Guide book
Session 4:
Elements at Risk

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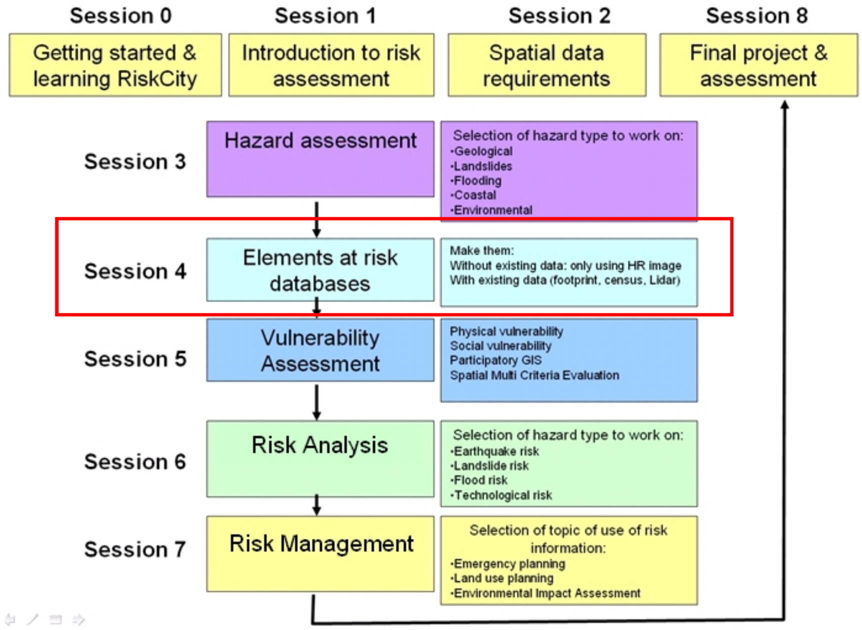
Objectives
After this session you should be able to:

- Understand the types of elements at risk;
- Characterize the elements at risk (buildings & population) in relation to different types of hazard;
- Know the sources for the mapping of elements at risk;
- Generate a basic elements at risk database for a situation where no information is available, except for a high resolution image;
- Generate an element at risk database for an urban area, using available data such as building footprint maps, census data and detailed elevation data.

In this session you will go through the guide book which deals with elements at risk mapping. We will look at urban land use first, and you will evaluate how you can identify different types of land use from high resolution imagery. You will also look at the relation between land use, building types and the population density.
We take two examples of elements at risk and look more in detail to those. First we analyze the characteristics of buildings that are relevant for estimating the vulnerability. We look at floorspace, construction type, and building costs. Three examples are given of the aspects related to building behavior for earthquakes, flooding and landslides. In the section on population we will look at the static and dynamic aspects of population and how you can estimate these. You can choose between 2 RiskCity exercises for making an elements at risk database: with or without existing data. The last part of the chapter deals with participatory mapping, and there you will also do a RiskCity exercise on how you can use information that was derived using Mobile GIS.

Section	Topic	Task	Time required		
4.1	Introduction		Day 1	0.7	1.5
		Task 4.1: HAZUS methodology		0.15	
		Task 4.2: Inventory of elements at risk		0.5	
		Task 4.3: Scales and types		0.15	
4.2	Urban land use			1.5	3
		Task 4.4: Make a land use legend for your area		0.5	
		Task 4.5: Recognizing land use types from Google Earth imagery		0.5	
		Task 4.6: List of identification criteria for landuse types		0.5	
4.3	Buildings		Day 2	1.5	6
		Task 4.7: Determine the important characteristics of buildings		0.5	
		Task 4.8: Generating an element at risk database from scratch		Choose one: 4	
		Task 4.9: Generating an element at risk database with available data	Day 3		
4.4	Population			0.75	0.75
4.5	Participatory mapping			1	4.75
		Task 4.10: Video on Community based approaches	Day 4	0.5	
		Task 4.11: RiskCity exercise on the use of Participatory mapping information		3	
		Task 4.12: Summary on the use of participatory mapping for disaster risk assessment		0.25	
		Total	**4 days**		**16 h**

4.1. Introduction.



The next step in a risk assessment, after analyzing the hazard, that we saw in the previous session, will be to evaluate the elements at risk. **Elements at risk** are the population, properties, economic activities, including public services, or any other defined values exposed to hazards in a given area. They are also referred to as "**assets**". Elements at risk also have spatial and non-spatial characteristics. First of all there are many different types of elements at risk (which will be treated in this session) and they can be classified in various ways. The way in which the amount of elements-at-risk are characterized (e.g. as number of buildings, number of people, economic value or the area of qualitative classes of importance) also defines the way in which the risk is presented to the end users (i.e. decision makers, emergency personnel and the general public). The interaction of elements at risk and hazard defines the exposure and the vulnerability of the elements-at-risk. Exposure indicates the degree to which the elements at risk are exposed to a particular hazard. The spatial interaction between the elements at risk and the hazard footprints are depicted in a GIS by simple map overlaying of the hazard map with the elements at risk map. The aim of the element at risk mapping is to build up a data base for the evaluation of the vulnerability of the elements at risk for certain hazards

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What are elements at risk?

- All objects, persons, animals, activities and processes that may be adversely affected by hazardous phenomena, in a particular area, either directly or indirectly. This includes: buildings, facilities, population, livestock, economic activities, public services, environment.

4.1.1 General classification of elements at risk

There are many different types of elements at risk, and also many different ways to classify them. Table 4.1 gives an example of such a classification.

Table 4.1: Classification of elements at risk

Physical elements Buildings: Urban land use, construction types, building height, building age, total floor space, replacement costs. Monuments and cultural heritage	**Population** Density of population, distribution in space, distribution in time, age distribution, gender distribution, handicapped, income distribution
Essential facilities Emergency shelters, Schools, Hospitals, Fire Brigades, Police,	**Socio-economic aspects** Organization of population, governance, community organization, government support, socio-economic levels. Cultural heritage and traditions.
Transportation facilities Roads, railway, metro, public transportation systems, harbor facilities, airport facilities.	**Economic activities** Spatial distribution of economic activities, input-output table, dependency, redundancy, unemployment, economic production in various sectors.
Life lines Water supply, electricity supply, gas supply, telecommunications, mobile telephone network, sewage system.	**Environmental elements** Ecosystems, protected areas, natural parks, environmentally sensitive areas, forests, wetlands, aquifers, flora, fauna, biodiversity.

In literature many different methods can be found to classify elements at risk, depening on the country, the setting (urban, rural, etc.) the objectives of the risk assessment, the scale, available resources etc.
For example the Asian Disaster Preparedness Center (ADPC) classifies the elements at risk into physical, economic, societal and environmental elements (see table 4.2) which can we linked later immediately to physical, economic, social and environmental vulnerability.

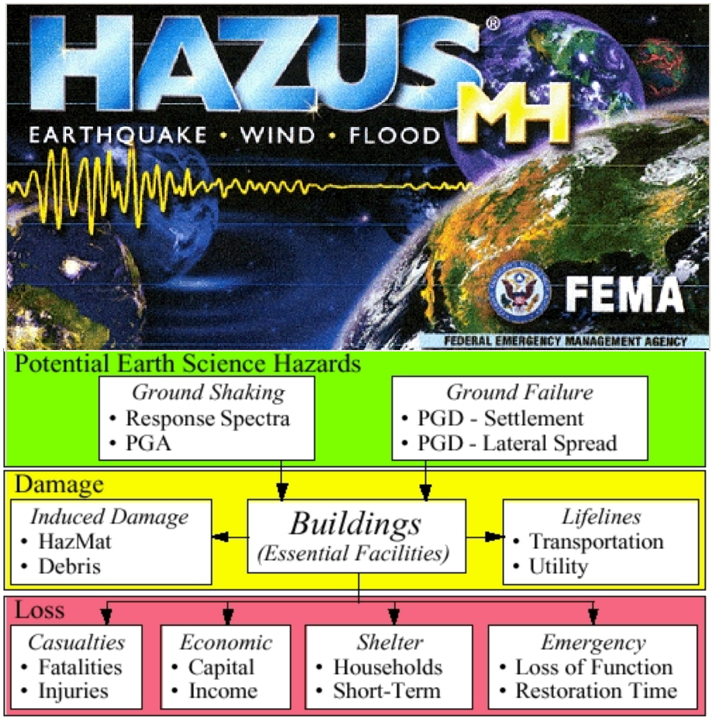
Table 4.2: Classification of elements at risk

Physical elements **Infrastructure,** for example: roads, railway, bridges, harbors, airports etc. **Critical facilities**, for example: emergency shelters, schools, hospitals, nursing homes, fire brigades, police etc... **Utilities**: Power supply, Water supply Services: transport, communications etc... Government services: all levels - national, provincial, local Machinery and equipment Historical structures and artifacts	**Societal elements** Vulnerable age group categories Low-income groups Landless/Homeless Disabled Gender Single parent households Etc.
Economic elements Business and trade activities, Access to work, Agricultural land, Impact on work force, Productivity cost Opportunity cost	**Environmental elements** Environmental Resources: air, water, fauna, flora Biodiversity Landscape

Villagrán de Leon (2006), classifies the elements at risk according to different sectors: housing, basic lifelines, health, education, agriculture, energy, infrastructure, commerce, industry, finance and telecommunications. The sectoral approach is proposed from a policy point of view because it promotes assigning responsibilities to those private or public institutions in charge of each sector (Government ministries or others).

