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ROLE OF GEOMATICS IN THE MANAGEMENT OF DISASTERS AND INFRASTRUCTURAL FAILURES

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Abstract

The article identifies the role of Geomatics in the highly interdisciplinary disaster management to include identification and mapping of hazard prone areas, deformation monitoring of hazard prone areas and massive engineering structures, production of rescue maps and assessment of damages among others. A case study of surveying activities in the proposed flood management of Asa River in Ilorin metropolis, Nigeria was presented. The study identified possible causes of the flood to include silting along the river, blockades of free flow of water resulting from human activities such as dumping of refuse in the river and natural causes such as growth of vegetation along the river channel. The study recommends the development and deployment of Geomatics potentials in the three phases of disaster management namely; pre-disaster phase, disaster phase and post disaster phase.

Keywords: *Geomatics, Disaster, Mapping, Assessment, Management*

Introduction

A disaster is defined as a serious disruption to the functioning of the society or infrastructure, causing widespread human, material or environmental losses beyond the management capability of the affected society using only its own resources (European Environment Agency (EEA), 2006). Such disasters which could be natural and/or man-made are on the increase worldwide in amount and magnitude in the recent times. The human and materials losses resulting from these disasters have also been astronomical (http://www.emdat.be/natural-disasters-trends; Tekeli-Yeşil, 2006). Some of the factors responsible for the disasters include rapid population growth with consequential over-exploitation of natural resources; global climate changes which in the long term result in earth warming and an increasing ocean level; seismic activities and massive earth movements and landslides, high incidences of infrastructural failures, technological accidents, epidemics, terrorism, drought and famine (UNEP Year Book 2010).

Thus efforts have had to be intensified worldwide to manage or mitigate disasters in order to minimize their impacts or outrightly prevent the catastrophes. The Federal Government of Nigeria in tune with the global trend established by Act 12 as amended by Act 50 of 1999 The National Emergency Management Agency (NEMA) to manage disasters in Nigeria. NEMA is reported to be working with other stakeholders in disaster management to produce a National Disaster Management Framework for the Country. According to the report the framework would among others focus on institutional capacity building for disaster risk reduction, disaster preparedness and mitigation, disaster response and recovery. The multi-sectoral and interdisciplinary approach to disaster reduction requires input of experts from a large number of disciplines. Significantly, about eighty percent of decisions that are taken on disaster management are spatially referenced Magel (2005), signifying the importance of geomatics in the management of disasters and infrastructural failures. Management of spatial information forms the significant component of the three phases of disaster management, viz-a-viz: pre-disaster phase (mitigation, forecasting and preparedness); disaster phase (emergency response) and post-disaster phase (damage assessment, recovery and remediation).

Phases of Disaster Management

Pre-disaster phase (Mitigation, Forecasting and Preparedness)

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Deformation monitoring of hazard prone areas

The main focus of disaster risk management is often dedicated to monitoring the risk evolution process of objects, areas, regions or even the whole earth with the aim to give early warning of an impending disaster. Disaster reduction measures are based on a continuous assessment of vulnerability, hazard analysis and monitoring.

Geomatics products, whether based on satellite imagery, air photography or ground surveys, are fundamental foundations for disaster mitigation planning efforts. Areas prone to seismic activities resulting from crustal movements or explorations, for example, need to be monitored to minimize the disastrous effects of phenomenon such as earthquakes, volcanoes and landslides. Space geodesy techniques using Very Long Based Interferometry (VLBI), Satellite Laser Ranging (SLR) and Global Positioning System (GPS) are used for taking the precise and repeated measurements of carefully chosen points established in such areas to detect crustal movements that can lead to volcanoes, earthquakes and landslides (Onyeka, 2009). Photogrammetry is an efficient tool in deformation measurements with respect to location, form and shape for spatial objects of large areas like volcanoes or mass movement landslides (Altan, 2005). Its main advantage to other measuring techniques lies in the fact that the measurement is done on images of the hazard prone area.

