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DIPLOMARBEIT

Titel der Diplomarbeit

„Hazard mapping – A GIS based tool in disaster management“

Verfasser

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angestrebter akademischer Grad

Magister der Naturwissenschaften (Mag.rer.nat.)

Wien, 2012

Studienkennzahl lt. Studienblatt:	A 455
Studienrichtung lt. Studienblatt:	Diplomstudium Kartographie und Geoinformation
Betreuerin / Betreuer:	Univ.-Prof., DI Dr. Wolfgang Kainz

Abstract

While we realize the devastating capacities of natural hazards and we presume that they are unavoidable, we also have to think that it is a problem that we could do something.

Studies about hazards pave the way to minimize its impacts on our societies. As the hazards create disasters only when it is confronted with human use systems, the preparedness and capacity building measures for relevant communities would lead to reduce the losses in future events and sustainable disaster mitigation.

Geographic information systems provide new possibilities in cross disciplinary approach in disaster mitigation. It enables better understanding of spatial relationships and processes. As well, geographic information systems could also be utilized to present new information in maps that are invaluable in disaster mitigation.

The main objective of this work is to study the role of hazard maps as effective tools and their cartographic aspects in spatial risk communication. A conceptual framework to assess and present the tsunami hazard risk in an affected coastal area is discussed at the end of the study.

Kurzfassung

Während wir die verheerenden Kräfte von Naturgefahren verstehen und wir davon ausgehen müssen, dass diese unvermeidbar sind, müssen wir auch bedenken, dass dies ein Problem ist, wo wir etwas tun können.

Studien über Gefahren ebnen den Weg, um seinen Einfluss auf die Gesellschaft zu reduzieren. Da Katastrophen nur dann aus Naturgefahren entstehen, wenn diese mit menschlichen Systemen konfrontiert werden, sollte die Bereitschaft in den relevanten Gebieten steigen, um die Verluste in zukünftigen Ereignissen zu minimieren und somit eine nachhaltige Katastrophenvorsorge zu erlangen.

Geographische Informationssysteme bieten dabei neue Möglichkeiten im interdisziplinären Ansatz in der Katastrophenvorsorge. Damit ist es möglich ein besseres Verständnis von den räumlichen Beziehungen und Prozesse zu erhalten. Außerdem können Geographische Informationssysteme verwendet werden, um neue Informationen zu gewinnen, die von unschätzbarem Wert für die Katastrophenvorbeugung sein können.

Das Hauptziel der vorliegenden Arbeit ist es, die Rolle von Gefahrenzonenkarten als wirksames Instrument und deren kartographischen Aspekte in der Risikokommunikation zu beleuchten. Ein konzeptioneller Rahmen, um das Gefahrenrisiko von Tsunamis in betroffenen Küstengebieten zu beurteilen und darzustellen, wird am Ende der Arbeit präsentiert.

Acknowledgements

I want to recollect and pay my gratitude to late Prof. Ingrid Kretschmer who gave me moral support and advices at my early stage of studies. Similarly I am forever grateful for all the professors members of the department of Geography and regional research for their encouragement and support in many ways.

My greatful thanks also go to my friends in Vienna and Sri Lanka, who encouraged me, criticized me, helped me and offered their friendship.

I would also offer my heartiest greetings to Prof. Dr. Wolfgang Kainz for introducing me this field of study and guiding me towards to complete the thesis.

Finally I offer my regards and thanks and owe much for my father, sisters and brother, for their love, support, and encouragement, even without seen me for months and years.

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Abbreviations

CAD	computer–aided design
CEN	European Committee for Standardization
DMC	Disaster management centre
GIS	Geographic information system
GPS	Global positioning system
ISO	International standard organization.
MIS	Metadata information systems
OGC	Open GIS Consortium
SVG	Scalable vector graphics
WLV	Wildbach und Lawinenverbauung (Austrian Service for torrent and avalanche control)

1 Introduction

In recent years the world has been confronted with a large number of natural disasters. Sometimes these events are due to the evolution of planet earth, respectively geohydrodynamical or geophysical circumstances. It also has been noted that climate change also contributes and increases the disastrous hazardous situations on earth. At the beginning of 2011 there was a series of floods and landslide events in Asia due to the El Niño phenomenon, which is considered to be a consequence of global climatic changes. Furthermore, natural disasters possibly originate under manmade circumstances. They are mainly technical hazards and there is a possibility that these type of hazards to produce a larger impact on earths eco systems.

Normally the prevention of a natural hazard is impossible. Long term soil conservation would manage to avoid small scale landslides at least in some cases. Other events like for example events resulting from high scale global crustal evolution and tectonics can hardly be prevented.

Nevertheless, there is a possibility of minimizing the potential of the disaster originating in a natural risk even if the disaster is hardly preventable. Whilst we realize the enormous disaster capabilities of natural hazards we also have to understand that there may be something that we can do about. There is a wide range of activities and actions that could be undertaken by individuals, communities, organizatons and governments to reduce the risk of happening of those events or to respond to them with enhanced capacities. In this case, it is of major importance to estimate how vulnerable the communities are for a specific risk event. Then this information has to be properly and timely made available and shared with the affected communities and relevant decision makers and all stakeholders. Hazard maps are one of the best ways to communicate the nature and degree of a particular risk in a comprehensive but an understandable way to all communities involved.

The hazard map as a tool reveals a detailed knowledge of the related risk event and provides the planners with an orientation for localizing the endangered area thus helping in the mitigation processes. It also helps the relevant community to ascertain and weigh their degree of exposure to the risk event.

This study was aimed to engage with the application of maps to communicate hazard related data and to consider their cartographic aspects. The consideration of hazard maps as effective communication methods in disaster mitigation activities refers following research questions.

1. Which characteristics of geophysical hazards are important for monitoring, prediction, and the planning of mitigation strategies that leads communities to be more resilient and less vulnerable to natural disasters?

2. Which are the features of hazard maps that qualify as useful instruments in communicating the nature and extent of risks caused by natural disasters?

3. How could geographic information science be utilized to create hazard maps?

4. What are the cartographic aspects and guidelines to be followed in spatial risk visualization?

The objectives of this research are,

1) To examine the tools in risk communication process, especially on hazard maps and their utilization.

2) To examine the application of Geographic information systems in hazard mapping process.

3) To develop a thematic map with disaster management elements and hazard zones for a tsunami affected coastal area

All the hazard events have a probability and they have temporal and spatial characteristics. Although there are numerous hazard events according to their origin or triggering factors, all have some common features. Consideration of these characteristics is essential when modelling the events. The first question deals with those common characteristics of natural hazards.

As thematic cartographic representations hazard maps are mainly generated to visualize the result of a hazard assessment. As a communication medium they are intended for a wide spectrum of end users and these require some special cartographic design rules that satisfy the needs of all end-users and at the same time preserve the validity of hazard assessments. These features make them valuable instruments in risk communication.

Most hazard maps are the information products of Geographic Information Systems. The Geographic Information Systems and its application in disaster management are to be considered as the third question.

The fourth question engages the generation of a hazard map applying cartographic design rules for a tsunami affected coastal region in southern Sri Lanka.

Methodology

At the beginning by means of literature studies, it is intended to clarify the terminology and procedures used in disaster management.

Special emphasis is given to the tools used in risk communication, such like hazard maps. While acknowledging the fact that the Geographic information science as an integral element in every stage in emergency management processes the developments in the last decade in this field identified.

In the mapping process in this study the inundation records and wave heights of the latest tsunami event considered. Further attempts are made to identify potential hazard zone with the digital elevation model, topographic base maps and other available information. The data would be integrated into a data base and processed with ArcGIS package. In the map along with vulnerable areas additional tsunami mitigation information is to be visualized. The arrangement of graphic elements in hazard maps generally done in an easy to understand way to meet the requirements of different user groups.

This study is structured in five chapters. The first chapter starts with the general introduction of the hazard concept and its scale as a global problem and its physical dimensions. The following chapter deals with key terminology of disaster management subjects and concepts which are widely used in literature. The third chapter shall give a theoretical background of Geographic Information Systems and their application in disaster mitigation.

As cartographic materials play an effective role in risk communication as well as in all the four phases of disaster management, the fourth chapter introduces in major lines hazard maps and their predominant visualization technics with examples. Chapter five presents a hazard mapping work in a tsunami affected area with the application of geographic information systems. At the end of the chapter a brief overview is given on the methods used and problems encountered and some proposals are given for further improvements.

2 Environmental hazards

With the global trends it is obvious the increase of risk caused by natural hazards. This is evident when we look at the disaster statistics of last decades. The comparison and classification of the large number of natural hazard types, provides the possibility to identify their similar characteristics and thus to make a generalization of various events. This chapter is devoted for brief introduction of hazard types and their classifications. Further an overview is given about various physical parameters of natural hazards and their potential ability to cause physical damages.

2.1 Global trends

According to the historical hazard statistics there is a clear upward trend for number of events, especially from the second half of 20th century. With the beginning of industrial revolution and advancement of technological knowledge we tend to use more and more resources upon the earth without allowing adequate space to regenerate them. Or we use or change them in such a manner that it could not attain its initial state.

In this way reveal an increasing number of researches the global warming of the atmospheric conditions as prime factor to increase the number of meteorological hazard events.

Although there was no significant evidence of increase the number of Geophysical events the numbers of losses in both lives and properties in last decades by those events have significantly increased. The global population growth, urbanization and location of settlements in hazardous regions connected with unplanned land use are recognized as secondary factors that increase the losses in these kinds of events.

In last decades there were many media reports about technological hazard events that are originated by numerous anthropogenic activities. These hazard events apart from causing long lasting impacts on lives and human use systems delivers an adverse impact on earth`s environmental systems.

As a result of these twofold factors both natural and manmade circumstances we expose to many hazardous situation that however have to cope with. Some of these hazards are within our influence or capacities. And some are so extreme that we cannot undertake more against its occurrence.

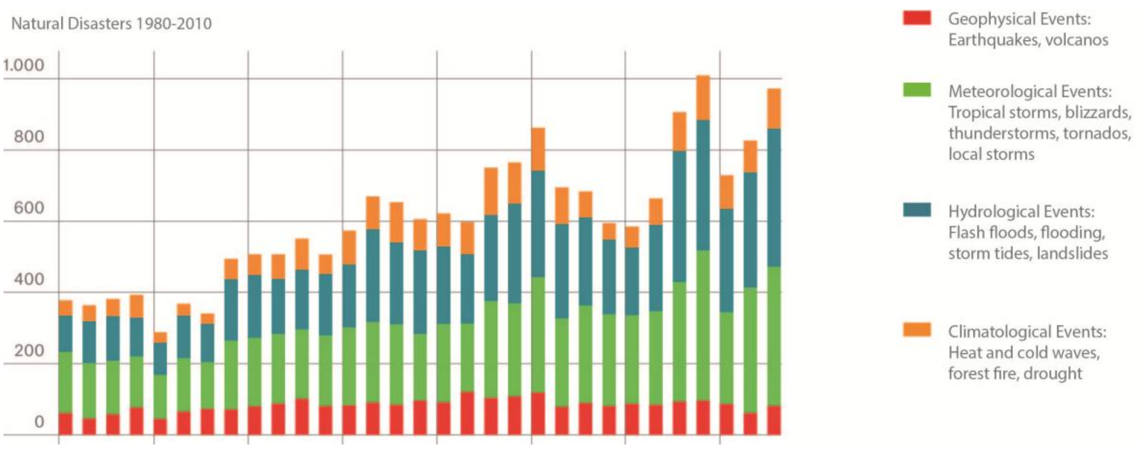


Figure 1: Natural disasters 1980-2010. (Source: Modified after Löw and Wirtz (2011) p.44-47 Data – Münchner Ruckversicherungs)

Another significant development in recent years is the enhanced media attention on natural hazards. Every hazard event occurrence in any remote location on earth is promptly taken in media attention. These also contribute to the trends in hazard statistics.

2.2 Hazard types

There are considerable types of events that could be considered as Hazard events. But in this chapter it is intended to go through most common types and special attention is given to the coastal hazards.

All hazards have a spatial extent. Landslides occur mostly in areas where endogenic, exogenic, or manmade triggering factors prevalent. They are also induced by and another events like Floods or excessive rainfall. However they occur in slope areas and it is limited to these areas. Likewise earthquakes and tremors are prevalent along the tectonic fault zones. So every hazard has a specific spatial distribution.

The likelihood that a hazard may occur is always given as a probability. In case of flood hazard it can be every ten years or hundred years. There can be areas where this probability is minimum and as well there can be areas it is more, according to prevalence of triggering factors. The probability is always considered with a specified period. This temporal factor is a part of many hazard types particularly for those occur from natural circumstances.

Every hazard has a capability to devastate the elements that are exposed to the event and make losses. This capability is depend upon the amount of energy released by the event. If it is a volcano eruption or earthquake the more energy released it has a more devastating capability. This magnitude or intensity is a predominant character of a hazardous event. (VAN WESTEN et al.2010)

There have been disagreements about early hazard studies about the way that the researches to be carried out. The consideration of the fact that disasters originate when vulnerable conditions come into contact with hazards, required the need of the attention of human behaviours and use systems along with physically based hazard studies.

The hazards originate from different sources. Because of this reason they are not always natural. The traditional classification of hazard based on the physical process connected.

Table 1: Natural hazards classified by physical process. Source: Modified after Tobin and Monts (1997) p.50

Category of hazard	Types of event
Meteorological	Tropical cyclones/hurricanes Thunderstorms Tornados Lightening Hailstorme Windstorme Ice storms Snow storms Blizzards Cold waves Heat waves Avalanches

	Fog Frost
Geological	Earthquakes Volcanoes Tsunami Landslides Land Subsidence Mudflows
Hydrological	Floods Droughts Wildfire
Technological	Industrial accidents

2.3 Physical dimensions of Hazards

The hazard as a phenomena incooperate a wide variety of events ranging from local level to continental or global scales that could be classified under different perspectives. To compare or to analyse them hazards are considered under five main different characteristics. (VAN WESTEN et al.2010)

- Magnitude
- Duration
- Frequency
- Spatial occurrence
- Time of onset

2.3.1 Magnitude

There are standard procedures to measure the magnitude and energy released by the hazard events. In meteorological events like snow storms or blizzards are classified on snow depth and wind speed or the function of these factors. In tornados the forward velocities of the rotational vertex allows meaningful comparison of events.

In hydrological events like floods the recurrence intervals of events are for magnitude measurements it also based on the catchment area and the response of hydrological system for a given value of rainfall.

In geological hazards the magnitude is measured with consideration the energy released. For instance the Richter's energy scale for earthquakes was developed and later modified for to adopt for various conditions. But the destruction caused by earthquakes is not always correlated with magnitude. (TOBIN and MONTS 1997)

The magnitude for hazards like landslides and avalanches are classified with geomorphological methods.