HAZUS MH methodology

Figure 4.1: Opening screen and general structure of the HAZUS method for Multi hazard risk assessment



HAZUS is by far the most advanced method for spatial multi-hazard risk assessment that is publicly available. HAZUS has been developed by the US Federal Emergency Management organization (FEMA) together with the National Institute of Building Sciences (NIBS). HAZUS is a software programme running under ARCGIS for estimating potential losses from earthquake, flood and hurricane hazards. HAZUS-MH software can be requested from the following website: www.fema.gov/plan/prevent/hazus
The HAZUS method also has a very extensive module dealing with the inventory and classification of elements at risk. In this chapter we will present parts of that. However, HAZUS is developed for the USA, and the elements at risk classification cannot be used directly in other countries, and particularly not in developing countries, where building types, population densities etc. will be completely different from those in the USA. Also the hazard characteristics may be quite different in the USA as compared to other countries. HAZUS requires a very extensive data input in terms of the elements at risk information and the hazard information, which is often not available in developing countries. Therefore the methodology often has to be simplified.

Task 4.1: HAZUS methodology (duration 10 minutes)

To get a first idea on the HAZUS methodology, please visit the Website
http://www.fema.gov/library/viewRecord.do?id=3299
Download and read the introduction.
You can also obtain it from the background materials directory for Session 4 on the course DVD.

A survey of elements at risk is always incomplete, and therefore a risk assessment study nearly always focuses on specific groups of elements at risk, such as buildings or population. In the exercises that we will do using the RiskCity case study we will in fact concentrate only on building and population as the two main types of elements at risk.

An important distinction to be made here is also the differentiation between **tangible** and **intangible elements at risk**. Tangible elements at risk are those things that can be identified, localized, mapped and quantified (For examples, most of the physical elements). Intangible elements are those things that are very difficult to quantify or map, as they do not have a particular spatial dimension (for instance, the cultural values, the wellbeing of communities, psychological conditions, and sociological behavior). When a disaster hits also these elements at risk may be severely impacted.

Task 4.2: Inventory of elements at risk (duration 30 minutes)

Imagine the neighborhood/city/country in which you live would be hit by a hazard event. Which elements at risk would be impacted?

- Make a selection of a particular hazard type (e.g. flood, landslide, earthquake, windstorm, explosion of an industry, major accident etc.)
- Select the scale: your neighborhood / city / region / country
- Think about the type of area where you live. What are the main characteristics in terms of buildings, population, economic activities, infrastructure etc.
- Create a table in which you list the elements at risk according to the different types indicated in the tables above.
- Define whether the elements at risk can be mapped, and quantified.

Hazard type: __________________

Element at risk	What is the effect?	Can it be mapped?	Can it be quantified?

Compare your results with that of the other course participants.

4.1.2 Elements at risk mapping versus scale and objective of the study.

Elements at risk inventories can be carried out at various scale levels, depending on the requirements of the risk study. In the previous chapter on hazard assessment, four different scales have been identified, ranging from small scale to detailed scale. In table 4.3 an overview is given of 4 scale levels versus the detail of the elements at risk that could be used. In the RiskCity case study we work at medium to large scale at the urban level, where information needs to be as detailed as possible, preferably at the individual building level, or at a slightly more aggregated level of mapping units or building blocks with homogenous land use type. In table 4.3 the areas with a red border indicate the elements at risk and the scale that is used for the RiskCity exercises. In these exercise we concetrate on the evaluation of risk for buildings and population. In fact many of the risk assessments concentrate on these two aspects.

Table 4.3: Elements at risk mapping versus mapping scale (red boxes indicate the combinations that will be used in the RiskCity GIS exercises)

Elements at risk type	**Scale of analysis**			
	Small < 1:100.000	**Medium 25-50.000**	**Large 10.000**	**Detailed >1:10.000**
Buildings	By Municipality • Nr. buildings	Mapping units • Predominant type (e.g residential, commercial, industrial) • Nr. buildings	Building footprints • Generalized use • Height • Building types	Building footprints • Detailed use • Height • Building types • Construction type • Quality / Age • Foundation
Transportation networks	General location of transportation networks	Road & railway networks, with general traffic density information	All transportation networks with detailed classification, including viaducts etc. & traffic data	All transportation networks with detailed engineering works & detailed dynamic traffic data
Lifelines	Main powerlines	Only main networks • Water supply • Electricity	Detailed networks: • Water supply • Waste water • Electricity • Communication • Gas	Detailed networks and related facilities: • Water supply • Waste water • Electricity • Communication • Gas
Essential facilities	By Municipality • Number of essential facilities	As points • General characterization • Buildings as groups	Individual building footprints • Normal characterization • Buildings as groups	Individual building footprints • Detailed characterization • Each building separately
Population data	By Municipality • Population density • Gender • Age	By ward • Population density • Gender • Age	By Mapping unit • Population density • Daytime/Nighttime • Gender • Age	People per building • Daytime/Nighttime • Gender • Age • Education
Agriculture data	By Municipality • Crop types • Yield information	By homogeneous unit, • Crop types • Yield information	By cadastral parcel • Crop types • Crop rotation • Yield information • Agricultural buildings	By cadastral parcel, for a given period of the year • Crop types • Crop rotation & time • Yield information
Economic data	By region • Economic production • Import / export • Type of economic activities	By Municipality • Economic production • Import / export • Type of economic activities	By Mapping unit • Employment rate • Socio-economic level • Main income types • + larger scale data	By building • Employment • Income • Type of business
Ecological data	Natural protected areas with international approval	Natural protected area with national relevance	General flora and fauna data per cadastral parcel.	Detailed flora and fauna data per cadastral parcel

Task 4.3: Scales and types (duration 10 minutes)
Compare your results of task 4.1 with the table 4.3. What can you conclude?

4.1.3 Basic units for risk assessment

Risk assessment should be done based on certain basic spatial units. These could be administrative units, such as countries, provinces, municipalities, wards or even individual buildings. Table 4.2 also gives suggestions for the best basic mapping unit to use. Even at large scales a risk assessment is normally not done at individual building level. This has several reasons:

- The attribute information required to do such a detailed risk assessment is generally not available, or very difficult to collect. For instance in the case of an earthquake, the behavior of each individual building is characterized by many factors which can vary from building to building. One would need to make a detailed structural engineering evaluation of each building in order to determine how this building would behave under particular earthquake acceleration. This study would be too time consuming, and therefore buildings are classified into groups. Individual study of buildings is only done for the critical facilities, such as hospitals.
- Displaying risk at individual building level is not realistic given the uncertainty in data and models. The vulnerability study is normally done using so-called vulnerability curves, which indicate the general behavior of buildings of a certain class (e.g. masonry two story buildings) and not for individual buildings.
- Displaying risk information at individual building level would lead to undesirable legal consequences, as it could have a large effect on real estate values, and possibly even on insurance premiums.

Therefore even at large scale, risk assessment is normally carried out for groups of buildings, located in so-called homogeneous units.

A **homogeneous unit** is a mapping unit that has more or less the same characteristics in terms of elements at risk. For instance the same landuse type or the same building types.

