
Urbanization and Crisis Management Using Geomatics Technologies

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<http://dx.doi.org/10.5772/intechopen.76415>

Abstract

Substantial work has been done by Geospatial Information and Communications Technology (GeoICT) and Disaster Management communities to evaluate and develop tools and applications that integrate the complex interrelationships that are required for adequate preparedness, planning, mitigation, response, and recovery from extreme situations. GeoICT technologies have contributed and are contributing to saving life and property throughout the globe. Over the past decade, extensive research has resulted in more advanced GeoICT technologies. This has helped to maximize the demand for these tools, with a noticeable pattern of adoption and expanding user community. This chapter provides an overview of selected rising stars in GeoICT technology and their applications in disaster management. This discussion evaluates the trends in technology development, with emphasis on data collection, processing, and visualization.

Keywords: GeoICT technology, emergency management, resilience

1. Introduction

The concept of GeoICT attempts to utilize telecommunications technologies to link between various geospatial technologies including Geographic Information System (GIS), Remote Sensing, Global Positioning system (GPS), Photogrammetry, Computing, the Internet, Databases and Visualization Systems. As the name suggests, it integrates various domains of knowledge that require specific skills and abilities to synthesize and integrate. Over the past decades, extensive research on utilizing GIS has resulted in many new technologies. As the name suggests Visualization Systems, integrates various domains of knowledge that require specific skills and abilities to synthesize and integrate. Over the past decades, extensive

research on utilizing GIS has resulted in many new technologies. The usage and request of these technologies have vigorously endorsed the way that GIS and other integrating spatial technologies attempt to find ways and means to determine incongruence and heterogeneity of information from numerous sources, specifically for disaster management. In this way, the integration of different geospatial technologies, supported by advanced Information and Communications Technology (ICT) infrastructure is one of a kind technology-based approach for securing straightforward and useful access to information over various platforms, specifically for disaster management applications. This has made GeoICT integration and, to some extent, its interoperability, as a focal innovative work activity. This convenience of interoperating GIS-based spatial technologies remains the focal point with the objective to have a viable framework, which inevitably relies on how well we are able to handle different circumstances.

Natural disasters are among humanity's most costly, deadly, and dreaded occurrences [1]. Jie et al. [2] have characterized natural disasters as an occurrence that has an enormous effect on the general public. Despite what might be expected, there is no solid definition for natural disasters, as the recognition and elucidation differ with the perspective between the audiences. For example, disaster or emergency, perception varies between social scientists, natural scientists, and information technologists; each of them has a particular field of interest and a special recognition to disasters. Despite that, the typical issue to all catastrophic scenarios is that: floods leave behind a trail of death, with many injured and significant loss in economy.

Disaster management is an applied science, which attempts to use systematic observation [3], monitoring, and analysis of environmental parameters to reduce or eliminate the loss that might occur. However, monitoring and analysis of environmental parameters for the purpose of disaster management cannot be easily documented in a flow chart, since disasters are non-linear processes [4]. In any case, the disagreement in the definition of tragedy certainly reflects on the approaches that disasters are managed.

Disaster management is an applied science, which endeavors to utilize systematic perception, monitoring, and examination of fundamental parameters to lessen or dispose of the misfortune that may happen. Nonetheless, observation and consideration of environmental parameters with the end goal of disaster management is difficult to be recorded in a simplified project flow chart since catastrophes are nonlinear processes [5]. Regardless of these considerations, the different circumstance about the meaning of disaster has unquestionably mirrored no understanding in the ways that disasters are overseen. What was agreed upon are the phases of disaster management cycle, which are mitigation, preparedness, recovery, and response as shown in **Figure 1**.

Geospatial technologies support a cost-effective means for spatial data acquisition, processing, and presentation for the application of emergency management [6]. Nevertheless, planning a geospatial information application requires an in-depth, detailed information, and analysis of the constituents of the event, be it disaster management or emergency situation, under each of the mentioned stages.



Figure 1. Disaster management cycle.