2.3.2 Duration

The duration of the geomorphological hazard is an easy to measure feature. But there by the after effect of the hazard has to be considered after the actual event already happened. The duration would be limited to few seconds and in some events up to years. An earthquake would last within few seconds or minutes but its devastating impact would prevail some hours more. Tsunami would hit a shore during minutes or hours depending on the wave length. A drought has a long on set time but its human impacts would last many years. The volcanic eruption can be varied in duration according to location. In some cases it is slow moving or the activities would continue years. In meteorological events the duration is variable where landslides and torrents prevail for a short duration. (TOBIN and MONTS 1997)

While the event itself prevails only for some minutes the background requirements would have already begun for months.

2.3.3 Frequency

Frequency of a geohazard is an important temporal characteristic as it provide some clue about a possible occurrence of an event in a given period.

Most of the geophysical events are random. But there is still possibility to approximate their occurrence exploring frequency of a geophysical event enable to delineate it in a temporal scale. (TOBIN and MONTS 1997)

"In the sense of geohazards frequency is the temporal probability of a hazard event with a given magnitude occurs in a certain area with a given period of time" (VAN WESTEN et al. 2010 p3-14)

Exploring historical data and there frequencies it is possible to pre estimate the future occurrence. There is reciprocal relationship between the hazard with magnitudes and frequencies. For instance for given period it is likely to occur hundreds of tremors that are noticeable or not but only few of them have really destructive effects.

2.3.4 Spatial occurrence

As spatial occurrence some researchers mean combination of factors based on location characteristics, the presence of triggering factors and its dimensions. (VAN WESTEN et al. 2010)

In hazard assessment process to explore the spatial occurrence available topographical, geological, hydrological and meteorological data are used. According to hazard type the analysing procedures likely to vary. For instance the probability of a storm surge to a particular region is highly dependent on the location based topographical characteristics. To define the probability of possible future events the magnitude frequency data of past events are considered.

2.3.5 Time of onset

Time of onset or rate of onset means the time between an event first appears and to reaches to its peak in intensity. This can be very short for events like landslides, earthquakes and avalanches. Slow onset events are such that it takes a considerable time for initial development of the event. Flooding and cyclones as slow onset events allows some time for preparedness arrangements while in short onset hazards allows almost no time for preparedness activities. (PAUL 2011)

For analysis task this hazard specific characteristics are helpful as they provide a broader perspective. But for assumption the impact of an event, considering only these characteristics is not advisable as the events are dependent on many other factors. An impact of a tsunami to a coast largely depends on the coastal geomorphology of the area additional to the waves speed and frequencies.

3 Disaster Risk Concepts and Disaster Risk Management

Since the middle of the last century, especially over the last few decades our living environment has become more hazardous. This is evident every day in mass media and scientific publications. When we see the statistically based analyses it is clear that the number of people thereby affected and properties exposed to danger have increased significantly. This trend is a composite outcome of some other factors including global atmospheric changes due to extensive utilisation of environmental resources by the ever expanding earth population. The amount of losses incurred by life and materials has gone up not only because of the increase in hazardous events but also by the increase in exposure to such events.

The aim of this chapter is to engage with key terms used in natural risk analysis and to engage in qualitative and quantitative approaches to recognize hazard concepts.

3.1 Hazard

Hazard as a spatial phenomenon is combined with other factors including time. There are many definitions for the terms “hazards” and “disaster” in specialist literature. In some definitions it is agreed that the first is primary cause and the other as a secondary event thus making a distinction between the two terms. Hazard as the initial phase means that when a hazard is not properly addressed and prevented it can develop into a disaster. In one of the most common definitions the United Nations recognizes hazard as an event that causes a threat to human activities and well-being and states it is various possible appearances.

“A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage”. (UN/ISDR 2009)

Hazardous events are traditionally considered as natural phenomena triggered by natural forces but there are some hazards that are originated by human activities. According to some hazard researchers whether a hazard turns out to be a disaster or not or which hazardous events turn out to be a disaster would considerably depend on the community involved. Thus natural disasters are formed by the interaction between hazardous events with vulnerable conditions created by various socio, economic, political and cultural factors. MAURO (2004) recognizes this relation as an interface between two factors.

Figure 2: The disaster as the interface between hazards and the vulnerable community. (MAURO 2004)

3.2 Risk

Risk as a term is understood in various disciplines in various contexts. It is always accompanied with hazard or loss. In psychology or philosophy it is associated with the term "perception" which is a subjective process. Risk perception is different among the individuals in the society. People react against a risk based on their personal perception or ability. Every living being or humans, only against the perceived risk counter measures taken. In geographic perspective it is a spatial problem and deemed as a probability of damages that can be brought by an impending hazardous condition for an area. So that the risk can be expressed, communicated through maps.

When a hazard hits an area the damages incurred are spatially variant. While in some parts of the affected area the elements at risk are less, in another area the damages can be relatively more. This spatial variation emerges not solely due to changing locational intensity of the hazard itself but because of few other factors that have multidimensional components**.** Analyses of these components pave the way for successful disaster mitigation strategies and eventually minimize the possible losses incurred.

3.1.1 Risk definition

As mentioned early risk as concept is expressed differently according to the application scenario. Risk is taken as dependant phenomena on three other factors. (VAN WESTEN et al. 2010)

Risk = Hazard * Elements at risk * Vulnerability

In this quantitative risk assessment approach the output value of the risk is dependent on the way the elements of risk are defined. For the hazard component the probability of occurrence of an event in a specified period is considered. The equation is further modified to calculate specific risk for a specific element. For example for buildings located in a coastal area the possibility of being affected by a coastal hazard.

Rs = Pt * Pl * V * A

Where Rs = Specific risk

Pt = temporal probability of occurrence of a specific hazard scenario

Pl = Locational and probability of occurrence of specific hazard scenario

V = the physical vulnerability

A = Quantification of elements at risk (VAN WESTEN et al. 2010)

3.1.2 Risk assessment

Risk assessment is the detailed understanding about the qualitative and quantitative consequence of the any future hazard. The proper understanding about the hazard allows to plan strategic alternatives. It also provides the space for capacity building and minimize losses.

“A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend.” (UN/ISDR 2009)

3.2 Vulnerability

Natural hazards emerge mostly on physical factors or any other reasons. When the hazards are not well addressed or correctly responded, there is the tendency it to develop into a catastrophe. As mentioned early hazardous events are complex phenomena because it combines many other factors including people who behave in different ways in a given space. In a disaster risk management procedure if the concentration is only on the physical processes and the magnitude and spatial propagation of the event, then it would be only a part of the mitigation strategy. The same hazardous event in the same magnitude would affect different localities with relatively different consequences. Why and in which way the same event has different effects on elements at risk are described in the term "Vulnerability".

In the literature the high number of definitions for the term suggests its complex nature. United Nations international strategy for disaster reduction suggests the following definition that highlights its multi-dimensional character.

"The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard." (UNISDR 2009)

"The characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from impacts of a hazard." (BLAIKIE, et al. 1994)

The terms *characteristics* and *circumstances* refer to the physical, social, economic, and cultural features of the community. These circumstances could be changed with time and thus the vulnerability too. It can be expressed in various scales from individual, community-based or national levels. Fundamentally it refers to elements at risk in a place. It has a spatial appearance too that can be expressed through maps. Basically vulnerability could be understood as a product of social and economic disorganisation which in case of a hazardous event influences negatively to worsen the situation.

Expressing vulnerability

Based on above definitions four types of vulnerabilities are recognized.

- **Physical vulnerability**

The component of vulnerability caused on physical structures, lifelines and lives in hazard zone. It could also be considered as the degree to which the damage may occur by an event of a specified magnitude. In vulnerability curves and other risk analysis procedures vulnerability is considered as a value between 0 (No damage) and 1 (Full damage).

- **Economic vulnerability**

The degree of impact could be on economic infrastructure, lifelines, community livelihoods and processes including their indirect and secondary affects.

- **Social vulnerability**

The degree of impact on particular social groups (Aged, disabled, children, gender).

- **Environmental vulnerability**

"The degree that effects the event on the environment" (VAN WESTEN et al. 2010)

The multidimensional nature of the concept is clearly given by "pressure and release (PAR) model" developed by BLAIKIE et al. (1994).

The progression of the vulnerability begins with root causes and combines with dynamic pressures and unsafe conditions thus reducing the overall coping capacities of the community. This model explains the involvement and interaction of many other factors which appear as unsafe conditions thereby creating the space for disasters.

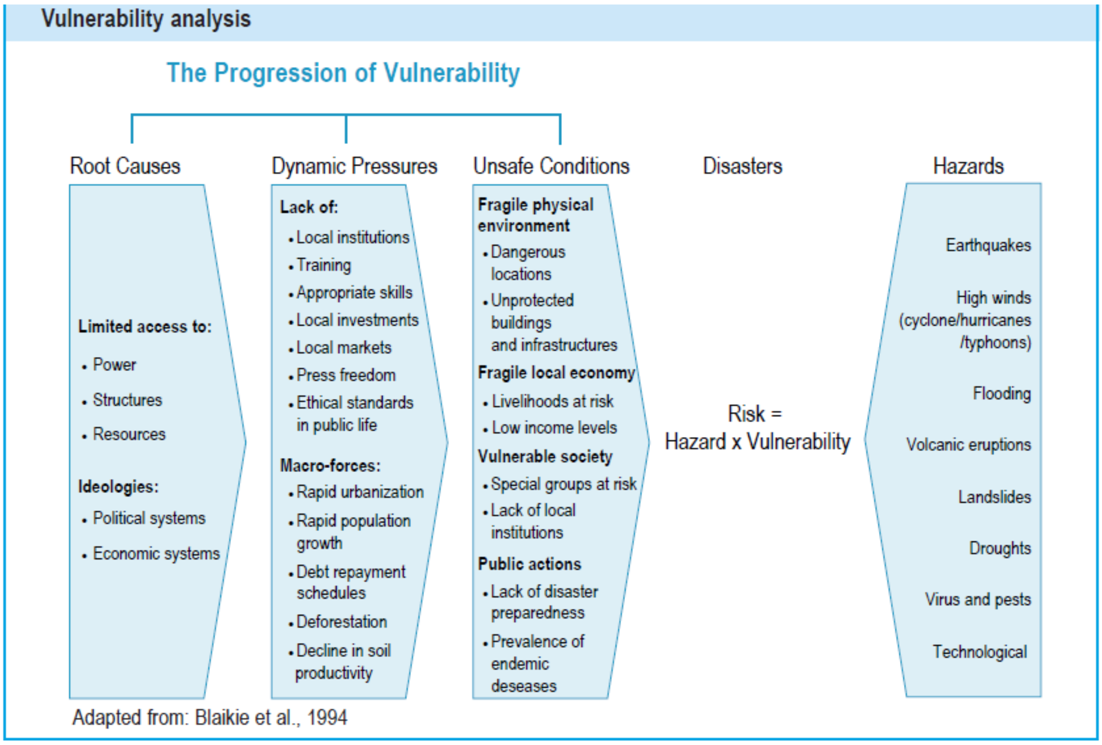


Figure 3: Vulnerability as a combined effect of many factors. (Source: UNISDR 2004/71 adapted from BLAIKIE et al., 1994)

3.3 Elements at risk

Elements at risk are all the physical and non–physical components that are subject to exposure by the hazardous event. The involved population and animals, urban or rural infrastructures, lifelines, economic activities and environment are considered as the physical elements. They are also differentiated as tangible elements at risk (VAN WESTEN et al 2010) which can be identified and mapped whereas social behaviours and cultural components etc. are considered non tangible elements. In case of a disaster both these kinds of elements are affected. Among the many classifications that are deemed necessary for risk assessment procedure, the classification of Asian Disaster Prepared Center (ADPC) recognises four classes as physical, economic, societal and environmental. (ADPC 2012)

The elements at risk can be expressed in different ways. While the number of people affected is given in absolute numbers the other physical elements could be given as financial values. There are damage functions to calculate the cost incurred by a hazardous event. The level of data available represents the credibility of the final outcome of the overall analysis.

Mapping of elements at risk

Elements at risk are mapped to be incorporated in the risk assessment process. Apart from basic spatial units an appropriate scale is to be established according to the extent of the study area. Spatial units are based on the building or spatial elements characteristics and are normally not considered as single units. Single units are mostly not applicable even in large scales because of several reasons including legal matters.

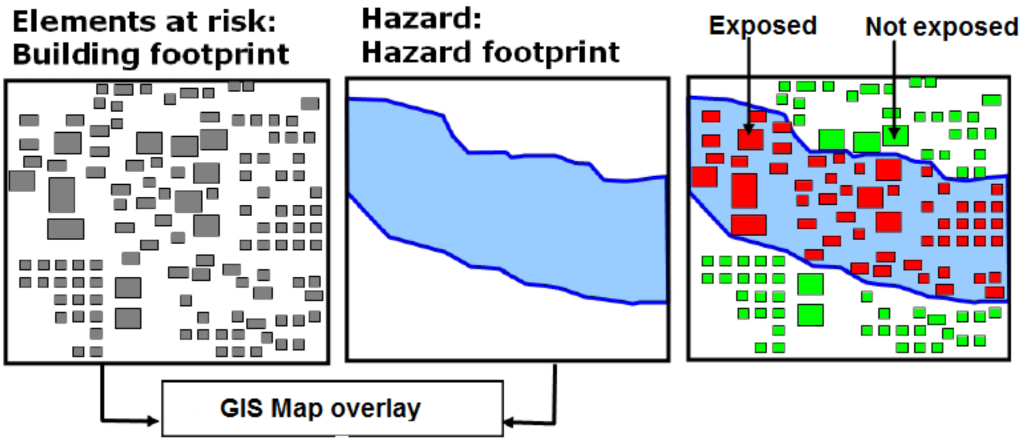


Figure 4: Mapping elements at risk. (Source: Van Westen et al. 2010)

3.4 Disaster risk management

Since globally accepted standard procedures regarding the various phases of disaster management process are not available, there are numerous definitions and procedures accepted by numerous national and international agencies. However these procedures contain all the sustained efforts and the relevant assistance programs to prevent and to minimize damages in case of a hazardous event. They also contain short as well long term counter measures to minimize and prevent disastrous situations in the future.

"The systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster" (UNISDR 2009)

3.5 Mitigation

These are short and long term measures aimed either to minimize the possibility and occurrence of a hazardous event or to prevent it turning into a disaster. Since the increase of Hazardous events from mid last century there are a number of measures that are being implemented by various national and international organisations. These tools are in application in various regions along with specific measures to suit the affected community. The actual disaster mitigation measures that vary according to hazard types could be as structural and non-structural means separated. (MILETI, 1999) classifies these sustainable disaster mitigation measures in five points. They help a community to tolerate and overcome the damage made by an event, to increase reduced productivity and the reduced quality of life thereby paving way to a quick normalcy. He defines mitigation measures. (MILETI, 1999)

1. **Proper spatial planning**

   That discourages the encroachment of sensitive and hazard prone areas, thereby preventing the exposure to hazards and reducing any form of vulnerability. Most of the natural hazard affected areas now use a zoning process as a direct mitigation activity. In hazard communication the information on hazard specific zones are exchanged with the community. Additionally information regarding the zones is made available with hazard maps through web based portals. Although the introduction of land use regulations are done by national or territorial governments the enforcement of these laws are done by local authorities. This sometimes leads to problems especially in developing countries where local and regional political figures enjoying regional powers might oppose any moves that affect their vote base. Free open spaces including those used for agricultural purposes serve as mitigation elements for most hazard types. It has also been noted that the massive relocation drives would result in new social problems connected with the livelihood of the affected communities and thereby increasing their vulnerability.