In the HAZUS methodology the loss estimation is done based on the census tracts. The census tract is considered as a homogeneous unit, and all estimations are given for that unit. Figure 4.2 gives an illustration of the various levels of elements at risk data that were available for RiskCity. The basic information was available in the form of individual building footprints, which lacked any attribute information. This level was considered too detailed as data collection for each individual building was too expensive. On the other hand, most of the attribute information related to population was linked to a polygon map of the wards of the city (see Figure 4.2.C). The detail of these units was considered too low, as the hazard varies significantly within one ward, and the integration of hazard data with general ward data would lead to non-reliable results. Therefore so-called mapping units were introduced as an intermediate level of elements at risk. They are considered to be more or less homogeneous units with respect to buildings types, socio-economic level and urban land use (See Figure 4.2.B). This mapping was done through image interpretation using the very high resolution imagery, and their boundaries are mostly formed by streets. The attributes from the higher and the lower levels were then converted to this intermediate level. For instance, the number of buildings per mapping unit was measured by overlaying the building footprint map with the mapping unit map. The average height of the elements at risk was estimated using the difference between the LiDAR DEM and the surface DEM generated from the contourlines with 2.5 meters contour interval, in the location of the building footprints (See Figure 4.2.D). Information of predominant urban land use was not available, and therefore had to be generated, based on detailed image interpretation (See Figure 4.2.E). Population information was only available at ward level (Figure 4.2.C), and the population values had to be distributed over the mapping units, based on the urban landuse, the height of the buildings and the footprint area, from which the total floor area per mapping unit and landuse class could be calculated. Population density was also calculated for different temporal scenarios (e.g daytime / nighttime / commuting time) using the urban landuse as the main criteria. Figure 4.2.D. illustrates the need for regular updating of the element at risk database, as around 560 of the building footprints displayed in the map (around 30000) were destroyed by floods and landslides during a recent disaster (see chapter 1 for more information).

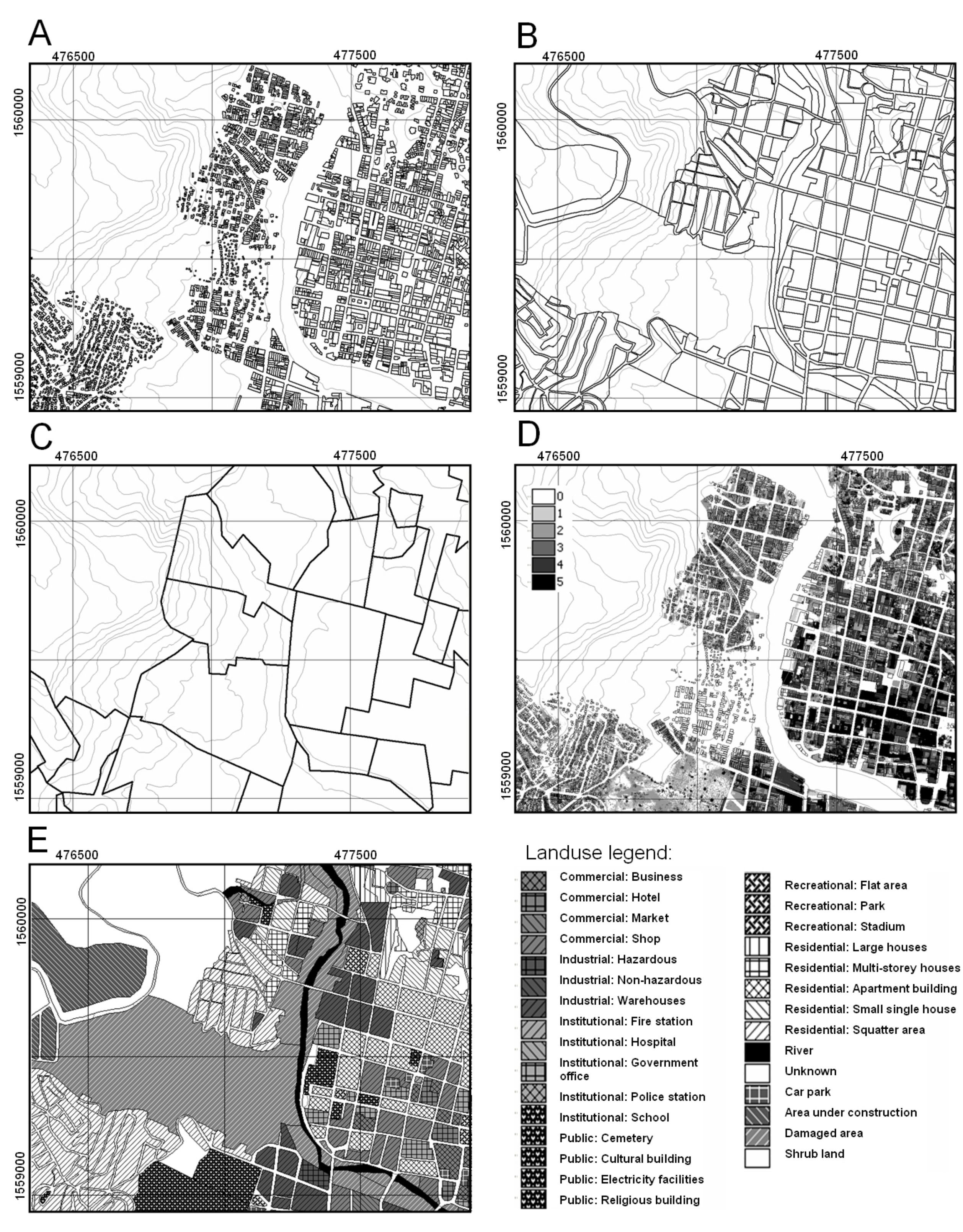


Figure 4.2: Different types of information that are important for the generation of an elements at risk database in RiskCity. A: Individual building footprints obtained by screen digitizing on airphotos and field verification , B: Mapping units, representing zones of more or less homogeneous urban landuse and building types, which are mostly coinciding with the street pattern C: Wards, for which aggregated population information is available D: Building height, in number of stories, generated using LIDAR data, and E: Land use classification of the mapping units, which forms the basis for assigning attributes to the buildings in the various classes, and for estimating the population density in different temporal scenarios (daytime, nighttime, commuting time).

4.2 Urban land use as main entry point

One of the most important spatial attributes of the mapping units for elements at risk inventory is the land use. The land use determines to a large extend the type of buildings that can be expected in the unit, the economic activities that are carried out, the density of the population in different periods of the day, etc.

4.2.1 Classification schemes

Table 4.4 gives the land use classification which is used in the Radius methodology, which is a simple method for estimating seismic losses in cities carried out in the International Decade for Disaster Reduction (1990-2000) (http://geohaz.org/contents/projects/radius.html).

Table 4.4: Urban land use classes used in the Radius methodology for earthquake loss estimation.

Code	Description
RES_1	Informal construction. Mainly slums, row housing etc. made from unfired bricks, mud mortar, loosely tied walls and roofs.
RES_2	Unreinforced masonry (URM) – Reinforced Concrete (RC) composite construction - sub-standard construction, not complying with the local code provisions. Height up to 3 stories.
RES_3	URM-RC composite construction - old, deteriorated construction, not complying with the latest code provisions. Height 4 - 6 stories
RES_4	Engineered RC construction - newly constructed multi-storied buildings.
EDU_1	School buildings, up to 2 stories.
EDU_2	School buildings, greater than 2 stories.
MED_1	Low to medium rise hospitals.
MED_2	High rise hospitals
COM	Shopping centers
IND	Industrial facilities

Table 4.5 gives the land use classification used in the HAZUS methodology for the US. In their methodology they refer to it as occupancy classes, as they are directly linked to buildings.

Table 4.5: Building occupancy classes as used in HAZUS.

Code	Occupancy Class	Example
Residential		
RES1	Single Family Dwelling	House
RES2	Mobile Home	Mobile Home
RES3	Multi Family Dwelling RES3A – RES3F (2 to ≥ 50 units)	Apartment/Condominium
RES4	Temporary Lodging	Hotel/Motel
RES5	Institutional Dormitory	Group Housing (military, college), Jails
RES6	Nursing Home	
Commercial		
COM1	Retail Trade	Store
COM2	Wholesale Trade	Warehouse
COM3	Personal and Repair Services	Service Station/Shop
COM4	Professional/Technical Services	Offices
COM5	Banks	
COM6	Hospital	
COM7	Medical Office/Clinic	
COM8	Entertainment & Recreation	Restaurants/Bars
COM9	Theaters	Theaters
COM10	Parking	Garages
Industrial		
IND1	Heavy	Factory
IND2	Light	Factory
IND3	Food/Drugs/Chemicals	Factory
IND4	Metals/Minerals Processing	Factory
IND5	High Technology	Factory
IND6	Construction	Office
Agriculture		
AGR1	Agriculture	
Religion/Non/Profit		
REL1	Church/Non-Profit	
Government		
GOV1	General Services	Office
GOV2	Emergency Response	Police/Fire Station/EOC
Education		
EDU1	Grade Schools	
EDU2	Colleges/Universities	Does not include group housing

In Table 4.6 the classification is given that is used in the RiskCity exercises.