Deformation measurements of engineering structures

Precise monitoring surveys at regular intervals was encouraged to be carried out on massive and critical engineering structures such as dams, telecommunication masts, oil and gas infrastructures (Ehigiator – Irughe *et al*., 2010; Otakar and Pavel, 2004; Yunus *et al*., 2010) including speculative diagnostic analysis of liquefaction potential of soils for foundation stability (Jimoh and Ige 2011) as proactive measure to infrastructural failures. Nigeria, for example has several small dams and over eighteen large dams with the Lower Usuma dam in FCT reported to be among the ten largest dams in the world (http://en.wikipedia.org/wiki; URL 2, World's largest dams in Yunus *et al*., 2010). This situation brings great risk to public safety of people living near the dam in case of natural hazards or infrastructural failure. Monitoring of these infrastructures after construction and during operations enables the timely detection of any behaviour that could deteriorate the structure, resulting to its failure. Deformation monitoring involves the establishment of a network of geodetic control points on areas without expected movements; the coordinates of monitoring points (signalized targets) located on the surface of the structure are periodically observed from the network of geodetic control points to assess the nature, directions and velocities of deformation of the structure. Any movement(s) of the monitoring point locations calls for concern on the structural integrity of the feature. The surveyor is needed to design, develop and implement the respective measurement systems as well as to evaluate and analyse the measured quantities. Instruments that have been used successfully for this exercise include GPS, close range photogrammetry and classical terrestrial methods e.g. leveling, angle and distance measurements (Ehigiator – Irughe *et al*., 2010; Otakar and Pavel, 2004; Yunus *et al*., 2010).

Land Use Planning for Disaster Management

The severity of the impacts associated with natural disasters is greatly affected by the appropriateness of the built human environment and settlement patterns (Geis, 1996). A powerful earthquake, for instance, in an unpopulated area is not a disaster, while a weak earthquake which hits an urban area with buildings not constructed to withstand earthquakes, can cause great misery (International Federation of Surveyors (FIG), 2006).

Traditionally, local mitigation and disaster management activities take the form of stronger building codes, stricter code enforcement, new construction methods and materials, and public education programmes. While these actions are beneficial in terms of disaster response, land use planning has the ability to reduce the vulnerability of a community and the economic impacts associated with disaster events through proactive measures (Devlin, 1998). While building codes consider the built environment as a series of individual structures, land use planning considers structures within the context of the community and regulates their locations and proposed usage purpose to create a more appropriate and disaster resistant human environment.

Land use planning for disasters is based on mapping the extent and impacts of natural hazards and designing land use and building policies accordingly. Natural hazard policies must be based on spatial data that defines the extent and distribution of hazards and hazard prone zones. This data may include topographic information such as land elevations and geomorphology, flood heights and water flow directions, bush fire paths, acid sulphate soils, degraded land and storm surge heights (Ireland, 2001). Mapping such data guides the Engineers, Architects, Town Planners etc in coming up with the appropriate policies, ordinances and building codes, control of population density and expansion to guide development for particular areas thereby minimizing losses.

Disaster Phase (Emergency Response)

Availability and timeliness of spatial data is instrumental to an effective and efficient Emergency Response System. The speed and quality of decisions taken in different disaster situations are critical factors for people to survive. Gathering data and development of crisis map with accompanying, evacuation routes to transfer people; rapid identification and location of landmarks, streets, buildings, emergency service resources, disaster relief sites, shelter and housing locations is fundamental in dispatching human and material resources in emergency situation and rescue operations. GPS is reported to have played a vital role in relief efforts for global disasters such as the tsunami that struck in the Indian Ocean region in 2004, Hurricanes Katrina and Rita that wreaked havoc in the Gulf of Mexico in 2005, and the Pakistan-India earthquake in 2005.