2. Early warning systems

In case of a hazardous situation, an effective early warning to the affected community would significantly reduce the people's exposure to the event. It allows the community to take precautionary measures which have been communicated to them earlier. There by the lead time plays a significant role as it is the actual amount of time available to the community at risk to react. In sudden onset hazards like earthquakes or tornados the lead time could be a few minutes and in slow onset hazards the lead time might be hours or days in which the people may have time to be prepared.

Figure 5: Tsunami early warning. (Source: http://www.unesco.org/new/en/unesco/resources/publications/unesdoc-database)

In the international conference in Kobe in 2005 a comprehensive action plan called Hyogo Frame work for Action 2005-2015 [1] was agreed upon for worldwide disaster mitigation. The priority of the agreement was to form a foundation to establish early warning networks all over the globe. In the process it is meant to further develop the prevailing systems and to integrate them in a global system.
An impending hazard can be communicated to the people at risk by both technological and non- technological means. Normally several methods are applied by responsible authorities. They all are focused on people at risk and communicate clear warnings and information. The early warning is only a secondary part of a continuing public awareness programmes e.g. through, mass media, campaigns, placards, workshops and all information channels.

3. **Enhancing physical Structures.**

   Here (MILETI,1991) implies a combination of laws, regulations and other legislative activities that could be considered to increase the physical structure of the build environment against an impending hazard.

4. **Insurance**

   As in other cases, hazard relevant insurance programmes may help the affected community to share the losses with other populations. The insurance industry could offer incentives to the clients who follows the mitigation efforts and at the same time offer no insurance for structures in high hazard zones. This policy would have an indirect positive effect on hazard communication measures.

5. **Physical Measures (Structural mitigation methods)**

   According to MILETI's classification all those mitigation tools mentioned earlier are to be recognized as non-structural mitigation measures.

[1] http://www.unisdr.org/we/coordinate/hfa [02.08.2012]

4 Geographic Information Science (GIS)

The engagement with spatial information has a long history. This began with the attempts of the human being to visualize the living environment in maps. There are evidences about maps from the very early periods of human civilization. The changes of abilities and the methods to process and model the real world information are understandable when we see the developments in historical cartography.

The era of digital geographic information began in 1960s when Roger Tomlinson used computers to model land inventories for the Canadian government. Since then this new discipline changes at an enormous manner like a swell of wave.

GIS enable to create process and evaluate spatial information everywhere in the globe. As an applied problem solving methodology with its unique analysis tools it is applicable in many scientific fields including natural hazard analysis.

For this reason this entire chapter provides an overview about the features and aspect of GIS. At the end of the chapter its applications in hazard specific problems are given.

4.1 Historical developments

When the first steps to create Geographic information systems were taken in the 1960s the most of the concepts and terms that are related with present spatial data handling were not available. The system was designed to accommodate 1:50,000 topographical map data and was driven as a mainframe system. The main intention to create the new system was to get maps and spatial data into the computer. The system was never available in commercial form. Since then this new branch of technology has rapidly flourished and for today its components have been useful tools in our everyday life.

Due to the high infrastructure expenditure and related technical impediments till the beginnings of the nineties the usage of GIS was mainly limited to governmental organizations and universities. But by the end of the seventies and the beginning of the eighties GIS began to emerge in commercial form. ESRI (Environmental Systems Research Institute) and Intergraph were the earliest commercial organizations that were engaged in development of GIS software. But today there is a long list of stakeholders - commercial and non-commercial - in this branch.

Further development of the technology continued with the tremendous changes in the computer hardware industry and the availability of high performance personal computers at more affordable prices. Parallel to these improvements the theoretical foundation of the discipline gradually improved. e.g. Topology and related graph theory considered as effective ways to represent two- dimensional neighbourhood characteristics. Furthermore spatial data structures and algorithms were developed. At the same time there were some international symposiums and conferences about special data handling which were mainly engaged in the issues of recognition and research of the new technology. In the 1990s there was a breakthrough with the recognition of Geoinformatics as a professional activity and the special information theory as its theoretical foundation. (KAINZ, 2004)

GIS could be sometimes seen as a complex thing with different capabilities and appearances. To some it could be a system that automates mapping whilst for the authorities it could be a system to be utilized in decision making. Others could use it as a record system to maintain inventories combined of data with geographical reference. An insurance firm uses information from a GIS data base to verify the land blocs in actual risk to conclude claims. A crisis management team would use it for planning and executing its overall strategy in case of an emergency. A hand held navigation system would help us to reach the correct footpath in a forest. The different appearance and adaptations of GIS made it necessary to create a variety of software to accommodate various requirements. A leading GIS software producer like ESRI offers in this way a bunch of applications to suit specific needs.

With the rise of commercial internet providers in the late 1980s and early 90s the application of geographic information systems reached a sudden boom. The GIS has benefited greatly with new Internet Protocols, Browsers, tools and languages and thereby approached a new dimension. The Internet as a widely established network delivers web based GIS applications successfully and GIS can be considered as an application that many compelled to use in the web. In this way the improvement of internet and GIS complements each other. (Goodchild 2001)

4.2 Terminology and Definitions

As mentioned above the first Geographic Information system was the Canada geographic information system in the mid-1960s, and since then there are numerous definitions in use. Sometimes these provide a simple explanation and sometimes describe it with all its extensive features and capabilities. Some may consider it as a *"*computerized tool to deal with geographic data and other as a digital representations of various aspects in the geographic world " or simply "a container of maps in digital form". (Longley et al. 2001)

WORBOYS and DUCKHAM (2004) advance their definition from a general *Information system* and emphasized the specific inclusion of geographically referenced data in a geographic informationsystem.

"*A geographic information system is a computer–based information system that enables capture, modelling, storage, retrieval, sharing, manipulation, analysis, and presentation of geographically referenced data*." (WORBOYS and DUCKHAM , 2004)

BILL (2010) classifies Geographic Information Systems according to its functional areas and its capabilities as a technology and describes it as a product or scheme to handle geographic information.

„Ein Geo–Informationssysteme (GIS) ist ein rechnergestütztes System, das aus Hardware, Software und Daten besteht und mit dem sich raumbezogene Problemstellungen in unterschiedlichsten Anwendungsgebieten modellieren und bearbeiten lassen. Die dafür benötigten raumbezogenen Daten/Informationen können digital erfasst, redigiert, verwaltet und reorganisiert, analysiert sowie alphanumerisch und graphisch präsentiert werden. GIS bezeichnet sowohl eine Technologie, Produkt als auch Vorhaben zur Bereitstellung und Behandlung von Geoinformationen.“ (BILL 2010 p. 8)

In the definition he emphasizes the exclusive relationship of the system with geo information. Spatial informations are the geographic details which are directly or indirectly related with the earth. They are object oriented, constructed and incorporated geometric primitives with graphical and thematic descriptions. This definition by Bill could be considered as a more extensive and complete definition for geographic information systems.

4.3 Features of a GIS

The anatomy and the functional areas of GIS have grown in recent years, especially in the last decade. According to BILL (2000) a GIS could be seen as a combination of features. Hardware, software, data and applications coupled with functions of processing, managing, analysing and presentation. LONGLEY at el. (2011) classify six components involved in a GIS. Namely people, hardware, software, data and procedures connected in a network.

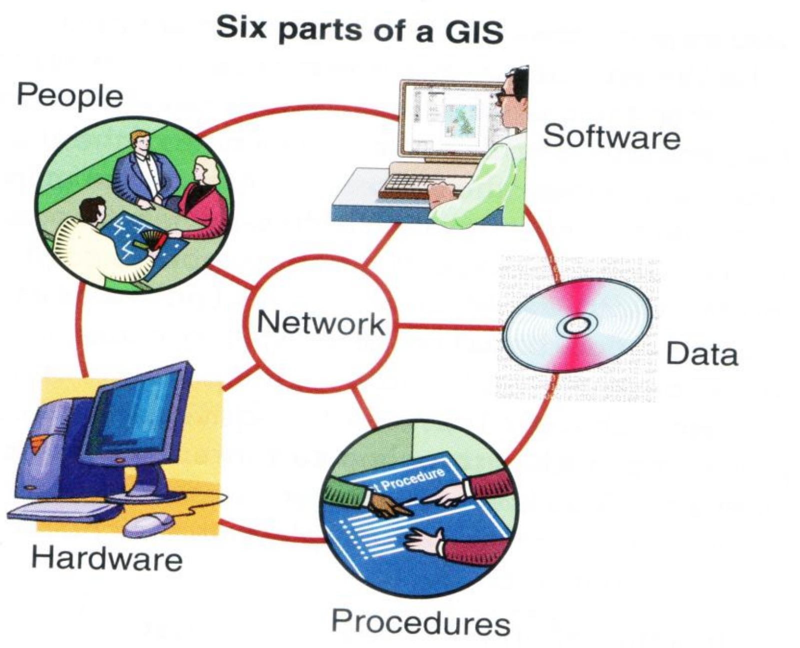


Figure 6: The six component parts of a GIS. (Source: Longley et al. 2011, p.25)

4.3.1 Hardware

The first part of a GIS system is the hardware that the user interacts with for data Capture, managing, processing, and output purposes. Earlier everything was connected with an office desktop but today it also possible to carry out GIS functions in small handheld computers and there is a range of mobile instruments and network peripheral devices. For data capture the instruments range from handheld GPS devices to high resolution satellite sensors depending on the channel of data capture. Webservers too are increasingly becoming important hardware components in a GIS system. With the newly emerging concept of distributed GIS all the components mentioned earlier as well as the hardware can be remotely located. According to BILL (2010) hardware alone cannot behave as a system. To be functional hardware should combine with software depending on the application scenario, computers - and a number of other apparatus such as used in mobile GIS - and a wide spectrum of system components are used.

4.3.2 Software

Various applications are possible with GIS software. They are available as commercial products or as free open source products. In addition to the main operating systems and data bank systems, web–GIS software can be used to provide a wide range of services, data and functionalities through browser technologies.

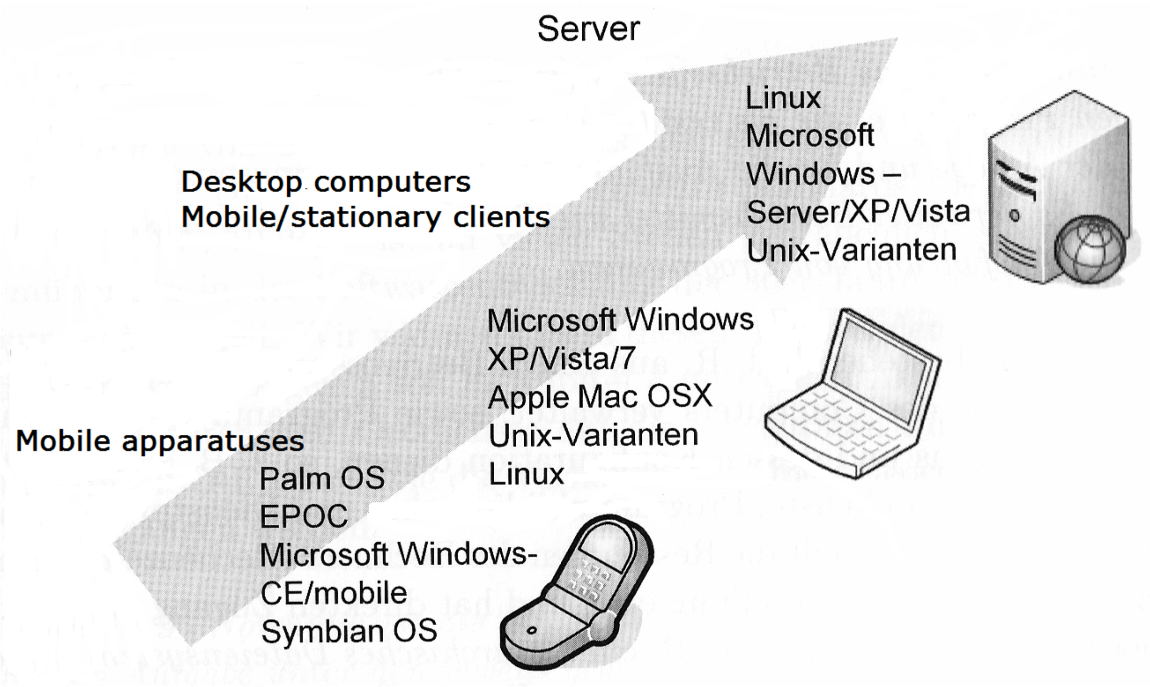


Figure 7: Prevalent operating systems for GIS. (Source: BILL 2010, p.122)

In the last decade the GIS software packages (e.g. ESRI, Mapinfo, Intergraph, etc.) have become more and more extensive with many sets of tools and functionalities on how to handle the demand of any GIS project in multiple platforms. The special software for Windows mobile operating systems, GPS and mobile data processing devices form a new generation in the software domain.

4.3.3 Data

The centrepiece of every GIS system is its spatial data. They are the information concerning spatiotemporal characteristics, Extractions of existing, changing and disappearing elements of the real world. As they exist in space they have spatial or geometric characteristics. They relates to *geographic time* whose effects are observable. Some have many thematic characteristics too and they intern as layers in GIS. (KAINZ 2004)

The geometric data subdivides to Vector and Raster components. Besides pictures and images, videos, animations and panoramas could also be integrated. All the ingredients of the geo data base are described with relevant Meta data.

4.3.4 Procedures, Network and People

All the components of a GIS are associated in a network. It needs further procedures such as controlling and managing mechanisms. For effective implementation it needs partnerships, legal procedures and measures to be within budget limits. At the same time the system activities must meet its requirements.

With all these components it requires people who are spatial thinking and capable of performing the relevant activities

4.4 Main Functions of a GIS

The functions undertaken in GIS could be categorized in various manners. Generally its main activity could be considered as steps that are followed in a full project implementation. These activities are,

1. Capture and compilation of geo spatial data from various channels.

2. Conversion and storing them effectively for use in multiple situations.

3. Analysis and transformation of data models into useful information.

GIS softwares are so designed to fulfil these requirements. In recent years the application domain and capabilities of GIS software have been largely enhanced.

The basic functions of a GIS implementation can be further described under four categories. (RIEDL 2004)

- **Data acquisition and processing**
  - Digitization (Manual and Scanning)
  - Edition (Geometric and attributes)
  - Generalization of linear features
  - Reference system defining
  - Data import/export in different formats

- **Geodata Management**

Geospatial information in suitable formats, and deemed as an inherent part of a GIS. In the geodata base the relevant geodata are structured, organized and stored and it is the central data repository. It can be a single user or multi-user unit according to the application scenario involved.

