PowerBI", n.d.).

The authors' purpose is to describe in detail the case study, how it was developed and the conclusions that were drawn. In the following section we elaborate further the methods, and outline the details of the program implementation.

4.1. The training of engineers

MTPTC engineers who were to be deployed on the field were given a three days course, including a final written examination. The purpose of the training was to enable the engineers to correctly perform detailed damage seismic assessments and evaluate repair strategies. 380 MTPTC engineers of the 550 that were trained passed the test and had subsequently been deployed on the field. The course was organized in various Haitian cities (e.g. Port-au-Prince, Les Cayes, Jeremie, Anse-a-Veu, Miragoane), in order to attract professionals from all the affected areas. The content of the training was based on the internationally recognized ATC-20 (ATC 2005) guidelines (ATC-20, 1989) and the MTPTC 2010 seismic guidelines (MTPTC, n.d.). Many of the engineers were already familiar with the relevant seismic engineering principles, as they had worked on the 2010 earthquake emergency response under these standards. The training addressed: (i) the principles of seismic engineering, the typical structural seismic weaknesses and the behaviour of constructions under horizontal forces, (ii) the typical damage patterns, including the ones occurring to confined masonry buildings as per MTPTC standards, (iii) how to evaluate the safety of a building and assign a tag.

4.2. The data collection campaign

Among the engineers who passed the test, the most qualified ones, based on the test score, were selected as division leaders and team leaders. One division consisted of three teams of six engineers each, plus a division leader (19 engineers per division). Each team had three couples of engineers and one of them is the team leader (6 engineers per team, see also Figure 2). Engineers always carry out the damage and repair assessments in pair, to foster accountability of their work, internal discussion and to mitigate mistakes. At maximum capacity, 20 divisions were deployed on the field, which corresponds to 300 evaluation engineers, plus 60 evaluation engineers who are also team leaders, plus 20 division leaders (380 MTPTC engineers in total, see also Figure 3).

MTPTC engineers were supervised by five division engineers, six department engineers, one regional engineer and two international experts from Miyamoto International. They were responsible for technical support, quality control and assurance. 180 social communicators, one for each couple of engineers carrying out the evaluations, completed the team, reaching a total of 574 staff members simultaneously deployed on the field.

The data collection was executed though an application on a tablet and it included a social and a technical survey. The latter will be discussed in detail in section 4.3. The social survey was directly managed by UNOPS and it aimed to gather information on the vulnerability of the households and the impact that the earthquake had on its livelihood. During the site visits, the social worker was the first and last point of contact for the building owner. For all the buildings' use, not only the residential one, the duty of the social facilitator was also to explain to the owner the scope of the visit and make sure they understood the tag assigned to the building.

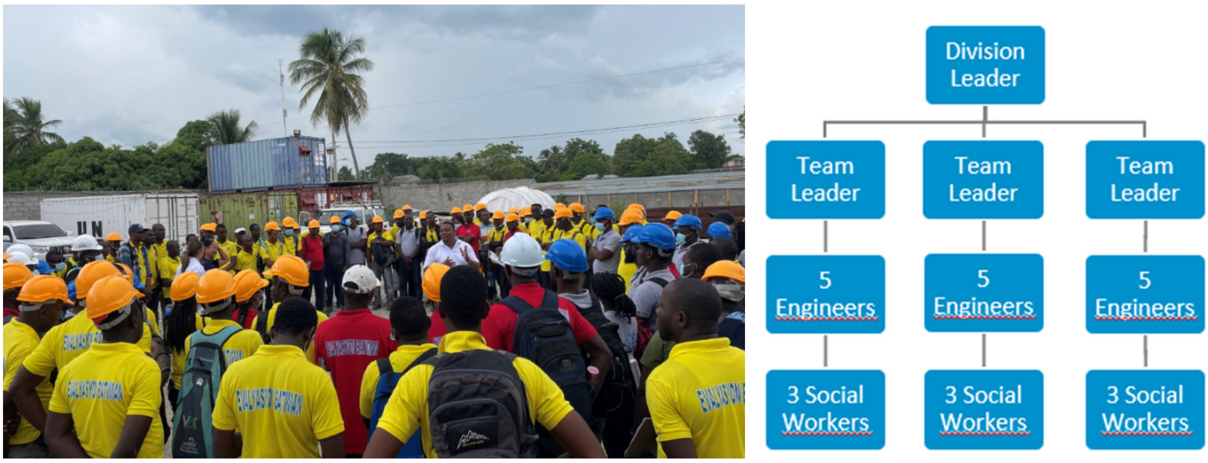

Figure 2. On the left, early morning meeting: division leaders (blue shirt), team leaders (red shirt), evaluator engineers (yellow shirt), social mobiliser (grey shirt), Miyamoto International engineers (white and black shirt). On the right, engineers' division organigram.

