Article

Identifying Users' Requirements for Emergency Mapping Team Operations in Small Island Developing States: Caribbean Perspective

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Abstract: Small Island Developing States (SIDS) increasingly face natural hazards that overwhelm their capacity to generate and share spatial-information to reduce human–economic losses. Under such circumstances, the emergency mapping team (EMT) enables a common operational picture of the impacted communities. This paper aims to identify user requirements for EMT operations in the Caribbean and, based on those findings, improve the level of preparedness to deliver information-services that contribute to disaster risk management in the region. The results are built upon a case-study and a survey targeted for technical personnel responsible for emergency mapping in three Caribbean states: the Dominican Republic, Saint Lucia and Sint Maarten. Our findings revealed five user requirements for EMT operations: institutional arrangements, implementation of a Cloud-based spatial data infrastructure, linking community stakeholders, partnerships and capacity building. This study provides the foundation for future EMT developments in the Caribbean region and in others SIDS with similar settings in the world.

Keywords: emergency mapping team; users' requirements; disaster risk management; geospatial information management; small island developing states

1. Introduction

1.1. General Introduction

Each year, the Small Island Developing States (SIDS) face potential challenges in achieving sustainable development, especially due to their social and economic characteristics and vulnerability to natural and human-made disasters (United Nations 2014). Herein, SIDS future annual losses related to natural disasters will represent almost 20 per cent of their total social expenditure [1].

The Caribbean is one of the most disaster-prone regions in the world. Just in the last 10 years, Caribbean SIDS have been impacted by 139 natural disasters [2]. The 2017 hurricanes Irma and Maria, as well as the 2010 magnitude 7.0 earthquake in Haiti, are clear examples of how disasters heavily affected the well-being and economic development of the Caribbean countries [3,4].

In this context, researchers and practitioners have widely recognized the crucial role of geospatial information to enhance information-based decision-making during natural disasters [5–7]. However, Caribbean SIDS present major setbacks when attempts are made to share and access necessary information for disaster risk management (DRM)

actions [8]. With such time and resource limitations, government agency capabilities might be constrained for the generation and sharing of geospatial resources for disaster risk managers [8,9].

In response to disaster events, emergency mapping teams (EMT) have emerged as a solution for improving the performance of government agencies to meet the huge demand for spatial information and services in a short period of time [8,10]. The EMT focuses on supporting decision-makers on the definition and sharing of a common operational picture (COP) regarding the status of the impacted communities [11–13]. The COP is described as a single dissemination of critical information regarding the status of damages and disaster response activities, thus enabling effective decision-making, coordination, and integration between emergency response organizations [9,10].

Despite the significant support that can bring EMT operations to the different stake-holders in charge of DRM, there is a serious gap on the identification of what and how to prepare beforehand for a timely and efficient integration between the government task-force and the EMT in Caribbean SIDS.

The central problem, as defined for our paper, thus reads: "What are the users' requirements for EMT operations in Caribbean SIDS?" In regard to this central problem, we shall deal with the following questions in this paper: who are the key users involved in EMT operations, and what are their users' requirements for EMT operations in Caribbean SIDS?

Previous research has shown interest in the study of user requirements in the field of spatial information and services for DRM activities. For example, Menold et al. [14] studied end-user requirements for generating a smartphone application to enhance communication during emergency response in the U.S.A. Another study in this field by Leitinger et al. [15] focuses on user requirements for a mobile disaster documentation system in the Alpine regions. Neuvel et al. [16] reported on a network-centric approach to identify relevant geoinformation and geotechnology for risk and emergency management in The Netherlands. Diehl and van der Heide [5] identified critical factors to establish a geoinformation facility to support the public order and safety sector. A more recent study by Rosario et al. [12] provided a good comprehensive analysis of EMT operations in the Dominican Republic (DR). Accordingly, standardization, establishment and maintenance of a spatial data infrastructure (SDI), as well as partnerships, effective communication among stakeholders and capacity building, are essential for EMT operations at the national level.

Although the aforementioned literature provides insight on user requirements of geospatial technologies for DRM, empirical research to date has been primarily on technological challenges in developed countries. In this sense, there is a paucity of research that analyzes social and technological user requirements in developing country settings—in particular, SIDS at the Caribbean region.

This research focuses on the identification of users' requirements for EMT operations in Caribbean SIDS. The contribution of this work will serve as a basis for a deeper theoretical understanding and for deriving sound and practical solutions for improving EMT operations for effective DRM in the Caribbean region and in other parts of the world with similar settings.

The methodology used in this research relies on a case study of three Caribbean SIDS: the Dominican Republic, Saint Lucia and Sint Maarten. The results are built upon an online survey questionnaire that focused on each main task of the EMT operation workflow for disaster response in the selected countries. To our knowledge, user requirements for EMT operations in Caribbean SIDS have not been identified, analyzed and compared to each other before. The results contribute to a better understanding of what needs to be prepared in order to deliver information and services during future emergency mapping actions for DRM tasks.

The paper is structured in the following way. The remaining part of Section 1 introduces a theoretical overview, including basic concepts of emergency mapping team and user requirements identification, followed by the geographical settings of the study area in the Caribbean SIDS. Section 2 explains the methodology used in this research. Section 3 shows the survey

results. Section 4 then presents a discussion of the survey results. Section 5 closes the paper with the main conclusions on the identification of user requirements for EMT operations in Caribbean SIDS.

1.2. Literature Review

This sub-section briefly introduces the key terms emergency mapping team and user requirements identification.

1.2.1. Emergency Mapping Team

The term Emergency Mapping Team (EMT) refers to a collaborative group of mapping specialists, often on a voluntary basis, to support decision-makers in defining and sharing a common operational picture regarding the status of damage and disaster response activities [9]. EMT operations are commonly focused on the creation and distribution of disaster-related maps (including reference, operational and statistical maps), sharing geospatial data generated during the response period and delivery of location- based services [15,16]. Figure 1 illustrates the general workflow for EMT operations.
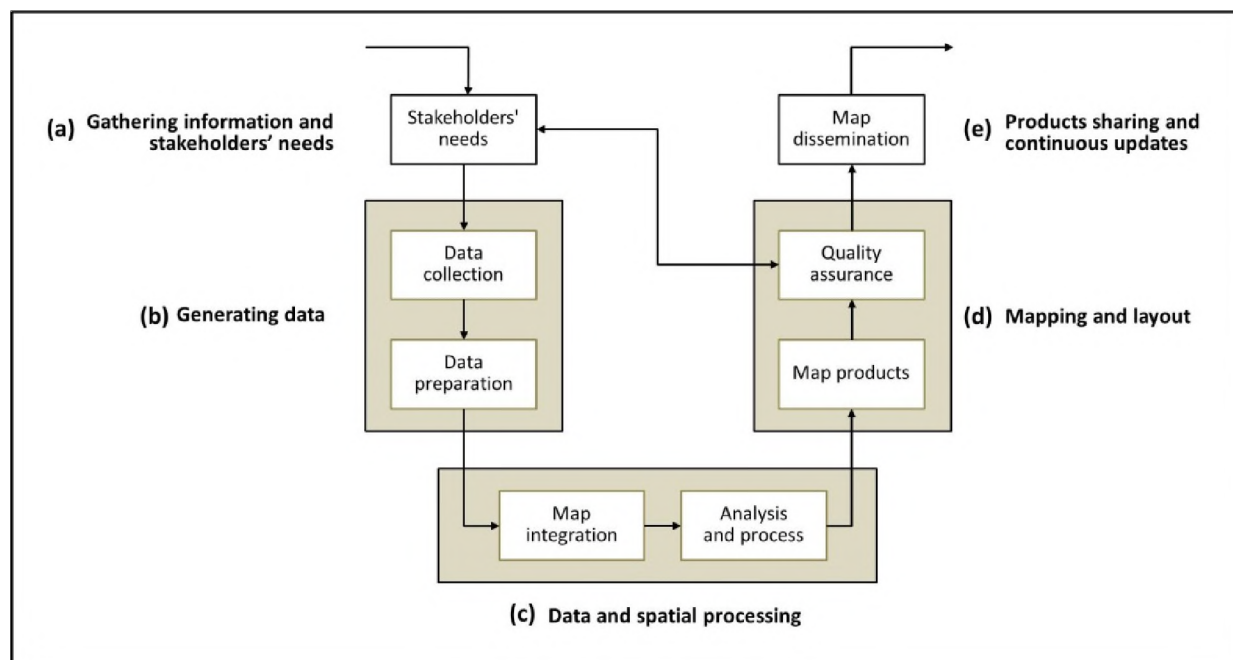