According to the structure of the data being organized in a database it can be categorized as “The Geodatabase“. It is the collection or storage of all the different elements and,

- Flat files: A table as a single file

- Hierarchical: Existence of sub files for every entity
- Relational: Data in table form and related tables are linked with a key
- Object-oriented: Supports data modelling as „Objects“ and defining specific classes, their properties, and methods.
- Object- relational: Object oriented data model but still support relational concept.

- **Geographic Analysis**

In a GIS implementation the most important episode is its spatial analytical part. Although it requires comparatively more time for data input than data analysis, the process itself is the core function which can be further recognized as a combination of following sub activities. They use the spatial and non-spatial attribute data stored as layers in the database to derive or create new information to answer real world problems. In the process it is further required to create models of the real world phenomena which help in finding underlying specific information. It is this underlying new information (which is mostly presented through maps) that helps to find the solutions for real world problems and depends on the objectives of the GIS implementation. In this way it is possible to find solutions for real world problems in faraway places at any time. This unique capability distinguishes GIS from other information systems.

- Data query (searching, sorting, and linking functions with graphical or tabular results.
- Measuring (distance, extent, size, volume, etc.)
- Map overlay
- Buffer
- Interpolation
- Network analysis
- Terrain modelling.

- **Visualization of spatial data**

The results so obtained through spatial analysis are to be communicated or presented in various forms. It involves the preparation and presentation of the analysed output as a more understandable, readable and interesting spatial phenomena. For this, basic functions like displaying, panning, zooming, and layers are used. One or two decades ago soft or hard copies of a variety of maps were the most commonly used mode. Today however GIS provides greater flexibility with a wide spectrum for visualisation of geospatial phenomena contributing a powerful tool for decision makers. These include multi-dimensional dynamic representations within interactive computer environments.

4.5 Modelling in space

The complex phenomena of the real world have to be prepared and illustrated as to be suitable to be included in the digital environment of the computer. The resulting product called spatial data „model" is the heart of any GIS implementation. The data model is thereby a prototype of the real world and the user has to interact with it to perform the required tasks. The real world is a voluminous phenomenon which is accompanied by an infinite amount of information. But the computer systems have limited capabilities and therefor a selection has to be made about the data to be represented in the model. Therefore the complexity of the real world has to be simplified and generalised to suit the capacities of the system and at the same time remain within the limits to meet the requirements of the system.

At the beginning the spatial modelling was mainly based on CAD and graphical data models. At present geo relational data models are abundant with the combination of raster and vector oriented systems in all scale levels.

In the International standard ISO 19109 for Geographic Information the guidelines for geographic modelling have been defined. Here under the heading „general feature model" a methodology to describe real world phenomena using object classes and their relations with UML diagrams are prescribed.

Model Abstraction

When representing the real world in a GIS, a sequence of steps are followed which is also the same for creating other types of databases. Longley and Goodchild present four consecutive phases in Geodata abstraction. The real world is complex and contained infinite amount of information that may or may not be included in the GIS. So a selection would be made according to problem domain and the main types of objects and relationships to be included in the system are defined. The *conceptual model* created in this manner contains the important entities and relationships. The objects and their relationships are further described through diagrams and tables and attributes for every entity and relationships between them are specified. This *logical model* presents what a GIS could use and its application domain and its capabilities. The last modelling phase that leads to *physical model* represents the exact representation of the model in a database. It describes how the files and other database tables are arranged.

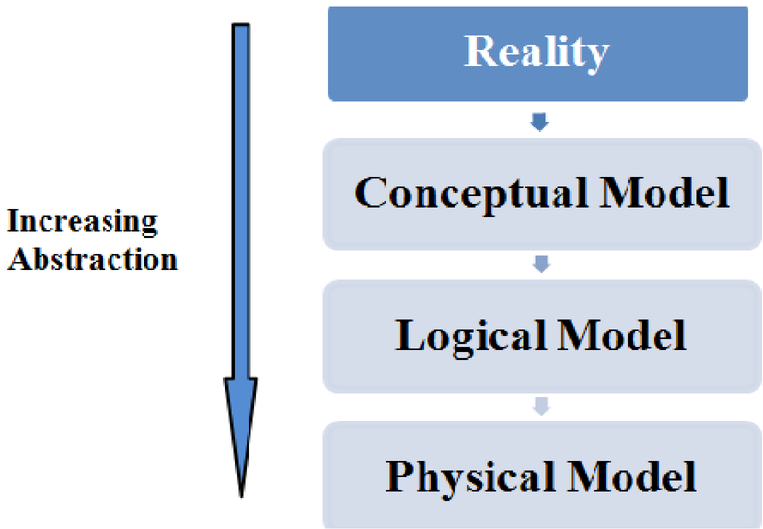


Figure 8: Levels of Data abstraction relevant to GIS data model. (Modified after LONGLEY et al. 2001, P.184)

4.6 Geographic data models

The most significant element of any GIS is its data model.

„In general, modelling can be described as creating a structure preserving mapping (morphism) from a domain to a co-domain. In our case the domain is the real world, and

the co-domain is the real world model. Such a mapping normally creates a smaller (i.e. abstracted, generalised) image of the original." KAINZ (2004, p.34)

The abstracted co-domain behaves in the same way as the spatial phenomena but in a simplified way. In this process the entities of the same geometric types are grouped together. Such a group or a layer represents a part of the area being modelled and with the integration of more layers a composite object or a model could be created, thus enabling multiple representation of the real world.

From the time of earliest GIS different types of geographic data models were in usage. Most common were models based on computer–aided design (CAD) combined with images. But these basic CAD data models never became more applicable because they lacked some essential components that are vital for representation of spatial objects. The local co-ordinates systems used in CAD systems and absence of features to store topological relationships were among the core deficiencies in CAD systems. Despite these limitations the CAD systems were used with image data models such as scanned aerial photographs and Satellite images.

Figure 9: Modeling and ascertainment the spatial extent of a territorial flood is a geographic problem. Source: (http://lesjoyeusesboucanieres.net/2011/02/08/floods-in-sri-lanka-displace-more-than-1-2-million)

In the attempt to describe geographic objects geometrically to model them in an information system two types of representation are distinguished namely Raster and Vector representations. The basic geometric elements used to represent in these forms are points, lines and areas. In the raster model the geometrical form of the real world is modelled with a tessellation which doesn`t separate points, lines and areas. In other words the real world prototype is divided into small cells called *Pixels* and the whole space to be represented is given as sum of matrices that comprises of columns and rows. The variations within the square or cell are denoted by assigning properties to the cell. Rasters are mostly applicable in scales of 1:10,000 and till about 1:000,000. Most of the raster representations used in GIS systems come from remote sensing Sources. The usefulness and the richness of the information derived from these raster based data depend upon the spatial resolution of the picture. Spatial resolution is the Pixel size or cell size of an image depicting the surface area of the earth. In the case of Landsat images that is 30m and high resolution commercial satellites like GeoEye provides 0.41m, in panchromatic or black and white mode. Apart from satellites, there are aerial photographs that are derived from special cameras, and secondary sources like scanned maps and Ortophotos. All the raster images originating from satellites are further processed to rectify the geometric distortions that emerge due to the varying ground elevation.

Rasters are mostly applicable in aerial datasets and storing them requires only the original coordinates of the matrix. But they induce more data volumes and intensive CPU loads although they are economically attractive against the vector systems. The dependence of pixel size makes it less applicable to represent linier objects or network connections. In complex analysis processes the data access takes a sequential order thus slowing machine speeds. In cartographic production processes matrix formation in raster based system makes it compatible with raster based output instruments but the graphical quality depends mostly upon the input data resolutions.

Figure 10: Rasters are symbolized by assigning colors to cell values. Elevation, Hill shade and Temperature. (Source: ORMSBY et al. 2004, p.117)

In physical science the term *vector* means a quantity which is associated with displacement and direction. But in special databases based on vectors we consider a geometrical methodology of a discrete object view to define the elements in the real world with well- defined boundaries. It is a commonly used representative method because of the many applicable advantages and the internal data organisation. In the vector data set the real world is classified with points, lines, and polygons. Points are single discrete objects like wells, lighthouses, hospitals or springs. A point object can be stored as a single coordinate pair. Line features such as streams, paths and highways are recorded as a group of coordinate pairs. Areal features or polygons like land cover types, built areas and properties are marked with enclosed line segments. Linear features could also be represented as a curve which can be given by a mathematical function. According to the geographic objects involved vectors are arranged as a simple features data or with topologic features. As the geo objects accompanied spatial and structural relationships with vector implementation, these relationships could also be well presented. The structural relationships between the geo artefacts in space called topology are the central concept in GIS. The topological relationships associated graph theory is applied to validate the geometry of geographic entities (vector based) and it is considered as the theoretical framework for geographical information systems.

A substantial amount of cartographic or spatial data is integrated with a GIS system through manual digitizing. Although vector data are more preferred to have in a system because of its advantages over raster the acquisition of vector can be more time-consuming. That is because of its unique structure with associated topology and attributed data which also need to be processed. Even with experienced personnel to capture data the task can be much time consuming. Especially a topographic or geologic map contained with contours would cost a considerable time to be fully digitized.

To rectify this time consuming data capture procedure, in recent times researchers have developed suitable automated raster to vector conversion methods. As a result apart from classical GIS software packages the general graphic programmes like Abode Illustrator and Photoshop offer a bitmap conversion into vector.

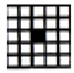
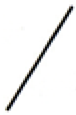
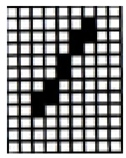
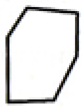
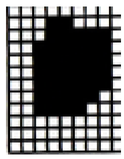
Element	Vector		Raster	
	Digital	Analog	Digital	Analog
point	x,y,co-ordinate	•	Pixel	
Line	x,y,co-ordinates		Pixel	
Area	Looped set of co-ordinates		Pixel	

Figure 11: Vectors define real world with points, lines, and polygon, Rasters in Pixels. (Modified after BILL 2010, p.34)

Vector data are predominantly meaningful in big scales (e.g. from 1:100 till 1:10,000) but they are available in almost all the scales. The GIS based systems such as land information systems, energy networks, transport and motor traffic network management systems and hydrological information systems are mostly vector oriented.

The first vector based simplest data model called the Spaghetti Model was a simple line to line translation of a paper map (PEUQUET 2002). Further development came with the in- cooperation of topological features to the vector representations by the U.S Census Bureau in 1969 in their census data. To overcome retrieval inefficiencies in these earlier models, a hierarchical arrangement was later introduced to each type of data element e.g. polygons, lines, nodes, and points. The earliest thus arranged hierarchical vector model POLYVERT was capable of representing more complex data and was more efficient in storing and retrieval functions.

Raster and vector combination

A Geoinformation system is Raster oriented when the database comprises mainly of raster graphic and associated thematic data. Equally when the system contains mainly vector graphics it is considered as vector based. A latest development is the combined modelling of these two graphic elements. The main objective of this combination is to acquire the advantages of both systems. Hybrid systems are abundant among web GIS applications. An example would be the modelling of a forest area which has many segmented sub-areas. Predominant corner marks and boundary lines are given in vector form while the rest of the area is represented in Raster as it is more suitable for areal phenomena. In the same manner often digital orthophotos are overlaid with vector elements in land registers.

4.7 Geographic Data

"The terminology for geographic data is so vivid and is used interchangeably. Geographic information, geographic data, spatial related data, spatial information, geospatial data, are all terms used more or less interchangeably." (GROOT et al. 2000)

Geographic data or spatial data are data that are relevant to a certain space or location in the earth. They describe the earth in two, three or four (including Time) dimensions. All elements or ingredients that existed in the spatial extent are considered beyond the scope of personnel observation. As per the key issue involved, or our particular requirement, we try to gather as much information as possible. But it is often beyond what we can see or imagine.

There are a few characteristics that distinguish geographic data from other types of data and therefore make them difficult and complex to implement in a data base. Geographic boundaries are essential elements that have to be stored and they are relatively irregular and might in some cases be fuzzy. To represent locations a number of reference systems are utilized including location addresses. This specified requirement for spatial data make the storage volumes bigger and complex in data base maintenance. At the early stage of geographic data modelling CAD systems were popular. But a drawback of these systems was an absence of utilization of reference systems and topological relationships which represent an inherent element of geographic data.

4.7.1 Data capture

The real world is infinitely complex and with of too much of information. In a GIS system the data for the required analysis is collected and recorded manually or by means of sensors. The features of a geographic environment are observed, measured, scanned, counted, sketched or photographed and stored using a variety of data capturing methods. The acquired data can be geometric, temporal and non-graphical thematic features. Sometimes it is necessary to transform the already captured data by a sensor in such a manner so that an information system could use them. But in most cases modern data processing systems allow the captured data to be stored in a database without additional conversions and thus function as full automated systems. Principally the data capturing method could be seen in two forms.

In original form the required data is captured directly at the real world object or phenomena. This can be mostly through geodetic surveying methods. Further Photogrammetric and remote sensing methods are widely in use to acquire geospatial data. Furthermore thematic information such as hydraulic or population data are being collected in field work or from the appropriate resources. Presently the location based services too plays an important role in primary data collection.

In the secondary form to create new geospatial information the already acquired primary data sources are principally used. As an example the collection of data from a printed map can be considered. But this secondary acquired information demonstrates some disadvantages against the primary data because they are already undergone in a generalisation process. They might lacks of actuality and the amount of data could be derived is limited.

4.7.2 Geospatial Meta data

As stated above data acquired from various methods form the input to a geographic information system. Before beginning the implementation of the task it is required to ascertain some characteristics regarding data to check whether they are suitable to attain the intended targets. These include the origin, spatial extent, the structure, accuracy, format, applied reference systems, relevance, actuality, copyright, accessibility and some other information. These formal and complete descriptions of the Geodata are called *meta data.* The term could be further described with more attributes and features and these additional attributes are featured in relevant Metadata documents. In the ISO 19113:2002 *Geographic information – quality principals* and ISO 19114:2003 *Geographic information – Quality Evaluation* the standard quality parameters are supplied. The extensive information about the data helps the users to compare the available data from various sources and to identify and combine the most appropriate elements for the intended task.

4.7.3 Data quality

In a GIS the application of appropriate geospatial data is a prerequisite to achieve the given objective. The suitability and fitness of data for a particular GIS implementation could also depend upon the requirements of the end user. Therefore data quality is a composite of fitness, appropriateness and completeness and usability of spatial data for a given task. The term could be further described with more attributes and features.

In a GIS application the quality of data used represents the degree of fitness of the system for a particular task.

4.7.4 Geodata Formats

One of earliest problems that is encountered at the beginning of any GIS project is the procurement of suitable data in usable formats. The data needed for a particular project are gathered from different sources. As earlier discussed these data are sometimes generated for another purpose and for application in different conditions and in support for a particular task. Some commercial software producers design their own formats for their products. There are also standard data formats for Geoinformation systems based on both Raster and Vector. These standards were through the International Standard Organisation and in Europe as stipulated by CEN (European Committee for Standardization). Further OGC (open GIS Consortium) has engaged in standardizing geographic data formats.

