Strategic Framework for Unmanned Aerial Systems Integration in Public Organisations in the Dominican Republic disaster management context

Abstract

In the Caribbean region, there is a significant yearly number of natural events incidents. The impact of those events has affected the well-being, social and economic structures of the countries in this region. The investment in disaster management strategies is a fundamental decision to the region for improving capabilities, understanding the liabilities, dealing with the disaster stages, and integrating systems and tools to obtain greater results in resilience strategies. Therefore, information technology and robotics have played an effective role bringing innovation to the traditional approaches by improving the capabilities of personnel and serves as a catalyst to rapid data collection tools for effective decision-making during disastrous situation, as has been the case of the Dominican Republic. The organic adoption process of Unmanned Aerial System (UAS) has represented a large step forward regarding this matter. Examples of the adoption process occurs based on their flexibility in their regulatory context, funding investments in testing the applications of UAS, such as surveying, delivering medical samples and spray disinfection during the COVID-19 pandemic. However, there are only some mature applications that address a future-proofing concept as well as the integration into a typical institutional workflow. Therefore, this paper aims to be an introductory guide for decision and policymakers, educators and technicians to reduce the scepticism, lack of knowledge and know-how in the adoption of reliable, practical and effective tools by providing a combination of theories from socio-technical systems (socio-technical change impact model (SCI)) and organizational level (technology-organizational-environmental) frameworks of the UAS adoption process for natural events, tasks and critical roles in disaster management taking into account the Dominican Republic context. Qualitative cases of studies were evaluated from nine (9) professionals related to disaster management in the Dominican Republic, and a semi-structured interview were used to approach the adoption process of Unmanned Aerial System (UAS) in these organisations.

The findings of these studies reveal the lessons learned from the internal strategies and policies in the adoption process between public and private institutions. The task of capturing images and videos has been shown to be a faster way to acquire data, which allow infrastructure projects to tend to be a significant benefit at the moment of applying UAS for 3D reconstructions and simulations of seismic behaviour, and finally, identification of inaccessible vulnerable areas after disasters. Other tasks, such as search and rescue, are also mentioned. Recommendations for policymakers are related to establish guidance for learning organizations approaches on focusing on digitalisation of cities through UAS applications as an additional complement of the Regional Comprehensive Disaster Management Framework of 2014-2024.

Keywords: Visualisation, Disaster Management, UAS, Futureproofing, Built Environment

Article Type: Research paper

1. Introduction

A natural event is a phenomenon that occurs by the natural processes of the Earth. The event can be categorised as a disaster by the adverse or negative conditions caused to humans. The Sendai Framework 2015-2030 exemplifies the four priorities for preventing new or existing disaster risks by actuating the understanding of risks, strengthening governance, investing in risk reduction and also resilience that enhances responses from a readiness perspective linked to hazards and human activities (United Nations, 2015). There are two types of risks which are differentiated by the impact to humans: natural events and technological or human-made events.

Natural events occur spontaneously on a physical basis. They are classified accordingly by their medium of manifestation: geophysical, hydrological, climatological, meteorological, and biological. On the other hand, human-made risks are events unleashed in or near a populated settlement or area. Normally, these risks include complex conflicts, population displacement, famine, industrial and transport accidents. In that same sense, human-made disasters are caused by technology or human intervention, such as nuclear explosions and air pollution (Gaspar, Yan, & Domingos, 2019). However, through time other environmental and human variables have emerged and have been counted such as climate change, unplanned urban growth, epidemics, and pandemics (COVID-19, Zika, H1N1, etc). This has provoked the reconsideration of humanitarian assistance, risk reduction, industries, and country development. The major inconveniences of disasters are the aftereffects associated with a cascading event (Zuccaro, Gregorio, & Leone, 2018) as well as a combination of natural and human-made events, the loss of human life and the detriment of built environment conditions (GFDRR, gfdrr.org, 2019).

As discussed, in the Caribbean region, there is a significant yearly number of natural events occurrences and, occasionally human-made disasters. The natural events in the region are earthquakes, hurricanes, floods, wildfires, seaweed invasions, dust storms and the recent COVID-19 pandemic that can be presented as a cascading event in line with human-made disasters. The impact of these events has significantly affected the well-being, social and economic structures of the countries in this region. The investment in disaster management strategies is a fundamental decision for the region by improving capabilities, understanding liabilities, dealing with the disaster stages with proper expertise and integrating systems and tools to obtain greater resilience expertise on disaster cycles aligned to the guidelines of the Comprehensive Disaster Management Strategy 2014-2024 for resilience cities and communities (Caribbean Disaster Emergency Management Agency, 2014). Therefore, in long term goals, information technologies and robotics play an effective role bringing innovation to the traditional management strategies by enriching the capabilities of personnel and serving as a catalyst for rapid digital data collection strategies for decision-makers during the cycle of disaster management for post-pandemic societies. In addition to this, it produces a migration to a nationwide vision, which is the case of the Dominican Republic.

Unmanned Aerial Systems (UAS) or Drones have been used to acquire successful, faster, high-resolution 2D data and support 3D reconstruction of the disaster sites. The viability of the UAS applications against and in combination with traditional methods have been explored from a different perspective in the last five years with positive results in construction, agriculture, and photography. A field to explore the application and improvements perceived from UAS is disaster management. The UAS has contributed to professionals in the field by optimizing public safety operations, quantification of damage with visual data, virtual reconstructions of the geometry of buildings, and search and rescue of people in case of accidents (Erdelj & Natalizio, 2016; Izumi, Shaw, Djalante, Ishiwatari, & Komino, 2019).

UAS has demonstrated its effectiveness in the context of disaster prevention, preparedness, response/relief and recovery for earthquakes, floods, wildfires, landslides, tsunamis, hurricanes, pandemics as well as human events on the tested built environment side (Chowdhurya, Emelogu, Marufuzzaman, Nurre, & Bian, 2017; Chamola, Hassija, Gupta, & Guizani, 2020). The benefits of the UAS have significantly reduced human risk exposure and the time for task completion in this context. In some cases, these aerial robots have been used as a method for transporting humanitarian aid due to the damage inflicted to streets, bridges, and between long distances communities. However, the challenges of UAS and its adoption are primarily: technical difficulties, restrictive regulatory environments, site-related problems, weather, and organisational barriers that can only be addressed by exploring the workflows in the format of cases of studies (Hamed Golizadeh, 2019; Greenwood & Zekkos, 2019).

For policy makers, it has been an arduous challenge to develop frameworks that encompass the technicalities of UAS operations. The European Union Aviation Safety Agency along with other bodies, practitioners and researchers have been proactively shaping and ensuring safe industry development with simple, complex and futurist cases of this technology (NESTA, 2018; Zhou, Irizarry, & Lu, 2018; Duffy, et al., 2017). However, there are still never-ending barriers for the current stage of the aerial robot development until standards of UAS operations types and applications are identified and agreed upon.

In terms of application, there is still scepticism within organisations and institutions, unaware of UAS capabilities and the improvements that can be achieved with them in terms of disaster management, oriented towards the built environment utilizing aerial robots. Therefore, the purpose of this paper is to:

- Map the current application of UAS in a developing country in general aspects as well as the geolocation of the Caribbean.
- Provide scientific recommendations for the acceptance and embracement process of UAS for practitioners intended to be involved in disaster management on the basis of wisdom obtained from a tested context.
- Formulate a general strategic framework for technology integration in public organisations undertaking the roles of UAS in the Dominican Republic’s disaster management context.

The following section will be focused on the framework perspective in which UAS technology is currently behaving and the literature regarding the three main elements (regulation, social and technical) that describe the adoption and endorsement of robots in society.

2. UAS Theoretical Framework perspective

From a research perspective, there are some theories that can describe the UAS acceptance process and its applications, such as the task-technology fit (Hamed Golizadeh, 2019) and system theory perspective (Haula & Agbozo, 2020) theories. In a more practical manner, frameworks such as Technology-Organisation-Environment (TOE) (Hart O. Awa, 2017) and automation and robotics feasibility indicators such as CARSAM (Construction Automation and Robotics for Sustainability Assessment Method) (Pan, Linner, Pan, Cheng, & Bock, 2018) could explain the decision making for the acceptance process of these technologies. After identifying a series of trends of applications, policies, hardware and software development, the socio-technical change impact model (SCI) (O'Hara, 1999) has explained the social and technological aspects of change management and relationships within the organisation throughout the discussion of technology, tasks, structures, and aspects relating to people. The SCI model consists of two sub-systems: the social and technical sub-system. Social sub-system is those involved with people and organisational structures, and the technical sub-system are those that cover technologies, processes, and the physical environment.