Table 4.6: Urban land use classes used in the RiskCity exercise.

Code	Occupancy Class	Example
Residential		
Res_1	Res_squatter	Low income houses: squatter areas
Res_2	Res_small_single	Small single family houses, mostly in rows
Res_3	Res_multi	Multi-storey apartment buildings
Res_4	Res_mod_single	Moderately sized single family houses
Res_5	Res_large	Large free standing houses
Commercial		
Com_b	Com_business	Offices
Com_h	Com_hotel	Hotels
Com_m	Com_market	Market area
Com_s	Com_shop	Shops and shopping malls
Industrial		
Ind_h	Ind_hazardous	Hazadous material storage or manufacture
Ind_i	Ind_industries	Non hazardous industries
Ind_w	Ind_warehouse	Warehouses and workshops
Institutional		
Ins_f	Ins_fire	Fire brigade
Ins_h	Ins_hospital	Hospitals
Ins_o	Ins_office	Office buildings
Ins_p	Ins_police	Police station
Ins_s	Ins_school	Institutional : schools
Public buildings		
Pub_g	Pub_cemetery	Cemetary
Pub_c	Pub_cultural	Cultural buildings such as musea, theaters
Pub_e	Pub_electricity	Buildings related to electrical supply
Pub_r	Pub_religious	Religious buildings such as churches, mosques or temples
Recreational		
Rec_f	Rec_flat_area	Flat area or football field
Rec_p	Rec_park	Park area
Rec_s	Rec_stadium	Stadium
Vacant areas with no buildings		
Vac_c	Vac_car	Vacant : car parking and busstation
Vac_u	Vac_construction	Vacant area which is prepared for building construction
Vac_d	vac_damaged	Area recently damaged by hazard events
Vac_s	Vac_shrubs	Vacant land with shrubs, trees and gress
riv	River	River

Task 4.4: Make a land use legend for your area (duration 30 minutes)

Compare the result of your inventory of elements at risk that you made in Task 4.2 with the classification of land use types in tables 4.4 to 4.6

- Make a land use classification for your area, and for the hazard type that you selected.
- Indicate for each class the importance of this class for estimating losses of buildings and population. What makes each class different from the rest?

In the following pages we will illustrate the various land use types with examples from (mostly) RiskCity taken from high resolution imagery.

4.2.2 Residential areas

We start with residential classes. In total five residential classes have been identified. Most of them are rather straightforward to identify on imagery. Below three classes are shown in figure 4.3.

Figure 4.3: Example of residential building classes

One of the most important urban land use classes for risk assessment are the slum areas, or squatter areas, as they will normally have the highest vulnerability to natural disasters. According to UN-Habitat 18% of all urban housing units (some 125 million units) worldwide are non-permanent structures and at least 25% of all housing (175 million houses) does not meet urban construction codes. This figure, in reality, is probably much higher. For every 10 non-permanent houses in the cities of developing countries, 3 or 4 are located in areas prone to floods, landslides, hurricanes and earthquakes (Source: http://www.unhabitat.org/)

The UN-Habitat uses five criteria to determine an area as a slum:

1. **Access to improved water** (access to sufficient amount of water for family use, at an affordable price, available to household members without being subject to extreme effort);
2. **Access to improved sanitation** (access to an excreta disposal system, either in the form of a private toilet or a public toilet shared with a reasonable number of people);
3. **Durability of housing** (permanent and adequate structure in non-hazardous location)
4. **Sufficient living area** (not more than two people sharing the same room).
5. **Security of tenure** (evidence of documentation to prove secure tenure status or de facto or perceived protection from evictions

Slums are characterized spatially by a number of aspects (R.Sliuzas, http://www.itc.nl/library/Papers_2004/phd/sliuzas.pdf).

- The buildings are poorly constructed, in an unplanned manner, which makes them more vulnerable to the impact of events like earthquakes and flooding.
- They are normally also constructed without building permits, and therefore do not follow construction standards.
- The density of buildings is very high, to such an extent that over 90 percent of an area is covered by roofs.
- This means that the density of population us also very high, leading to a large population vulnerability. Also the lower level of schooling, low income levels, as well as high percentage of infants, and unemployment contribute to the increased population vulnerability.
- The buildings generally have a general lack of spatial order, which makes such areas easier to interpret from high resolution imagery (See figure 4.3 and 4.4). However it is often not possible to map out the individual buildings within a slum. For mapping of slum areas a participatory mapping approach is most suitable (See section 4.5)

- Slums also have a lack of access and poor quantity and quality of infrastructure which makes rescue work and fire fighting activities very difficult. Slums have a lack of public facilities (schools, health, cemeteries, parks and sport fields). This causes that there are less locations that can be used for disaster preparedness activities.
- Many slums are located in hazardous, for instance on steep slopes or in areas with frequent flooding or water stagnation. These are the areas that were still free in the city and that are normally owned by the government.
- On the other hand slums also have often an advantageous location with respect to the short distance to the major places of informal employment (e.g. city centers) and the workers therefore have a lower travel costs.
- Many slums have been made illegally by invading terrain that belonged to others (either private owners or the government). Therefore land tenure is not secure, and there is always a risk of eviction. It also happens frequently that slums are made legal after a certain period of time. However, in such situations land ownership is still a major problem.

Slums have different stages of development. They can be in the starting phase with initial occupation of land and construction. They can also be in the consolidation phase where some basic services are provided and where the slum expands until the mature phase.

Figure 4.4: Example of slum areas on extremely steep slopes prone to landslides in Guatemala

Other residential building classes are easier to identify. In figure 4.3 and 4.5 four other classes are shown. The differentiation of the various residential classes is important because:

- The land use classes are often also linked to building types, and therefore can be used to link them to vulnerability curves. Class Res_5 generally has better quality buildings than the other ones.
- The land use classes define the number of people that will be present in the land use class at a given moment in time, which is required for population loss estimation (See also section 6). Multi-story apartment buildings for instance will have a much higher density of population as the same building is used by many individual households.

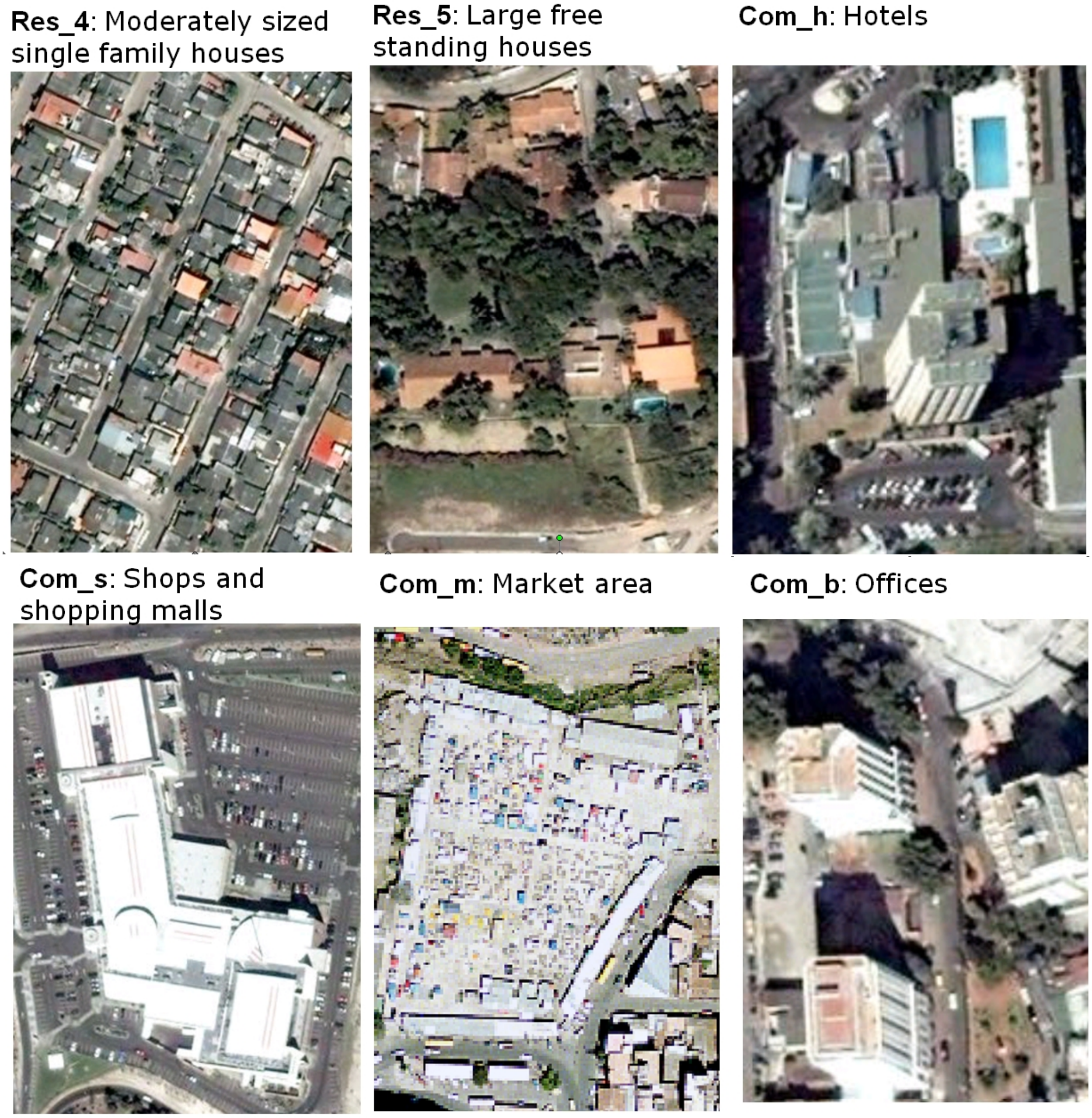
From a mapping point of view it will be often difficult to distinguish the different types of residential land uses on the basis of image interpretation alone.

