Developing a National Database Framework for Natural Disaster Risk Management

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Abstract:

Natural Disaster Risk Management (NDRM) is a complex and critical activity that can be more effectively addressed with the support of Geospatial technologies and Spatial Decision Support Systems (SDSS). The development of better processes, capacity, and systems integrating Geographic Information Systems (GIS), Remote Sensing (RS), and Geospatial Modeling is a rapidly evolving field in Vietnam. The effectiveness and growth of these systems is however dependent on an understanding and development of a National Disaster Management Database (NDMD) underlying the varied scope and activities pertaining to NDRM. A national database provides a common frame of reference for all provincial and local agencies and establishes the framework for managing and organizing the data required to support the disaster risk management activities of responsible organizations.

The efficient exchange and assimilation of data on climate, remote sensing, urban and rural planning, forestry management, land management, and coastal / river dyke construction represent a challenge considering the inter-disciplinary nature of the information required to support Natural Disaster Risk Management and further link the analysis of the same back into more effective project, program, and policy formulation. Working across standardized data structures to dynamic updates and data-feeds from multiple sources, the NDRM database takes on the sense of a data-portal that has the ability to drive the growth of GIS-based reporting and analytical decision making. As the back-end to web-GIS solutions it also provides key decision makers with the geospatial understanding of events and pertinent data helping in easier and more responsive action without much delay in access to information.

This paper addresses the need, the technical structure and the potential solutions facilitated by the creation of an effective database at a national level and draws upon experience from work in Vietnam and practices from India.

Introduction:

Natural disaster are extreme events within the earth's system that result in death or injury to humans, and damage or loss of valuable goods, such as buildings, communication systems, agricultural land, forest, natural environment etc. caused by the increased vulnerability of the global society, and also due to the global warming. Natural disaster are inevitable, and it is almost impossible to fully recoup the damage caused by the disaster; but it is possible to minimize the potential risk by developing disaster / disaster early warning strategies, preparing and implementing developmental plans to provide flexibility to such disasters, and helping in rehabilitation and post disaster reduction.

The use of remote sensing and GIS is becoming increasingly frequent in natural disaster management studies, where satellite images can be used to provide advance warning for specific hazardous events to monitor the concerned, or for a quick evaluation of the damage and therefore support the decision-making process in the relief operations. The use of remote sensing data is not possible without a proper tool to handle the large amounts of data and combine it with data coming from other sources; therefore, together with the growth of the remote sensing applications, geographic information systems have become increasingly important for natural disaster management.

Remote sensing has been successfully applied to landslide, flood monitoring, deforestation studies, forest fires detection, co-seismic displacement monitoring, cyclone, and many more. During the last decades remote sensing has become an operational tool in the disaster preparedness and warning phases for landslide, cyclones, droughts and floods. It can be utilized in the various phases of disaster management, such as prevention, preparedness, relief, and reconstruction, in practice up till now it is mostly used for warning and monitoring *(Álvarez et al, 2003)*[1].

Objective:

The natural disaster management and mapping objective of a national database is the cornerstone of preparedness planning as well as planning and implementation of a mitigation program. All data is of critical use in the preparedness plan as well as in the actual response operations. It must be recognized that the development of these databases in country has to be built bottom up from the lowest administrative unit in country i.e. the sub-district and district corresponding to the level of the disaster preparedness plan. The district databases would feed into the state / provincial database and then into the national database.

Key objective of a national database for natural hazard management would be for;

1. Hazard Assessment Mapping
2. Vulnerability Assessment
3. Demographic Distribution
4. Infrastructure, Lifelines and Critical Facilities
5. Logistics and Transportation Routes
6. Human and Material Response Resources
7. Communication Facilities

Classification of Natural Hazards:

Table - 1: Natural Disaster Categories, its Origins, and Example

Hazard Category	**Origins**	**Examples of Hazards**
Astronomical (Extraterrestrial hazards)	Hazards with origins in space	Collision of celestial bodies with Earth, geomagnetic storms, solar flares
Biological (Biospheric hazards)	Hazards with origins in living organisms, ecosystems, or other levels of the ecological hierarchy	Fire; microbial pathogens; poisonous, aggressive, or otherwise dangerous plants and animals
Hydro meteorological	Hazards with origins in the	Avalanches, drought, erosion, floods, fog, glacial