However, the subject of policy shall be reflected in this model as an external framework affecting the social and technical aspects of UAS adoption. The theory that incorporates environmental aspects and is aligned with the SCI model is the TOE (Hart O. Awa, 2017). In addition, TOE allows factors such as cost and productivity that the SCI may not include directly to be perceived. For these reasons, the SCI model and the TOE are suggested to be applied to theoretically describe the UAS adoption from a general perspective as shown in Figure 1.

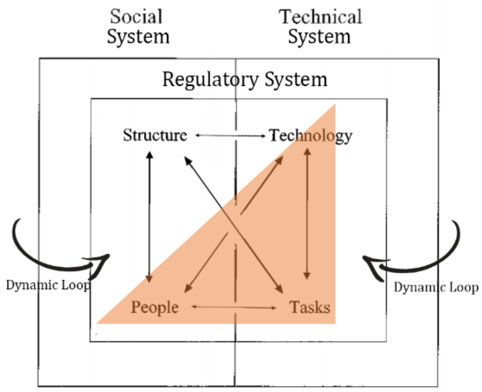


Figure 1. Framework SCI and TOE combination

The theoretical framework reflects a single order alignment of multiple stakeholders (Neville & Menguc, 2006) by showing in essence the influence of the power of regulatory bodies in the development of the professional tool in discussion. For disaster management, this theoretical framework involves the principles of the Hyogo Framework that later is involved in the regional Comprehensive Disaster Management framework. However, the inconsistency of fast paced ever changing policies in UAS makes the SCI-TOE framework vary from country to country, creating a dynamic loop with the internal influences of the organisations. For example, if UAS are banned due to a country's legislation or due to privacy issues, another technology shall emerge replacing it. In other words, the evaluation of UAS acceptance in organisations are required to be understood by the dynamic loop of the regulatory boundaries and processes within UAS operations. Other remarkable examples are the Extended-Visual Line of Sight (E-VLOS) and Beyond Visual Line of Sight (BVLOS) operations, UAS size regulation, restricted airport proximity and extreme weather conditions that may constrain the spread of UAS. Other countries may need further qualification or time to carry out missions that are intrinsic in the UAS application above. In the aspects of organisation, the main relationships that are promoting the integration of UAS are the interactions between people with the technology itself and successful task accomplishment. Therefore, UAS application is utilised inside organisations to automatise employee productivity by incorporating other technological supports in the process (Vanderhorst, Heesom, Suresh, Renukappa, & Burnham, 2020). Organisations are taking the knowledge obtained from UAS integration to provide business to business services by opening a new industry that could bring wealth and prosperity for the world. Therefore, in the following section each aspect of this framework is explored by understanding the embedded details and how in different countries regulations may contribute positively to the integration of UAS, most importantly if it is guided by disaster management purposes.

3. Regulatory System of UAS

Researchers focusing on various fields, such as ecology and built environments, have contrasted the different UAS regulations according to their field or from distinct UAS regulations (DeBell, Anderson, Brazier, King, & Jones, 2015; Duffy, et al., 2017; Irizarry & Costa, 2016; Zhou, Irizarry, & Lu, 2018). Nevertheless, disaster management has not been given national importance to specialise pilots for the operation requirements of UAS. Instead, the industry along with other agencies have appointed general ethics on the topic but not in depth in regard to technical or social aspects. In this frame of reference, the Humanitarian UAV Code of Conduct & Guidelines was founded. This set of guidelines encompasses the social aspects of the UAS operations such as data protection, community engagement, effective partnerships, and conflict zones sensitivity. However, the technical side of UAS operations could be covered by academics letting the knowledge of safe data capturing, development of new UAS types and UAS aerial corridors.

Concentrating in the technical aspects of operations (Cunliffe, Anderson, DeBell, & Duffy, 2017) describes the process of obtaining a Permission for Aerial Work (PFAW) or its other alias, Permission for Commercial Operation (PFCO), General VLOS Certificate (GVC) in the United Kingdom (UK). (Cunliffe, Anderson, DeBell, & Duffy, 2017) provide an operational manual for researchers that are intended to grant permission or qualification for UK operations as well as a framework. This method allows professionals in specific fields to document their operations and share with the crew and corresponding authorities their internal capabilities and management of the UAS. However, the lack of specialised researchers in the UAS sector limits significantly the transfer of knowledge to different educational levels and fields. For example, knowledge exchange on practice and studies that each sector may need to address from different perspective are currently limited even though the same tools and software are used within other sectorial domains. Some tasks such as such as pattern recognition, detection of people, 3D reconstruction, photogrammetry methods and information management are well applicable between different disciplines such as environment studies for construction, architecture, environmental science, and disaster management. However, the civil aviation authority's mindset is wisely oriented to provide safety boundaries and qualify pilots via a test method rather to professionalise each field. Therefore, the specialization perspective of regulations will enable the harmonizing of UAS regulations internationally.

In the case of Europe, the European Union Aviation Safety Agency (EASA) announced that from December 31st 2020, there will be regulations introduced for manufacturers (2019/945) and operators' (2019/947) that would last almost 3 years. The guidelines are aiming to harmonize the pilot certification process, attempting to make the local UAS manufacturers equivalent and the knowledge of EU (European Union) countries based on UAS weight categories (C0-C4) and standard operations (Open (A1, A2, A3), Specific and Certified Categories). It is intending to introduce a method of testing under the premise of standardized proof cases with low-level of risk involved in the operations. The method is in agreeance of the commercially Federal Aviation Administration (FAA) regulation of the United States of America (USA). In addition, other countries would adapt the baselines of these tests methods and incorporate it into student curricula by its easily comprehensible process. In contrast to EASA, which is intensively intending to ground the current scenarios of UAS application through the certification of manufacturers and operations. It is assumed that the regulations may positively avoid the risk of a country licensing UAS as occurs in the United States with DJI. This action aims to assure the development of the industry in their countries but could be extremely extensive and unpractical for the industry. In addition, no specialization is mentioned.

Furthermore, the upcoming changes in European regulations could help spearhead the acceptance of UAS technologies in different organisations in conjunction to help explore the contingencies on this emerging industry. However, the "Know-How" of UAS application is one of the key success factors for a digital strategy integration in terms of resilience and maintenance of the economy as is the current case of COVID-19 for the built environment. In other words, the "Know-How" of UAS application would integrate data for resilient cities development, design, and performance changes where satellite data has not yet been used to develop a 3D reconstruction of them, and novel transport methods are aiming to be incorporated. Data-driven and automated robotics societies can significantly improve the decision-making process in any context and even more so in disaster management topics.

An example of this research and development is focused on UAS applications involved with the effectiveness and safe management of air traffic risk prevention, complex reconstruction of structural shapes in difficult environments, the development of UAS materials (wood, polymers, or biological material) and the interaction of emerging technologies such as artificial intelligence, internet of things and swarm technology. These examples of research and development have shown the opportunities and challenges of UAS and have delivered prudently this understanding to policy makers and the industry to enhance their methods to surpass the social and technical hurdles for its integration.

In addition, scientists from this field provide understanding of the different digital strategies for disaster management. The panorama of UAS seems to be arriving to an international consensus between nations, but many variables could expand or reduce the harmonization by the UAS. Therefore, the following section explores the taxonomy, workflows, and trends within the technical and social aspects of UAS.