2. Methods

The method for conducting this work involved reviewing the state-of-the-art GeoICT systems, supported by urban case study, that attempts to address emergency management issues in the City of Jeddah, Saudi Arabia, based on evaluation of data products and applications for the use of GeoICT. This has been investigated from the perspectives of acquisition systems, processing systems, and presentation and visualization systems. Current geospatial technologies have significantly evolved to provide geodata and geoprocessing such as routing and geocoding. The emergence of advanced, sophisticated technologies such as sensor webs, Internet of Things (IoT), and advanced Web mapping protocols have made day-to-day activities simpler and easy, such as Google Maps. As a result, many new platforms are integrated using advanced telecommunications protocols and infrastructure. As such, significant numbers of applications have been rapidly developed. This section discusses these developments from the perspective of GeoICT integration for the purpose of data acquisition, processing, and presentation. It specifically addresses the user interest in these technologies and the capabilities provided by each of the researched themes.

Geospatial information coordination is the procedure that includes gathering information from various sources at different accumulation modes and bringing these data together in a sizeable database to give complete information environment to preparing, displaying and perception.

Light Detection and Ranging (LIDAR) is a surveying technique that measures the distance of an object known as a target by sending laser pulses to hit the target and return to the transmitter. LIDAR is an acronym for Light Detection and Ranging (sometimes Light Imaging, Detection, and Ranging), was initially a blend of light and radar. LIDAR is used to make high-determination maps with applications. LIDAR is also called as laser filtering and 3D checking; with earthbound, airborne, and portable applications, the airborne LIDAR Bathymetric technological framework includes the estimation of time of flight of a flag from a source to

its arrival to the sensor [7]. According to [8], unmanned aerial vehicles (UAVs) are currently being utilized with laser scanners in addition to other remote sensors, as a more conservative strategy to filter smaller territories.

UAVs, generally known as “drones,” are little-to-medium-sized flying machines that automatically fly, without human pilots’ intervention. The majority of UAVs are remotely guided [9]. They are checked and worked from ground stations that give full insights about the UAV flying data, including flying way, height, information accumulation, and time stamping different information items obtained from the UAV, which is recorded, installed, and additionally transmitted to the ground control station. In any case, there is another kind of UAV, which is known as self-governing UAV [10].

Autonomous Underwater Vehicles (AUVs) are automated frameworks that are equipped to perform tasks submerged underwater, utilizing their outline and their application [11]. AUVs are an improved version of the long referred marine information gathering innovation known as remotely operated vehicles (ROVs). The ROV is linked to the base station’s locally available vessels, where it sends information and gets directions over wired correspondence conventions. In particular, they can plunge, float, or skim in shallow or deep waters, completely autonomous of any human steering or control [12]. Indicated that AUVs advancements have reformed the path in which hydrographic looking over is directed and the methods for delivering hydrographic information items, for example, profundity soundings and sweep symbolisms of the ocean depths. The UAV systems, as shown in **Figure 2**, are utilized as a part of complex applications for the observation, upkeep, and establishment of submerged framework, for example, media transmission links and submerged oil and gas pipelines, and typical citizens’ areas. **Figure 3** shows the AUV platform for underwater collection.



Courtesy of Heikki Saari-VTT, [Novel MEMS and Piezoactuated Fabry-Perot spectral imagers for atmospheric studies]38th Annual European Meeting on Atmospheric Studies by Optical Methods, [Fabry-Perot Interferometer Hyperspectral Imaging Technology Transfer to Space Applications]3th ESA Round Table on Micro and Nano Technologies for Space Applications, Jere Kaivosoja/MTT, [UASI Potato Monitoring flight campaign preliminary results]Finnish Remote Sensing Days 2012

Figure 2. Different UAV types.

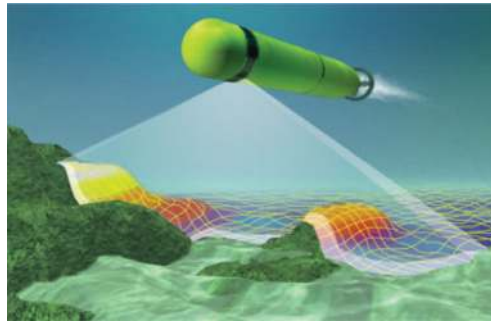


Figure 3. AUV platform, image courtesy to (<http://www.mbari.org/>).