Figure 1. General workflow for EMT operations (adapted from [12]).

As shown in Figure 1, the EMT's work begins by gathering information about the needs and general affairs for generating and sharing a COP of the impacted communities. Then, it proceeds to collect, organize, analyze and process information from different sources. The process follows with the creation and sharing of map products and services to meet different stakeholders' applications, mainly emergency command centers, local governments and general public. As time progresses, the EMT continuously updates all geospatial resources to meet stakeholders' needs [17,18].

1.2.2. User Requirements

User requirements (UR) refers to the features/attributes your product should have or how it should perform from the user's perspective [19]. User requirements are also perceived as high-level, abstract requirements based on end users' and other stakeholders' viewpoints [20]. In this study, UR mean a user's description of the functionality and performance characteristics of the proposed product [21]; herein, UR refer to the description

of geospatial and non-geospatial information and services necessary for the EMT operations to achieve their goals.

1.3. Geographical Settings of the Study Area: Caribbean SIDS

This sub-section briefly presents the geographical setting of Caribbean SIDS, followed by a short profile of the Dominican Republic, Saint Lucia and Sint Maarten.

1.3.1. Caribbean SIDS

The Caribbean is home to 16 UN-member SIDS and 7 non-UN-member SIDS (UN-OHRLLS 2011) (Figure 2). Together, these countries have a population of over 43 million inhabitants. In the Caribbean, more than half of the population lives within 1.5 km of the shoreline [22]. Caribbean SIDS in particular base most of their livelihoods on revenues from tourism [23].

Figure 2. Location of selected countries: the Dominican Republic, St. Maarten and St. Lucia.

Caribbean countries are extremely vulnerable to climate change and natural disasters. The impact of hurricanes and floods alone in the region is approximately 2 percent of GDP per year [24]. For instance, in Sint Maarten alone, Hurricanes Irma and Maria (2017) caused an estimated physical damage of more than USD 1.18 billion [3].

In the Caribbean, institutional efforts toward regional disaster risk management are based on active outcomes from the Caribbean Disaster and Emergency Management Agency (CDEMA). CDEMA is a regional inter-governmental agency with the primary responsibility of the coordination of emergency response and relief efforts, as well as the promotion and engineering of a comprehensive disaster management approach in the Caribbean community [25].

1.3.2. Dominican Republic

The Dominican Republic (DR) is the second most populated state among SIDS, with 10.5 million inhabitants and more than 3.3 million citizens living in the capital city [26]. Hurricanes have the most severe impact in terms of lives lost in the Dominican Republic [27]. Major earthquakes and tsunamis are a constant threat to the DR, mainly due to the interaction of the North American tectonic plate with the Caribbean tectonic plate on which the island is located [28]. The Inter-Institutional Geospatial Information Team (EIGEO, in Spanish) is the government unit responsible for executing EMT operations in the DR. Map products generated by EIGEO are used by government officers who coordinate disaster

response efforts in the National Emergency Operations Center. These maps are also shared among local response agencies via the National Integrated Information System (SINI, in Spanish), which is a tailored clearinghouse system for disaster response purposes [12].

1.3.3. Saint Lucia

Saint Lucia has a population of approximately 166,000 inhabitants, of which 72% lives in rural communities [29]. The country has an area of 620 km^2, with an exclusive economic zone of about 15,484 km^2 [30].

Hurricanes and landslides are the most common natural hazards [31]. From 2010 to 2016, there have been five major disasters in Saint Lucia, comprising two tropical cyclones, one drought, one flash flood and one riverine flood [2]. The National Emergency Management Organization (NEMO), jointly with the Department of Physical Planning, is responsible for emergency mapping activities in Saint Lucia.

1.3.4. Sint Maarten

Sint Maarten is located in the northeastern Caribbean Sea. The country population is estimated at around 37,224 inhabitants, living in a total area of 34 km^2. The geographical location of St Maarten, which is part of the Lesser Antilles volcanic arc, means the island is subject to two major natural phenomena: tropical cyclones during the annual hurricane season, and earthquakes. Furthermore, it has a high level of seismicity and is prone to flash floods, cyclonic swell and tsunami [32]. The Ministry of Public Housing, Spatial Planning, Environment and Infrastructure (VROMI, in Dutch) is the key stakeholder for spatial planning and mapmaking for disaster management activities in Sint Maarten [33].

2. Materials and Methods

In this paper, we have aimed at identifying users' requirements for EMT operations in SIDS. Since this purpose seems to be too broad, an in-depth examination of this phenomenon has to be performed in a different context. Therefore, a case study method seems to be the most appropriate approach for this research. A case study method is described as an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and its context are not clearly evident [34].

In this research, a case study of three SDIS in the Caribbean region will be examined, in which the research as a whole cover the same research questions for each of the individual selected country. The unit of analysis for this case study is the EMT operations. The EMT is organized, trained, and equipped to perform the following tasks within general workflow for EMT operations: (a) gathering information and stakeholder needs; (b) generating data; (c) geospatial data processing; (d) mapping and layout; and (e) product sharing and continuous updates.

In order to identify user requirements for EMT operations in the selected countries, we applied a four-stage general methodology to analyze user requirements, as proposed by Maguire and Bevan [35]. Figure 3 presents the research stages followed in this study.