4. Technical and Social Aspects of UAS

4.1. UAS Taxonomy

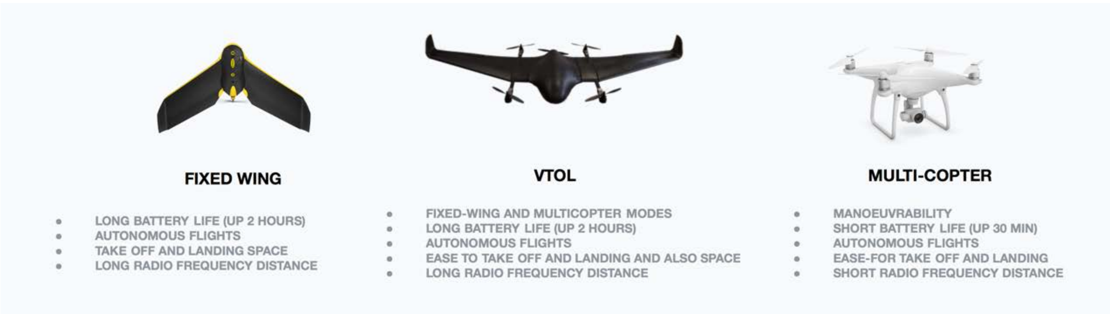
The UAS has different acronyms and a detailed taxonomy according to its context, weight, and country in which it is used as discussed by (Clarke, 2014; Greenwood & Zekkos, 2019) (Table 1 and Figure 2).

Table 1. Acronyms

Name	**Abbreviation**	**Context used**
Drone	-	Commercial Name, references to autonomous operations or remote controlled
Unmanned Aircraft	UA	For drones more than 150 kg by JARUS and Singapore Regulation
Remotely Operated Aircraft	ROA	Named Before 2001
Remotely Piloted Vehicle	RPV	Degree of Autonomous piloting
Unmanned Aerial Vehicle	UAV	Technical Aspects
Unmanned Aerial System	UAS	Commercial National Regulations
Remote Piloted Aircraft System	RPAS	International Regulations

By 2013, the term aerial robot had been adopted by civilians to solve day-to-day problems, utilizing quadcopters in most cases. The acceptance process within an organisation is more regularly embraced when UAS is used to reduce harmful scenarios; acquire, increase, and share data, then, finally enhance the speed of organisational processes. The selection of UAS depends on the capabilities associated to its design taxonomy (Figure 2) and by the cost. Currently, the UAS quadcopter on the market have a battery life between 15min – 30 min, depending on the model (Greenwood & Zekkos, 2019). For surveying, the fixed-wing UAS is utilised as it has a larger operation time of 30 min- 2 hours. However, the most popular UAS quadcopter in the market are the ones with a RGB cameras due to its simplicity for imaging, filming, data capturing at low costs. The range of prices for professional UAS that weigh less than 55kg are around US$1,200-US$72,000, depending on the model.

Figure 2. Taxonomy example of UAS



4.2. UAS Sensors, workflows, social implications

The current UAS sensors are RGB cameras with a resolution capacity of 12-20 megapixels for aerial shots, videos, and 3D reconstruction utilising photogrammetry techniques. Other sensors such as LIDAR technology, thermal imaging (Borrmann, et al., 2014), chemical pollution (Rosser, et al., 2015), and solar radiation (Abdollahnejad, Panagiotidis, Surový, & Ulbrichová, 2018) are created to enhance the potential and applications of these sensors. Some of the sensors and software related with UAS have been conceived to solve a specific problem. But the versatility of UAS allow researchers and practitioners to enlist innovative solutions for disaster management such as electromagnetic radiation maps as an example. In literature, can be found several other applications that are regulated by the UAS capabilities (battery life, design, and cost-effective solution against actual methods). For

example, UAS for cargo has been used to supply goods in case of a collapse in infrastructure and uncommunicated communities.
However, it is important to note that not all the experiences have been successful for implementation in various disaster events. The tasks of damage assessment, situational awareness, risk to communication systems, transportation of urgent goods or hazard material sampling, disaster defence and search and rescue are performed accordingly to the current capabilities of UAS, software's, and the sensors related to the outcomes desired In addition, the most common UAS workflow tasks utilise commercial software for reconstruct areas with photogrammetry and LIDAR. For example: LIDAR sensors with their own manufacturer software tend to be used for acquiring terrain models for dense forests in contrast to photogrammetry which is mostly used to describe and extract the current situation exactly as appear.

Therefore, the available sensors and future developments give the possibility of easier and smoother work on disaster response as well the readjustment of relief functions, mitigations plans and finally restoration of the built environment. Figure 3 presents the technical workflow and software examples for UAS integration for any situation. Furthermore, figure 4 presents scenarios and sensors intended to be developed in the future for UAS by contributing to disaster management.

Figure 3. Workflow exemplar of UAS in disaster management

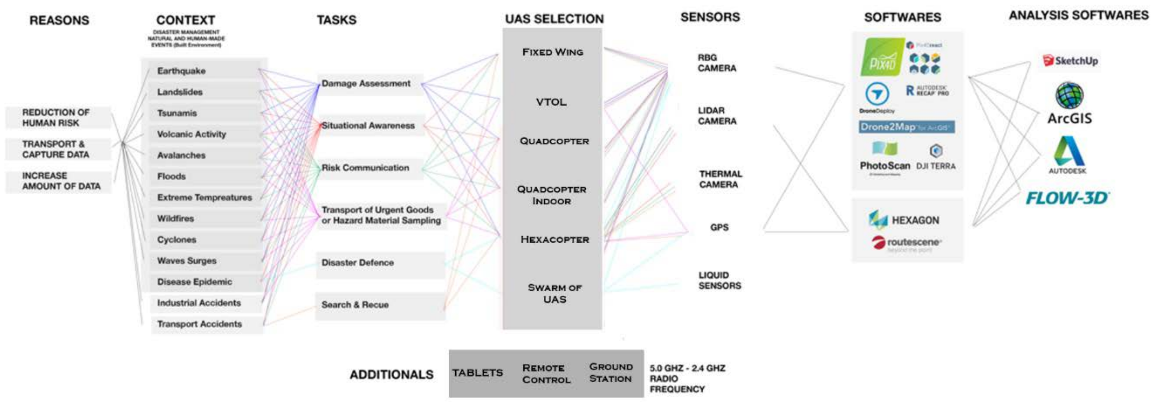


Figure 4. Other scenarios embedded in UAS applications

Tasks	Damage Assessment Risk Communication Situational Awareness	Damage Assessment Risk Communication Situational Awareness	Transport Disaster Defence	Virtual Reconstruction Software Analysis
Action	Images and video production	Images, geometrical, noise and pollution data is taken to produce a virtual models	The RPAS is used for lift and transport goods.	Softwares are used to understand virtual models
Sensor	Sensors utilised are: RBG Camera Thermal Camera 360 Camera Multispectral Camera	Sensors utilised are: LIDAR Sensor Pollution Sensor Chemical Sensor Decibels Sensor Radiation Sensor	Programmed RPAS Hexacopter RPAS Octacopter Internet Spray Desinfectant	Softwares: BIM Schedule Tracking Artificial Intelligence GIS Softwares Photogrammetry Software
Outcomes	Pictures and Videos Reports 360 Pictures and Videos VR Experiences	Orthomosaic Georeferenced Surveying - Contour Lines	Cargo Food Cargo Medical Samples	Urban Analysis Multidimensional Risk Assessments

It is important to understand that different software used during post processing of UAS data may have faster processing algorithms for photogrammetry, which is the most used tool in general. The awareness of the processing speed, in cases where time is crucial for decision making, is relevant to note and measure. According to (Alvares, Costa, & Melo, 2018) Agisoft Photoscan processed faster than the normal Pix4D software. Therefore, commercial changes on Pix4D have been made in terms of point cloud density birthing the *Pix4Dreact* which generates 2D orthomosaics in lower resolution than normal in faster time. Furthermore, processing in the cloud or natively on a computer can significantly increase or decrease the time and reconstruction accuracy of the site.

The investment in robotics and technology can be difficult or unjustified for some of the public and private organisations by all the legal and technical implications and hurdles related to the process. However, after the current global pandemic, and social distancing, the idea of integrating technology in organisations have been taken seriously by providing novel methods to deliver communication and assessing the impact of events on humans. The emergent importance of adopting the tools of the 4th Industrial Revolution is easing the mitigation and crisis management of natural and human-made events. For this, UAS is exemplary of the step forward on digitalisation strategies for disaster management. Moreover, in the future, sensors such as 360° cameras could provide immersed experiences of the disasters site, and also, the material generated can be used for replicate in the future the scenarios in virtual reality training. Nevertheless, until the technology arrives to this point, it is worth exploring the current state of UAS applications in disaster management along with some of the author's ideas of the role in addressing events.