Given the number of different formats available it is necessary to use Open Application Programming interfaces to transfer data between the programmes. At present most of the GIS software systems are capable of reading themselves the many formats of other origins. The Esri ArcGIS system open source product ILWIS 3.4 capable of importing and exporting several data formats that are widely in use

4.8 GIS architectures

Today technological and infrastructure improvements are so dynamic that the structural changes that take place in many sectors including that of geographic information make it hard to imagine any limits. The developments are predominantly in the three phases of data processing, analysing and visualization. The constant and fast changes that prevail in this field have made it necessary to compare and weigh the classical definitions for GIS. The GIS play its ever changing role as a global data infrastructure, a tool that can be improvised, or a tool in hand held devise connected with a global network system. In this sense it is to observe the functionalities that GIS offers have been splitting according to different application arenas. The inherent functionalities that belong to the GIS are in some architecture either omitted or they serve as a part of another system. Following in summarised form are the categories that GIS could appear in. They do not serve as an explicit classification.

4.8.1 Desktop mapping systems

With the emergence of satellite technologies and other Geodata abstracting procedures it has created the necessity and usage of GIS desktop mapping tools. Whether it is disaster management or environmental protection GIS desktop software has become compulsory and a standard element. A typical tool provides the viewing, managing, querying, modelling and analysing sub tools along with visualisation. And the latest software versions have web based functionalities. These stationary or scattered systems allow a wide spectrum of applications among a wide range of branches. Normally they are stationary systems in the relevant computer but they could also be arranged with a server network connected to many clients. In the market they are available as product families or single products. The ArcGIS with its three variables and MapInfo professional, Geo media, Map3D and Open source ILWIS are some examples of these.

4.8.2 Geodata viewers

GIS viewers are limited to the function of visualizing, reading or limited querying of geospatial information. They are mostly appeared as low-cost and reduced variations of some standard product. With the emergence of online GIS application there was breakthrough of Geodata viewers most of which are free available. As examples ArcGIS explorer, SVG map viewer, Geomedia viewer, and earth browser Google Maps can be mentioned.

4.8.3 Geodata servers

Geodata servers are a central element of a scattered geoinformation infrastructure that allows a bulk of spatial information to be stored and managed whilst making them available for use by numerous clients. The supply of these services can be through a local area network, internet or any other means. In this way a relational databank system contained with both attributes and geometric data can be connected to a number of clients with a wide spectrum of mapping and analysing functionalities. (BILL 2010)

a. Geodatabases

Functionality: supplying spatial data for queries. E.g. ArcSDE, Oracle spatial, and PostGIS.et

b. Mapservers

Functionality: spatial information, visualization or viewing.   E.g. UMN Mapserver

c. GIS servers

Functionality: supplying spatial information for analysis. E.g. ArcGIS Server, Small world geospatial Server, etc.

d. Webservers

Functionality: supplying a wide spectrum of Geoinformation services.

Every major data producer improvises such systems with the combination of open interfaces.

4.8.4 Mobile GIS

The real world that we perceive is constantly changing. There is a growing need to include these latest changes in the models that we create. By abstracting spatial data in the field and partly processing them makes its further application practical and efficient. As an example, in case of a natural disaster scenario it is necessary to assess the damages and other loses at the earliest possible time. It is required to recognize and localise the areas damaged and elements at risk, and to assess the losses occurred to the communities concerned and to take prompt mitigation measures. It is necessary to derive information mostly with spatial reference and pass them to coordinating centres. With a mobile GIS connected with GPS and application of mobile handheld apparatuses, it is possible within a relatively short time to derive actual thematic information or to alter already existing data. The system could be online with a connected server.

Figure 12: Mobile GIS (Source: Bill 2010, p.69)

The GPS was initially funded by the US military and was not available for civil purposes, but later it was released for general use and with GPS application it possible to define any location on the earth with an accuracy of less than 10 m. The GPS has emerged as a new technology especially in the last decade and it has accelerated and conquered the process of primary data capture. The most inherent element of GPS is its mobile application possibility which in turn has catered to the emergence of a new sub branch called mobile GIS.

The application of mobile GIS is more and more common and a wide range of product families have emerged in this arena .They comprise of field computers, personnel digital assistants (PDA), and GPS receivers. For data capture especially topographic means there is another set of devices. All newly generated or altered data through mobile devices can be transferred to a stationery GIS.

To work with field clients compatible software systems are available from almost all major GIS software vendors. Some software allows PDS to display a background map while enabling to supplement in the field other location based thematic information. The Esri ArcPad offers the GIS functionalities in a hand held instruments. Possibilities are also there to extend the functionalities with applets according to the application scenario.

The open source GRASS is functional both in desktop and mobile systems. The mobile version is compatible with Linux–PDS.

The most popular usage of mobile GIS is in navigation and tracking. They are applicable in almost all the navigation types, agriculture, forestry, environmental and wildlife protection and many other branches.

4.9 Time as the fourth dimension of GIS

Almost all the objects and processes in the universe originate and exist for a specified duration, and then get transformed or changed and finally would disappear or pave the way for the origin of some other thing. Everything whether we perceive them or not are the ingredients of the space around us and are subject to a constant change or variation. They are dynamic phenomenon. We and everything in the real world move not only in space but also in time. This concept makes it necessary to engage these spatial temporal conditions and it is an important and challenging aspect in modelling and designing spatial databases.

Until recent times most of the geo object models were lacking this component. But in an event where the historic situation, the present and the future developments of real world phenomena's to represent the spatiotemporal models are more appropriate. For example for a flood hazard mapping project it is necessary to recognize the elements at risk in each return period, be they 10, 50 or 100 years. The temporal information has to be integrated in the data base and has to be appropriately retrievable and visualized. The integration of these temporal data for existing geometric, topologic and thematic data is a subject matter for present and future studies.

With the integration of Dimension "time" a spatial data base expands its capabilities. Bill (2010) categorizes the normal application constellation as follows.

- 2D + Time: For two dimensional geometric data time added. E.g. the historical Information systems based on previous cartographic products.
- 2.5D + Time: For the applications where height is stored as an function of co-

ordinates and as an attribute and time is added as another dimension.

- 3D + Time: In 3D GIS applications apart from x,y,z, coordinates Time (t) is considered as another dimension. Examples are in atmospheric models and geologic models that describe the historic developmental epochs or environmental simulations or Animations. (BILL 2010)

4.10 Geodata Infrastructure

Within a few decades the generation, management and usage of Geoinformation have tremendously increased. It is a precious commodity that is being stored and marketed. The need of Geoinformation is unlimited for regional planning, administration, environmental protection, disaster management or any similar branch. The availability of harmonized spatial information is a prerequisite for their efficient use in a community at national or global level. It is an infrastructure that has to be generated and maintained properly just like in the sectors of transport, communication or health services. It is a national or regional framework where the technical, organisational and legal components related to spatial information are embedded. With the co-operation of various actors the spatial data which have been generated and maintained could be well co-ordinated. And apart from the Geo basis data the relevant Meta data catalogues should to be prepared and made available to relevant government authorities, commercial and nongovernmental organisations, researchers and general users. The wide and open accessibility for all the interested parties with affordable prices is vital for its further developments, efficient usage and for its maximum benefits for human being.

The issuing of Spatial Information could be with soft or hard copies or via Internet using Geoportals. Geoportals provide users access to a wide variety of spatial information either free of charge or at affordable prices. The services could be through client applications and user friendly interfaces are offered to search relevant datasets.

The generation and maintenance of spatial data is a time-consuming and costly procedure and this makes necessary the intervention of territorial or regional administrative bodies. Furthermore, as a way of enhancing efficiency it requires adopting national policies to accommodate the usage of Geodata in all the sectors. Recently as a result of e – government concept, initiatives were taken all over the world to establish national spatial data infrastructures. Apart from global spatial data projects there are a few transnational spatial data projects.

The examples for well-established national spatial data structures are found in most industrialised countries. The US National Spatial Data Infrastructure[2] (NSDI) and Australian Spatial Data Directory [3](ASDD) are a few of them.

Global Geodata Infrastructures

The essential requirement to enhance and to build up the usage and application of geoinformation in all possible sectors including sustainable development programmes is well emphasised in AGENDA 21. The AGENDA 21 offers guidelines to maintain international development targets while preserving and fostering the well-being of the environment. It suggests the development of an international information network of national, sub regional, regional and global networks. The conference recognizes the status of spatial information as a valuable component to achieve targets in development goals and prescribes an action plan to generate suitable infrastructure and framework globally. Chapter 40.2 of the Agenda document indicates the exceptional need to establish widely accessible databases and the need of decision making based on reliable, actual and complete information.

„*While considerable data already exist, as the various sectoral chapters of Agenda 21 indicate, more and different types of data need to be collected, at the local, provincial, national and international levels, indicating the status and trends of the planet's ecosystem, natural resource, pollution and socio-economic variables. The gap in the availability, quality, coherence, standardization and accessibility of data between the developed and the developing world has been increasing, seriously impairing the capacities of countries to make informed decisions concerning environment and development*“[4] (AGENDA 21)

[2] http://www.fgdc.gov/nsdi/nsdi.html

[3] http://asdd.ga.gov.au/asdd/

[4] http://www.un.org/esa/dsd/agenda21/res_agenda21_40.shtml [19.06.2012]

Another initiative was to establish a global cartographic model with international co-operation. The aim was to create a global dataset in the scale of 1:1.000.000 with multi-layer thematic representation and easy accessibility of everyone. This concept was later implemented with the emergence of client and browser based earth viewers in the middle of the last decade.

4.11 Client based and browser based earth models

The most popular client based earth viewer is the software Google Earth. The application was initially made by Keyhole Corp. and produced in California. The Keyhole corp. was later acquired by Google Inc. and the software was made available with the new name Google Earth. To integrate local data elements and to transfer them in Google Earth one may use KML (Key Hole Makeup language).Along with Google earth there is set of other tools that can be combined. Furthermore it provides a platform to visualize geo referenced terrain models and other data. It is based on WGS 84 reference systems with cylindrical projection and apart from co-ordinates the addresses and place names too can be searched. With supplementary tools costly versions of the Google earth are available for specific functions. The functional palate of these versions is more extensive than the basic version which is available for free. Another client based viewer is the Microsoft Bing Maps 3D which is known for its realistic 3D models especially of urban areas.

Browser based web map services are normally organized with several data layers. According to the required application the required layer, satellite or hydride form is selected. Along with basic zooming and panning functions a number of scale levels are offered to view real ground information with adequate resolution. For this purpose Google map offers 19 scale levels with additional functionalities. Microsoft Bing map as a part of Microsoft search machine provides the high resolution web map services. It is a further development of MSN virtual earth and is a part of the explorer search machine. Freely available maps are combined with aerial photographs and satellite images.

4.12 GIS in disaster mitigation

The application of geographic information systems in hazard studies increased since 1960s.The technology provides the hazard researchers the possibility to understand various aspects and characteristics of natural hazards and become an integral part of all the four phases of disaster management.

At the beginning the GIS was used mostly for mapping damages and demographic information. But in following years with the advancement of remote sensing, internet and satellite communication the usage was expanded for other branches too. (PAUL 2011)

The potential use of GIS in disaster mitigation

- Rapid mapping of disaster affected area. Estimation of disaster losses. And damage visualization.
- Mapping elements at risk and vulnerabilities.
- Modelling Hazards.
- Application in mitigation activities. In Mobilization resources and personnel.
- Evacuation planning.
- For risk communication for different stakeholders. Web based applications.
- Early warning and monitoring.
- Real time monitoring

In hazard assessment process the role of of GIS as a thematic map output unit has gradually changed. VELPREDA (2004) classifies three stages where GIS been utilized.

- Modelling hazards with combination temporal parameters.

- Specific risk assessment – combining hazard assessment with economic evaluation of losses.
- Multihazard risk assessment combining various results. (VELPREDA, 2004)

He arranges GIS applications in hazard studies in three levels.

In first level the result is a display function with thematic maps as out elements.

In the second level specific GIS applications are generated to calculate the trend of Geo indicators.

The third level involves with comprehensive multi hazard risk assessments processes where the application of different type of data and interrelationships between physical components and economic evaluations integrated.

5 Mapping hazards and Elements at risk

Risk communication to the community at risk is a major and comprehensive part in sustainable disaster mitigation. As a precautionary measure it belongs to the so called non-structural mitigation methods and help to increase the risk awareness of the community and to prepare them for a possible hazardous event. The risk communication seeks to make the people aware of the risk in their neighbourhood and to enhance their knowledge about the disaster and to make them prepare for a possible disastrous event. It can also change their ability of risk perception and eventually change their attitudes which would be necessary for a meaningful mitigation process.

The community authorities could apply a number of measures or tools to communicate the risk. The measures to be adopted depend largely on the targeted party or community to whom the information is directed. Hazard maps as effective communication tools enable the passing on of information to all parties engaged in disaster management activities and are used in every phase of the process. This chapter introduces the main characteristics of hazard maps and their application and cartographic elements that qualify them as effective tools in spatial risk communication.

5.1 Hazard mapping

Since time immemorial humans as an intelligent living being were interested in locating their dwellings in safe places. Initially they wanted to establish their villages or cities in close proximity to a water resources or a river. So most of the earlier cities originated on the bank of a river. When they located the dwellings they tried to avoid floodplains and applied their indigenous knowledge to harmonize the way of living with the laws of nature. But the rapid increase in world population since the mid twentieth century intensified the utilization of land resources, forever expanding cities and other infrastructure. This caused also the intensive usage of areas that are prone to natural hazards. The consequences of such actions are obvious with frequent destruction of both lives and material.

Hazard or risk mapping can be considered as a first step to harmonize land utilization by paying attention to vulnerabilities at specific places and thus avoiding negative effects. It is one of the most important measures in risk governance and sustainable disaster mitigation.

The spatial extent as earlier mentioned is an inherent part of all hazards, be they natural or manmade. This spatial distribution of the event is the first question that arises when trying to present the effect of an event on human activities. Exploring and localizing the spatial distribution of the hazard is the beginning of any mitigation, preparedness, response and recovery initiative.

Normally hazard maps are created as the end result of a lengthy hazard assessment process. Hazard assessment is undertaken by subject specialists and during the analysis process a number of cartographic models are created based on various event related phenomena. These are incorporated in disaster management procedures. Since there are no internationally accepted guidelines on preparing hazard maps the procedures vary according to type of hazard considered and the intended visualising targets.

Few types of cartographic models are generated in risk analysis process.

a) Hazard maps

b) Vulnerability maps

c) Risk maps.

As described in an earlier chapter, Risk in relation to a given area could be represented as the product of Hazard, Elements at risk in the area and Vulnerability. As per this relation, with the integration of Hazard, Elements at risk and vulnerability maps are generated to present the composite risk for the area.