GIS as a tool promotes data capture, organisation, analysis, visualization and dissemination. In an emergency case, not only the location of the event but many other non-spatial information is needed, e.g. 'How many people are affected?', 'Which road network is available?', 'Where are the most nearby hospitals located?', 'How much and which kind of capacity do the hospitals have?'. Such questions can be answered very quickly if and only if reliable spatial data are available in digital form and if the data are processed in a GIS (Government of India, 2004).
Spatial Data Infrastructure (SDI), defined as the relevant base collection of technologies, policies and institutional arrangements facilitates the availability of and access to spatial data (Global Spatial Data Infrastructure, 2004). SDI is inevitable in the quick response to emergency situations. SDI provides information on available data, facilitates access to spatial data and sharing of such data between responsible organisations to respond to emergency situations within a short time. The response to the September 11 emergency situation is an example of the effective utilisation of spatial information and related technologies for efficient disaster response (Clarke, 2003).

Post-disaster phase (damage assessment, recovery and remediation)

In the post-disaster phase, Geomatics contributes in damage assessment, the rehabilitation of housing, infrastructure and public facilities and to reduce future vulnerabilities of human settlements. Photogrammetry, Remote Sensing and LiDAR are used in analyzing the damages in structures after failure. This is achieved through 3D-object reconstruction techniques, classification or image detection and their integration into a deformation analysis procedure (Altan, 2005; Lee *et al.*, 2006). This data acquisition technique allows allied professionals gain an efficient tool to determine whether a damaged building will be kept for retrofitting or demolished. LiDAR, ground and aerial surveys for example played critical roles in the damage assessment and structural analysis of 1st August, 2007 I-35 Westbridge Collapse into the Mississippi River in Minneapolis, USA. (http//www.rieglusa.com). Photogrammetry, Remote Sensing and LiDAR are survey methods that provide data very fast and enables the detection of the damaged parts of an object, city or residential areas. Conventional surveying techniques have also been employed in providing remedial measures after disasters.

Methodology

Case Study: 2008 Asa River Devastating Flood in Ilorin, Nigeria

Asa River is an important river that flows in the north-south direction through Ilorin metropolis, Nigeria. It serves as the main source of water for domestic and industrial activities in the metropolis. Starting from the stilling basin of the Asa dam built over it, the river runs over a distance of about 10.5 km within the built-up area of the city. In 2008, the river overflowed its bank, causing havoc on its adjoining area. There was also an overflow of the bridge over it along Unity road, making the bridge impassable. A post-disaster survey was carried out after the flood for the purpose of carrying out flood mitigation/remediation measures which could include the channelisation of the river within the portion where it flows through the metropolis and the possible development of some areas of the river banks for tourism. The improvement of the river channel for flood mitigation/control requires a reliable estimation of the magnitude of the maximum flood discharge.

The survey work carried out towards the realization of the afore mentioned goals includes: the hydrographic survey of the river channel to determine the profile of the river channel, identification and provision of positional information of blockades to free flow of water along the river channel. Other aspects of the survey include the topographic survey of both banks of the river to a distance of 30m on both sides of the river bank. Other survey works include the cross sectioning of the river channel at 25m interval which is needed for the determination of flood discharge; identification and mapping of flood heights at some strategic points and the identification and determination of the xyz values of the inflow points of the river's tributaries for the purpose of channelisation.

In executing the work, the river bed profile was determined using an echo sounder. Control points were established along the river banks and near bridge points using GPS. Topographic survey and mapping of details were carried out using a Total station. Flood heights were identified by flood marks made on near-by structures and from enquiries made from residents near the river. Total station was then used to determine the flood heights.