2.1. Research Stages
2.1.1. Information Gathering

At first, a semi-structured interview was conducted to define a list of potential users, stakeholders and information about processes that intervene in EMT operations. Interviews were targeted at senior professionals responsible for the coordination of emergency mapping tasks when there is a disaster. Interview outcomes were the basis for identifying a list of 29 key user respondents: the Dominican Republic (17), Saint Lucia (8) and Sint Maarten (4). During the second stage, a cross-sectional online survey was administered to identify EMT user needs in each of the three selected countries: theDominican Republic (August to September 2018), Sint Maarten and Saint Lucia (September to November, 2019).
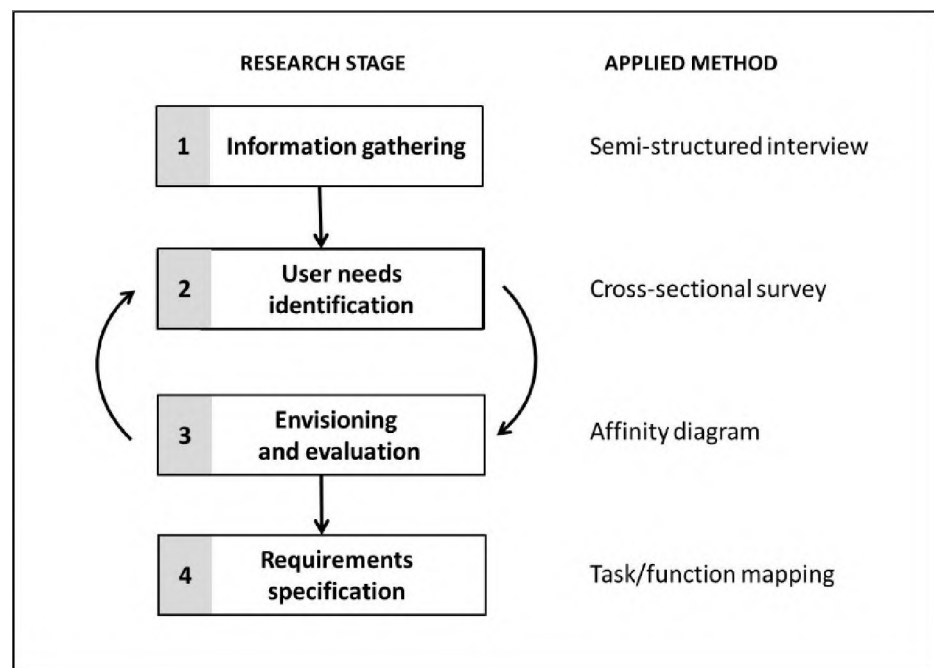
Figure 3. Research architecture to identify user requirements.

2.1.2. User Needs Identification

The questionnaire was designed to capture the respondents' insights on how to perform more effective EMT operations. The questionnaire consisted of 40 questions, including multiple-choice, close-ended, open-ended and four-point Likert scale questions. The questionnaire was divided into five sections. Each section was related to a main task of the general workflow for EMT operations [9].

The questionnaire also inquired about the type of organizational setting, capacity building program and stakeholder participation required for EMT operations. The questionnaire was pre-tested through interviews with experienced GIS professionals and EMT coordinators in each country for readability and clarity purposes. Technical and managerial personnel actively involved in EMT operations and processes were recruited to participate in the survey. The questionnaire link was sent, and responses were received via e-mail and an online web form to enable digital data collection from spatially distributed respondents. The survey was accessible at the following address: https://forms.gle/2WTxH9ZiuPNUCmK3A (accessed on 24 September 2019). In order to increase the response rate, three reminder emails were sent, and field trips were taken to each country.

The final survey sample yielded 28 responses out of 33 EMT members; hence, a response rate of 85 percent was achieved. Collected data were tabulated and analyzed using SPSS software.

2.1.3. Envisioning and Evaluation

At the third stage, affinity diagram technique was used to identify and index issues and insight on EMT users' needs [36]. All data relevant to a particular task of the general workflow for EMT operations were grouped together to form categories. These categories were the basis for evaluating and specifying users' requirements for the different tasks that they perform.

2.1.4. Requirements Specification

At the last stage (Stage 4), a task/function mapping technique [35] was used to specify key minimum users' requirements that lead to successful EMT operations in the Caribbean SIDS context.

2.2. Cases Selection

In this case study, the SIDS countries were selected on the basis of three criteria: (1) different level of geospatial infrastructure readiness, (2) previous experiences with emergency mapping operations, and (3) a variety of characteristics, including population and major natural hazards.

The Dominican Republic (DR) was selected because of its demographic characteristics, as it is the second most populated country among SIDS, with a high population concentration in urban areas. Since 2013, the DR has accumulated valuable experience, through the Inter-Institutional Geo-Spatial Information Team (EIGEO), while dealing with emergency mapping operations. Sint Maarten and Saint Lucia were selected because both islands have been widely hit by the latest severe hurricanes in the Caribbean region.

In particular, Saint Lucia is at the initial stage of strengthening their capabilities to respond to emergency mapping needs at the National Emergency Management Office (NEMO) and the Department of Physical Planning.

2.3. Survey Population

In this study, respondents were grouped by their country of origin (Q1): Dominican Republic (DR) (57%), Saint Lucia (LC) (29%) and Sint Maarten (SXM) (14%). Up to 70% of the respondents worked for government agencies, followed by a small representation from the military forces (7%) (Q2). Respondents mostly worked for geomatics (39%) and disaster risk management departments (25%) (Q3).

Respondents were asked questions regarding their educational and professional experience in the field of emergency mapping. Bachelor's degree accounted for 39% of survey respondents' qualification, followed by master's degree (36%) and technician (25%) (Q4). Respondents had professional expertise mostly in geographic information system (29%) and disaster risk management (11%) (Q5).

The respondents ranged in years of experience in emergency mapping from 1 year to 22 years with an average of 9 years (Q7). Respondents represented government agencies as auxiliary (46%) or formal (43%) members in EMT operations (Q8). Remaining respondents (11%) were external EMT members. Mapping and layout (75%), data collection (61%), coordination and data analysis (each at about 46%), were the main tasks executed for EMT operations (Q9) (Figure 4).
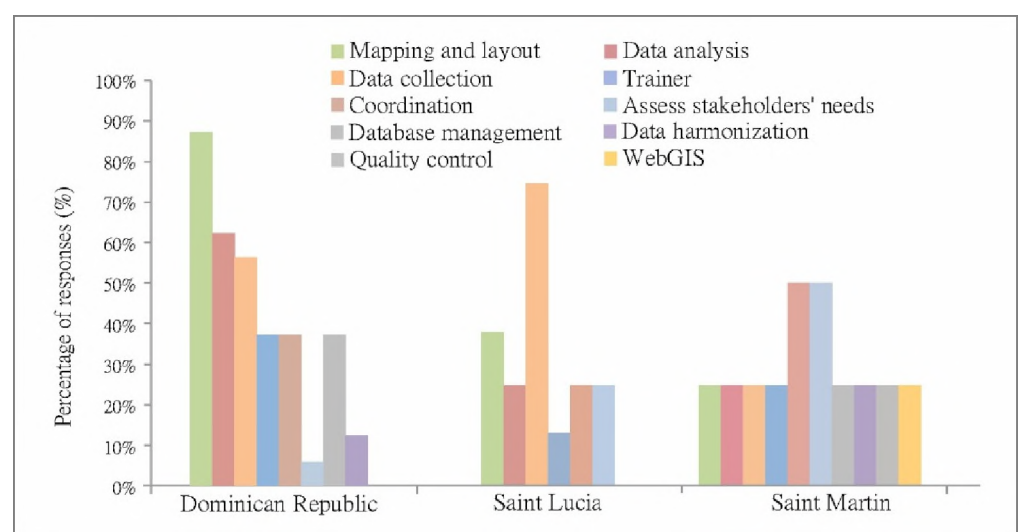

Figure 4. Distribution of responses by participants' tasks (Q9).

At this point, survey results suggest that EMT structure and functions are similar across the selected countries, which are mainly led by the government agencies.