The expression “sensor-web” has risen as of late as a system of sensors for natural checking is constructed associating distinctive ecological administration hubs [13]. Described as a detecting framework that uses the Internet to communicate with exceptionally small sensors in the field and sends estimations over the system to committed servers that take into account information

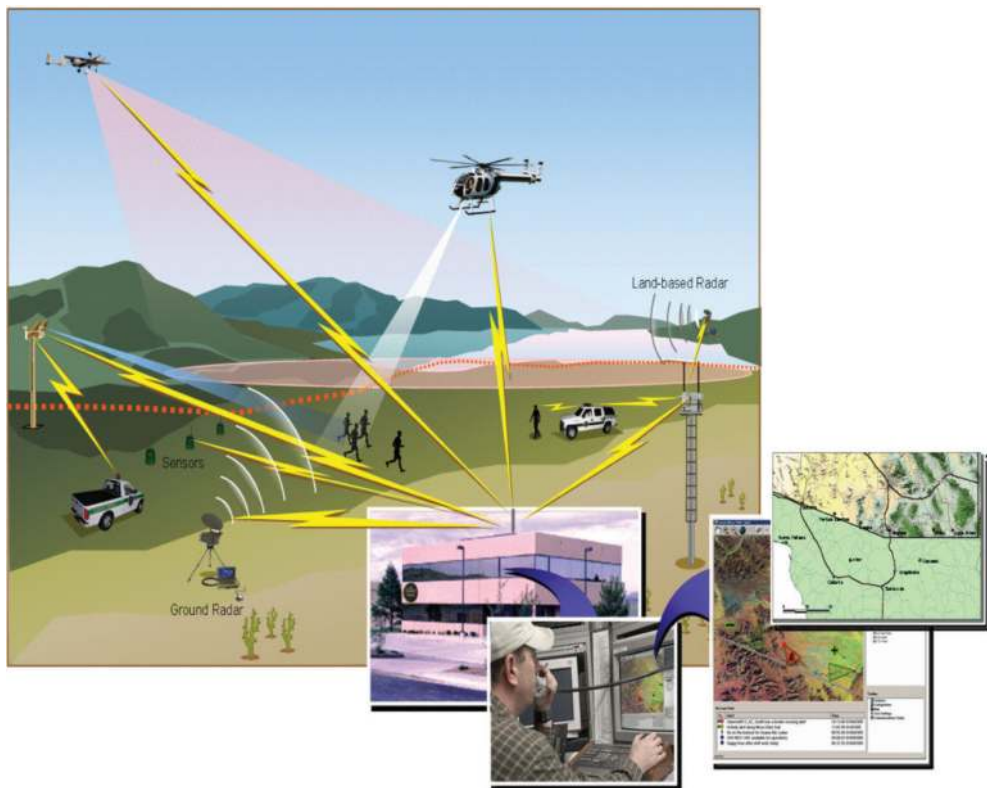


Figure 4. Sensor-network scenario in emergency operations center (EOC). (image courtesy of sensors online magazine (<http://www.mbari.org/>)).

administration, handling, and investigation. The key normal for sensor web is that the system of sensors are connected and cooperate, and a brought together the framework. Every hub in the system speaks to the spatial element and discuss remote premise with the server and with each other hub in the system. [14] The OGC standard for Sensor Web Enablement is discussed where every hub is spoken to by a sensor equipment that gives single estimation and can be connected to the sensor web over the system [15]. **Figure 4** shows the concept of Sensor Web application in emergency management operations.

3. The concept of urbanization crisis management

Environmental disasters are known to be devastating in many ways. The risk impact can be ascertained depending on the magnitude of hazard. In the past, the impact from environmental emergencies such as floods, earthquakes, tornados, and heat storms was enormous, specifically in urban centers, where the density of the population was higher and the possibilities for response were somewhat traditional in coping with such events.

Today's technology has significantly contributed toward saving lives and properties. Specifically, they are known as spatial technologies (GIS, GPS, Remote Sensing and Photogrammetry). The strength of these technologies stem from the fact that it offers detailed information on location in terms of positioning, visualization, simulation, and measurements for various applications.

The development of the Internet has added to the spatial technologies, specifically to the GIS domain allowing for what is known as web services for data processing, modeling, and visualization. This has provided a unique opportunity for exploring issues related to interconnect- edness between various geospatial elements as well as allowing for simultaneous access and sharing of data. This is crucial for emergency management as it requires rapid and effective response through being prepared for such exigencies.

The idea behind this research project was to provide lively application and solution for applied issues that touch everyone's life in the community. By carrying out the first phase of the project, this chapter has attempted to lay out the foundation framework for the second phase. The study conducted involved data sharing, meetings, and interviews with selected number of decision-makers to analyze the gaps in the current use of technology as well as to provide an insight of what could be done by adopting advanced technologies.