Task 4.5: Recognizing land use types from Google Earth imagery (duration 30 minutes)

Identifying land use types from high resolution images

- Use Google Maps (http://maps.google.com/) and zoom in on the area that you have selected for the previous tasks (your own neighborhood or city). Select the option
- Try to identify the land use types that you have made in task 4.4.

Figure 4.5: Moderate and large residential buildings and hotels



4.2.3 Commercial land use types

Another important class of urban land use is that of commercial buildings and activities. In the figure above several examples are given. Most of the commercial activities are characterized by relatively high population densities during working hours, and low during evenings. For instance shops, offices, and markets are normally very crowded during working hours, and sometimes also during the evenings, but will be more or less empty during the night. For instance the shopping mall that is recognizable in figure 4.5 is characterized by very large parking lots surrounding the building, which indicates that there may be a very high population density in some periods. This is not the case for hotels, which tend to have a reverse situation, with a much higher population density in the evening and night, but also a certain level of occupancy during daytime.
For commercial land uses also the content of buildings should be taken into account as these are often of a high value. There a large difference can be observed between the shopping mall and the market example in figure 4.5. The economic value of both the building and the contents is much higher for the shopping mall than for the market, where as the population density might be much higher for the market area.

4.2.4 High Potential Loss facilities

High potential loss facilities are facilities that are likely to cause heavy losses if damaged by a hazardous event, such as an earthquake. These high potential loss (HPL) facilities include nuclear power plants, dams, military installations, and hazardous industries. For instance if a dam breaches due to the occurrence of an earthquake, it may cause excessive damage due to catastrophic flooding downstream. Also if a nuclear power plant, or hazardous industry get seriously damaged, the secondary effects will be very high due to emission of dangerous toxic or radioactive clouds. Table 4.7 Shows the classification used in HAZUS for high potential loss facilities.

Table 4.7: Classification of high potential loss facilities used in the HAZUS method for risk assessment

Label	**Description**
Dams	
HPDE	Earth
HPDR	Rock fill
HPDG	Gravity
HPDB	Buttress
HPDA	Arch
HPDU	Multi-Arch
HPDC	Concrete
HPDM	Masonry
HPDS	Stone
HPDT	Timber Crib
HPDZ	Miscellaneous
Nuclear Power Facilities	
HPNP	Nuclear Power Facilities
Military Installations	
HPMI	Military Installations

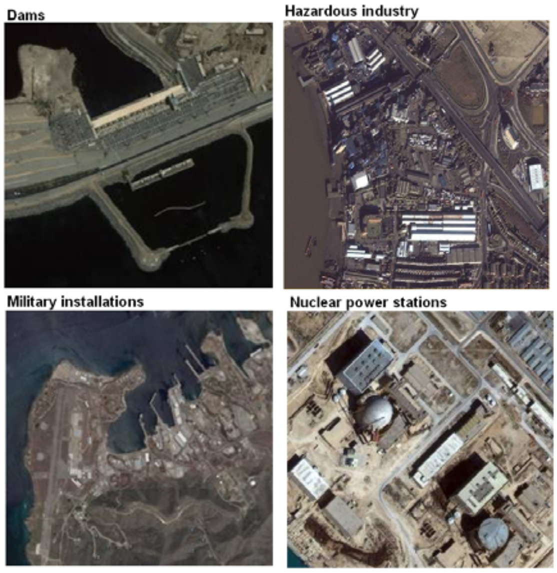


Figure 4.6 Shows examples of the classes of industry used in the RiskCity case study. We have differentiated industrial activities in three classes. Hazadous industry is a high potential loss facility, non hazardous industry might still have a substantial amount of workers in the industrial area, whereas for warehouses the density of workers will be much less.

Figure 4.6: Classification of industrial types in the RiskCity case study

Ind_h: Hazardous material storage or manufacture

Ind_w: Warehouses and workshops

Ind_i: Non hazardous industries

4.2.5 Essential facilities

Essential facilities are those facilities that provide services to the community and should be functional after a disaster event. Essential facilities include hospitals, police stations, fire stations and schools. The damage state probabilities for essential facilities should be determined on a site specific basis, as is the case for high potential loss facilities (i.e., the ground motion parameters are computed at the location of the facility). The classification used in HAZUS is given in table 4.8.

Table 4.8: Classification of essential facilties used in HAZUS

Label	Occupancy Class	Description
Medical Care Facilities		
EFHS	Small Hospital	Hospital with less than 50 Beds
EFHM	Medium Hospital	Hospital with beds between 50 & 150
EFHL	Large Hospital	Hospital with greater than 150 Beds
EFMC	Medical Clinics	Clinics, Labs, Blood Banks
Emergency Response		
EFFS	Fire Station	
EFPS	Police Station	
EFEO	Emergency Operation Centers	
Schools		
EFS1	Grade Schools	Primary/ High Schools
EFS2	Colleges/Universities	

Figure 4.7 Several examples of essential facilities as used in RiskCity.

The essential facilities can be subdived into those that are essential for providing emergency response (fire brigade, police station, army barracks, civil defence buildings) and those that are crucial for medical care. After a disaster has happened it is of utmost importance that the available hospitals can provide aid to the people injured during the event within the first 3 days. This period determines whether relatively simply injuries can be attended, and if not these might become worse and even fatal due to the outbreak of epidemics. Therefore the evaluation of the behavior of hospitals during a hazard event like an earthquake is very important, as well as preparatory measures such as a emergency power supply.
Also schools, churches, office buildings, cultural buildings, and stadiums can be considered essential facilities, although to a lesser extend than the emergency response and medical facilities. Public buildings may serve as shelters after the occurrence of major disasters. On the other hand the behavior of such buildings during the hazard event is also important to study, as these buildings contain very vulnerable population. Figure 4.8 displays several examples of land use types that can also play a role in the evacuation. It also shows some examples of land use types that are considered "vacant" in terms of buildings but that still have a large importance in the risk assessment.

Figure 4.8: examples of several classes of recreational and vacant land use types of table 4.?

For instance the class **Vac_d** shows evidences of recently destroyed buildings (lower right corner where you only see the remains of the walls of buildings, and where the roofs have been destroyed) and a bridge that was washed out. The class **Vac_c** shows a situation where the amount of elements at risk (in this case cars and people) is very flexible over time. Depending on the time of the day and year, a disaster striking in such an area might cause no damage at all, or considerable damage. The class **Vac_u** shows an area that is under construction. In this particular example a new bridge is constructed. This illustrates the importance of updating the spatial information on the elements at risk, as there are constant changes in landuse that are taking place.

Task 4.6: List of identification criteria for landuse types

Based on the information in this section and task 4.5, now try to make a list of criteria for the various land use types, with emphasis on interpretation from high resolution imagery.
You might not want to describe all of them, but make a selection.
Are there also classes that you cannot identify from high resolution images?