To each division was assigned a map of the geographical area that they had to assess, the division leaders organized their team accordingly. The maps were revised weekly. One bus was dedicated to each division to travel to the respective assigned assessment area. The most affected areas of the Sud, Grand'Anse and Nippes regions have been covered. As the assessment program moved further, different types of accommodation and transportation were found (e.g. motorcycles or SUVs to reach remote areas). The logistic was provided by UNOPS.

The division leader was responsible to return the tablets and upload to the database the completed evaluations at the end of each day. The average time for one full assessment was 30 minutes. In the rural areas most of the time was spent to travel to the assessment area and between buildings.

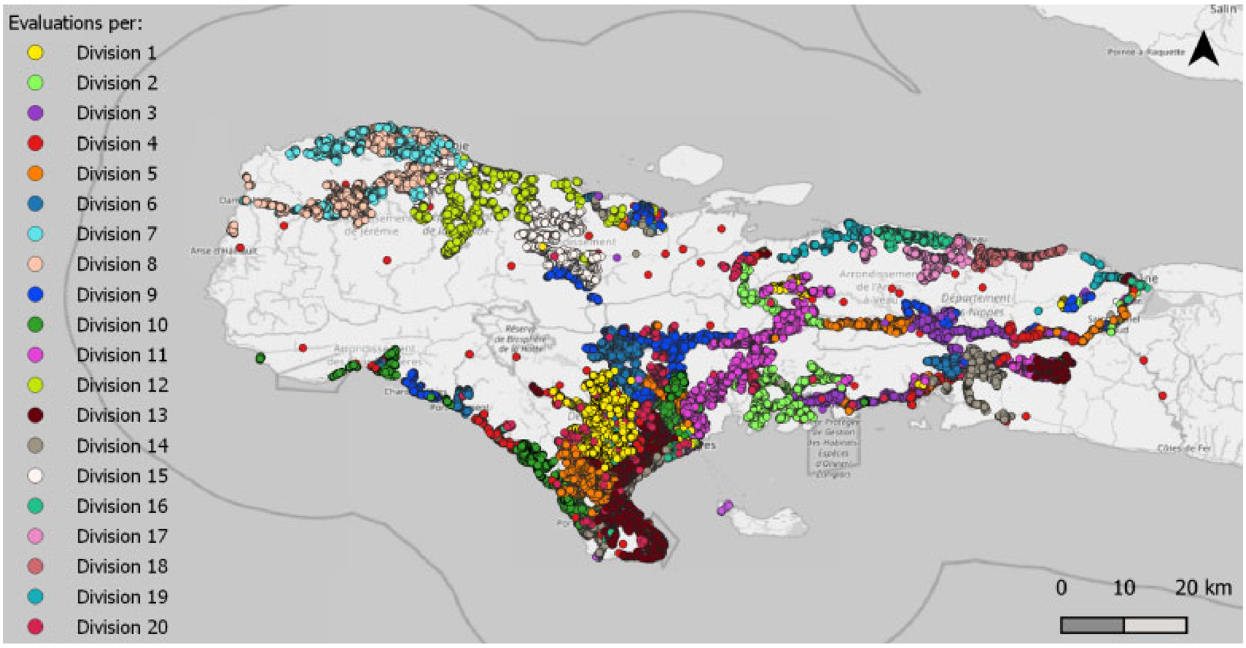

Figure 3. Twenty divisions evaluated 179,800 buildings across the Sud, Grand'Anse and Nippes departments.