There are many challenges for researchers working in this field including the challenge of getting the data in addition to getting useful feedback from some of the personnel involved in the field. However, the role of research is to provide solutions to these problems as we have done in the first phase and what we continue to do in the second phase is to provide as comprehensive coverage of the problem as possible.

4. Urbanization and emergency management

Many researchers including [17, 18] have provided comparative study models for emergency management. This model is unique as it addresses emergency management between two

large metropolitan centers to examine the role and advancement in GeoICT, which provides an insight on how ICTs can help effective decision-making and enhance the rate of return in spending.

The role of GeoICT in emergency management is characterized by the effective utilization of GeoICT data to provide decision-making models [19]. A framework for using GeoICT in disaster management may consist of:

Development of online interactive hazard maps, categorized by natural hazards, such as floods, earthquakes, dust storms, pandemic potential, and any other potential hazard based on hazard identification strategy for the city.

Development of online risk identification interactive maps, including categorization and prioritization of risks for the city based on what was identified in the risk assessment models.

1. Building various what-if simulation preparedness scenarios that can help decision-makers to optimize the response they need to provide a solution for stakeholders involved.
2. Preparation of potential response policies and procedures that define the role and responsibilities of various departments involved in responding to various risks and examination of their capabilities and responsibilities dealing with each and every risk or threat identified.
3. Advanced integrated visualization systems that provide online 2D, 3D, and 4D visualization of identified risk and response operations, which might be of help for planning groups that are dealing with enhanced emergency response operations.
4. Interactive online mapping with accurate GPS identification of the extents and limits of most vulnerable communities and identification of their type of vulnerability identified whether due to topography or other reasons.

These are the main functions where GeoICT can be used as a utility for emergency management. It has been determined that many of these items listed on the framework are either ready or being developed by the concerned authority, and are discussed in the following sections.

4.1. Decision-making models

The disaster management decision-making models are solely administrated by the Civil Defense Directorate, which is a department of the Ministry of Interior. They work on providing preparedness, planning, and response operations in the City of Jeddah. Many other departments help with providing access to updated data and information related to various alternatives dealing with specific risks. Recent study by Samad et al. [9] indicated that the City of Jeddah has some gaps in the use of early warning technology that can be used for preparedness and response. This was illustrated in the 2009 flooding event that struck the city. It was also found that the Civil Defense Authority was lacking both the policy as well as the level of adoption for the use of technology in locating causalities. This has initiated the need for

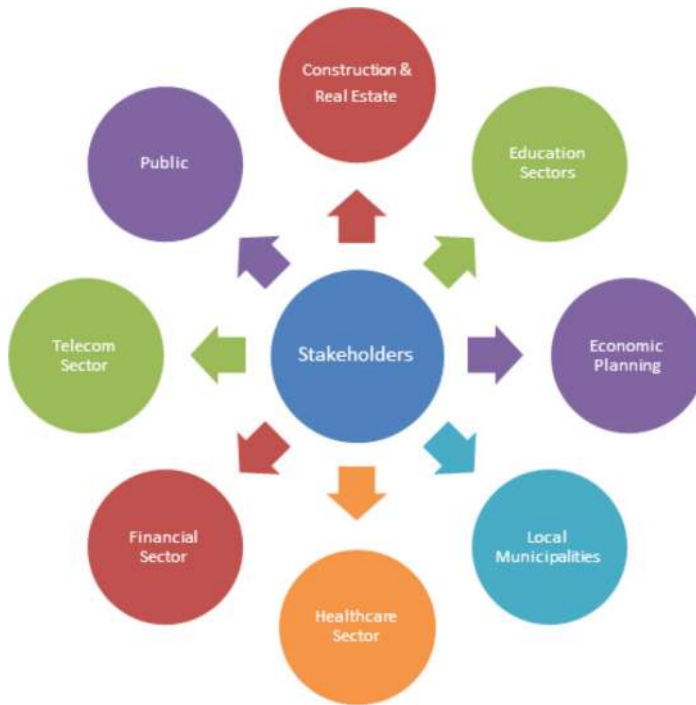


Figure 5. Stakeholders of emergency management systems.

expedited protocols that help with natural hazard communication and reporting, where the GeoICT stands out as a very effective tool to address gaps identified from historical events. **Figure 5** shows typical emergency management stakeholders.