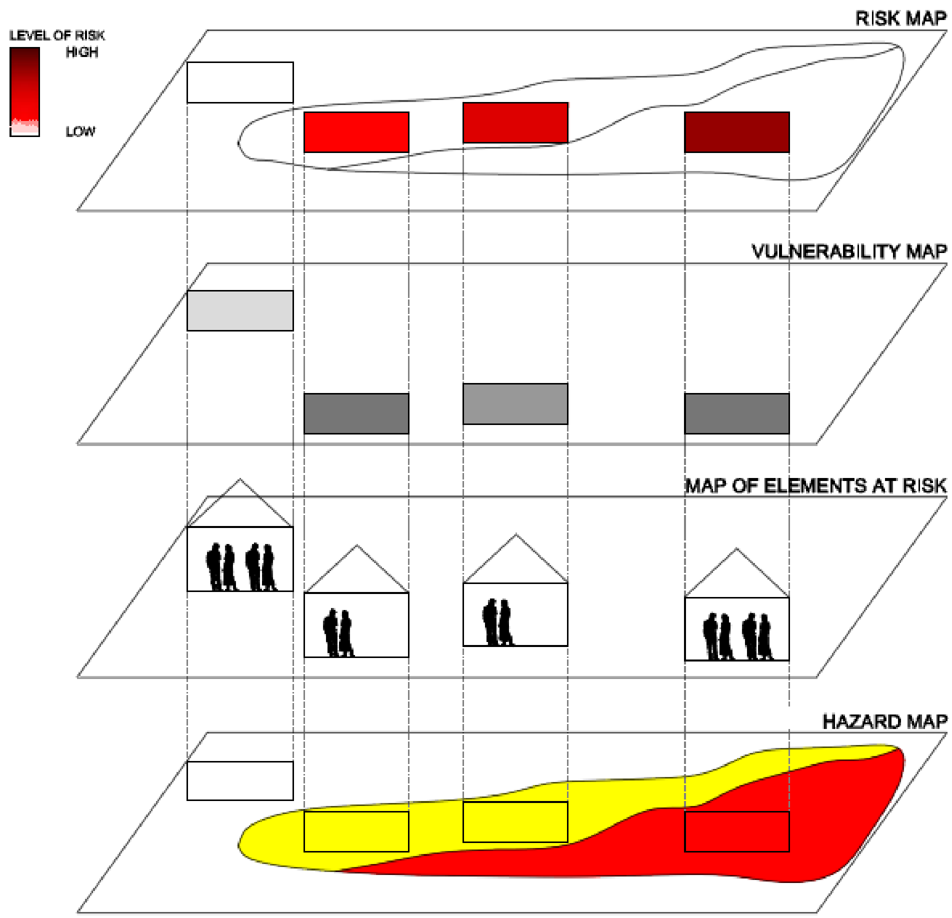


Figure 13: The components of risk: Risk = f (Hazard, Elements at risk, Vulnerability). (Source: modified after MÜLLER, 2012, p.35)

5.2 Scales and classifications

In case of hazards we are inevitably confronted with their temporal, dynamic and spatial capacities. The classification of all cartographic materials for special risk visualisation is extensive and they mostly depend on the hazard events and their spatial and other characteristics and their intended utilization.

Figure 14: Hazard related communication. Evacuation map of Santa Barbara, California. (Source: COVA et al. 2003, p. 780)

The hazard related representations can be simply differentiated under the situations that they generated. The product “Hazard map” is created within legal framework and is used for spatial planning. In many countries the generation of hazard maps is a standardized process. But there is another set of cartographic representations (Maps of hazard phenomena, reconstruction of historical events) which are not bound by any guidelines but be utilized for other purposes. Such in disaster mitigation activities and other hazard related communication processes. They are mostly generated for specific user needs. (KUNZ and HURNI, 2011)

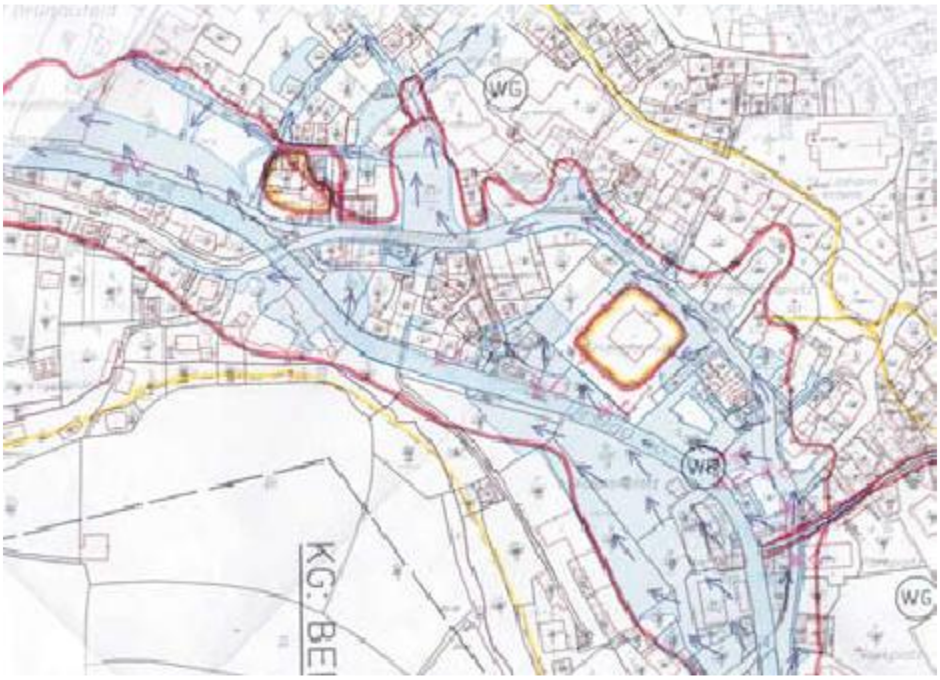


Figure 15: Hazard maps are generated within a legal framework. Source: Austrian Service for Torrent and Avalanche control (WLV 2007)

But for hazard maps the famous cartographic grouping according to scale is always preferable. In alpine regions where various hazard events like landslides, rock falls, avalanches and debris flows are present, numerous cartographic materials have been developed since decades to communicate the associated risk. In Avalanche cartography the available wide spectrum of hazard related cartographic products are classified by KRIZ (2001) based on following factors.

5.2.1 Thematic based

Thematic classification considers to which extent a particular cartographic product involves itself in the theme and whether it is of direct or indirect means. As the primary approach all the avalanche cartographic products considered which are specifically the theme visualize. Avalanche hazard maps and Ski touring maps containing avalanche hazard zones are examples for this sub group. The secondary approach is to recognize such cartographic products which are involved with the theme indirectly. The maps with thematic contents like average snow height, wind direction and speed in mountainous regions give indirect indications of avalanche activity. (KRIZ, 2001)

5.2.2 Application based

The numerous cartographic materials in avalanche cartography also can be recognised after their application and use. Map related presentations and animations are well suited to depict Avalanches as dynamic hazard events apart from classical representation in hazard maps. The maps based on historic events including chronologies and those marked with areas that are prone to possible future events are developed with quite different methodologies.

5.2.3 Scale based

The term scale has so many meanings depending on the context. In cartography and GIS the scale is the relation of a feature in the real world and its relevant depiction in a map. The relation means the ratio of a distance on the map to the relevant distance on the earth. If the fractional numeral is big we consider it as a small scale which sometimes leads to confusion. A large scale map with a small fractional numeral means a map with plenty of geographic information but of a relative small area. The term *large* and *small* regarding map scales leads to confusion and therefore some authors use the terms *course* and *fine*. (GOODCHILD, et al. 2011/104)

Hazard maps are generated in all scale levels in consideration of the presence of hazard phenomena. This could be from regional level (1:500 – 1:50,000) scales to continental or global level scales (1:1:000,000 or smaller). Hazards maps for events like Landslides, Rock falls or floods has local potential and to provide rich hazard related information a coarse spatial representation is necessary.

Although avalanches are local events that spread in a relatively small area they are present in a wide scope of scale levels with appropriate generalisation. They are local scale 1:1,000 – 1:50.000, regional or medium scale 1:75,000 – 1:500,000 and with small scales e.g.1:500,000 to cover avalanche related secondary information. (KRIZ, 2001/53)

The generation of hazard maps are mostly based on the assumptions made of the magnitude and potential of the hazard phenomena. Their scales are dependant not only about the available data types but the intended purpose that the maps are being used to. Another classification is based on scales but at the same time considering their specific usability. (VAN WESTEN 2009)

Investigation site scale: 1:200 – 1:2,000; Maps of neighbourhood, primarily to be utilized for structural mitigation measures.

Large/Local scale: 1:2.000 - 1:25,000; For a town or municipality to be used for risk assessment.

Medium scale: 1:25,000 - 1:100,000; the maps represent a distinct town or a catchment area etc.

Regional scale: 1:100,000 – 1:500,000 as support material for regional or national decision making.

National and continental scale: Smaller than 1:1.000, 000 to create awareness for general public or organizations.

5.3 Hazard zonation

The actual demarcation of hazard prone area is generally undertaken after a comprehensive assessment process by the subject specialist. The data preparation and process analysis of any possible hazard phenomena is based on reliable scientific methodologies. The most of the hazards are followed by some secondary events too which it requires multi hazard assessments. For example in case of an earth quick or volcanic hazard assessment, there are many secondary events to be considered which makes the task really complicated.

Generally the hazard zonation could be done by using one or more following methods.

a. Methods using historical information

The historical information on natural hazard provides valuable evidence in modelling future events. These information are normally prevailing in latent manner. The inhabitants of the area sometimes possess much information about the past events. Their experience about the events can be integrated to the modelling processes and the coping methods with hazard can be helpful for mitigation planning.

b. Morphological methods

In case of geometereological events the morphology of a particular area can give some insight about past events. As the hazard events are spatial processes the extent of the processes in the morphology visible.

c. Empirical and statistical methods

d. Physical and Mathematical models

Numerical models and simulations with geographical information systems. (WLV 2011)

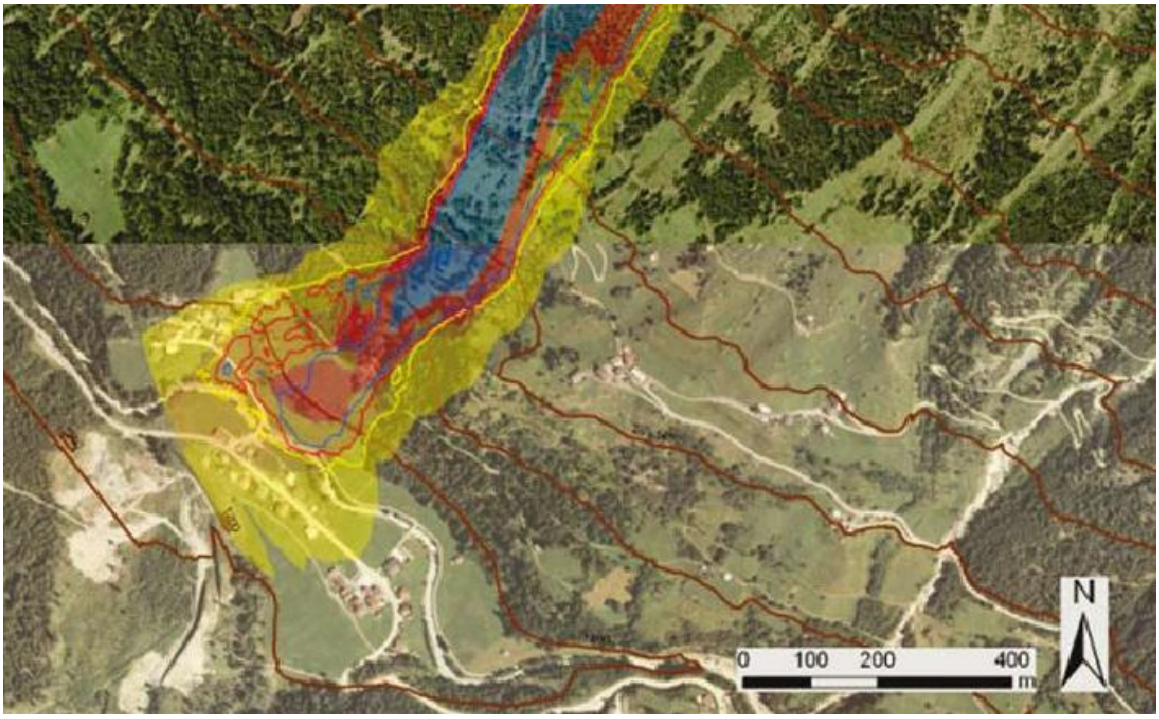


Figure 16: computer based process modelling ©Austrian Service for torrent and avalanche control (WLV 2007)

Mostly the creation of hazard maps is a standard procedure sometimes regulated by law. They have to undergo a comprehensive approval procedure both in technical and administrative level. In Austria provisions regarding this issue are given in forest act 1975. After the initial assessment the results are presented in a suitable scale for the hazard type involved. In case of torrent related hazards an area is presented in 1:2000 scale based on digital parcel cadastre. After few weeks for public inspection the maps are recognized by commission comprised with technical and administrative authorities. This comprehensive procedure enables broad public participation –which is an important aspect in mitigation measures and broad consensus at all technical levels with high planning quality and validity. The hazard maps of WLV serve as important instruments in land use planning as they represent a sum of all possible hazards in the area. (WLV 2007)

Application the content of hazard maps in spatial planning leads generally to conflicts as these might oppose other land utilization interests. The hazard zoning in maps could be sometimes be understood by landowners as devaluation of properties.

5.4 Cartographic aspects of hazard visualization

In order to achieve successful risk communication it is important to present thematic information in maps in a comprehensible manner. As the result of a hazard assessment contain complex information to depict them for different groups is a cartographically challenging task.

To avoid presentation of many data layers in a single map, it is possible to customize cartographic presentation according to intended user groups. Otherwise the supplementary information can also be introduced in other formats.

In an interactive web based environment the users are supplied to prepare layers as their own needs. But in print materials a balance have to be achieved in simplicity and a usability generally the result of a hazard or risk assessment process could be transferred into map with following elements.

- As thematic layers on the base map
- Supplementary texts to exploring high risk hazard zones and related information.
- Photos and diagrams (WLV)

Shortcoming of in data presentation in hazard maps could lead to overloaded maps with resulting misinterpretation. The visualization of hazard related information in maps requires the engagement with following map elements.

- Colour
- Basemaps
- Legend
- Data classes (KUNZ and HURNI, 2011)

Colour

The hazard zones and related vulnerable areas are presented in hazard maps using numerous colours and textures. This follows associative application where colours are depicted according to the phenomena to be depicted. Normally the colours to be applied are given in guidelines to be followed in maps generation. In hazard maps of Austrian Agency for Torrent and Avalanche following colour system is adopted.