Code	Occupancy Class	Identification criteria
Res_1	Res_squatter	High density of individual small houses in irregular pattern, unpaved streets or footpaths
Res_2	Res_small_single	
Res_3	Res_multi	
Res_4	Res_mod_single	
Res_5	Res_large	
Com_b	Com_business	
Com_h	Com_hotel	
Com_m	Com_market	
Com_s	Com_shop	
Ind_h	Ind_hazardous	
Ind_i	Ind_industries	
Ind_w	Ind_warehouse	
Ins_f	Ins_fire	
Ins_h	Ins_hospital	
Ins_o	Ins_office	
Ins_p	Ins_police	
Ins_s	Ins_school	
Pub_g	Pub_cemetery	
Pub_c	Pub_cultural	
Pub_e	Pub_electricity	
Pub_r	Pub_religious	
Rec_f	Rec_flat_area	
Rec_p	Rec_park	
Rec_s	Rec_stadium	
Vac_c	Vac_car	
Vac_u	Vac_construction	
Vac_d	vac_damaged	
Vac_s	Vac_shrubs	
riv	River	

It should be noted that image interpretation alone is often insufficient to classify buildings according to the land use. For instance it is not possible to identify hazardous industries, essential facilities and other land use types. Even buildings that can be identified clearly on images, such as churches, might have changed land use type. Also it is not possible to identify mixed land use types, for instance mixed residential and commercial. Therefore it is important to always carry out field studies to characterize buildings and to use as much existing information as possible.

4.3 Building characteristics and response

Buildings are one of the most important groups of elements at risk. They house the population and the behavior of a building under a hazard event, determines whether the people in the building might be injured or killed.
In order to be able to assess the potential losses and degree of damage of buildings that are exposed to a certain type of hazardous event, it is important to define two things:

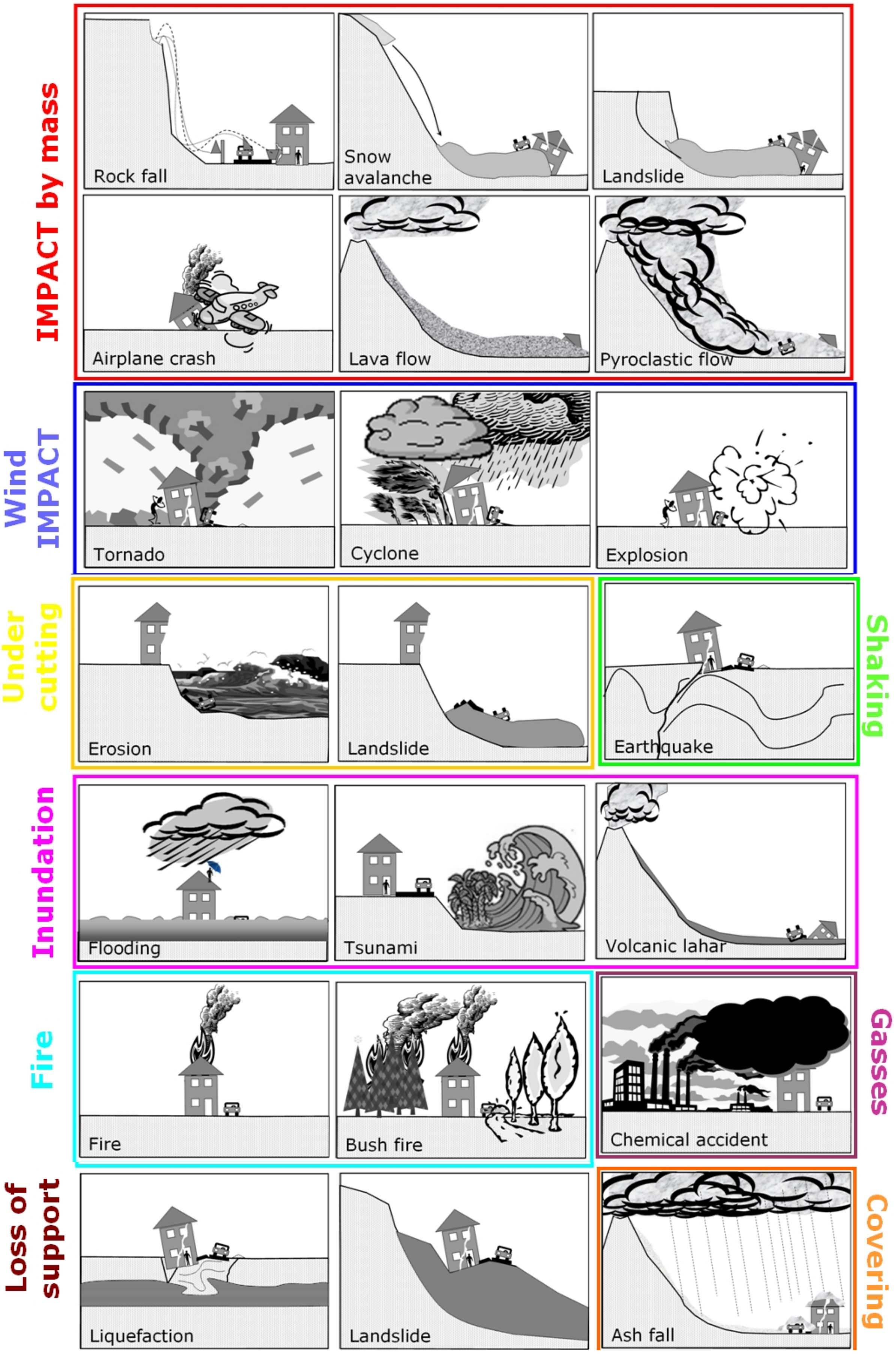
- The type of negative effect that the event might have on the building which is exposed to it.
- The characteristics of the building that define the degree of damage due to the hazard exposure.

The type of negative influence of the exposure can be in many different forms, which depend on the type of hazard that will occur. Figure 4.8 gives a schematic overview of the various hazard processes that may occur and that have a different effect on buildings. The following types can be differentiated:

- **Mass Impact**: the building is impacted by a phenomena that may have different characteristics:
    - Speed of impact. This could vary from a slow impact, for instance by a slow moving lava flow, to an extremely fast impact (e.g. snow avalanche, rockfall, or pyroclastic flow)
    - Medium of impact: impact can be by rock (rock fall), soil or debris (landslide), mud (volcanic lahar), snow, water (e.g. flashflood) or objects (e.g. airplane crash)
- **Wind impact**: the building is impacted by air, which may also create un underpressure or overpressure inside the building, which could lead to implosion/explosion of the building. Difference processes can be differentiated, such as tornadoes, cyclones or explosions.
- **Undercutting**: the building loses support because the soil below the foundation is eroded away by erosion (e.g. along coastlines, or along river channels) or landslides.
- **Shaking**: the building is subjective to ground shaking, as is the case in an earthquake.
- **Inundation**: the building is flooded, which can be suddenly and violently, in which case also the impact effect of water is important (e.g. flashfloods or tsunami). The flooding can also be slow and with a long duration, which will have a deriorating effect on the construction materials of the building.
- **Fires:** the building is subjected to fire, for instance in the case of a bushfire/forestfire, or in the case of an industrial accident.
- **Loss of support:** the building is subsiding as a result of underground cavities (e.g. due to mining), liquefaction or because the building is on a slow landslide.
- **Gasses:** the building is filled by toxic gasses, e.g. caused by industrial accidents nearby
- **Covering by materials:** the building is covered by materials which may weight on the roofs and would lead to roof collapse, as in the case of snow or volcanic ash.

Figure 4.9: Examples of buildings damaged by different processes (lahar, earthquake, cyclone, landslide, flood, debrisflow, tsunami).

Figure 4.10: Examples of the type of the hazardous processes to which buildings can be exposed. Each type of processes will have different effects.



Task 4.7: Determine the important characteristics of buildings (30 minutes)

Based on the information on the previous pages on the different hazard processes to which a building might be exposed, determine:

- What is the damaging effect of the particular hazard on the building?
- Which aspects of the building would make it most susceptible to be affected?
- Which characteristics of a building therefore should be taken into account for a vulnerability assessment?

Write the results in the table provided in the Excel file (task 47). If you can think of other processes that are not mentioned, please note them down below in the table.