5. Geomatics-based enhanced framework

Many researchers including [16, 17] have provided comparative study models for emergency management. This model is unique as it addresses emergency management between two large metropolitan centers to examine the role and advancement in WebGIS, which provides insight on how technology can help effective decision-making and enhance the rate of return on spending.

Effective emergency management is characterized by the effective utilization of WebGIS data to provide effective decision-making models [18]. A framework for using this technology in disaster management may consist of:

- Development of online interactive hazard maps, categorized by natural hazards such as floods, earthquakes, dust storms, pandemic potential, and any other possible danger based on hazard identification strategy for the city.
- Development of online risk identification interactive maps, including categorization and prioritization of risks to the city based on what was identified in the risk assessment models.
- Building various what-if simulation preparedness scenarios can help decision-makers to optimize the response that they need to provide a solution for stakeholders involved.
- Preparation of potential response policies and procedures that define the roles and responsibilities of various departments involved in responding to various risks and examination of their capabilities and responsibilities dealing with each and every risk or threat identified.
- Advanced integrated visualization systems that provide online 2D, 3D, and 4D visualization of identified risk and response operations, which might be of help for planning groups that are dealing with enhanced emergency response operations.
- Interactive online mapping with accurate GPS identification of the extents and limits of most vulnerable communities and identification of their types of vulnerability identified whether due to topography or other reasons.

These are the main functions where the technology can be used as a utility for emergency management. It has been determined that many of these items listed in the framework are either ready or is being developed by the concerned authorities in the city.

6. Case study

A case study was used to demonstrate the application of GeoICT Technologies in the City of Jeddah, as one of the largest urban centers in the Arabian Peninsula. The objective was to assess the use of GeoICT in disaster management in an urban setting. Jeddah is the largest city in the province of Makkah and the largest port of the in the Kingdom of Saudi Arabia. It is the second largest city in the country and located in the Red Sea coast in the western side of the Kingdom. The city is spread north–south with estimated area of 5460 km² [19] and an estimated population at 2,801,481 [20]. Jeddah is located in a coastal plain [21, 22] The city elevation is 12 meters and is known to be a part of the lower Hijaz Mountains in what is geographically known as Tehama Hijaz region [23]. The area is prone to many natural hazards [24]. As part of the regional system [25, 26], it is of dry climate [27] with temperature ranges from 15°C in winter to 43°C during afternoons of summer. Jeddah is home to many international organizations, and it is an active business center. **Figure 6** shows the location of the City of Jeddah in relation to the Kingdom of Saudi Arabia. The city has experienced many recent flood disasters in 2009 and 2011 [21, 23, 27–29]. There are many motivational factors that make people to prefer coming to Jeddah [30] these factors adds to the vulnerability of people in emergency situations.



Figure 6. Map of Saudi Arabia, showing the City of Jeddah.

7. Findings

An assessment has been carried out on the level of adoption of GeoICT technology for disaster management, where data have been collected from government authority, that is, the City of Jeddah and a private vendor. Historically, there have been numerous issues identified with data sharing and data collection as suggested by Lee [31]. It was a cumbersome task to evaluate the application of GeoICT technology, based on getting the geospatial data for this research. However, we were able to obtain shapefiles to assess the administrative boundaries for the City of Jeddah, including provincial boundaries, district boundaries, and municipal boundaries, including the Red Sea administrative boundaries for the City of Jeddah, as shown in Figure 7. The transportation dataset provided shapefiles for street centerline and street

curb for the whole city of Jeddah. The Environment dataset provided shapefiles for streams as extracted from the Radar, as well as floodplains layer showing the natural drainage system for rainfalls across the City of Jeddah. The Tourism dataset contained shapefiles for point features of public facilities. This was helpful with another privately created dataset for Points of Interest for the City of Jeddah. A digital elevation model in the form of Aster data was used for providing the required elevation information for the study area. Most of the datasets used were provided by the City of Jeddah, and it was in accordance with the guidelines provided by Pew and Larsen [32] who provided guidance by identifying potential layers. **Figure 3** shows details about the City of Jeddah geospatial data repository.

A major characteristic of the evolving GeoICT systems is their ability to investigate the level of details and the validity of sources for emergency management, based on the scope, purpose, and application. This scalability provides added value advantage to the user community. This is supported by the flexibility of the advanced system regarding hardware integration and software processing capabilities, backed by cloud-based data storage or a level of data distribution over a specific data management protocols. Advanced GeoICTs are also robust. This strengthens the process of data collection, processing, and manipulation.