- Red - High hazard - construction not allowed.
- Yellow - Moderate hazard - limited construction.
- Blue - Low hazard - reservation area.
- Brown – Reference area - Risk from other hazards.
- Violet – Reference area -Areas to be used but in protection. WLV (2007)

Figure 17: colour application for Hazard zones. Source: WLV (2007), p.10

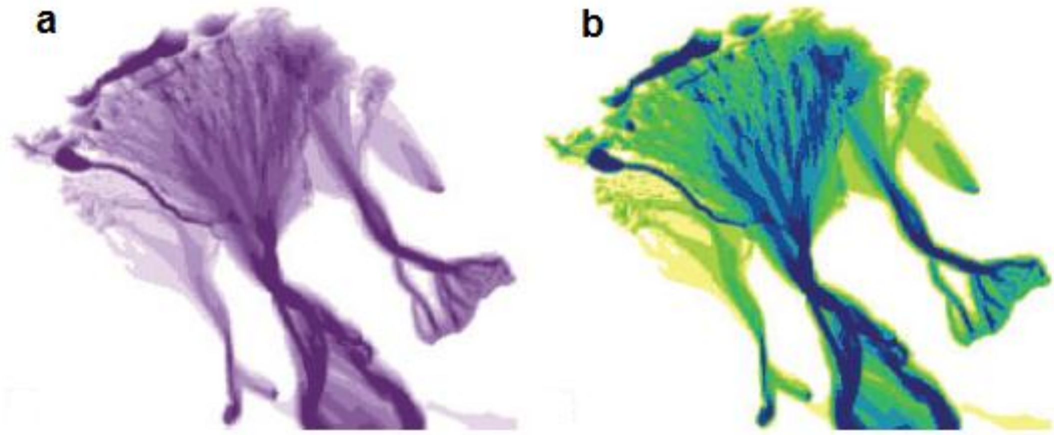


Figure 18: Single Colour scheme. b. Multi colour schemes with different colours in two ends of the class. Source: KUNZ (2011), p.67

Base map

Base map hazard zones and relevant thematic layers are presented in a suitable base maps. A proper selection of a base map with other background information is a prerequisite as this serves for location of the places. Aerial maps, satellite images and shaded relief with a geographic reference can be used given that it less dominant presented. In data processing this could be easily achieved with modern software systems. KUNZ and HURNI,(2011)

Legend

Legend is the feature of the map that describes the thematic elements in the map frame. The legend can be organized short or explanatory according to end user and to the scope of available hazard assessment results. The self-explanatory elements of the map kept omitted. The parameters regarding the classification of hazard zones can be included in legend given that it further helpful to ascertain hazard probability.

6 Mapping

The practical part of this study is to prepare a thematic map with disaster management elements for a Tsunami affected area in Southern Sri Lanka with the application of Geographic Information Systems. The map was intended to be used in risk communication activities and for the authorities to have an overview of the hazard zone and affected communities and Infrastructure thus to be utilized in decision making. The study limited itself for the first phase of a comprehensive risk analysing process namely for hazard assessment and more emphasis was given to the cartographic aspects of spatial risk visualization.

6.1 Disaster mitigation measures in Sri Lanka

Sri Lanka was long believed as place with less natural disasters. This idea was considerably anchored in the thoughts of its society till the end of 20 century. The country was prone to low frequency, low impact events and the disaster mitigation and preparedness was not among the prevalent tropics.

But the devastation caused by Tsunami 2004 made it clear that the island itself is prone to low frequency high magnitude disasters. Most of the other natural hazard events are caused by, floods, landslides, and cyclones.

Major floods in the island are associated with tropical monsoon periods. But the heavy devastating floods are not prevalent in every monsoon season. According to flood records major floods are witnessed in nearly ten year return period; especially towards the end of 20 century. This tendency has a correlation with global meteorological hazards events.

Generally flooding events are followed by tropical cyclones that originate south west and south east Bay of Bengal.

The central hills that reaches the altitude about 2300 (highest peak Pidurutalagala 2350m) is prone to landslides after a heavy rainfall. Deforestation, vulnerable geological background combined with unplanned land use methods leads to more landslide events in seven districts in central hills. (DMC 2005)

Being the close proximity to most active tectonic boundaries miner tremors are sometime experienced in many parts of the country. The first recorded earthquake was in 14 April 1615 with significant damages to the capital. Especially after devastation undersea earthquake in Java/Sumatra (2004) the seismic activity of the area has been increased. With the assumption of newly formed tectonic boundaries in the area the measures for seismic hazards are also included in disaster mitigation initiatives[5].

At the end of 20 century there were some initiatives taken by consecutive governments to mitigate damages caused by natural disasters. They were mainly limited to relief and recovery measures after an event. But this approach was converted into a proactive role with the emphasizes on prevention and damage minimizing initiatives thus forming disaster mitigation as a continuous process with long term objectives[6].

The key legislation and initiatives taken before and after the tsunami are,

1. Coast conservation act no 57 of 1981

2. The grater Colombo flood control and environmental improvement project (1993)

   3. Landslide mapping project (1991-1996)

3. Establishment of national disaster management center. (NDMC) 1996.

   Sri Lanka urban multi hazard disaster mitigation project. (SLUMDUMP) 1997

[5] **http://ireport.cnn.com/docs/DOC-796746**

[6] **http://management.kochi-tech.ac.jp/PDF/IWPM/IWPM_Jayawardane.pdf** (20.08.2012)

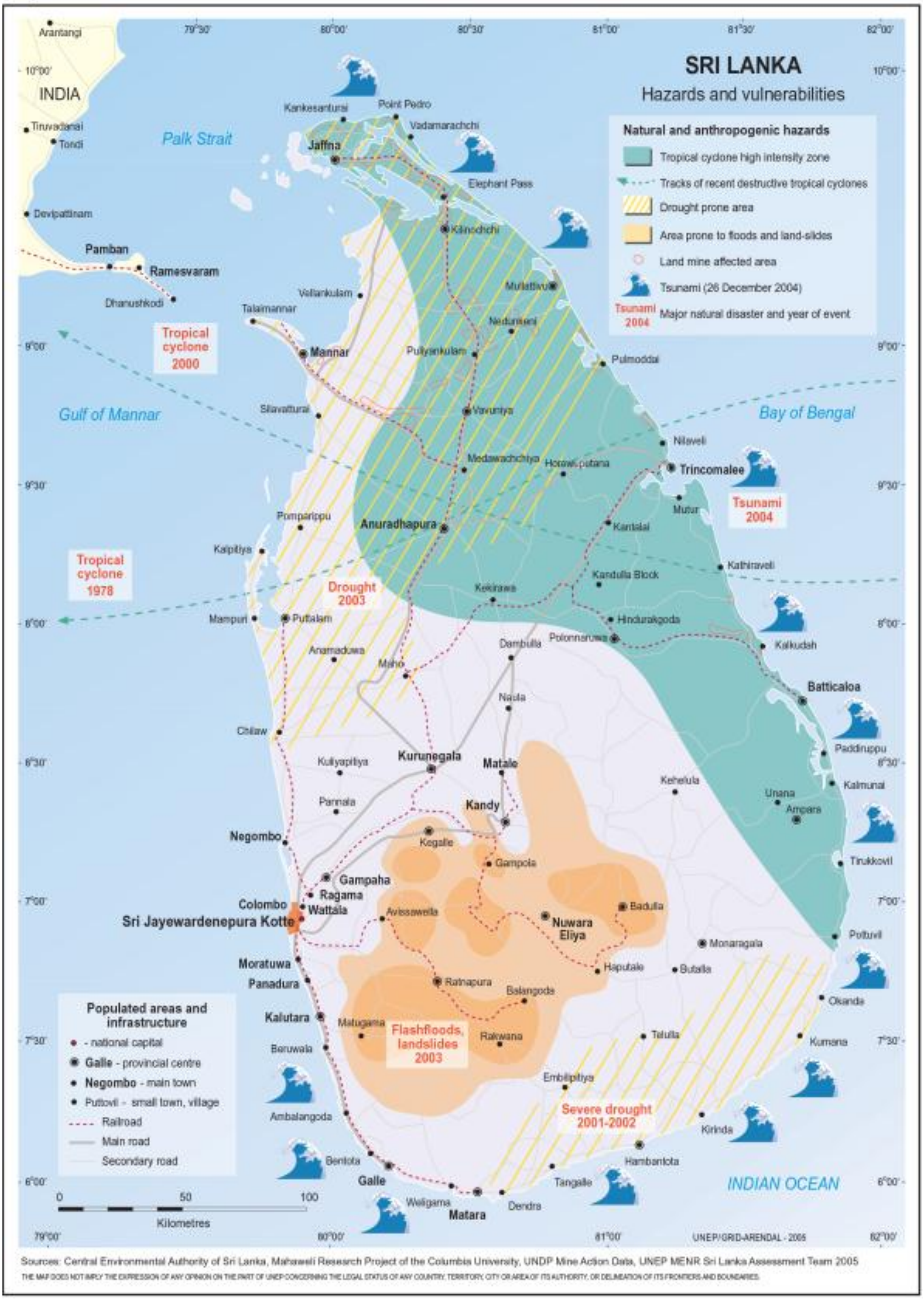


Figure 19: hazard and vulnerabilities. (Source: © 2005 United Nations Environment Programme)

6.2 The Tsunami hazard

On the 26th of December 2004 the eastern southern and western coastlines of Sri Lanka affected with the devastating tsunami waves originated from the massive submarine earthquake occurred in 400 km west of northern Sumatra in west Sumatra Seduction Zone. The resulting tsunami which triggered after the earthquake of 9.15 in Richter scale devastated the most of the coastal region of the island. The grate waves penetrated with an enormous energy in some places to more than 1000m and varies in height from 3 to 11 meters causing massive loses of lives, infrastructure and livelihoods. The tsunami waves unfolded similar devastations across the other Indian ocean states, Arabia, eastern and southern Africa.

6.2.1 Spatial distribution of Tsunami heights and inundation

There was a considerable variation of wave behaviour in all the coastal belts affected. As reported the first waves have reached the northern and eastern coast at 8.30 in the morning. Southern and western coastal line was affected after about 40 to 45 minutes. Eye witnesses express that the second and third waves are to be the highest and most destructive. The island wide variation of the wave height is given in Figure 20. The penetration of waves is greater in northern and eastern coastal belt in some places exceeding 1000 meters. In southern and western areas coasts the inundation extent is combatively lesser. (UNEP 2005)

The deepest tsunami inundation in southern area is up to 3000 meters near coastal town Hambantota. Deep penetration is notable near the lagoons and bays along the southern coast. A stretch of coastline shows in the figures without significant Tsunami damages caused by relative higher elevation. The coastal line From Galle to Matara affected severely with relatively deep penetration in some places occurring wave height of over 9meters. (WIJETUNGA, 2006)

Figure 20: Spatial distribution of wave height and penetration. (Source: © 2005 United Nations Environment Programme)

6.2.2 Actual Tsunami hazard mapping projects

After the devastating Tsunami waves which brought a worst natural calamity that the country never experienced there was a need of an extensive and systematic assessment to recognize of the changes has being occurred. It had caused tens of thousands lives and severe blow to the infrastructure and built environment. The damages happened to the coastal environmental were predominant and a comprehensive assessment was the need of the hour to plan the future mitigation activities. In this sense United Nations environment program with the ministry of environment and natural resources implemented an island wide systematic assessment to cover all sectors of the situation and later documented the results. This assessment report contributed valuable guidelines and concepts in post tsunami reconstruction efforts. It further highlighted the need while implementing overall mitigation activities the importance of restoring coastal areas and planning the sustainable use of vulnerable ecosystems. Under the strategic intervention activities the report acknowledge the need of an coastal zone mapping ideally with one 1m intervals up to 10m elevation. Among other suggestions modeling of wave behaviour that would guide for location of defensive structures, plantations and other structural mitigation activities considered. (UNEP 2005)

Another step in this context was the declaration of overall disaster mitigation plan by the disaster management center – the central governmental body in the coordination of disaster mitigation issues. The important step towards the disaster mitigation by the DMC was the official announcement named as “road map for disaster risk management” in which a comprehensive multi hazard risk and vulnerability assessment plans were suggested. Following key mapping projects have been suggested to be completed in short medium and long time basis. (DMC 2005)

1. Landslide hazard zonation mapping at 1:50,000 scale for hazard prone areas. At 1:10000 scale for vulnerable localities.
2. .Collection of data and GIS databases.
3. Establishment of a GIS unit at DMC and enhancing related infrastructure.
4. Generating of Flood inundation maps for major river basins.

5. 1:10000 tsunami hazard maps for coastal areas.
6. A vulnerability Atlas at 1:50,000. (DMC 2005)

Figure 21: Location of Study area in Southern Sri Lanka. (Source: http://www.tageo.com/index-e-ce-v-34-d-m3067877.htm)

6.3 Data used in Hazard mapping

The central part of this study is to analysis of Geodata from two different sources and to be used them in mapping process. There was a gap between the actual data needs and data used for the mapping. At the end of the chapter this point to be further discussed.

6.3.1 Raster data

- **a.** SRTM Elevation model
- **b.** 1:50.000 Topographic maps – Sheet Nr 90 (Sri Lanka Survey department) was used for visual inspection.
- c. Google Earth browser to identify elements at risk.

6.3.2 Vector data

The topographic information of Sri Lanka Survey department in shape files.

Line vectors for hydrological areas,

Line vectors for utilities and transport networks.

Polygon vectors for hydrological areas,

Polygon vectors for administrative boundaries,

Polygon vectors for buildings.

6.3.3 Census data

GN Divisions (community) based population data and disaster preparedness information was provided by divisional secretary's office of the study area (Habaraduwa).

6.4 Data processing and mapping

The pre-processing of data was done in two steps.

First SRTM tiles N06E080 and N05E080 were from ftp://e0srp01u.ecs.nasa.gov in zipped form downloaded. The unzipped two tiles were stored in Arc GIS geodata base. Although the downloaded tiles represented whole southern region of Sri Lanka the study area had established in two tiles.

The data was stored in arc catalogue. The minimum elevation of the study was between 0 and 72m. The reference ellipsoid WGS 1984.

Group layers from SDSL (9008, 9009, 9010, 9013, 9014, 9015,) contained following vector layers as illustrated in figure.

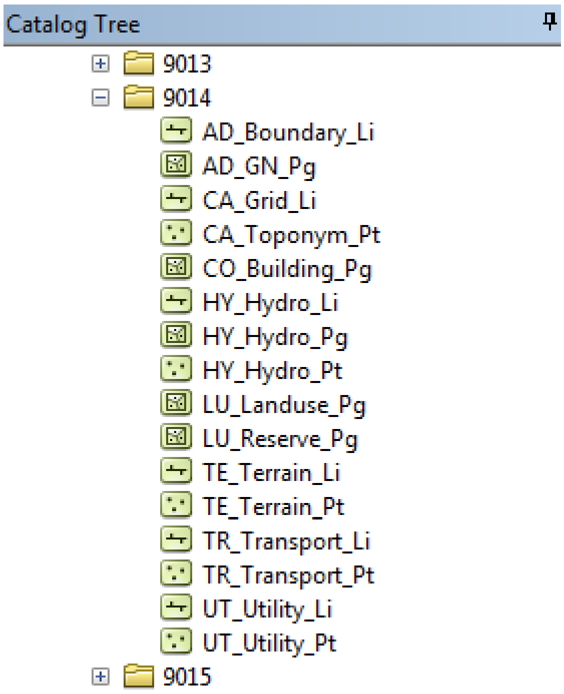


Figure 22: Group Layers.