3. Results

3.1. Gathering Information and Stakeholders' Needs

In this section of the survey, respondents were asked questions regarding communication strategy and technologies used for capturing the stakeholders' demands of information and services. A four-point Likert scale question (ranging from never to always) was used to ask how frequently the respondents use a listed communication channels to gather information about the users' demands (Q10). More than half of the respondents (57%) cited e-mails as the most used communication channel. A majority of respondents (80%) are still relying on face-to-face meetings with stakeholders.

One survey question was asked to determine which missing stakeholders should be involved in EMT operations (Q11). Most of the respondents agreed that the universities, research institutes and drone owners should participate in EMT efforts (Figure 5).
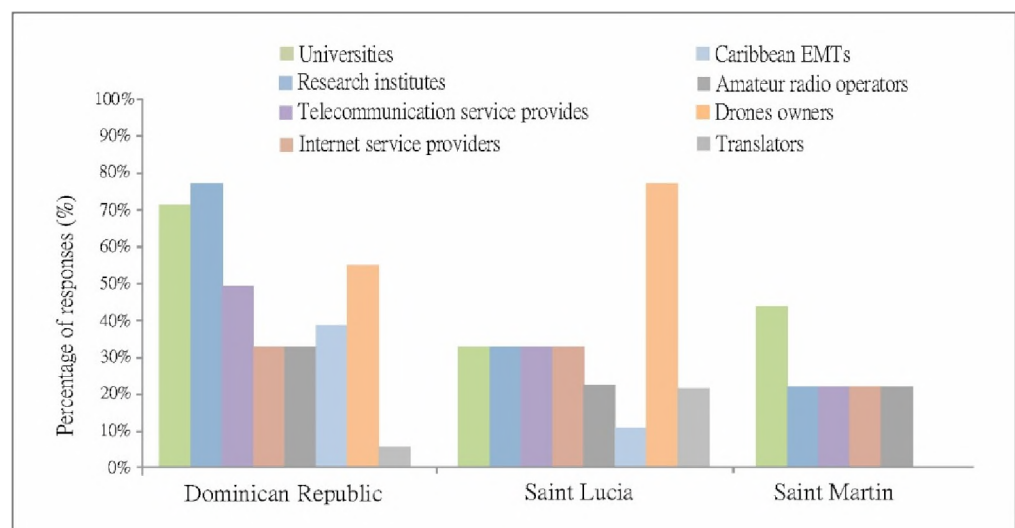

Figure 5. Missing stakeholders in EMT operations (Q11).

One open question asked the respondents to indicate the needs of stakeholders regarding necessary information gathering (Q12). Most of the respondents agreed on necessities about the standardization of data and metadata, tools for data collection and capacity building. In particular, LC respondents mentioned the need to improve the quality of base maps. DR and SXM respondents similarly suggested a necessary improvement in community support and timely communication with EMT stakeholders.

Respondents were openly asked to mention what information is needed for capturing EMT stakeholders' requirements (Q13). Having a clear idea of technical specification of the information and its purpose and a database of stakeholders' profiles were deemed crucial by most of the respondents. LC and SXM respondents similarly cited the necessity to create mechanisms to capture lessons learned and feedback from technical and strategic stakeholders, while DR respondents suggested clarifying the stakeholders' information workflow.

At the end of this Section 2.3, an open question was asked to determine what improvements should be implemented for anticipating EMT users' needs (Q14). The implementation of an effective communication channel among the stakeholders, including social network, workshops, and automation and standardization of data collection processes, were the most cited recommendations (Table A1 in Appendix A). DR and LC respondents reported similar necessities on technical training and coordination mechanisms. Specifically, SXM respondents suggested the definition of technical specifications of the spatial data.

3.2. Generating Data

This section of the survey started by asking questions on the specifications of geospatial datasets, devices used for data collection and restrictions experienced while using EMT data. A four-point Likert scale question (ranging from never to always) asked the respondents how frequently they use listed core datasets in EMT operations (Q15). Up to 82% of the respondents indicated that they always or sometimes use satellite imagery, administrative division, geographic names and hydrography datasets. Alternatively, DR respondents (81%) indicated that they always or sometimes use digital elevation models, census and transport network datasets. Only 75% of SXM respondents indicated transport network as sometimes or always used. However, more than 88% of LC respondents also ranked with a high frequency of use topography and cadaster datasets.

This survey also asked the respondents which devices they use to acquire necessary EMT data (Q16). Printers (89%), GPS (82%), plotters (64%) and mobile phones (61%) are frequently or always used across the selected countries. When respondents were asked which data formats they use for generating thematic data for EMT operations, most of them listed text files (79%), excel files (75%) and shapefiles (50%) as main formats for storing spatial and non-spatial information (Q17).

A four-point Likert scale question (ranging from not relevant to extremely relevant) asked respondents which cartographic scales are relevant for generating EMT data and maps (Q18). A total of 80% of DR respondents marked the use of scales below 1:50,000 as relevant or extremely relevant. Alternatively, more than half of LC and SXM respondents similarly ranked scales below 1:20,000 as relevant. This range of scales used might be expected due to the differences in territorial extent among studied countries.

With respect to metadata information, the respondents reported that the most commonly used metadata format for EMT operations are Excel files (50%) (Q19). A few of the respondents (25%) also mentioned that they do not save any metadata information. One question asked respondents which database systems are mainly used to store spatial data (Q22). Most respondents mentioned that they mainly managed spatial data using ArcGIS Geodatabase (57%) and PostgreSQL (25%). The results revealed that different sources of information are needed to create EMT maps and services (Q20), while Google Earth (89%), Open Street Map (71%), and first responders' data from the field (50%) are reported as the ones most commonly used (Figure 6).
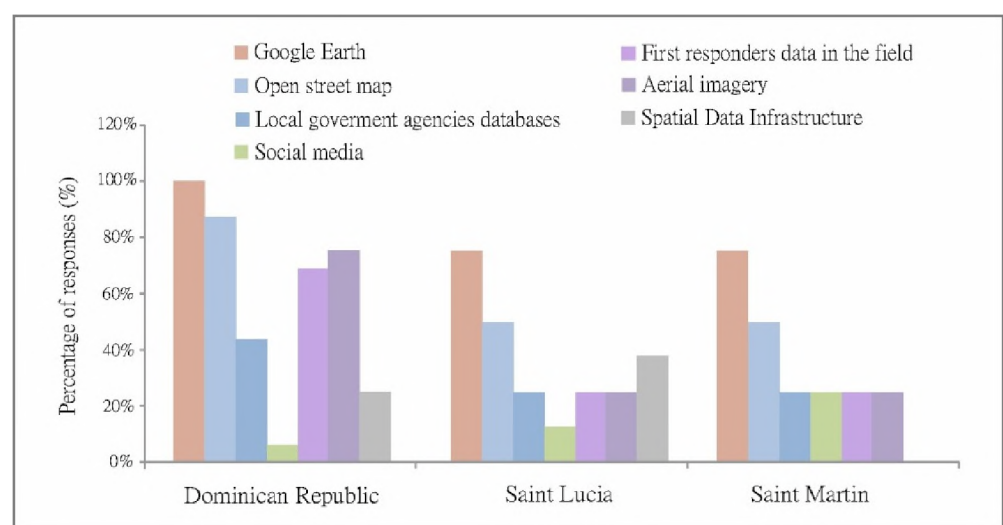

Figure 6. Utilization of data sources in EMT operations (Q20).