4.3. Damage and repair assessment

The technical survey was tailored on the ATC-20 (ATC-20, 1989) and MTPTC (MTPTC, n.d.) standards. The first step was a rapid damage assessment, which included a general evaluation of the characteristics of the building (e.g. number of floors, construction technique, type of roof, type of walls, type of foundations, footprint area, year of construction and/or renovation, and so forth). The level of damage was registered for each structural and some non-structural members: namely, null, minor, moderate or major damage for columns, beams, walls, stairs, slab, parapets, et cetera. One of the main outcomes is the colour of the tag assigned to the building subject of the evaluation: green (safe to be occupied), yellow (restricted entry, it cannot be occupied full time) and red (unsafe, entry is forbidden). A red tag does not imply that demolition is required. The tag is sprayed on the main façade, the colour is the colour of the tag (green, yellow or red) and the code is “MTPTC” plus the number of the division that did the evaluation (e.g. MTPTC 3, see Figure 4).

Figure 4. On the left, MTPTC engineers completing a seismic evaluation through the tablet (Les Cayes, 2021). On the right, MTPTC engineers assigning a yellow tag to a building and marking the code that identifies the building on the wall (the QR code is visible on the top of the left of the door).

If damage occurred, a second step, the detailed damage assessment, followed. It included a sketch of the plan of the building, that could be executed by hand on the tablet, or through an app installed on the tablet, or taking a photo of a hand sketch on a piece of paper. The different types of damage were recorded in accordance with 2010 MTPTC guidelines for Confined Masonry (CM) buildings (they are open source, see reference (MTPTC, n.d.)): a code (e.g. A1, B1, B2…) has been assigned to the main types of typical damage (e.g. A1: wall cracked in shear, C1: wall collapse out-of-plane, D1: lintel failure, G1: spalled concrete column…). Through the tablet application, the engineers noted the different types of damage’s code and their location on the plan of the building. For each type of damage, they also measured the principal dimensions of the damage and took a photo. For instance, in case of an A1 (see Figure 5) “masonry wall cracked in shear (X-cracks)”: they selected A1 in the tablet, they recorded length and height of the wall to be replaced, they noted A1 on the sketch of the plan where the damage is located, and they noted A1 with a marker on the wall.

4.1. Handling and communication to users of the damage reports

The whole campaign has been carried out by MTPTC engineers digitally, through tablets provided by UNOPS and the open-source application KoBoToolbox (“KoBoToolbox”, n.d.) (see Figure 4, on the left). The server has been provided by UN-OCHA and has unlimited space. The owner of the dataset is MTPTC.

The extent and main dimensions of every type of damage that occurred to a Confined Masonry building was recorded through the data collection app. The database was migrated to ArcGIS, an algorithm was incorporated to automatically calculate the quantity of the materials needed to repair the building. As a result, a BoQ (Bill Of Quantities) including the total quantities and the estimated cost to repair the house in compliance with the Haitian standards was generated.

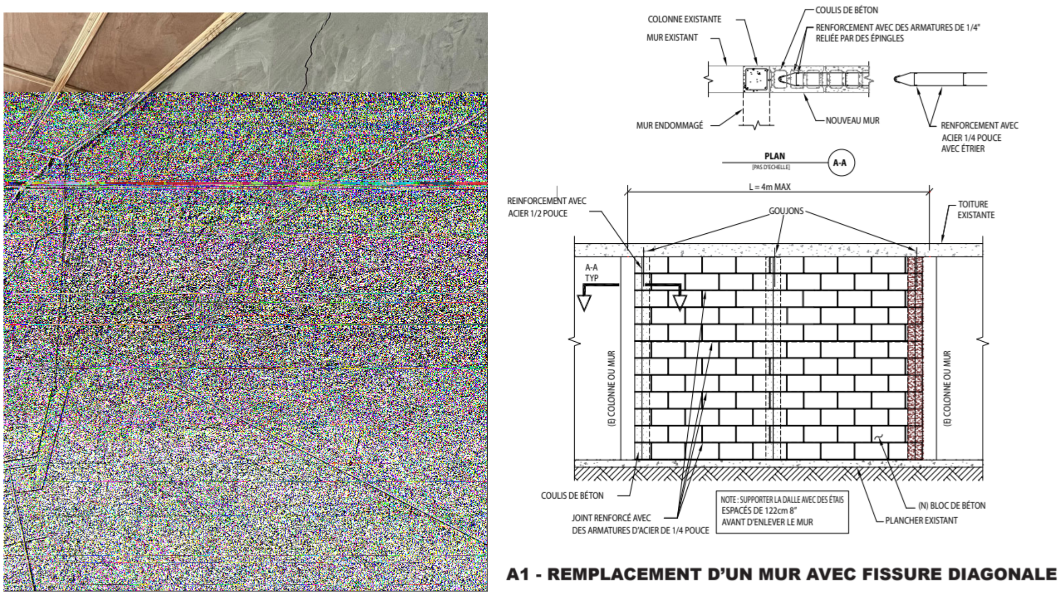

Figure 5. On the left: example of an A1 damage (Les Cayes, 2021). On the right: repair detail of A1 damages as per MTPTC guidelines (MTPTC, n.d.).