5. Unmanned Aerial System (UAS) Disaster Management

The concept of aerial photogrammetry has emerged since the Second World War, bringing the innovation of UAS applications for military purposes. UAS is applied against satellite imaging due to the high resolution and real-time images obtained by being accuracy and low-cost solution. (FranciscoAgüera-Vega & PatricioMartínez-Carricondo, 2017). The 2D and 3D reconstruction of terrain allows organisations to observe and appreciate the situation of a disaster in terms of space and time (Ham, Han, Lin, & Golparvar-Fard, 2016). Other software is used to produce final outcomes in field assessment as a geography information system (GIS), 3D reconstruction with building information modelling (BIM) or point cloud identification with artificial intelligence.

There are 5 categories of natural and human-made events, according to the International Federation of Red Cross and Red Crescent Societies (IFRC). They are classified as geophysical, meteorological, hydrological, climatology and biological for natural events and identified as complex emergencies or conflicts, famines, population displacement, industrial accidents, and transport accidents for human-made events. However, the applicable events for the disaster management of built environments with UAS is the main focus of the study.

The events have utilised the implementation of UAS risk reduction and crisis management (Luo, et al., 2018). The lack of UAS preparedness and each country's specific context may change the feasibility of the application of UAS. Regulation, environmental issues, liabilities, and organisations can be a significant barrier to adopt the aerial robot (Hamed Golizadeh, 2019). These challenges reveal that the lack of knowledge in undertaking digital strategies has reduced novel methods to address and investigate issues, such as the monitoring of sargassum migration to the beach coast of the Caribbean (Putman, Lumpkin, Olascoaga, Trinanes, & Goni, 2020) and acquiring situational awareness of sea oil overflow where the UAS could be feasible to gather relevant data for scientists. Furthermore, the applications of UAS for any geophysical, meteorological, and hydrological event is primarily surveying the field in search of physical data and then processing it to initiate a decision-making process in terms of risk prevention, the allocation of aid, rescue, reconstruction, and/or mobility of people.

Integration of UAS within the context of a smart city is presented as a merger between the digital process behind the preparedness and the response to a natural event. For instance, 3D reconstruction after the 2015 Nepal Earthquake for community resilience for damage visualisation (Pix4D, 2016), support of medical delivery in front of rapid infectious disease (Ochieng, et al., 2020; Edoh, 2018) and the spread of unfertile mosquitos against the proliferation of disease are some of the applications identified along with GIS (in some cases worldwide) that could consider this case as a smart city (Xie, Gupta, Li, & Shekhar, 2018; Vojinovic, 2008). In this perspective, the Humanitarian UAV Code of Conduct & Guidelines was founded. These ethical guidelines were developed by the industry and official bodies to empower harmonious integrations during disaster management. One of the major concerns in this field is the qualification methods for safety reasons and also, from a professional perspective, engineering for disaster management (Contretas, niles, Roudbari, Harrison, & Kaminsky, 2020).

The information gathered and developed from UAS telemetry, and cargo assessment are visual assessment of the current conditions; the replacement of humans from risky tasks; structural assessments; status of urban damage; the allocation of aids; access to uncommunicated zones; design and visualization of safe routes for human displacement; identification of infection source; 3D reconstruction for modelling; safe cargo delivery of medical samples; and thermal inspection. Evidences have shown that, in the Caribbean region, the main events that require or utilise implementation of the UAS are cyclones, storms and floods as well their cascading effects (Table 2). The literature shows the tasks in which UAS has been applied and seems to be useful.

Table 2. Literature map of the UAS in the Caribbean Region.

Type	Events	Cascading Events (1)	Cascading Events (2)	Tasks	Literature
Geophysical	2010 Haiti Earthquake			Damage Assessment Situational Awareness	(Voigt, Tobias Schneiderham, Monika Gähler, & Mehl, 2011; DesRoches, Comerio, Eberhard, Mooney, & Rix, 2011)
	2020 Puerto Rico Earthquake	Earthquake Replicates		Damage Assessment	(USGS Science for a Changing World, 2020; Hennen, 2020)
Meteorological	2016 Hurricane Matthew Haiti	Erosions		Damage Assessment	(Kijewski-Correa, Kennedy, Taflanidis, & Prevatt, 2018)
	2017 Hurricane Maria Puerto Rico	Floods	Tornadoes	Damage Assessment Situational Awareness Transport	(Health care IT News Australia, 2018; Kishore, et al., 2018; Colón-Ramos, et al., 2019)
	2005 Hurricane Wilma Florida	Ecological Shallow subsidence		Damage Assessment Situational Awareness	(Whelan, III, Anderson, & Ouellette, 2009; Adams, 2011)
Hydrological	Cloudburst	2005 Flash Flood St Maarten		Damage Assessment Situational Awareness	(Vojinovic, 2008)
	48h Rain Fall Storm	River Overflow	2004 Isla Hispaniola Flood	Site Reconstruction	(Glas, Maeyer, Merisier, & Deruyter, 2020; Brandimarte, Brath, Castellarin, & Baldassarre, 2009; Kousky, 2017; Sheller & Leon, 2016)
Combination of Climatological Human-made	2020 Dump Wildfire Dominican Republic	Air pollution		Disaster source visualisation	(Polanco, 2020)
Biological	2019 Coronavirus	Economic Crisis		Potentially Cargo aids and Spray	(WeRobotics, 2020)
Human-Made	2020 Venezuela Oil Spill	Tourist Crisis		Situational Awareness	(BBC, 2020)

Furthermore, the literature presented on the Caribbean Region, presents a paucity of information focusing on UAS workflows within the public sector or indeed focusing on real cases in disaster risk reduction. Additionally, the practices of the integration in public organisations were not found. Therefore, this paper aims to provide a strategic framework by mapping the application of UAS to reduce the scepticism, lack of knowledge and time for the adoption of reliable, practical and effective tools for disaster management in countries where natural events periodically occur, and for this study we took the context of Dominican Republic and its current adoption process, UAS flexible regulatory boundaries in public institutions and high productivity rates in obtained tasks such as surveys (Vanderhorst, Heesom, Suresh, Renukappa, & Burnham, 2020).

6. Case of the Dominican Republic: UAS and Disaster Management

The Dominican Republic is a country that shares its territory with the Republic of Haiti, located in the Caribbean Sea region near to the east of Central America. The country has been exposed to 39 Hurricanes, three earthquakes, one tsunami and a flood disaster since the last century up to date. In addition, the developing country has presented rapid spontaneous population growth in rural and urban areas avoiding city planning strategies. This spontaneous growth is causing vulnerable population to amass in front of rivers, on dry inlets, dolines built with zinc plate and brick blocks being at the highest risk in the face of floods such as the Isla Hispaniola Flood (Glas, Maeyer, Merisier, & Deruyter, 2020)., landslides, and infrastructure collapse in an earthquake as occurred in Haiti (Voigt, Tobias Schneiderham, Monika Gähler, & Mehl, 2011; DesRoches, Comerio, Eberhard, Mooney, & Rix, 2011; Rojas-Mercedes, Sarno, Simonelli, & Penna, 2019)

By the disaster records of the country, the government has appointed disaster management as a major point on its national strategy to increase resilience process and produce advancement on its mitigation strategies reducing the loss of human lives, detriment of the integrity of the infrastructure in rural and urban areas and lessen the negative social-economic impact of disasters on in the agricultural sector (GFDRR, gfdrr.org, 2019; Baker, 2012; Mendez-Tejeda & Delanoy, 2017).

Consequently, different agencies have invested in disaster risk reduction plans for this country (i.e. European Union, United Nations Development Program, United States Agency for International Development and World Bank (GFDRR, WDG, EU, & UNDP, 2015). However, there is points of improvement in terms of volumetric accuracy in the damage quantification assessments (Legal, d'Antonio, & Napoli, 2010), real-time communication process (Sukmaningsih, Suparta, Trisetyarso, Abbas, & Kang, 2020) and effective methods of consumable delivery on this type of situation (Jo & Kwon, 2017). The implementation of UAS in the country has been demonstrated by several tests involving aerial robots and the cargo of medical samples and multimedia uses.