As part of this survey, the respondents were asked to suggest currently missing datasets for improving EMT operations (Q23). The following disaster-related datasets were

the ones most recommended by respondents (Figure 7): gas stations (64%), shelters (61%) and emergency operation facilities (57%) datasets.
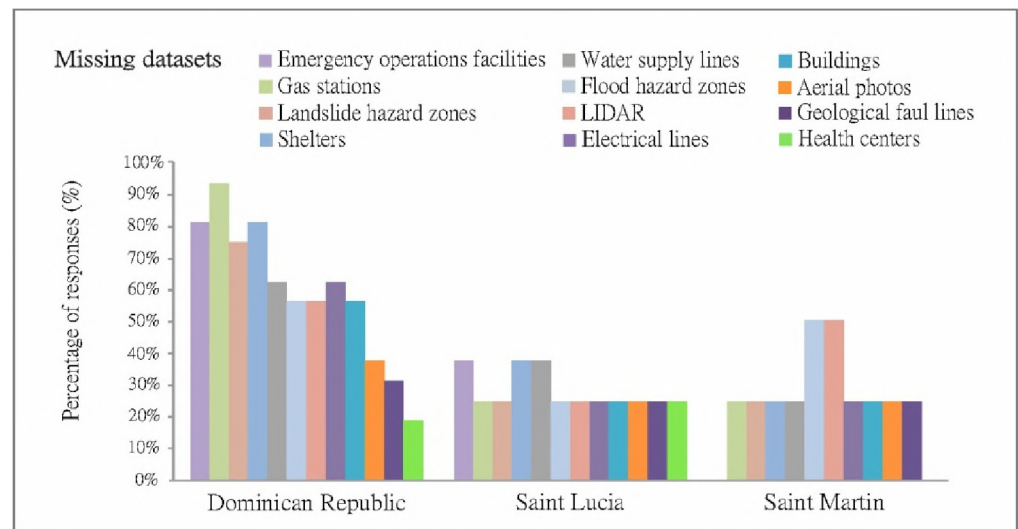

Figure 7. Missing datasets for improving the EMT operations (Q23).

One survey question asked respondents which restrictions they experienced while using data for EMT operations (Q21). The restriction mentioned the most by respondents was the fact that EMT data cannot be shared with the public (64%), while 24% of respondents also indicated that the data can be shared but just on a read-only capability (Figure 8). It was notable that SXM respondents reported the lowest level of restrictions using EMT data; nonetheless, they also reported the highest level of restrictions on data quality and availability.
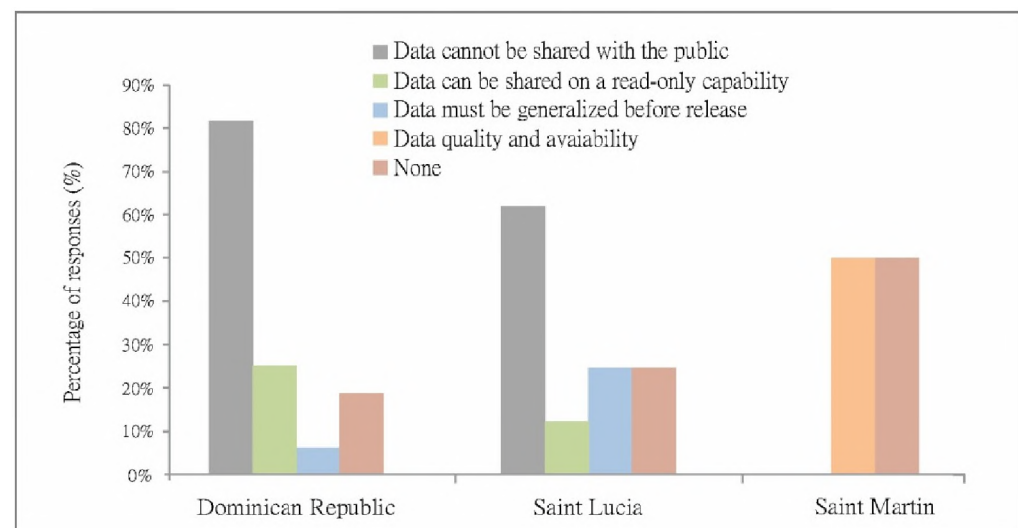

Figure 8. Restrictions using EMT data (Q21).

When the respondents were asked which tools they recommend to improve data gathering for EMT operations (Q24), the exploitation of satellite imagery (82%) was the most recommended tool. The next most preferred tools were volunteered geographic information (VGI) technologies, SDI and 3D maps, each at about 75%.

At the end of this Section 2.3, one open question asked the respondents to recommend improvements for data generation in EMT operations (Q25). Recommendations included a wide range of actions, mainly the following: implementation of a disaster- oriented

SDI, training on data capture trends, and applications of mobile phones for real-time data collection from the field (Table A2 in Appendix A).

3.3. Data and Geospatial Processing

This section of the survey was intended to inquire about processing tasks in EMT operations, as well as the actions that should improve data and geospatial processing in the EMT workflow.

At first, the respondents were asked which tasks are relevant to integrate spatial data for EMT operations (Q26). Survey results showed that nearly 90% of respondents considered updating old data as a relevant or extremely relevant processing task in EMT operations (Figure 9). The second most frequent responses were completing missing features, conversion of data formats and georeferencing tasks, each at about 89%.
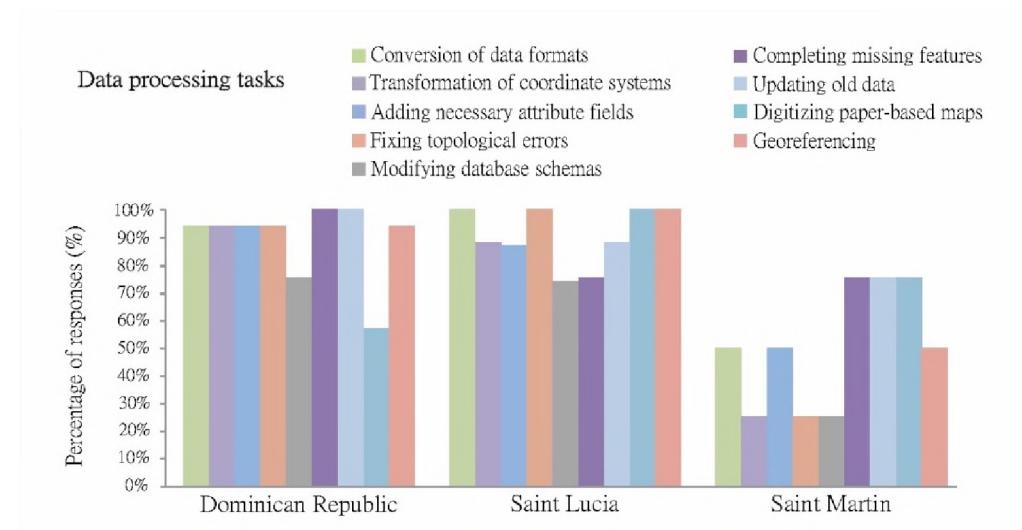

Figure 9. Data processing tasks in EMT operations (Q26).