The damage and repair report can be downloaded by the building owners through a QR code affixed to their house (see Figure 4, on the right). Scanning the QR code or through the code that has been written with a permanent marker on a wall, the owners have access to the damage report that includes the sketch and photos of their building, and to the repair report that includes the BoQ to repair their building. The purpose is to facilitate and expedite a sound reconstruction process. The report also provides clear reference to MTPTC guidelines to build back safer buildings (see Figure 5, on the right). Furthermore, a free call-centre attended by social facilitators and engineers has been established to answer to the building owners questions.

Through the download of the damage and repair report, building owners and masons have access to the information they need for the reconstruction, However, it is critical that they become familiar with the process and with the best practices. Therefore, training of 6,480 masons in 18 locations and of 14,400 homeowners in 12 locations has been executed.

4.5 Damage assessment in other Countries: a comparison with Italy

It could be useful to compare what has been done in Haiti with the Italian emergency management system, in order to better comprehend the differences between national approaches, as well as the most critical aspects that have to be faced by the t surveyors during an emergency.

In Italy, the management of the emergency phase that follows a natural disaster is in charge to the Civil Protection, a public Agency that depends on the Ministry of the Interior. The Civil Protection (CP) activates emergency Centres and Offices in the affected territory according to a hierarchical scheme, assuring their presence over the whole area hit by the disaster. The coordination among these centres is managed by a central office ("Di.Coma.C." – Central Command Direction), in charge of supervising the emergency activities and the organization of the operative teams. The first activities performed by the CP deal mainly with the recovery of the population, providing them with medical assistance and hospitality services, and with the recovery of public and civil services, i.e., aiming to re-establish hospital functions and / or the local public administration (DPCM 21.11.2006). Moreover, CP also coordinates the teams of volunteers and the teams who participate in the surveys (Galanti et al., 2008).

Once the first aid activities have been performed, the emergency operators address the installation of technical countermeasures, in order to avoid further collapses of the damaged buildings. The technical countermeasures consist mainly in shoring systems such as props, tie rods and hooping solutions made by steel cables (Bellizzi, 2004; Grimaz et al., 2010). The installation of these technical solutions is in charge to the National Fire Brigade (NFB), that is part of the Ministry of the Interior as the CP. According to the Italian legislation, due to the high level of dangerousness that usually affects an area hit by an earthquake, the execution of the countermeasures can be performed only by qualified personnel of the NFB, while coordination activities are in charge to CP (DPCM 03.12.2008). Thus, in the last decades, the NFB has instituted special operative units who are able to work in such difficult conditions, whose members are expert both in rescue and technical emergency activities. These units are called : USAR (Unit for the "Urban Search And Rescue"), STCS ("Short Term Countermeasures System" Unit), SAF ("Speleological, Alpine and Fluvial" Unit), and they are composed by members that have attended specific courses and examinations (DPCM 08.07.2014)[1] . The officers of the NFB operate in areas subjected to unsafety conditions, presenting elements and / or damaged buildings that can threat the safety of the population or the accessibility to public roads. These areas, called "red zones", are immediately identified by the NFB after the occurrence of an earthquake and they are characterized by restricted access conditions. The process for the identification of such areas is based on surveys performed by NFB teams, together with the CP personnel and other experts, such as University engineers and researchers. (Grimaz et al. 2016). Once the "red zones" have been defined, the NFB technicians make technical surveys aimed at identifying the most dangerous buildings, where the installation of technical countermeasures is necessary. The fire-fighters work in teams, using different technical forms that have been defined after the past emergency experiences (Mannino and Grimaz, 2013). During this phase, the communication between the teams and between the teams and the central offices is guaranteed by the installation of a local radio network, which allows for the possibility to share information also if the internet connection is absent.