The regulatory environment of UAS in the country has had a further change since the first regulation was promulgated in 2015 (Resolution 008-2015). This resolution was a basic guidance of UAS operations, restrictions of operations, and alternative in case of carry out operation beyond the limited established (more than 400ft, Swarm of UAS, UAS for cargo, etc). Then, the proliferation of these aerial robots has been progressively by public and private institutions in which changes were needed to put in place. For example, public institutions were exempted of boundaries on their operations in certain cases if safety measurement were taken in place by the institutions. Base on this kind of exemption, clarification on the operations liabilities would rise concerns at some point. In addition, the early adopters UAS operations regulation experienced cases in which improvements on: Overseas operators, incidents on operations close to people and airports, privacy concerns, and lack of specialised education of UAS.

For these reasons, two instances of Dominican Aeronautical Regulations (RAD) were introduced in 2020: RAD 48 and RAD 107. In terms of regulation structure, the current regulations present similarities to EASA and FAA policies but recently added the educational component in relation to training as the CAA does with the PFCO process. It means that the requirements for licencing UAS commercial operations with an UAS less than 5.7kg is required to pass a test from one of the organisations authorized to provide reglementary instructions for safe UAS operations. In terms of sanctions, the past and present regulations conceived the legal mechanisms for inappropriate use of UAS flight on restricted zones and transportation of harmful substances without government authorization. Furthermore, inappropriate application of UAS trigged sanctions which are implied by the regulation and by the military force.

However, clarification of the liabilities and examples shall be mentioned. In addition, the lack of knowledge on UAS capabilities and specialised professionals globally precede investigations in this field. One of the major inconveniences after the loss of human life, is the detriment of the built environment in which UAS application for mitigation plans and crisis management have been tested.

The thought process of adopting new technology and methods is based on a learning organisation's management. This concept contributes to incorporate novelties for designing and establishing urban planning and infrastructure parameters in rural and urban zones of the country, identifying vulnerable areas for effective financial resource management for agencies and the increment of communication. A thought pattern that will develop a relevant plan for organisation is carrying out novel strategies of implementing types of machinery, sensors, and IT solutions to save time, streamline aid allocation and the preservations of lives before and after a pre- and post-disaster. For this reason, it is inferred that the approach of generating, reconstructing and simulating 3D data during disaster management responses could increase the effectiveness of a community recovering. Therefore, the data gathered will open the possibility to incorporate the concept of Building Information Modelling (BIM) and Smart Cities, promoting the holistic digitalization of future-proofing the built environment which is vital for the recovery stage post-disaster. In more general aspect, nations looking for human centred societies will be induced to achieve higher level of well-being and happiness as defined by the concept Society 5.0 (Mavrodieva & Shaw, 2020) in other countries, that the Dominican Republic should contemplate in their agenda. In summary, the lack of UAS application framework, policies oriented to digitalisation of the built environment that later can be used for resilience and keep a culture of wise record-storage and digital data of the disasters events may difficult the adoption of technologies.

7. Research Methodology

The aim of this research is to present a strategic framework for UAS Integration in Public Organisations in the Dominican Republic for disaster management that can be utilised as a guide for other countries with similar public structure. The context-based was the Dominican Republic where technology has been promoted and it has significant positive results in the integration. According to the Disaster management law 147-02 there are 26 institutions decision-makers institutions, 35 in coordination levels, 4 internal units and finally the direct system of communication with the cities across the country as seen in figure 5 (United Nations, 2010).

The strategy used to incorporate technological tools in the decision-making process on a national level was to develop a monitoring centre that systematizes the knowledge of threats, vulnerabilities, and risks in national territory, aiming to evaluate and recognize the capacity of response of the institutions in the event of disasters. The geospatial and statistical data along with risk management plans and analysis is shared to a virtual library via institution's servers to strengthen early warning systems, the response capacity of the *Emergency Operations Centre's* foundations and, operating as a resource of the national directory. In addition, the monitoring centre is used as a source of primary disaster data for decision-makers who constitute the *National System for Disaster Prevention, Mitigation and Response* and directed by the President of the country. The *Integral National Information System* (SINI) (Gobierno de la Republica Dominicana, 2020) along with the international Information Geospatial Team (EIGEO) is the technical entity responsible for concentrating, gathering, collecting, and converting disaster risk data into manageable knowledge for decision-makers. SINI connects 14 public institutions (Table 3) responsible for identifying data of soil, seismic activity and evaluation, droughts, floods, rainfall, wildfire, highways, contour lines, and others. In other words, from the 26 decision-makers institutions, there are 14 interconnected institutions with the monitoring centre to provide accurate information to key stakeholders.

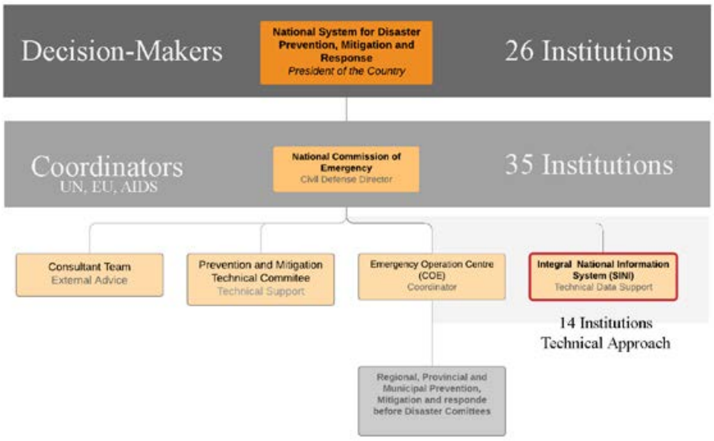


Figure 5. Disaster Management organisational emergency chart (Law 147-02)

The UAS application in different organization related to the built environment were identified. These institutions provided evidence regarding their inter-institutional work with UAS for disaster management related with the built environment. The dominican private sector has been utilizing and providing UAS services to the government since 2005. The public sector started to adopt UAS in 2015 by applying it to border surveillance. Later, in 2016, international aid contributes to addressing the need for training courses dedicated to UAS operations to institutions. Furthermore, and according to the current UAS regulation in the country, public institutions are practically unrestricted in their operations. Therefore, a qualitative case study was built from 7 organizations involved with UAS operations. The data and analysis of these semi-structured interviews were made utilizing

Nvivo software and identifying patterns and themes regarding the strategies and application of UAS built environment that influenced disaster management.

Table 3. Disaster Management inter-institution teams.

Acronym	Institution	Tasks	UAS on Board	Hire UAS
SINI	Integral National Information System	Online Platform and Condense information into 3D models that can be perceived the Floods, seismic, landslides, fires, refuge, Schools, hospitals, and capacities maps before and after disasters.	✓	
SGN	National Geological Service	Geological Fault, Landslide possibilities, floods.		✓
ONESVI	National Office of Seismic Assessment and Vulnerability of Infrastructure and buildings	Infrastructure, Buildings, Assessment, Schools and Hospitals assessment.		✓
CNS	National Seismology Centre of the Autonomous University of Santo Domingo	Seismic Events, Epicentres, and Intensity in the Ritch scale.		✓
INAPA	National Institute of Drinking Waters and Sewerage.	Aqueducts, Residual treatment plants, bomb stations.	✓	✓
MOPC	Ministry of Public Works and Communications (MOPC)	Redecoration of the city status with specialised machinery.	✓	✓
MENR	Ministry of Environment and Natural Resources.	Data of Rivers, Wildfire, Soil, Flood Vulnerable zones.	✓	
MA	Ministry of Agriculture	Soil, drought, geo-zones.	✓	
MINERD	Ministry of Education	Schools, Child-Care Facility, Special centres, Universities.		
ONAMET	National Office of Meteorology	Temperature, Meteorology and Hydrological Events, Huracan, Tsunami, Rainfall, and wind conditions.	✓	
ICM	Military Cartographic Institute	Highways, Buildings, bridges, lakes, ocean delimitations.		
INDRHI	National Institute of Hydraulic Resources.	Dam levels, river flows, rainfall data.	✓	
SIUBEN	Unique System of Beneficiaries.	Gender community segregation, Disabilities, houses, and vulnerable house areas.	✓	
IGN	National Geographic Institute.	Geographic, cartographic, and geodesic studies.		
IGU	UASD Geographical Institute.	Geographic studies and Contour lines		

8. Results

8.1. UAS Community in the Dominican Republic

The UAS community in the Dominican Republic was founded by the Civil Aviation Authority of the country (Dominican Institute of Civil Aviation, IDAC) and social media. The Civil Aviation Authority has records of the licensed pilots and permits granted for their deployment at events, and beyond UAS airspace limits. In terms of disaster management, there is no direct record of these operations based on the premise that government operations are exempted of restriction if the safety requirements are met.