One survey question asked the respondents to mention what software is frequently used to execute EMT operations (Q27). The majority of respondents replied that they frequently used ArcGIS (82%), followed by QGIS software (68%) for geospatial processing. Another survey question asked respondents to cite which hardware infrastructure is used to perform geospatial processing (Q28). Here, the analysis revealed that DR (67%) and LC (55%) respondents use stand-alone computers as hardware processing infrastructure, while SXM respondents reported more use of in-house local servers (50%). The respondents were asked which media they use to store information resources (Q29). In general, respondents claimed that the information is mainly stored using local databases/servers (79%), with a few respondents using cloud services (29%).

At the end of this Section 2.3, one open question asked the respondents to recommend improvements for enhancing data and spatial processing in EMT operations (Q30). According to respondents' recommendations, the availability of distributed processing capabilities in the cloud, standardization of data and metadata and technical training on geospatial technologies and disaster risk management were the most frequent answers (Table A3 in Appendix A). Again, the respondents were also in favor of the implementation of a disaster-oriented SDI as an alternative to improve the workflow of EMT operations.

3.4. Mapping and Layout

In this section of the survey, questions were asked about the type and purpose of maps generated in EMT operations, as well as alternative solutions for enhancing this step of the mapmaking workflow. A four-point Likert scale question (ranging from never to always) was used to request respondents to indicate the maps they generated most frequently

during EMT operations (Q31). The majority of respondents (71%) similarly mentioned that critical infrastructure, roads and shelter maps were the maps generated most frequently (Q31) (Figure 10).
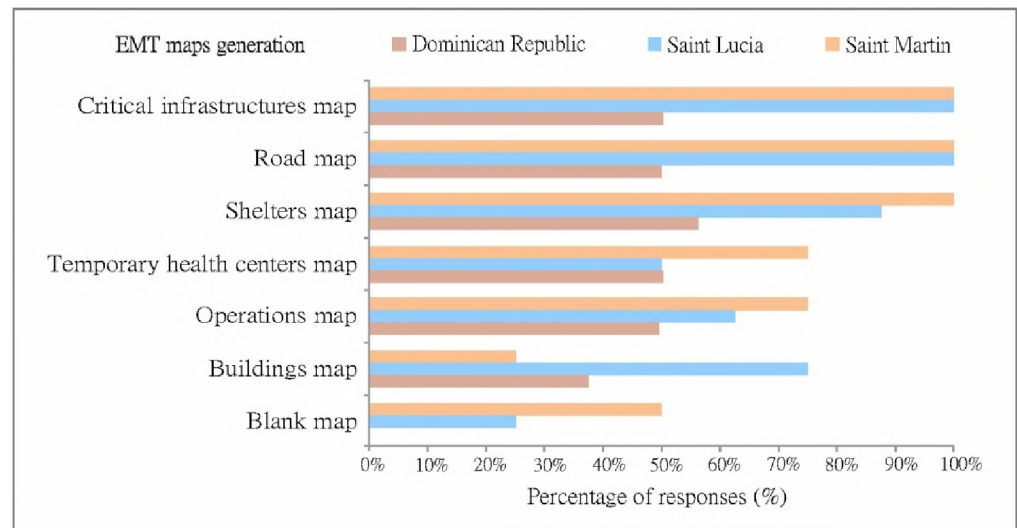

Figure 10. Type of maps generated in EMT operations (Q31).

One survey question asked the respondents to mention the main purposes of the maps generated for EMT operations (Q32). The results revealed that the EMT maps have a wide range of purposes, while the most frequent application was damage assessment (82%), followed by risk assessment and emergency planning and preparedness, each at 79%. In particular, it was notable that DR respondents (88%) also cited support of emergency management stakeholders as the main purpose of EMT maps (Figure 11).

In response to an open question inquiring about recommendations for enhancing mapping and layout in EMT operations (Q33), the respondents mainly stated that technical capabilities for real-time data collection and sharing were necessary. Respondents were also in favor of non-technical actions, such as strengthening organizational and coordination capabilities of EMT stakeholders (Table A4 in Appendix A).
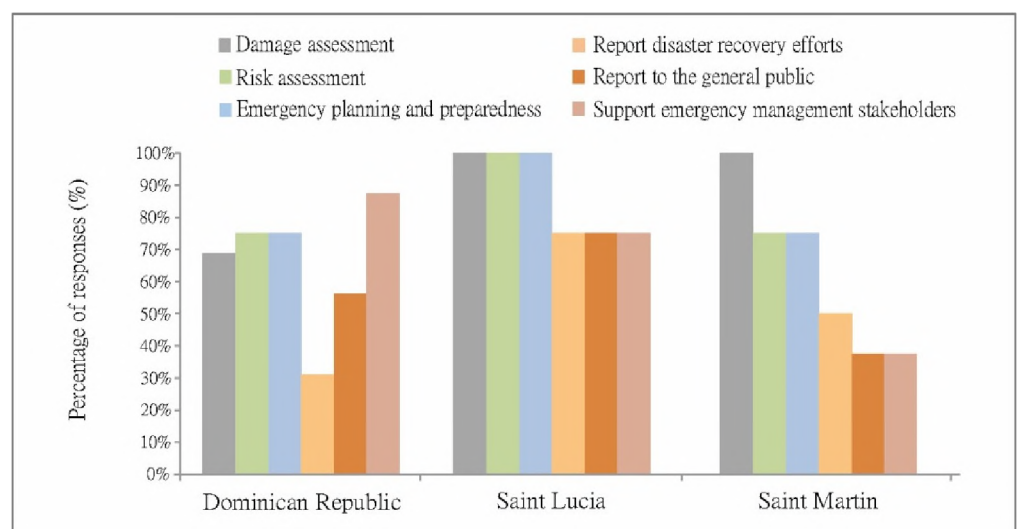

Figure 11. Main purposes of EMT maps (Q32).

3.5. Product Sharing and Continuous Updates

This last section of the survey aimed to understand the delivery channels used for sharing EMT products. Here, the first question asked respondents which channels are currently offered for providing access to emergency maps and data products (Q34). Up to 50% of the respondents claimed to use geoportals and e-mails for providing access to EMT geospatial resources. Alternatively, one LC respondent (13%) reported the continued use of file transfer protocol (FTP), while five DR respondents (12%) indicated the use of SDI to provide access to EMT data.

A four-point Likert scale question (ranging from never to always) was used to request respondents to indicate the most frequently used media for sharing EMT products (Q35). The majority of respondents reported that they frequently or always used GIS maps (93%) and digital images (83%) (Figure 12). In particular, LC respondents reported the highest frequency for the use of paper maps (88%).
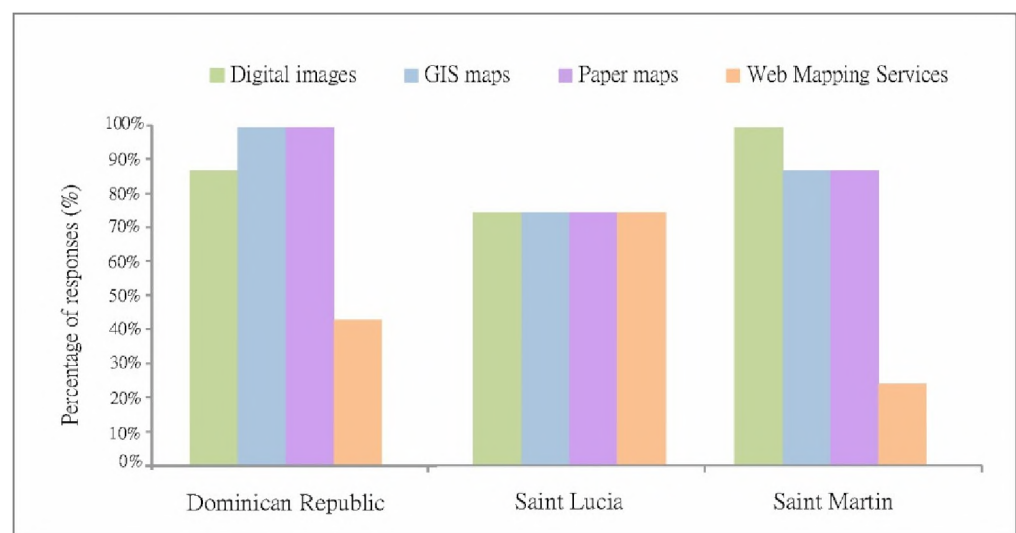

Figure 12. Main media for sharing EMT maps (Q35).