(atmospheric and Hydrological / hydrospheric hazards)	air or water	surges, hurricanes, icebergs, lightning, precipitation (e.g., freezing rain, hail, ice, rain, sleet, snow), storm surges, temperature extremes or fluctuations (cold and heat), tornadoes, waves, wind
Geological (Lithospheric hazards)	Hazards with origins in the earth	Earthquakes (and associated hazards such as tsunamis and landslides), landslides/rockslides (and associated hazards such as tsunamis), poison gas, volcanoes (and associated hazards such as fire, fumaroles (gas emissions), lahars (mudflows), jökulhlaups (glacial floods), and tsunamis)

Source: Disaster Management: A Disaster Manager's Handbook (Carter, 1992)[2]

Information Needs for National Database Design:

The information needs for national database design of natural disaster management fall into two distinct, but closely related, categories of activities viz:

- Pre-disaster activities: analysis and research (to improve the existing knowledge base), risk assessment, prevention, mitigation and preparedness
- Post-disaster activities: response, rehabilitation and reconstruction

Accordingly, there are two categories of disaster-related data:

- Pre-disaster baseline data about the country and risks
- Post-disaster real-time data about the impact of a disaster and the resources available to combat it

The capability of leaders and administrators to make sound disaster management decisions - to analyze risks and decide upon suitable counter-measures - can be greatly enhanced by the cross-sectoral integration of information. For example, to understand the full short and long-term implications of hazard i.e. flood, landslide, cyclone etc. and to plan accordingly requires the analysis of combined data on meteorology, topography, soil characteristics, vegetation, hydrology, settlements, infrastructure, transportation, population, socio-economics and material resources *(Pareta et al, 2010)*[5]. This information comes from many different sources and at present it is difficult in most countries to bring it all together.

Table - 2: National Database Specification and Information Required

S. No.	Database Specifications	Information Required
1.	Baseline Data	- Major location - Administrative boundaries - Traffic network - Hydrology network - Natural boundaries i.e. basin, catchment etc. - Topography
2.	Landuse and Soil	- Pedology - Soil classification

		- Soil erosion - Land use and land cover - Landscape classification within watersheds - Land capability classes
3.	Vegetation	- Classification of vegetation - Forest planning - Vegetation - Forest resources
4.	Environment	- Environment status - Ecological sensitive area - Observation point of water quality - Conservation of plants and animals
5.	Climate	- Evaporation - Solar radiation - Radiation photosynthesis - Humidity index - Hours of sunlight - Rainfall per month - Start and end temperature - Maximum temperature - Minimum temperature - Partition climate agriculture - Total temperature - Humidity
6.	Geology and Geomorphology	- Geology - Minerals - Geomorphology - Physiography - Slope - Digital elevation model (DEM) - Geomorphological terrain - Hydro-geomorphology
7.	Hydrogeology	- Groundwater - Hydrogeology - Water depth - Anthropogenic or natural building origins - Geo-hydrology

Source: GIS for Landslide Hazard Management (Pareta, 2009)[3]

Methodology:

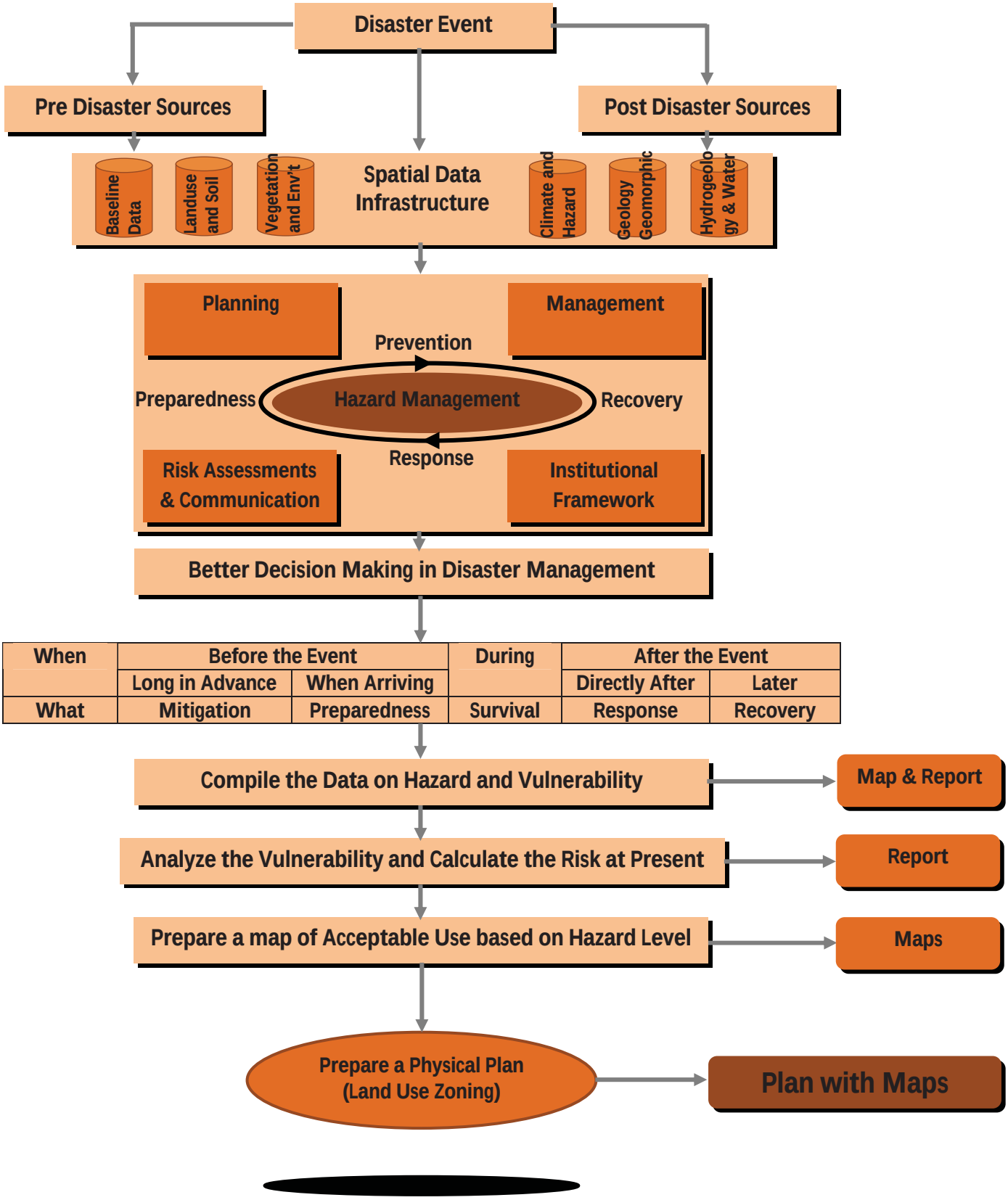

Figure - 1: Flow Chart of National Database Framework for Natural Disaster Risk Management *(Pareta, 2009)*[4]

A National Database Structure:

The development of a national database for natural disaster management is a critical activity that must be undertaken in the near future to sustain the effort of the DMC *(Pareta et al, 2010)*[5].