Layers were restructured to facilitate for further processing. The data set was filtered and number of layers that deemed unnecessary was removed.

The reference system was transferred from Everest 1830 to WGS 84. (Appendix)

As the next step the base map was prepared with all GN division boundaries.

In order to classify hazard zones following ground elevation values were considered.

0 -3 m High hazard level

3 – 4m Medium hazard levels.

4 - above low hazard level.

The demarcation of hazard zone was undertaken with pixel calculation in histogram Above classification was based on past inundation records. (WIJETUNGA, 2006)

As next step the selected thematic elements were established in the base map.

After initial lay out in Arc Map the results were exported to Abode Illustrattor for typography.

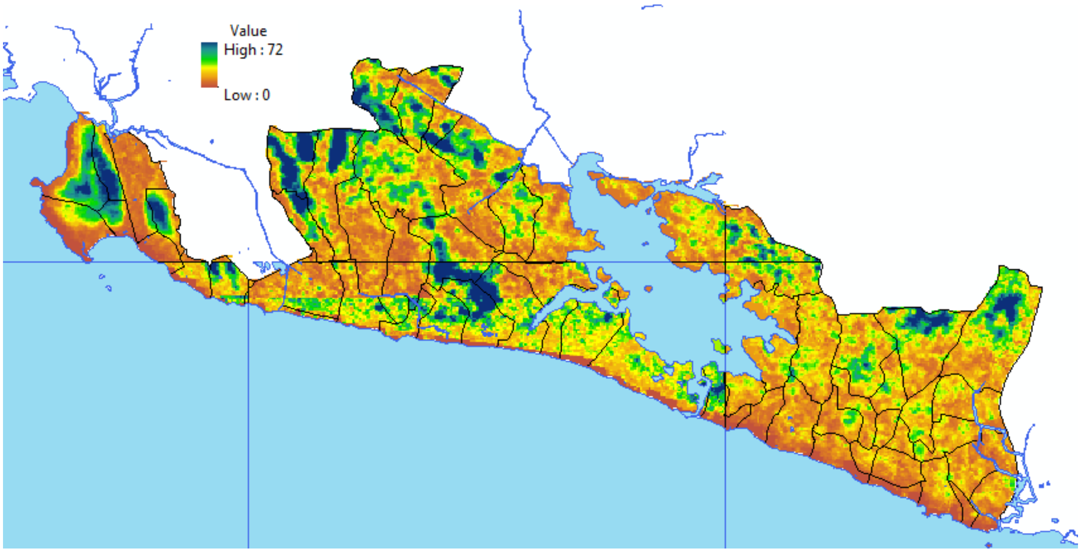


Figure 23: Clipped DEM

6.5 Analysis of the Map

This hazard map was intended to be utilized to communicate tsunami risk to the communities in their neighbourhood and to be used in mitigation activities. The aim was to represent the hazard prone areas in each GN division and attempt was made to avoid more background information and to maintain simple as well useful cartographic design. A careful selection of items to be visualized was made in this regard to avoid information overload. This suggested keeping away the 28 evacuation centers which are more appropriate to represent in a bigger scale (e.g. 1.25.000).The list of evacuation centres identified for each tsunami prone GN divisions are given in Appendix.

By selection of colours hazard areas was depicted as to clearly identify between ocean and low risk areas. The critical infrastructure, highway network was depicted in suitable symbols to identify them separately in hazard zone.

Along the coast in the hazard zone located a considerable number of buildings and other infrastructures, facilities related to tourism since the area serve as a major tourist destination of the country .In a comprehensive risk analysis process and connected mitigation measures these utilities with periodically fluctuating number of occupants and the free trade area zones characterized with high personnel mobility require special preparedness measures.

The result of the study highlights the problem of used data for analysing the hazard zones for given wave heights. The 1.50,000 maps of contour intervals of 30 meters were insufficient due to the absence of elevation data under this limit .Most parts of the coastal belt of Sri Lanka are flat terrains except few locations with coastal hills.

In the SRTM DEM the high elevation areas of Rumassala Hills (78m) in the west and other hills in the south eastern areas can be identified. But in order to identify terrain variations in smaller distances its resolution was too coarse. The vertical accuracy of the SRTM data is expected to be 20m and 16m with some regional variations (SMITH and SANDWELL, 2003). However it provides more detailed information for middle and small scale mapping.

7 Concluding remarks

The communities are becoming increasingly vulnerable to natural hazards. So that it is important to recognize the nature of hazards and their temporal and spatial capacities and their physical social, economic and environmental impacts. Proper communication among all the parties is an important factor in disaster prevention. The findings achieved by hazard assessment process have to be transferred to all the levels from decision makers to affected communities. The affected communities should be supplied with proper information about the vulnerabilities in their neighbourhood. A growing number of peoples and infrastructure are established in hazard prone areas because of other economic and important aspects of these areas. So that inhabitant of these localities to be well informed with information customized for their needs.

The geographic information system has enhanced the effectivity of hazard researches through variety of modelling processes and spatial analysis methods. Further it allows generating more interpretative thematic maps that can be achieved with combination of numerous hazard relevant data bases.

Hazard maps have proved as good tools to communicate hazard assessment results to all stakeholders. The crucial importance of the maps is evident with the common application in spatial planning and disaster mitigation activities. A legal frame work is established in many countries to regulate and standardize their generation and utilization.to achieve its maximum benefits it is also needed to create the maps according to cartographic principles by maintaining a balance between effortless readability and usefulness.

In this study an attempt was made to visualize hazard related information with cartographic guidelines.

In the map the inclusion of more information about the people in risk, infrastructure and other vulnerabilities were omitted due to many factors, including the scale which needs some considerable generalization. Although more information on spatial objects in the area was available in vector data set a balance had to be maintained in visualization. For this reason many other thematic elements were omitted by feature selection.

A methodological draw back of the study was the absence of a latest and extensive field survey to verify and acknowledge the actual changes in the area along with other topographical factors relevant to mapping. With the integration of georeferenced objects e.g. evacuation centers the usability of the map could have been improved.

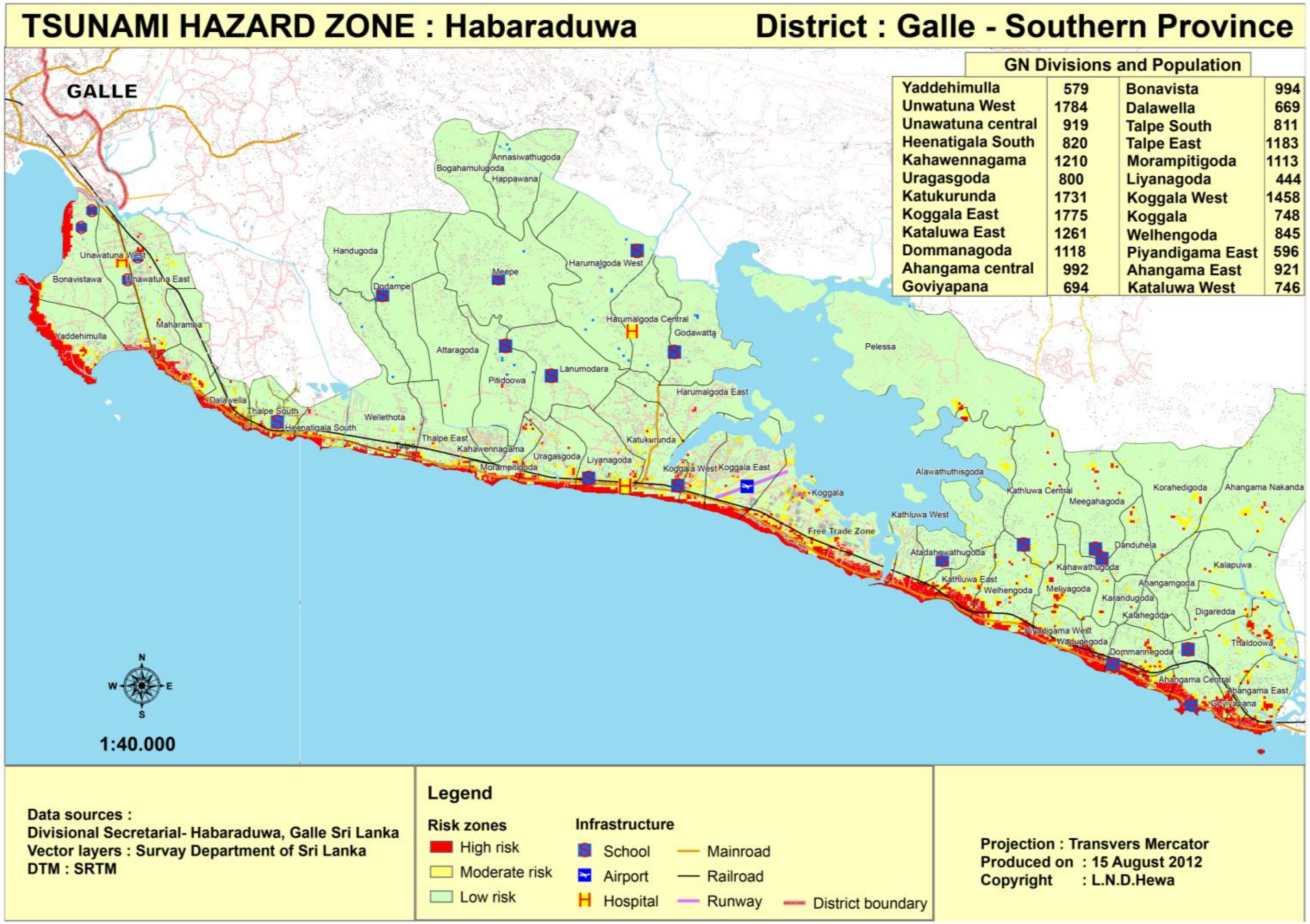
The spatial accuracy of the map to be further verified. As major constraint remains the availability of high resolution data for the affected coastal area. The elevation model used in this study was SRTM with 90m ground resolution. According to the latest reports initiatives are considered by Sri Lankan government in this regard. (DMC 2011)

The southern coastal belt including the potion of study area was among the high impact of Tsunami waves. Even within the study area considerable local variation of tsunami heights noticed. The wave height is dependent matter on many factors including the locational geomorphology and ground elevation.

Partly because of this reason and as it presumed that it goes beyond its scope, the study does not provide a detailed hazard map, but provide a conceptual framework on visualization of hazard related data with cartographic principles.

To conclude it is presumed the presented approach of hazard visualization would help to improve the risk communication and risk perception among communities, parties and contribute for sustainable hazard mitigation and environmental awareness.

8 Appendix


TSUNAMI HAZARD ZONE : Habaraduwa
District : Galle - Southern Province
GALLE
GN Divisions and Population
Yaddehimulla 579
Unwatuna West 1784
Unawatuna central 919
Heenatigala South 820
Kahawennagama 1210
Uragasgoda 800
Katukurunda 1731
Koggala East 1775
Kataluwa East 1261
Dommanagoda 1118
Ahangama central 992
Goviyapana 694
Bonavista 994
Dalawella 669
Talpe South 811
Talpe East 1183
Morampitigoda 1113
Liyanagoda 444
Koggala West 1458
Koggala 748
Welhengoda 845
Piyandigama East 596
Ahangama East 921
Kataluwa West 746
N
W
E
S
1:40.000
Data sources :
Divisional Secretarial- Habaraduwa, Galle Sri Lanka
Vector layers : Survay Department of Sri Lanka
DTM : SRTM
Legend
Risk zones
High risk
Moderate risk
Low risk
Infrastructure
School
Airport
Hospital
Mainroad
Railroad
Runway
District boundary
Projection : Transvers Mercator
Produced on : 15 August 2012
Copyright : L.N.D.Hewa

Reference System Parameters

Coordinates of Piduruthalagala - 500 000 N, 500 000 E

Transformation Parameters - WGS 84 to Everest Ellipsoid

Shifts X= 0.2933

Y= -766.9499

Z= -87.7131

Rotation X= 0.1957040 seconds

Y= 1.6950677

Z= 3.4730161

Scale Factor 1.0000000393

Projection Parameters - Everest Ellipsoid to Transverse Mercator Projecton

Everest India 1830

False Easting 500000

False Northing 500000

Central Meridian 80 46 18.16710 E

Central Parallel 7 00 1.69750 N

Scale Factor 0.9999238418

Note:

1:10,000 & 1:50,000 Topographic Mapping purpose, the False Easting & False Northing could be used as 200,000 & 200,000 respectively.

Source:

Data Survey Department Sri Lanka.

Save Locations in Habaraduwa Galle

	G N Division	Safe Location
1	No: 148A Talpe east	Ranwalagoda Viharaya
2	No: 148C kahawannagama	Kahawannangama kanda.
3	No: 144 B Morampitigoda.	Makandagoda Viharaya.
4	No. 132 Talpe south	Talpe ariyakara viharaya.
5	No: 136 Unawatuna East	Peellagoda chaityalankarama viharaya.
6	No: 137 Unwatuna West	Galketaya Devinuwararamaya.
7	No. 137 AUnawatuna Central	Ganahena Gananadarama Viharaya.
8	NO: 160 Piyadigama East	Wellwatta Thilakawardanaramaya.
9	NO: 161 Piyadigama West	Sri Siddhartha Viharaya.
10	NO: 141 Uyanagoda.	Pulinatharama Viharaya.
11	NO: 141 C Katukurunda	Chethiyarama Viharaya.
12	NO: 137 B Yaddehimulla	Danwalakanda.
13	NO: 157 Ahangama Central	Mahaviharaya.
14	NO: 156 Ahangama East	Jayasumanaramaya.
15	No: 148 Heenatigala South	Mahaviharaya.
16	NO:156 A Goviyapana	Visuddharama Viharaya.
17	NO: 161 Wadurugoda	Sri Siddhartha Viharaya.
18	No: 162 Kathluwa West	Nawamunisa Viharaya.
19	NO: 144A Koggala Extra.	Dewagiri Rajamaha Viharaya.
20	NO: 164 F Mallyagoda	Sri Vijayasundararamaya.
21	NO: 160 A Dommnnegoda	Wellwatte Sri Thilakawardhanaramaya.
22	NO: 164 Kathaluwa East	Kathaluwa Poorwarama Viharaya.
23	NO: 144D Koggala Extra I	Sri Gunadharshanaramaya.
24	NO: 132 A Dalawella.	Sri Sumanarama Viharaya.
25	NO: 137C Bonavistawa.	Bonavista Mahavidyalaya.
26	NO: 162 A Atadagewatugoda.	Chethiyarama Viharaya.
27	NO: 164D Welhengoda.	Kataluwa Poorwarama viharaya.
28	NO: 144D Koggala Extra II	Duwakanda.

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