The NFB teams often include officers and experts that come from other Ministries and public Agencies, depending on the typology of the surveyed building. For instance, the teams can include also officers of the Ministry of Culture in case the buildings to be surveyed belong to the Cultural Heritage, or technicians of the local administrations in the case of hospitals and/or other main administrative centres. In such situations, the involved technicians work together inter-disciplinarily, exchanging competences about specific issues and/or restrictions that the installation of the technical countermeasures should face. Furthermore, specific forms that must be filled during the damage surveys on Cultural Heritage also exist (DPCM 23.04.2015). They are the result of different past experiences, and have been tested during the previous Italian seismic emergencies (Lagomarsino and Podestà, 2004). Through these forms the functionaries of the Ministry of Culture can realize the level of damage occurred to the buildings and better prioritize the quantity and the distribution of interventions. Since the format of these technical survey sheets originally dates back to the seismic experiences of the last twenty years, the process for acquiring and sharing data in a prompt manner is not yet completely digitalized and it still has to be improved (Cacace, 2019). Data collected in the forms are then used mainly for quantifying the occurred damage, in order to define both the typology and the cost of the required restoration works. Despite data are public and available under specific requests, they are intended for an internal use only, so that they are not shared among the public Agencies and the population.

Finally, a third category of surveys is the one represented by the damage surveys performed for the ordinary buildings. These surveys are carried out by the use of a specific form ("AeDES technical sheet" – Usability and Damage in the Seismic Emergency), specifically designed for analysing the damage of residential buildings based on ordinary structural typologies (frames and/or regular partitions) and common building materials (i.e., masonry, concrete and/or reinforced concrete, steel, etc.) [2] . Such kind of surveys are accomplished in emergency scenarios not affected by special dangerousness conditions for the surveyors. As for the previous cases, the technicians in charge of conducting the surveys have been trained through specific courses and periodic updates. As for the previous ones, these surveys are also managed by the CP.

5. Overview of the damage dataset in Haiti

In respect to the above-introduced target of reaching 120,000 buildings in 3 months, in the time of 5 months 179,800 buildings were assessed, including schools, churches, hospitals, commercial, industrial and residential buildings (see Table I). Of these, 110,297 (61.4%) were damaged, while 69,503 buildings (38.7% of total) were tagged green (safe to occupy). Among the damaged, 73,297 buildings (40.8% of total) were tagged yellow (damaged and entry restricted) 28,364 buildings (15.8% of total) tagged red (damaged and

[1] See what is described in the website: https://www.vigilfuoco.it/aspx/Page.aspx?IdPage=4976 [accessed: 2023.10.11].
[2] See also the URL: https://www.vigilfuoco.it/aspx/Page.aspx?IdPage=4976 [accessed: 2023.10.11].

unsafe to enter) and, finally, 8,636 buildings (4.8% of total) were completely collapsed (see Figure 6).

Table I. Type of occupancy, for some buildings that were completely collapsed the type of occupancy could not be recorded.

TYPE OF OCCUPANCY	Residential	Commercial	Other	Schools	Religious
N	168,144	4,356	3,113	1,871	1,318
%	93.5%	2.4%	1.7%	1.0%	0.7%
	Healthcare	**Community Centers**	**Industrial**	**Governmental**	**Emergency Services**
N	287	270	174	107	64
%	0.16%	0.15%	0.1%	0.06%	0.04%

Among the 110,299 damaged building, 89,440 were deemed repairable (81.1% of the damaged buildings) and 26,464 fell directly under the scope of MTPT Confined Masonry repair guidelines. The estimated cost to repair these 26,464 damaged CM buildings is, in compliance with MTPTC guidelines, of USD 58 million. The average repair cost for a damaged Confined Masonry building is USD 2,200. The repairable buildings that did not fall under MTPTC CM standards were (i) either too complex to be included in those guidelines, and they needed a more detailed study, or (ii) they were not in confined masonry. In fact, 80,808 buildings, not considering the collapsed ones, were built in traditional vernacular techniques (e.g. timber and unreinforced stone masonry).