1. At a very basic level, the GIS database must include:
    - Land mass: Main land area, islands
    - Administrative geographies: National, province, district, commune boundaries
    - Surface water: Shoreline, rivers, inland water bodies
    - Topography: Surface terrain with more detail along coastlines
    - Bathymetry: Detailed bathymetry adjacent to shoreline of main land mass and islands
2. Man Made Features:
    - Land use: Broad existing land use patterns of urbanized, agricultural, forested
    - Major transportation systems/ networks: Roads, railroad, airports, sea ports
    - Existing dykes and protection measures
    - Proposed dykes, flood control structures
3. Information on Natural Resources:
    - Geology with information on rock formations, type, and influence on landslide potential
    - Soils with information on soil type and influence on landslide potential
    - Hydrology with information on flows and morphology of rivers to support flood analysis
    - Land cover with details on vegetated areas, including forested areas and coastal mangroves
4. Temporal and Dynamic Data:
    - Climate data by administrative Unit (for 10 years, however preferably for past 20 years)
    - Satellite Imagery: Coarse, moderate and high resolution imagery in true color, or multi-spectral imagery for past years, updated regularly to provide information for current conditions
    - Population: Location and density maps identifying settlements and urban areas, giving past, present, and project future growth
    - Livestock: Similar to above
5. Information on Past Natural Disasters:
    - Landslide and flooding: Extent of affected areas with detail on population, livestock, and infrastructure, time period, affected administrative areas, assessed cause
    - Coastal storms: Extent of affected areas with detail on population, livestock, and infrastructure, time period, affected administrative areas, associated named storm, data on storm surge and weather conditions

This information must be organized into a comprehensive geospatial database with associated attribute data, specifically linking the metadata on source, accuracy, scale, and time period. This database must be routinely and periodically updated and be supported by dynamic data feeds for climate information and for satellite imagery from national data sources. Specialized routine acquisition for a comprehensive imagery database must be undertaken on an annual basis to ensure adequate coverage, given the cloud cover over various parts of the country at different times, especially the coastal areas.

Types and Sources of Information Required:

Table - 3: Possible Secondary Information and Data Source

S. No.	Possible Secondary Information	Data Source and Documents
1.	Baseline Data a. Main land area, islands b. National, province, district, commune, and ward boundaries c. Shoreline, rivers, inland, and water bodies d. Surface Terrain i.e. DSM, DTM, DEM, slope, and physiography e. Bathymetry data for sea, river, lakes, tank, ponds, and reservoir	a. Satellite imagery b. Administrative boundary map, and topographical map c. Satellite imagery d. Elevated satellite imagery i.e. ASTER-DEM, SRTM, LiDAR etc. e. Sonar, satellite imagery, GIS, and field survey
2.	Man Made Features a. Land use i.e. broad existing land use patterns of urbanized, agricultural, industry b. Major transportation systems/ networks i.e. roads, railroad, airports, sea ports c. Existing dykes, protection measures, dam, check dam, gully plug etc. d. Proposed dykes, flood control structures, and bandh e. Landslide barriers, water & soil protection, and forest fire protection structure	a. Satellite imagery i.e. QuickBird, IKONOS, SPOT, IRS Series etc. b. Topographical map, satellite imagery, road atlas, other maps c. Hydrological map, proposed structure map, toposheets d. Hydrological map, high resolution satellite imagery, toposheets e. High resolution satellite imagery, structure map, toposheets
3.	Natural Resources and Features a. Geology, rock type and structures i.e. fault, fracture, dyke, joint, and lineament b. Soil type, soil compactness, soil erosion, and soil textures c. Hydrology, morphology of rivers, and geomorphology d. Hydro-geomorphology, hydro-meteorology, hydro-geology, and ground water e. Land cover i.e. vegetated areas, forested areas and coastal mangroves	a. Geological map, satellite imagery, geological structure map b. Soil map, band ratio of satellite imagery, field survey c. Geomorphological map, satellite imagery d. Hydro-geological map, satellite imagery e. Satellite imagery i.e. QuickBird, IKONOS, SPOT, IRS Series, LANDSAT
4.	Temporal and Dynamic Data a. Climate data i.e. evaporation, solar radiation, humidity index, sunlight, precipitation, temperature with past 10 to 20 year b. Pre-disaster and post-disaster satellite imagery with true color, or multi-spectral or panchromatic c. Elevated satellite imagery i.e. ASTER-DEM, SRTM, LiDAR, RADARSAT etc.	a. National climatic data center, IMD, Vietnam Meteorological Department, Climatological Information Department b. Historical satellite imagery, SPOT, QuickBird, IKONOS, LANDSAT, IRS Series, GeoEye, WV, etc. c. ASTER-DEM, SRTM, LiDAR, RADARSAT etc.