With regards to web service applications during EMT operations, a four-point Likert scale question (ranging from not relevant to extremely relevant) asked respondents to indicate the most relevant web services for improving efficiency in sharing EMT map products. Most of the respondents deemed web mapping services (WMS) as relevant or extremely relevant (82%) for improving efficiency in map product sharing (Q36). DR and LC respondents similarly stated web coverage service (WCS) and web map tile service (WMTS as relevant for delivery of EMT products) each at about 75%.

The respondents were also asked an open question to recommend improvements for products sharing and updating in EMT operations (Q37). The most recommended actions were the implementation of a SDI that opens spatial information to all stakeholders (Table A5 in Appendix A). Participatory mapping and capacity building were also mentioned as strong strategies to build relevant and up-to-date spatial information at the local level.

Regarding capacity building, a five-point Likert scale question (ranging from not important to very important) asked the respondents to rank the importance of a listed training courses to strengthen EMT operations (Q38). Specifically, all DR and SXM respondents ranked training on the use of GPS as fairly important or very important, followed by data collection techniques and big data, each at 75%. All LC respondents were more in favor of geospatial database management and metadata trainings.

At the end of this study, one open question asked respondents to mention missing elements that had to be tackled in the questionnaire (Q39). Most of the respondents expressed their satisfaction with the experience of completing this survey. Specifically, two

DR respondents suggested that internal bureaucratic procedures and the role of statistical tools and trainings to improve EMT operations were missing in this survey. One LC respondent believed that limitations related to human resources should be included in the study.

4. Discussion

The main goal of our study was to identify users' requirements for EMT operations in Caribbean SIDS. This research combined a case study method and a questionnaire survey to identify grounded arguments and a set of users' requirements for EMT operations in small island developing states.

Our results showed that EMT products and services have the potential to increase resilience and DRM effectiveness in SDIS, by providing quick access to relevant spatial information and maps for damage and risk assessment, and emergency planning and preparedness. This finding aligns with previous studies showing that effective information sharing among all stakeholders is essential for successful management of disasters [34–36].

Our findings suggested that direct communication with stakeholders using social networks and cloud-based platforms would be highly helpful to lead real-time coordination, communication and knowledge transfer for EMT operations in future DRM scenarios. In this regard, other authors similarly denoted social networks attributes in facilitating a two-way communication channel for knowledge sharing and reuse across all stakeholders in emergency circumstances [4,6,37,38].

Regarding data generation for EMT operations, our results evidenced that significant attention is paid to the potential use of volunteered geographic information. This collaborative approach comprises the generation and sharing of user-generated geographic information to spatially enable local businesses, research institutes and relief organizations as key stakeholders for EMT operations in affected communities [39,40]. As stated by Haworth et al. [6] and Genovese and Stéphane [41], VGI presents opportunities to boost citizens' participation in the collaborative production of local knowledge for decision making. This VGI potential becomes more relevant when there is an urge for the most up-to-date information of unfolding events in the field.

In terms of data and geospatial processing, our findings revealed that the lack of standards and technical specifications for data and metadata capture, processing and sharing, constitutes a strong barrier for effective EMT operations in Caribbean SIDS. Ajmar et al. [17] and Rosario et al. [18] reported similar findings, stating that the enforcement of standards (cartographic workflow, symbology, map template, etc.) allows users to increase efficiency in emergency mapping operations.

Regarding technology infrastructure to build and share a common operational picture of the landscape, our results suggested that there is a great potential for the implementation of a cloud-based SDI tailored to EMT operations. Similarly, other authors recognized the significant contribution of cloud-based platforms as an effective method for capture, access, analysis, distribution and integration of data and map products in emergency response efforts [42]. However, basic electricity and internet services might be interrupted for days in the immediate aftermath of a humanitarian emergency; hence, these severe circumstances might prevent cloud-based platforms from being fully accessible for sharing and processing large quantities of data from the most vulnerable communities in the SIDS. Other authors also highlighted the lack of interoperability as one main drawback of using cloud computing, meaning that users must decide between flexibility and ease of use [43].

In terms of human resources, there was a strong consensus among the respondents regarding the necessity to increase capacity building initiatives to fill the gap and disparities of knowledge in terms of geospatial technologies and disaster risk management strategies. This may be explained by the limited number of skilled professionals involved in the integration of available technologies that have not been formally used for emergency mapping response [12]. In this sense, previous studies have also recognized capacity

building as an influencing factor for information sharing and coordination in multiagency emergency response [44].

This research also showed that there is a strong interest in opening collaboration channels for exchanging information and resources with other non-traditional EMT stakeholders, including universities, research institutes and drone owners. Previous research shows that such a collaborative approach can be realized through institutional arrangements and partnerships that enable stakeholders to work together ([5,41,42]. These instruments should ease and make possible the integration of externally developed spatial data solutions and knowledge into existing inter-organizational processes [43–46].

There are some limitations in our research approach. First, the limited number of countries studied might be considered a concern and a restriction for the applicability of the findings to a broader domain. Furthermore, potential stakeholders in EMT operations, such as research institutes, academia, private enterprises, NGOs and regional organizations are likely underrepresented in the study. However, the paucity of the existing literature on the region and the need for relevant information on the topic justify the approach. This research is likely relevant not only for developing states in the Caribbean region, but also for the other 52 SIDS in the world.

5. Conclusions

This research demonstrates the potential application of a user-centric approach to investigate user requirements for emergency mapping team operations in the real context of the SIDS in the Caribbean region. The identification and analysis of user requirements can be considered as a first step toward designing a roadmap for anticipating information and service needs for disaster preparation and response.

Despite the differences in the degree of maturity of the EMTs in the studied countries, our findings have revealed a set of five (5) essential user requirements that likely lead to practical implications for improving EMT operations in the Caribbean SIDS:

Requirement 1: Institutional arrangements. Currently, EMT users face major restrictions for sharing data and map products with stakeholders and the general public, while encountering difficult and time-consuming challenges trying to access and standardize heterogeneous data from different agencies. Therefore, institutional arrangements between key stakeholders are crucial. Institutional arrangements provide the framework for better inter-agency coordination and collaboration capabilities [47,48]. Institutional arrangements should be established beforehand as instruments to enable the development of standards, technical specifications and protocols for data collection and information sharing across all stakeholders involved in the entire disaster risk management lifecycle.