Process	Hazard	Damage	Important Building characteristics
Impact by mass	Rockfall	Impact by rock blocks	
	Snow avalanche	Impact by snow mass	
	Landslide		
	Pyroclastic flow		
	Lava flow		
	Debris flow		
	Airplane crash		
Impact by wind	Tornado		
	Cyclone		
	Explosion		
Under-cutting	Erosion		
	Landslides		
Shaking	Earthquake		
Inunda-tion	Flooding		
	Tsunami		
	Debris flow		
Fire	Fire		
	Bush fire		
Gasses			
Loss of support	Liquefaction		
	Subsidence		
	Landslides		
Covering	Snow		
	Ash fall		

Buildings are consisting of different components. The main difference is :

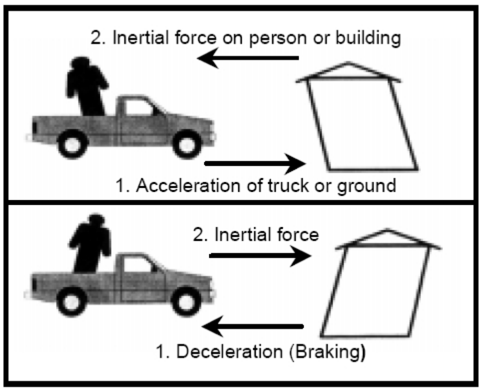
- **Structural elements**: those elements of buildings important for maintaining the structural integrity of the building: the building's structural support systems (i.e., vertical- and lateral-force-resisting systems), such as the building frames and walls. If these elements fail under a hazard impact, there is a large chance that the structure might fail.
- **Non-structural elements**: all those elements of a building not essential for its structural integrity. The failure of a non-structural element will not lead to the collapse of the building. Examples are: chimneys, infilled walls, water tanks, and of course all the contents of the buildings.

In the following section some examples are given of the effects that particular types of hazard have on buildings. We will do this for earthquakes, flooding and landslides.

4.3.1 Building behavior under an earthquake

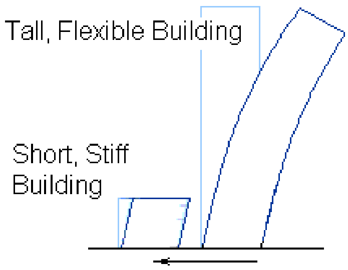
A summary of information on the behavior of buildings under an earthquake can be found at: http://www.conservationtech.com/FEMA-WEB/FEMA-subweb-EQ/index.htm and

Figure 4.11: Comparison between a person in a car and the behavior of a building in acceleration an deceleration movements.



During a strong earthquake a building may experience sudden movements in both horizontal as vertical direction. The building gets thrown back and forth by the earthquake movement, whereas the base part of the building, connected to the ground that is actually moving, has the first movement (See figure 4.11 with a resemblance of a person in a car). The rest of the building is "lagging behind" in this movement, which creates large frictions in the building. The force F that an upper floor level or roof level of the building should successfully resist is related to its mass m and its acceleration a, according to Newton's law, F= ma.
The heavier the building the more the force is exerted. Therefore, a tall, heavy, reinforced-concrete building will be subject to more force than a lightweight, one-story, wood-frame house, given the same acceleration. Damage can be due either to structural members (beams and columns) being overloaded or differential movements between different parts of the structure. If the structure is sufficiently strong to resist these forces or differential movements, little damage will result. If the structure cannot resist these forces or differential movements, structural members will be damaged, and collapse may occur.
Earthquakes are series of complicated interwoven series of waves, which a certain frequency (See also chapter 3 on the earthquake hazard part). All objects or structures have a natural tendency to vibrate. The rate at which the object wants to vibrate is its fundamental period (natural frequency). Which can be approximated by:

$$f_n = \frac{1}{2\pi}\sqrt{\frac{K}{M}}$$



Where K= Stiffness, which is the property of an object to resist displacement, and M=Mass.
Buildings tend to have lower natural frequencies when they are either heavier (more mass) or more flexible (that is less stiff).
One of the main things that affect the stiffness of a building is its height. Taller buildings tend to be more flexible, so they tend to have lower natural frequencies compared to shorter buildings.
There is a general rule of thumb that relates the number of stories to the natural frequency of buildings:

$$\mathbf{F_n = 10/n}$$

Where Fn = natural frequency of buildings, and n = number of floors. The relation between number of floors, natural frequency and fundamental period (1/frequency) is shown in table 4.9.

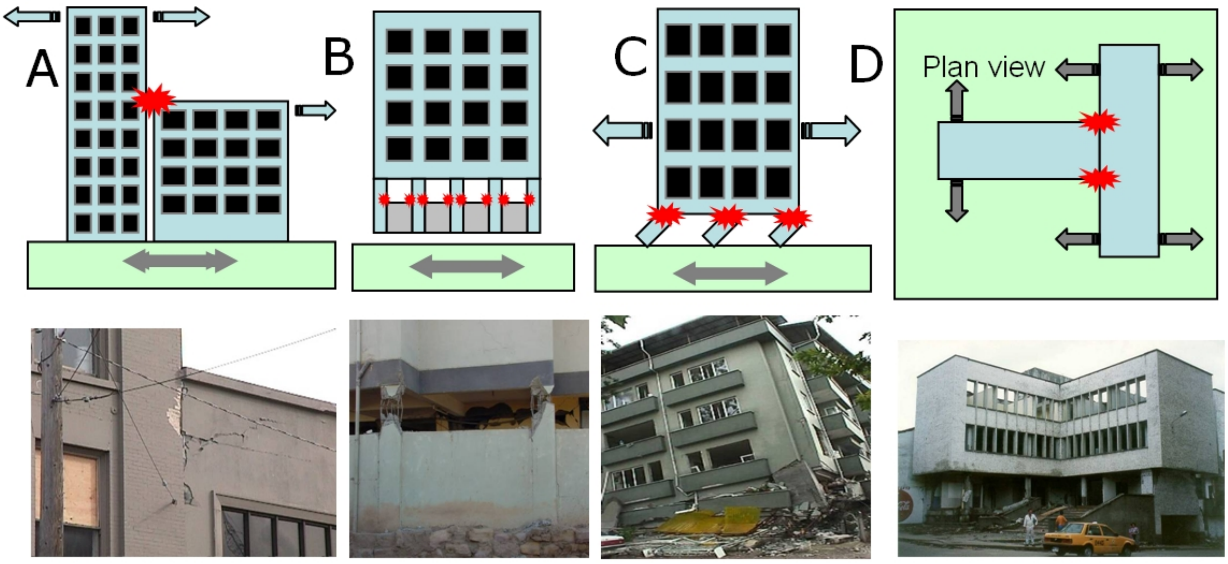
Table 4.9: General relation between number of floors, natural frequency and fundamental period of buildings according to the rule of thumb

Type of object	Natural frequency (Herz)	Fundamental period (Seconds)
One-floor buildings	10	1
2-5 floor buildings	5-2	0.5 – 0.2
5-10 floor building	2–1	0.2 - 1
10 – 20 floors building	1 – 0.5	1 - 2
20-40 floor buildings	0.5 – 0.25	2 - 4

Factors that influence the behavior of buildings under an earthquake are:

- **Duration and severity of ground shaking**. Large earthquakes tend to shake longer and harder and cause more damage. Earthquakes with Richter magnitudes less than 5 rarely cause significant damage to buildings, since acceleration levels (except when the site is on the fault) and duration of shaking for these earthquakes is relatively small. In addition to damage caused by ground shaking, damage can be caused by degradation of the building foundation, landslides, fires and tidal waves (tsunamis).
- **Soil types**. Soil also has a natural frequency which is determined by the soil type and the soil thickness. If the natural frequency of the soil is the same as the natural frequency of the building, the building will start to resonate. This can be compared with an opera singer that manages to break a glass by singing a pure tone with a frequency that is exactly the natural frequency of the glass. Soft, loose soils tend to amplify the ground motion and in many cases a resonance effect can make it last longer. In such circumstances, building damage can be accentuated.
- **Height of the building**. The height of a building determines its resonance frequency. Low buildings have a high resonance frequencies (large wavelengths), and tall buildings have a low resonance frequencies (short wavelengths). This means that low-rise buildings are susceptible to damage from high-frequency seismic waves from relatively near earthquakes and/or shallow depth. High-rise buildings are at risk due to low-frequency seismic waves, which may have originated at much greater distance and/or large depth

Figure 4.12: Examples of earthquake damage to buildings. A: Pounding of nearby buildings; B: Short column effect, causing break of columns; C: Soft storey effect, causing collapse of building over lower floor often used as parking lot; D: Torsion effect due to irregularly shaped building