5.	Information on Past Natural Disasters a. Landslide and flooding: Extent of affected areas with detail on population, livestock, and infrastructure, time period, affected administrative areas, assessed cause b. Coastal storms: Extent of affected areas with detail on population, associated named storm, data on storm surge and weather conditions	a. Historical satellite imagery, past disaster affected maps, natural disaster report b. Historical satellite imagery, past disaster affected maps, natural disaster report
6.	Social and Economic Data a. Demographic / Population: Location and density maps identifying settlements and urban areas, giving past, present, and project future growth b. Housing, household and family status c. Economic status d. Education and literacy levels e. Ethnic and cultural patterns f. Communications g. Social and political structure h. Policy framework for gender and development and natural disaster management i. Disaster impacts	a. Statistical offices, regional databases, Census reports b. Statistical offices, Census reports, time and allocation study reports c. Poverty assessment reports, status of women reports d. Statistical offices, Census reports e. Community development reports, special study reports f. Public utility departments, Industry reports g. Government information divisions, institutes of higher learning h. Disaster agencies, women's and gender departments, community and social development agencies i. Situational disaster reports, news articles, web pages, hospital records, hotline records
	Possible Primary Information	
7.	Physical Resources a. Size b. Location c. Ecological zone d. Type of housing e. Access to public utilities f. Land tenure pattern g. Housing tenure pattern h. Agricultural resources (land, livestock, crop, irrigation)	a. Data collection through different survey method
8.	Socioeconomic Resources a. Educational and literacy levels b. Employment and job skills c. Income sources, savings, credit	a. Data collection through different survey method

	d. Property insurance e. Time and activity allocations f. Household and community food security g. Household headship and power within the household h. Family size i. Incidence of family violence j. Feeling of isolation/ powerlessness	

Sources: GIS for Landslide Hazard Management (Pareta, 2009)[3]

Advantage of National Database:

A national database should be provided the fallowing advantages: provides capability of interfacing with revenue monitoring and variable-rate application equipment, provides ease of use in joining map-linked data tables to external relational databases, offers additional advanced GIS analysis capabilities including spatial statistics, provides the capability of DGPS input for on-the-go mapping, provides temporal and spatial indexing for data tables and maps, provides 3D, contouring, or color-ramping for contouring elevation and other z-related data, provides access to elementary GIS analysis functions, capable of accepting digital data in the form of maps, images and attribute data through file transfer protocol (FTP) or modem communications from remote sources *(Rennolls et al, 2004)*[6], provides temporal or historical trending for important parameters, provides indexing maps and tables for ease of review, spatial data maps and tables are most efficiently stored in a GIS, spatially distributed statistical data analysis, GIS overlay and neighborhood functions for spatially mapped data, and GIS charting and graphing engine.

Conclusion:

Natural disaster management is a complex and critical activity that can be more effectively addressed with the support of geospatial technologies and spatial decision support systems. The development of better processes, capacity, and systems integrating GIS, remote sensing, and geospatial modeling is a rapidly evolving field in Vietnam. The effectiveness and growth of these systems is however dependent on an understanding and development of a national disaster management database underlying the varied scope and activities pertaining to national disaster risk management *(Varela et al, 2003)*[8]. This paper addresses the need, the technical structure and the potential solutions facilitated by the creation of an effective database at a national level.

A national database provides a common frame of reference for all provincial and local agencies and establishes the framework for managing and organizing the data required to support the disaster risk management activities of responsible organizations. It supports disaster preparedness and anticipation by documenting baseline data on past natural disasters, risk assessment, prevention, mitigation and preparedness; and post-disaster activities-such as mitigation, response, rehabilitation and reconstruction. With effective information gathering and exchange systems it would also be possible to move towards almost real-time data about the impact of a disaster and the resources available. Key components of national database structure are-hazard assessment mapping, vulnerability assessment, demographic distribution, infrastructure, lifelines and critical facilities, logistics and transportation routes, human and material response resources, communication facilities.

The recommendations are development of national capacity on natural hazard management and database structure, which is supports to national and regional institutions on the process of capacity building, hardware, software, network, WebGIS, and decision maker to use database and reliable disaster information for decision-making. Conceptualized using ESRI technologies, this database architecture are replicable and conforms to all open-GIS solutions standards.

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