The social media community on Facebook, under the name of *Drones Dominicanos*, has an important number of members that belongs to the UAS community (3,2k members). From this community, several WhatsApp groups are linked regarding to the UAS market in the Dominican Republic. Some announcements of temporal airspace restrictions and UAS regulation changes are communicated by social media and chat groups (Table 4). In addition, a Drone Innovation Centre exists in the country with the aim to test different platforms and uses of UAS. In the case of disaster management, active members spontaneously and organically capture images and videos when floods and post events occur for situational awareness and visual damage assessment. Social media represents a preponderant role for the UAS community, and it is seen as a cultural communication mechanism for professional and non-professional purposes. Therefore, the amount of data collected by the UAS community has provoked decision makers to promote technologies in the public sector.

Table 4. Community Groups of UAS in the Dominican Republic.

No.	Date	Description	Participant	Knowledge asset	Purpose
1	21/06/2015	Red Flag Drone Racing	77	Built and Racing Drones	Hobby
2	20/12/2015	CompaDrones	58	Photography Service Providers	Hobby
3	03/09/2016	Dominican Asoc of Drones	148	Drones Association (All Types)	Professional
4	29/04/2017	Full Drone DR	72	Photography Service Providers	Hobby
5	14/06/2017	Drones Santo Domingo	147	DJI Distributer Clients	Hobby
6	22/08/2018	Drones SDQ	7	Trainers Drones	Professional
7	20/09/2018	ASODRONE	56	Photography Service Providers	Professional
8	30/10/2018	SDQ Drone Community	35	Photogrammetry Trained Drones	Professional
9	11/11/2018	OpenBIM RD	249	BIM Professionals	Professional
10	06/08/2019	Drone-Enfoque Digital	70	Photogrammetry Drone Skills	Professional
		Total	919		

8.2. Emergency Function Framework in the Dominican Republic

The public sector has been developing strategies for incorporating a technological component as a part of their decision-making tools. In disaster management, the abstraction of the monitoring centre as the technological component were created with the purpose to concentrate, gather, collect, and convert disaster risk data into manageable knowledge for decision-makers. This component summarises the knowledge of threats, vulnerabilities, and risks at a national level, with the purpose to evaluate and recognize the responsiveness of the institutions in the case of disasters. The geospatial and statistical data are used for risk management plans and effort allocation. The monitoring centre relays to the other institutions in order to avoid confusion and misleading information. Another fact is that institutions, during the collection process of internal and external data, have been implementing UAS for completing disaster reports, evaluations and monitor vulnerable areas. In between institutions, there has been a heightened competitiveness and improvement of their capabilities for the integration of technology. The general emergency function framework is shown in Figure 6.

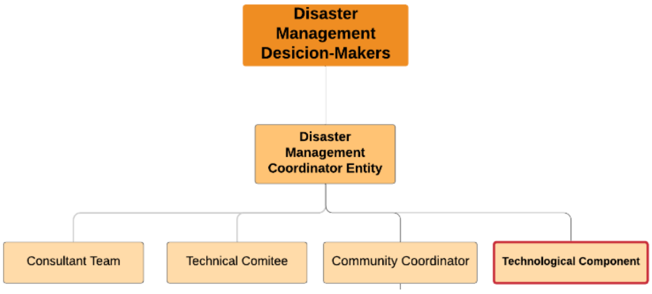


Figure 6. The general emergency function framework for technology adoption in Disaster Management

8.2.1.UAS Integration and Workflow Process

The UAS integration process starts with the arrival of the technology to the institution by the intention of streamlining work tasks. In some cases, UAS has arrived by hobby purposes and/or the development of know-how or via external contractors. The ownership of the UAS could be assumed by the director of the department or by an employee willing to make their work easier and faster. Then, the technical or management departments assess the tasks that requires visualisation, improvement of safety, or increasing the amount and speed of data management. In other cases, organisations approach the institutions to show how the aerial robot can contribute to their normal workflow, or in an informal meeting where UAS benefits are displayed.

However, the adoption of UAS officially occurs after remarkable strategic reasons are identified for the implementation of UAS. These reasons were associated to attempting innovation, keeping digital records of events and work, visualizing the sites, obtaining higher resolution images than satellites, reducing costs by improving effectiveness, and enhancing the practicality of the institutional workflow. The most notable reason to acquire UAS is the benefit of saving time in operations contrasting traditional (normal) data collection methods for the disaster team in a specified province. The implementation of RGB cameras in quadcopters or the DJI Phantom 4 represents a safer tool for evaluating remote and vulnerable areas and reduces the risk of exposure to employees when dealing with tasks of visual damage assessment, situational awareness, and communicational risks. Other tasks such as the application of disinfectant spray and the transportation of hazardous goods still need further technological development to accomplish the purpose efficiently. However, this last application has been tested but is still at an early technological development stage.

After the reasons are justified and assigned for UAS adoption, a project test is carried out to accommodate this new tool to the institutional workflow. There is a learning curve that decides if the benefit and knowledge obtained are needed recurrently or seasonally, with the purpose to acquire a UAS for the organisation or continue hiring a professional until the learning process is done. After several cases, the technicians present the feasibility of UAS to their directors for the acquisition or for seasonal hiring of experts. In addition, institutions decide just to hire an outsourced service in the case that the tasks require more than the current UAS capabilities. UAS is mostly used for technical reasons. The helicopter is still being used but for certain predicaments that require the corresponding authorities to supervise it. Some of the software utilised for processing the reconstruction of real events was Drone Deploy, Recap from Autodesk and Pix4D. Price issues for licensing may arise during this process.

In some cases, the cost, and implications of UAS could significantly change or delay the decision of keeping the UAS. Finally, the outcomes of the UAS are shared between institutions giving the opportunity to replicate the process of adopting the UAS or hire contractors to deliver the same quality outcome for institutional meetings or internal work. The interaction between public institutions is purely collaborative regarding UAS, and there is no fee for addressing internal operations from other institutions in seasonal tasks. However, the lack of awareness, knowledge of the strategic reasons mentioned above, how this can apply to institutions, its implications and the insertion into workflow represent the major barriers for UAS integration.

8.2.2.Application Cases of UAS in Disaster Management

UAS have been evaluated in different organisations, presenting evidence of its innate reliability for specific tasks. Institutions have expressed that the most utilised application is acquiring high-resolution images, in RGB format with GPS coordinates for visualization and surveying. In disaster scenarios, UAS is used for visual reporting before and after a natural event. In Table 5, we can appreciate the mapping of the applications found for disaster management within the interviewee's organisations.

8.2.2.1.Damage Assessment

The process of damage assessment with UAS is simple, merely deploying the UAS and capturing images and videos of the areas of interest as well as for surveying these places. Images of the site are taken to provide record of the current situational state of the area and can be accompanied as well by videos. After, the acquired images and videos are presented at meetings and used for risk and crisis management. Visualization of the situational state allows decision-makers to understand conditions and discuss options with the same view. It was reported that UAS was being used for surveying lands, rural communities, and the state of buildings. An example of crisis management was the landslide in figure 7. UAS supported the management of the disaster by helping to reduce the fire during the event. Positive results came from mapping and keeping records of the management of the crisis, which allows future cases to be addressed more effectively, procure different regulation of waste management, and increase the capabilities of technicians in this domain. If further initiatives on improving the risk and crisis management of the built environment are placed there is an opportunity to be explored in this context. However, the lack of digital strategies such as Building Information Modelling (BIM) regarding the virtual reconstruction of the built environment may influence the delayed of development of digital simulations of the risk and crisis management recovery process.