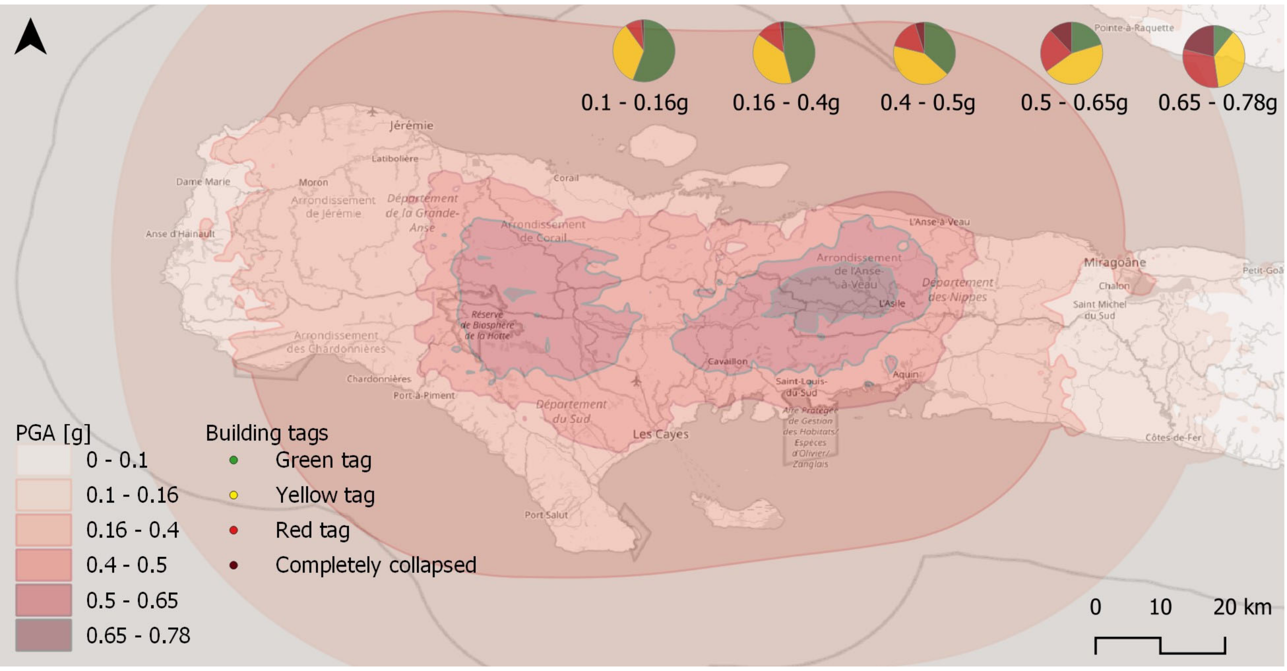

Figure 6. Green (building is safe), yellow (entry is restricted), red (unsafe) and completely collapse tag plotted on the Peak Ground Acceleration map. In areas where PGA is higher green tags visibly reduce.

6. Discussion

The implemented digital approach sped considerably up the assessment process. The advantages connected to the implemented digital approach that the authors found are: (i) the outreach, as a remarkably high number of beneficiaries (600,000) have been reached in only 5 months; (ii) the rapidity of the execution of the damage and repair assessment; (iii) the possibility to consult, review, revise and analyse the results of the assessments in real time, also from remote, for each individual building; (iv) the creation of a centralised digital dataset, with the advantage that digital data stored in a database are easier to post-process than paper-based evaluations; (v) the ease of run post-processing calculations, which can be automatically executed for thousands of assessments through algorithms.

The challenges that the team had to face during the project were: (i) the management of big data: almost 180,000 evaluations led to a significant size of the dataset. Several photos of the existing damage were encouraged, which led to issues in the data upload to the server and in the data download for the post-process analysis; (ii) the reliability of the collection platform: the whole project depended on the functionality of the KoBoToolbox application, which had some issues managing data collections of such size; (iii) QR codes logistic and unique identification of a building: duplicates of QR codes were erroneously printed and an additional system to uniquely identify the building had to be introduced (i.e. GPS coordinates and building owner phone number); (iv) scarce connectivity on the field and network reliability: the uploading of the evaluations had to occur only when a robust wi-fi connection was established, which is not common in rural areas. In a few cases the evaluations were not uploaded; (vi) maintaining a high quality of the data collected with hundreds of assessors on the field.

The lessons learnt lead to the following suggestions for future similar programs: (i) a proprietary application for data collection that is fully under the team control should be preferred; (ii) in order to reduce the size of the databases and simplify data management, it is not recommended to use the same survey form throughout the whole campaign (e.g. change every month or use different forms for different data collection teams) and limit the number of photos that can be taken (e.g. provide clear indications for a few meaningful photos); (iii) a unique source should print QR codes to avoid duplicates and a redundant system to associate the evaluation to the building should be in place; (iv) upload the surveys to the server only when connected to reliable wi-fi (e.g. only in the office) and do not delete any evaluation from the tablet unless there is certainty that the data was uploaded in the server; (v) use an application to produce sketches and avoid hand sketches on the tablet; (vi) an error notifications system that alerts when absurd measurements of damage types are entered in the evaluations should be introduced.