Result and Discussion

The river profile showed that the river bed at some downstream portions of the river have higher average elevations than upstream portions of the river indicating the possibility of silting at such downstream portions. Such presence of silting reduces the water pass-way making it insufficient to accommodate the flood time flow. The survey identified factors responsible for blockades of the river flow to include grown vegetation and fallen trees in the river channel as shown in Figure 1; disposal of industrial and domestic wastes into the river channel as seen in Figure 2 and construction of structures on the river flood plain and its banks as shown in Figure 3. Farming activities which could lead to increase in erosion activities of the river's adjoining areas was common in the river banks and adjoining areas. Figure 4 shows the river bed profile between Chainage 9+000 and 10+450 indicating areas of possible built up of silt in the river channel.

Figure 1 River channel overgrown with vegetation at Ch 3 + 300 and Ch 4 + 800

Figure 2 Dumping of wastes into River channel at Ch 6+950

Figure 3 Wall fence close to River channel at Ch 6+850

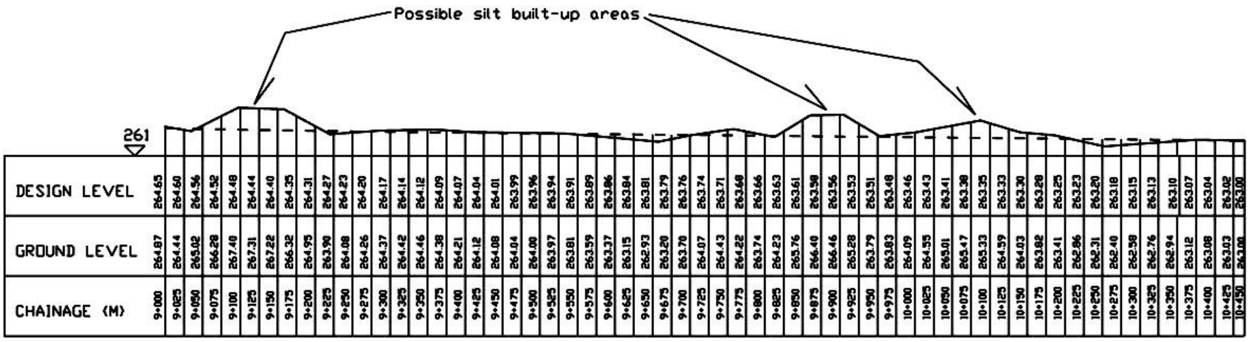

Figure 4 River bed profile drawing of a 1.45 km stretch (between Ch 9+000 – 10+450)

Conclusion

Geomatics is fully involved in disaster management as accurate spatial data is inevitable in all the three stages of disaster management namely; pre-disaster phase, disaster phase and post-disaster phase. Efforts should therefore be made by all governments and communities to put in place the necessary machinery to harness the capabilities of geomatics for effective disaster management.

The survey of Asa river channel and its immediate environment is revealing as it identified where there are possible silting along the river profile. Blockades to free water flow resulting from human activities such as dumping of refuse, land reclamation and natural causes such as growth of vegetation along river channel were also identified.

Recommendations

i. Nationwide identification and mapping of hazard prone zones by Federal, State and Local Governments and agencies such as NEMA, for the production of hazard maps. Appropriate land use planning policies should be put in place for such zones and strictly enforced.

ii. Rescue maps should be produced at necessary scales and periodically updated for purpose of emergency response management. Such maps will include route locations/maps, locations of infrastructures such as hospitals, identified possible disaster management centres, possible shelter and resettlement locations etc.

iii. Researches should be carried out on route network analysis especially in urban centres, to identify the best routes (routes of least resistance) for rescue operations for different disaster scenario.

iv. Early disaster warning systems should be sustained and improved through periodic deformation monitoring/measurements of massive engineering structures such as dams, telecommunication masts etc. Deformation monitoring/measurement of areas prone to seismic activities should be made mandatory.

v. The use of GIS, GPS, LiDAR and recent survey technologies should be promoted for utmost benefit of their capabilities

vi. Human capacity development to meet the above requirements should be pursued.

vii. Periodic hydrographic survey of river channels especially where they flow through built up areas to identify possible silting and blockades to free river flow.

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