8.2.2.2.Situational Awareness and Risk Communication

In this context, if the team in the province is within possession of UAS, the data is gathered in order to be sent to the headquarters and be processed. In the case that the UAS is not in the field, headquarters' team is responsible to gather data and make the corresponding analysis regarding risk and crisis management. Initiatives of UAS live-streaming telemetry has turned up but the issue of access and high-speed internet has ultimately delayed this application. For example, in the case of an outbreak of cholera, UAS was used to identify the contamination source at the river. The water changes colour after pouring the bacteria and its companion elements were identified near an unregulated human settlement at the river edge. Flights with no more than 70m of altitude are carried out with DJI Phantom 4 for the identification of people in forests. In addition, GPS positioning is used for accurate location.

Moreover, some of the experience gathered reveal that after risk evaluation, as in the case of landslides, can help to understand swiftly the issues on site without having access to the field. For example, measuring a landslide deformation during crisis management is vital for predicting if the event would require an immediate displacement or relocation of a human settlement. Sometimes, landslides occur in remote areas that have difficult access for the technical teams. Considering this, UAS mapping has greatly helped the process of data gathering and analysis. In addition, in the case of risk probability assessment for earthquake damage, the visual representation of the buildings and geometries in congested areas helps to provide a preview of the number of houses or families can be affected.

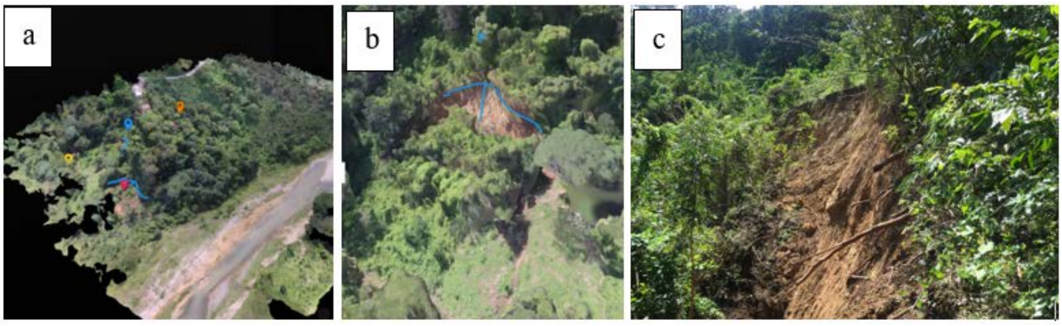


Figure 7. Landslide example.
(a) 3D reconstructio of Landslide Area; (b) 3D measurement of landslide; (c) Landslide ground visit.

Table 5. Disaster Management Interviewees UAS assessment

UAS Assessment Purpose	Purpose for adopting UAS data	Risk Management	Crisis Management
• Visual Data Acquisition • Site 3D reconstruction	• Risk Reduction from our team, allowing to approach inaccessible and vulnerable zones. • Faster outdoor surveys and assessments • Keep records and visual information of the site conditions for decision-makers. • Flood and landslide assessments	√	√
• Urban Expansion monitoring • Population growth evaluation • Multi-Risk Plans • Mining Assessments	• Reach unexplored detailed site conditions. • Generate high-resolution maps. • Higher Amount of data acquired. • Cost-effective solution against satellites. • Manoeuvrability and flexible data collection method.	√	
• Buildings construction methods map. • Building and infrastructure inspections. • Accountability of the buildings and infrastructure authorised vs-built in. • Overlay blueprints and the site construction.	• A faster method of tracking and inspecting construction work process. • Produce a record of existing structural and architectural buildings. • Obtain an overview of the site.	√	
• Geometrical reconstruction and digital reconstruction of the seismic building's behaviour before earthquakes. • Multi-Risk prevention plans.	• Visual identification of the cities risks environments • Record manifestation of tectonics behaviours • Try innovation approach to reduce fatigue inspections	√	
• Infrastructure Maintenance • Monitoring Illegal actions • Follow up Construction Progress • Aqueduct video Reports • Identify pollution agents around source for Cholera Diseases • Visualise and exploring aquifers on higher and inaccessible points.	• Allow access to difficult water source and infrastructures sites after a natural event. • Keep Records of the rivers, aquifers, and natural environments. • Evaluation of Risk Reduction • Faster Assessments and achieving institutional goals.	√	√
• Photomontage • Building integration into the area	• Visualisation of the city status • Site Management	√	√

9. Discussion

9.1. General Strategic Framework for Integration UAS in Disaster Management

All the condensed information is delivered on the strategic framework presented in Figure 8. It presents the theoretical behaviour and recommendations of the adoption process and experience of UAS. The most relevant reasons are related to its innovation and capabilities and improving the response time on data collection. Different institutions are utilizing UAS in-house or outsourcing from the private sector or another institution. UAS provide images, videos and survey imaging that can easily advance the decision-making process during disaster stages. The amount of data gathered support various operations during a disaster management process according to the observer of the data. Furthermore, 3D reconstruction of the site, software and storage can significantly become issues during the implementation of this tool. 3D reconstruction supports the resilience process throughout the Geographical Information System (GIS) and the visual assessment of the site, especially in rural towns and cities. In Figure 8, we can see the framework based on the social-technical change impact model (SCI) as well as the applications found classified by event type that can be used as a guide for other contexts in Table 6. In addition, the technical implications on the adoption process in a disaster management organisation is presented in Figure 9.

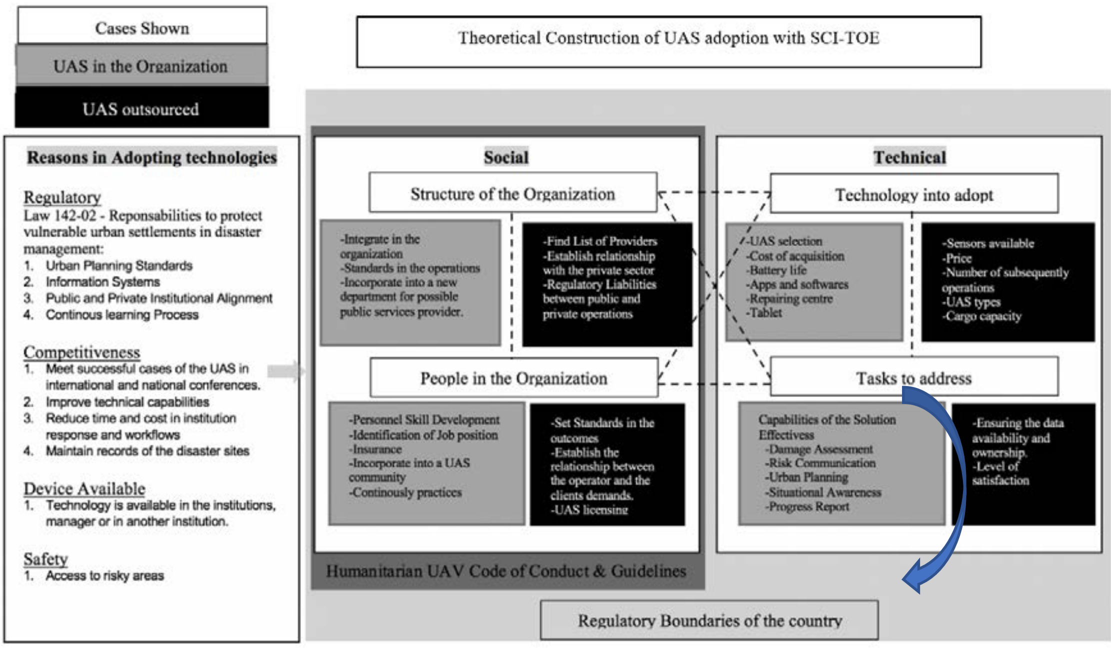


Figure 8. Strategic Framework of the UAS integration from SCI-TOE perspective

Table 6. Disaster Management summary UAS assessment

Type	Events	Tasks	Data Used purpose
Geophysical	Earthquake	Prevention and Damage Quantification and Visualisation	• 3D Reconstruction of Buildings • Simulation of seismic behaviour of buildings and infrastructure • Survey damages and identify vulnerable areas for aids allocations
	Landslide	Prevention and Damage Quantification Visualisation	• Deformation levels and the probability of occurrence. • Urban vulnerability assessment • Risk assessments
	Tsunami	Damage Visualization	• Development of evacuation plans
Meteorological	Cyclones	Damage Visualisation	• Visualisation of aids allocation • Infrastructure inspection and repairment