Requirement 2: Implementing a Cloud-based SDI. In emergency circumstances, decision–makers urge the generation of a common operational picture of the affected communities. Therefore, the implementation of a disaster-oriented Cloud-based SDI is necessary to enable dynamic integration and delivery of information datasets from multiple spatially-distributed sources.

Requirement 3: Linking stakeholders at the community level. In the case of emergencies, the information about unfolding events in the field changes very fast. The development of a real-time communication platform, based on standardized smartphone applications and social networks, is required to support timely interaction and participation of stakeholders in the field. This platform should make stakeholders' contributions easier and more efficient in the collection and dissemination of the most current information for early warning and facilitating emergency response at the community level. Research has shown that citizens with access to internet and standard mobile phones can contribute to rapid data measuring and mapping and to reporting data about space and events that concern them [49].

Requirement 4: Partnerships. Large-scale disastrous phenomena, such as hurricanes and earthquakes, typically obstruct limited government capabilities to supply up-to-date geospatial information and services for decision making. Therefore, partnership arrange-

ments become crucial as a framework to develop these government geospatial capabilities, as necessary. Partnerships allow fostering the participation and trust of external stakeholders, namely, private enterprises, research institutes, universities, NGOs and local organizations, to become active contributors in the EMT operations.

Requirement 5: Capacity building. EMT operations bring together people (experts and non-experts) from a wide range of disciplines and experiences. Hence, technical trainings on data collection techniques using GPS, geospatial and data processing, metadata and information management should be a strong pillar for standardization and sharing of geospatial knowledge among team members. Continuous capacity building training programs enable each team member to support others' objectives in an effective and collaborative manner. They are also required as a first step to achieve more local community involvement to support EMT operation from the field, even when they were not used to working together before.

Our findings also highlight the necessity to regularly update these user requirement studies in order to suit the changing needs of the disaster risk management lifecycle in the SIDS context. Non-technical actions, including strengthening the organization and coordination capabilities of emergencies response agencies, involvement of local community and first responders and development of technical documentation and procedures for EMT operations, are also important.

The results of this study would lead to practitioners and regional organizations' improvement of their understanding of what needs to be prepared for an efficient EMT operation in future mapping actions for humanitarian emergencies. This new knowledge would also offer a sound foundation for the development of regional mechanisms to support multilateral cooperation and sharing of geospatial resources among decision makers and emergency response agencies in the Caribbean region and other SIDS all around the world.

The results of this study may also be useful for international agencies that are helping SIDS to enhance resilience to respond to disasters. Before embarking on their tasks of cooperation, these agencies would study the user requirements of EMT operations in the SIDS they are going to work for.

For future research, we would extend our focus to identifying important and feasible factors for enhancing SDI performance to facilitate the disaster risk management process in the SIDS context.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Recommendations for anticipating EMT users' needs (Q14).

Category	Dominican Republic	Saint Lucia	Sint Maarten
Effective Communication	- Link stakeholders - Use of social networks - Specific communication channels - Workshops to identify users' needs	- Reduction of efforts to obtain information - Analysis of past events and associated responses	- Feedback system to provide a framework on which to evaluate and assess
Automatization of processes	- Identification of workflow and missing data sources - Stakeholders profile database - Modeling of emergencies scenarios	- Tools and techniques for data collection	- Drone surveys prior to calamities
Training	- Trainings in information management - Trainings	- Continuous technical trainings	- No response
Coordination	- Logistic support and incentives - Monitoring mechanisms for mapping operations	- Clear directives - Provision of the right resources	- No response
Standardization	- Standardized information gathering processes - Request form for maps output - Graphic outputs of the maps	- No response	- No response
Data specification	- No response	- Up-to-date geospatial data - Sharing and storage of data in a central area - Data analysis	- No response

Table A2. Recommendations for EMT data generation (Q25).

Category	Dominican Republic	Saint Lucia	Sint Maarten
Geospatial data and metadata	- National SDI for DRM - Accessibility to updated data - Access procedure to updated data - Satellite data to monitor hazards - Continuous update of existing datasets	- Capturing imagery after events - Georeferencing data - Mandatory metadata	- Integrated multi-actors geospatial databases - Collection, storage and exploitation of geospatial data
Human resources and capacity building	- Technical personnel exclusive for emergency mapping - Volunteers to collect data - Trainings on data capturing trends - Trained team in information management	- Training of staffs in stakeholder agencies - Trained specialists - More trainings to increase efficiency	- A GIS unit to conduct the data capture, analysis and dissemination

Table A2. *Cont.*

Category	Dominican Republic	Saint Lucia	Sint Maarten
Tools for data collection	- Mobile Apps for capturing data - High precision on data capturing	- Tools for real-time data collection from the field - Provision of better equipment - Utilization of smart phones in data gathering	- No response
Standardization	- Data capturing procedures - Unified national data capturing template - Users' experiences analysis	- No response	- Data capture methodology
Coordination	- Logistical support and incentives - Monitoring mechanisms for the mapping operations	- Getting more public involvement	- No response

Table A3. Recommendations for EMT geospatial and data processing (Q30).

Categories	Dominican Republic	Saint Lucia	Sint Maarten
Distributed processing	- Web services applications to reduce redundancy - Rapid response to updated information - Software and hardware update	- No response	- Decentralized and cloud-based storage along with local hosting - Distributed computer processing capabilities
Spatial data infrastructure	- National SDI for disaster management - Supported with skilled personnel and the latest technologies	- Migration of GIS capabilities to the Cloud	- No response
Standardization	- Standardized protocol for data and geospatial processing	- No response	- Metadata - Data format - Metadata to be collected and saved to use alongside data
Capacity building	- Enhance technical skills in emergency management - Strengthen theoretical and technical capabilities - Trainings for technical staffs - Continuous training	- Users' need assessments for anticipating future events - Trainings	- Trainings on geospatial and data processing

Table A4. Recommendations for EMT mapping and layout (Q33).

Categories	Dominican Republic	Saint Lucia	Sint Maarten
Standardization	- Emergency symbology - Map template - Automotive processes - Geospatial information platform	- No response	- Map layouts - Map symbology
Technical capabilities	- Strengthen the hardware infrastructure - Technical trainings	- Mobile apps for real-time data acquisition - Sharing of files and information - Equipment and updated software - Updated software licenses	- Mobile GIS apps for real-time data collection and updating - Real-time operational GIS data dashboard
Geospatial information	- Continuous access to base data - Real time post-disaster information	- Up-to-date road maps - Mapping of critical infrastructures	- Accurate data as the workflow progress
Organizational capabilities	- Involvement of local authorities	- Planning and preparedness for mitigation purpose	- An organizational structure

Table A5. Recommendations for EMT products sharing and continuous updates (Q37).

Categories	Dominican Republic	Saint Lucia	Sint Maarten
Spatial data infrastructure	- National SDI for DRM - Open data approach - Easy access	- Accessible to the public - Dissemination of spatial data to all stakeholders	- Local level SDI - Scalable computer servers - Increased storage capacity - Reliable ICT tools
Participatory mapping and capacity building	- Knowledge reutilization for developing required tools - Local users involvement to provide accurate and relevant information	- Continuous training	- No response
Standardization	- No response	- Standardization of map and data products - Clear guidelines for product sharing and updates	- No response

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