To the knowledge of the authors, this is the largest disaster response program, in terms of beneficiaries reached, executed through a digital application and tablets over 5 months. In good agreement with other pieces of research (Aitsi-Selmi et al., 2016) (Stute et al., 2020) and acknowledging the challenges outlined herein, our experience corroborated the positive impact that digital integrations can have to expedite and improve the quality of disaster responses.

6.1. Main highlights emerging from the comparison with the Italian methodology

The activities that have been previously illustrated offer an interesting example of how damage surveys can be performed during an emergency, as well as which are the main advantages and criticalities of the process that has been tested in Haiti. Through a brief comparison between that methodology and the Italian one it is possible to highlight the main differences. First of all, it can be noticed that the size of the affected area is remarkable in the case of Haiti, while it is normally less extended in Italy. This is due not only to the geological characteristics of the sites, but also to the fact the Italian CP organization generally allows to manage little districts, providing a capillary presence of qualified personnel, means and materials on the territory. This first advantage is due mainly to the high number of previous emergency experiences, which have allowed for a better organization of the recovery activities on the field. Secondarily, the Italian situation is characterized by a great efficiency in the management of emergency activities, in spite of lower effectiveness in the direct acquisition of digital data. In any case, the capability to directly acquire and promptly manage digital data has been increased also in Italy during last years, even if data sharing among the surveyors and the population is someway limited.

Concerning the procedure followed by the Italian Authorities for data acquisition and processing, it is longer and more complex than the one that has been developed in Haiti. This is due mainly to the complexity of the Italian built environment, which presents a great variety of building typologies, exhibiting different materials and techniques also in the same building, and to the necessity to firstly complete data acquisition over the whole affected territory, in order to let the Government better organize the distribution of public resources and funds allocated for the restoration and reconstruction of damaged buildings. This normally requires longer times for starting and accomplishing repair and reconstruction interventions, while the emergency countermeasures can be timely executed by the NFB, since they are in charge of public safety.

The presence of a variety of construction and building techniques requires multiple competences from the surveyors. Thus, when dealing with specific buildings such as the ones belonging to the Cultural Heritage, the damage surveys are carried out by interdisciplinary teams, made by technicians and functionaries that come from the NFB, the Ministry of Culture, the CP and eventually from lists of qualified professionals. These teams can rely on different technical forms which identify the main damage typologies that can occur to specific parts of the buildings (*macro-elements*), being formulated and tested during previous seismic emergencies (Doglioni et al.,1994). Due to the high complexity and the urgency that usually characterize a seismic emergency, the technicians in charge of realizing the damage surveys should prove to have specific skills and abilities, acquired with training courses and examinations. These skills must be acquired in advance and must be checked and updated regularly, aiming to improve both the organization of the surveyors' teams and the availability of skilled resources in the affected territory.

7. Conclusions

The scope of this paper is to share experience on the field with the disaster response community and provide evidence of a unique case of digital approach in a disaster response. Thanks to the World Bank, the Government of Haiti, MTPTC, UNOPS, Miyamoto International and the effort of 574 professionals deployed on the field, it was possible to implement an innovative methodology and assess 179,800 buildings in a 5 months period of time. Tablets were used to carry out the damage and repair assessments. QR codes were affixed to the structures to identify them and allow the owners to download the damage and repair reports. Detailed information on the damage was collected in compliance with ATC-20 and MTPTC guidelines, generating a massive database rich of technical information and aligned with the local context. An algorithm calculated the estimated material quantities and repair cost for all the 26,464 damaged Confined Masonry structures that fall under MTPTC standards.

The choice to pursue a digital approach had some advantages, such as the velocity of the data collection that allowed to reach a remarkable number of beneficiaries in only 5 months (600,000), the advanced review, revision and analysis that could be carried out in real time and from remote on the database, and the versatility that the digital features offer. Some barriers were also encountered, such as the dependency on adequate internet connection and on the reliability of the data collection application, in addition to the challenges inherent to big data management. The overall impression is that, within the limitations outlined herein, the implemented digital features improved and expedited the disaster response program.

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