Hydrological	Floods	Damage visualisation and Quantification	• Aids allocation • Infrastructure inspection and repairment • Medical Support
Climatological	Wildfire	Identification of wildfire source	• Extinguish the fire • Allocate reforestation or resources efforts
Biological	Cholera	Visual identification of illegal settlements	• Urban Planning • Reduce the infection focus

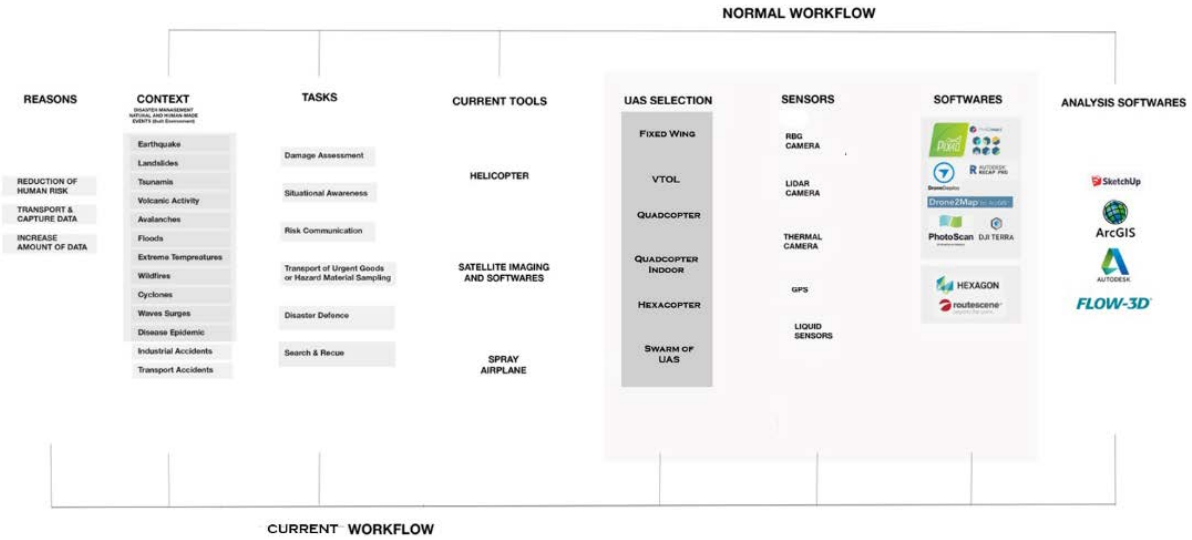


Figure 9. Technical workflow of a disaster management context with UAS with Spray airplane.

9.2. Challenges of UAS in Disaster Management

However, during the initial stage several issues appear such as operational liabilities on the UAS by the ownership in some cases, UAS replacement and insurance for the pilot. In addition to airspace and safety concerns regarding to flying UAS on risk and crisis management stages were considered for operations under congested areas. The aspects of big data storage and UAS location are assessed by the pilot and the organisation willing to make a confirmation of the social media awareness or further risk and situational studies. Another relevant concern regarding the exploring the capabilities of the UAS is the 3D reconstruction of the field. It has been a useful tool for observing the site from a virtual perspective. However, there are challenges in software, tools and data showed up. The number of hardware resources to run and maintain 3D models of large zones can be in certain cases outside of the current capabilities of the institutions. Furthermore, 3D models are difficult to manage between institutions based on interoperability and personnel skills.

The issues of location, weather conditions and the area range of the disaster site can implicate a less effective strategy against a helicopter. For example, if there is not a UAS in a specific site or near and the decision-makers are at a reduced distance, a helicopter flight is addressed, and images are taken. In addition, satellites images are utilised if there is a real-time data available or the satellites licensing is available for damage assessment. Therefore, the UAS is utilised to supply the need of high-resolution real-time data of the site. However, for the technical evaluation a UAS is required. The UAS application, based on advanced photogrammetry techniques from surveying and engineering professionals, supports the adoption of digital strategies on national levels. However, these strategies shall need to be developed in order to promote the Comprehensive Disaster Management Strategy 2014 – 2024 focusing on develop educational and training materials and integrate systems for fact-based policies and decision-making process. Therefore, the following recommendations for theoretical framework of social and technical approach is presented.

10. Conclusion and Recommendation

The theoretical framework of social and technical approaches of integrating UAS technology reflects on three major aspects: regulation, industry, and science. These aspects were encountered to explain the questions that will arise when implementing UAS. In terms of regulation, it is recommended for policy makers to incorporate the topics of data management, the development stage of the technology and the alliance between innovations centres and policy makers for avantgarde technology. The fact that novel technology emerges, and policy makers still handle the regulatory aspects clearly define the need of research and development at the institutional level. In the future alliance between academics, innovation centres and funding opportunities will pave the next steps of UAS development.

Furthermore, the comprehensive disaster management framework can be updated to require UAS outcomes as a minimum requirement for technology and communication integration. Therefore, the development of disaster management operational manual will allow teach and shape the behaviour of operators during events. Currently, in the Dominican Republic is shared the restriction by the community groups. For disaster risk reduction perspective, the following recommendations are made:

- **Digitalization of the vulnerable areas against natural and human made disasters**. The identification of communities on risks of tsunamis, floods, earthquake, gas explosions, etc, allow the team to forecast the disaster behaviour and the impact on humans' settlements. The alternative of risk reduction developed from a 3D model, for example: dam rehabilitations, alternative bridge routes, sewers restauration, and water force dissipation shall be shared with the ministries accordantly. Therefore, the appropriate responds before specific disaster can be carried out.
- **Empowering communities' committees for UAS data management and risk assessments.** The government unit closest to the citizens are councils. Therefore, the UAS data simulation, damage quantification and aids allocations shall be guided by the council's data collection and reports. Live streaming can be assessed with UAS for sharing a real-time perspective to the public and principal operational centre to avoid issues on UAS location.
- **Evaluate cost-effective solutions** for operation requirements. It is imperative to understand the implication of UAS operations further than videos and imaging that could influence the decision to adopt it or incorporate a higher degree of digitalisation on the institution or community.
- **Liaison alliances between UAS communities and public and private institutions** in order to assess data management and multiple UAS operations during a crisis. For example, WhatsApp groups or sharing interlinked national services that store UAS data, photogrammetry outcomes and other analysis.
- **Public list of services providers** in case that special or specific UAS are unavailable at the institution or location for gathering data.
- **Development of standardized processes of UAS** operations that can be referred to as an operational manual for the institutions.
- **State clear regulatory boundaries** regarding liabilities and exceptions of UAS operations and incorporate cases in which restrictive zones change during disaster management.
- **Clear statement of the ownership of the UAS.** It is recommended to be aware of the possible future needs of the institutions and the pilots. In addition, the issues of images copyrights in situational awareness on social media and/or more profound investigations. In disaster management, it is required to understand the spirit of cooperation by sharing UAS data for higher purposes.
- **A culture oriented to wise record-keeping.** The amount of information gathered from UAS need large quantities of storage space. Some software have made this challenge easier by providing solutions on the Cloud. In addition, reviewing previous and post events can be assessed after a relevant database is compiled. A policy on reporting and data management shall be established to assure the sustainability of

disaster governance. Non-personal data storage such as building, infrastructure and forests information shall be kept as a part of its institutional assets. Accidents and personal data shall be kept as anonymous records.

In conclusion, for research perspective is critical to be aware of the diverse solutions in the market that can contribute to address tasks easier than the current methods. The training and education field shall be more developed in order to overcome all the possibilities that robots could bring to humans as a servant and digitalises. The current cases presented are holding a small range of sensors and applications that with the incorporation of other technologies and types of robots, a more autonomous and complex situations can be addressed faster. The current challenges of the actual UAS implementations are regarding power energy and the suitability of each specific tasks or element to be observed. For example, autonomous maritime operations for under the water reconstruction or tsunamis report events shall be emerged at some point. Therefore, it is suggested focusing on research and development from a professional perspective the UAS field.

11.Acknowledgement

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