The expected major trends for the near future is the expansion of adopting more UAV and AUV systems and integrating data sharing from these platforms with real-time image processing systems. The original features of integrated data systems regarding sophisticated on-the-fly quality assurance modules, processing, and transmission of data are growing. The quality of

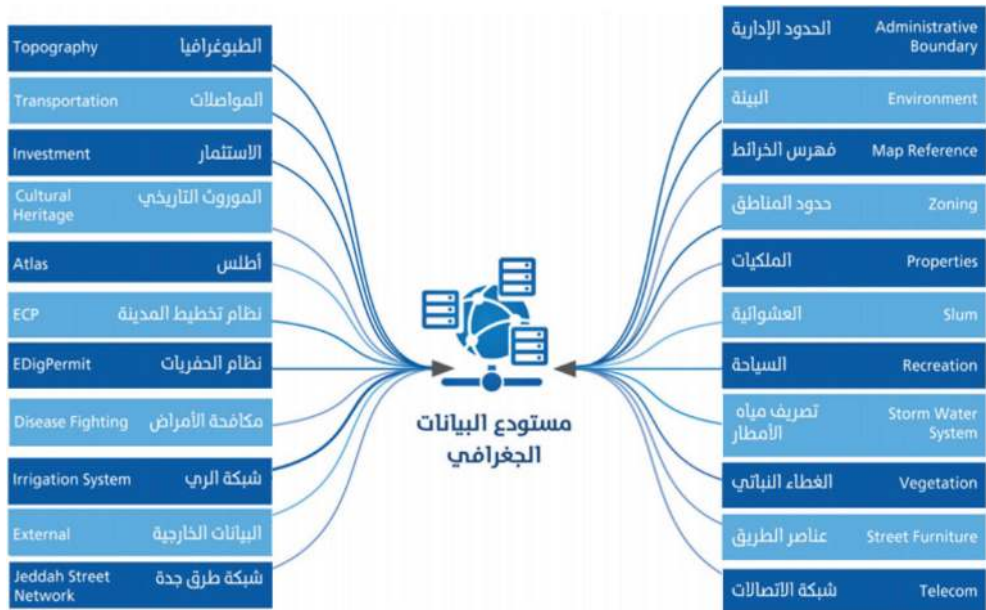


Figure 7. The City of Jeddah. (geospatial data repository source (www.jeddah.gov.sa)).

sensor data, infrared data collection, and on-the-fly decision support is increasing. It is expected that real-time processing and quality control (QC) modules as well as automated data flow will further shorten the production cycle, minimize the human interaction, and will consequently enable a smooth transfer of integrated data systems to many platforms.

The need for adopting advanced GeoICT is supported by the growing user community with diverse applications requirements. In the field of disaster management, GeoICTs are getting a broader user community because of the less technical expertise required and the expanded public participation in disaster management. Between voluntary or crowdsourcing data products, to substantial involvement in the response operations to disaster and emergency management, all these are supported by the trend in ubiquitous, robust, and affordable computing.

The indicators of efficient use of technology in both public and private domains, in the field of disaster and emergency management support are justified by the availability of systems and the practical use of these systems, as well as by the ability of upgrading technology infrastructure, as the case with various emergency management authorities. Data and procedures standardization and mature policies are among the essential factors for advancing the role of GeoICT in emergency management. ICT infrastructure and open, transparent systems are primary factors in developing advanced procurement policies and fostering interoperability between disaster management sectors. However, the challenges relating to the system security and interoperability remain. However, they do not significantly impact the use of this technology.

8. Conclusions

Based on the reviewed technologies and the case study used in this research, it can be concluded that disaster and emergency management operations in urban environments rely heavily on leading Geomatics Technologies. These technologies have maximized the planning and response operations and contributed to saving life and property in many situations, including but not limited to coastal zone tsunamis and earthquakes. The fast pace of development in advanced computing have significantly contributed to disaster management by providing more robust telecommunications, and through growing utilization of the technology, based on a broader standardized user base, and less required technical expertise. The rapid growth in GeoICT has helped disaster management community by expanding public participation along with first responders' advanced capabilities of responding to extreme situations. Geomatics has been instrumental in providing effective approaches and tools for dealing with crisis management from the point of view of urbanization.

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