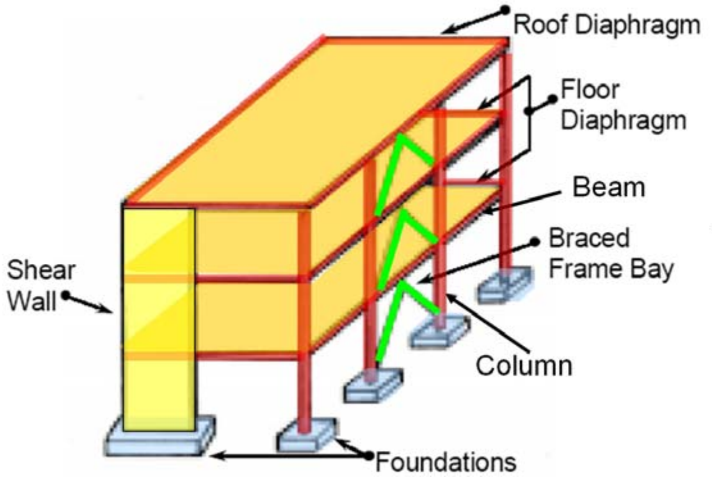
- **Spacing of buildings**. Earthquake damage can be also caused by tall buildings that are close together and that are pounding against each other (see figure 4.12)
- **Building materials.** Under small earthquakes buildings behave elastically, deforming as force is applied and returning to its original shape when removed. However, if the shaking is very strong that limit of elasticity is reached, and ductility becomes important. <u>Ductility</u> is the property of certain elements that have inelastic deformation before failing. Ductile materials, such as wood, steel or reinforced concrete withstand earthquakes better than so called brittle materials such as unreinforced masonry.
- **Structural types.** The following structural systems can be differentiated:
  - **Bearing wall systems** consist of vertical load carrying walls located along exterior wall lines and at interior locations as necessary. Many of these bearing walls are also used to resist lateral forces and are then called <u>shear walls</u>. Bearing wall systems may use some columns to support floor and roof vertical loads. This type of system is very common and includes wood-frame buildings, concrete tilt-up buildings and masonry wall buildings.
  - **Building frame systems** use a complete three dimensional space frame to support vertical loads, but use either shear walls or <u>braced frames</u> to resist lateral forces. Examples of these include buildings with steel frames or concrete frames along the perimeter and at intervals

throughout the interior supporting vertical loads from floors and roof. Building frame systems typically use steel braced frames or concrete or masonry shear walls to resist lateral forces..

- o **Moment-resisting frame systems** can be steel, concrete, or masonry construction. They provide a complete space frame throughout the building to carry vertical loads, and they use some of those same frame elements to resist lateral forces. Shear walls (and braced frames) are not used in this system.

Structural systems using concrete or masonry shear walls are stiff and result in buildings with short periods, whereas more flexible moment-frame systems have longer periods. In general, a large portion of the earthquake energy is contained in short-period waves. Therefore, short-period buildings with stiff structural systems are designed for larger forces than long-period, flexible, buildings. This concept is also applicable to the amount of force individual structural seismic elements and their components must resist. Stiff elements must be made stronger because they will attempt to resist larger earthquake forces than flexible elements in the same structural system.

Figure 4.13: Building elements used to used to transmit and resist lateral forces. Diaphragms serve primarily as force-transmitting or force-distributing elements that take horizontal forces from the stories at and above their level and deliver them to walls or frames in the story immediately below



- **Connections**. Strong building connections allow forces and displacements to be transferred between vertical and horizontal building elements. In addition, strong connections increase the overall structural building strength and stiffness by allowing all of the building elements to act together as a unit. Inadequate connections represent a weak link in the load path of the building and are a common cause of earthquake building damage and collapse.
- **Damping**. Damping diminishes the resonance by pulling the energy out of the system as heat - in the way that a shock absorber in a car dampens a car's vibrations from bumps in the road. Damping is imparted to a building by the cracking and inelastic movement of its structural elements and it can also be deliberately added by installing shock absorber-like devices into the building's structure.
- **Weight Distribution**. Buildings that are wide at their base and have most of their weight distributed to their lowest floors generally fare better in earthquakes than tall, top- heavy buildings which act like an inverted pendulum. Inverted pendulum buildings usually experience greater displacements than those shorter and heavier near the base.
- **Building Configuration**. Square or rectangular buildings with floor plans with symmetrically place lateral force resisting elements tend to perform better in earthquakes than buildings composed of irregular shapes or 'those with large foyers or lobbies that create a soft story condition. Buildings with irregular shapes cannot distribute lateral forces evenly, resulting in torsional response that can increase damage at key points in the building. (see figure 4.12)
- **Maintenance of the building**. Especially in the case of steel and wooden buildings, poor maintenance leads to a decrease in the strength of the supporting frame. Decades of neglect in the form of lack of antirust paint for example, can lead to the weakening of steel frame systems.

4.3.2 Building behavior during a flood

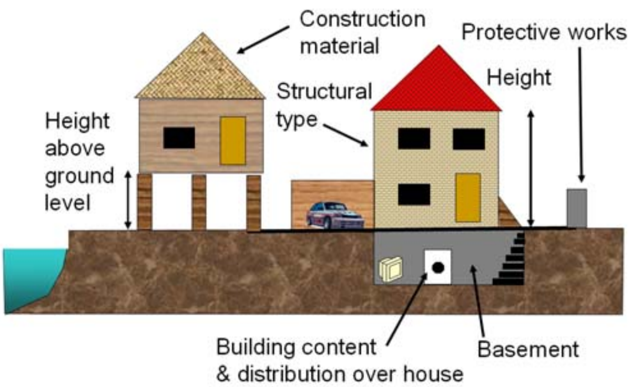
Damage to buildings from flooding is caused by a number of factors:

- **Type**: different flood types may cause different degrees of damage to buildings and their contents, e.g. coastal flooding, riverine flooding, flashflood. They will determine a number of the following factors.
- **Velocity**: fast flowing waters will have the capacity to impact the structure, and the lateral forces caused by the flood may produce collapse of buildings. High velocity floods may cause erosion/scouring of embankments, slopes, levees, and building foundations;
- **Height**: flood depth is an important factor as it will determine how much of the building will be submerged under water, and together with the velocity will determine the impulse of flooding. Impulse is velocity multiplied by height.
- **Duration**: flood duration is very important in relation to the construction materials of the building and the way they may deteriorate under the influence of water. For example masonry buildings will be heavily affected by salt water in the case of coastal flooding, which may have a long duration effect on the building.
- **Sediment**: the amount of sediments will determine the way in which a building and its contents is damaged and it will determine the clean-up costs.
- **Pollution:** polluted water will have a deteriorating effect on buildings and its contents.

The following building characteristics are important for determining the damage due to flooding:

- **Building use**: the use of the building will determine the number of people present in the building in different periods of time, and the contents and the value of the contents. This was already discussed in the previous section of this session.
- **Building materials**: the type of building materials will determine how they behave under water saturation, also with a long duration. Wood and masonry materials will have substantial large damage compared to steel or concrete.
- **Structural type**: the structural type, as mentioned in the previous section will determine whether the building can withstand the impact of fast floods
- **Height above the ground**: the height above the surface will determine the degree of flooding and which types of building contents are damaged.

Figure 4.14: illustration of building characteristics that are important for flood loss assessment.

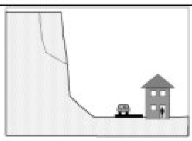
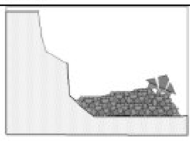
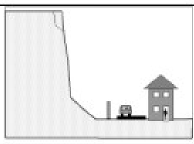
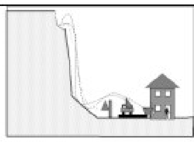
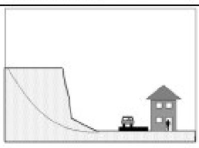
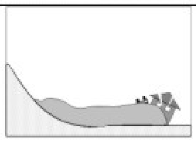
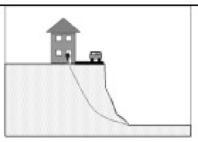
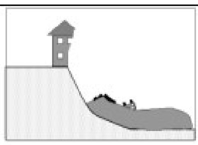
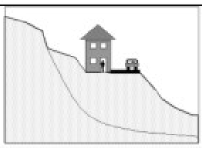
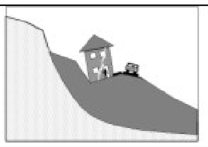
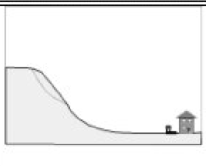
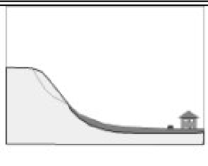
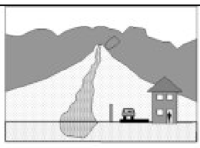
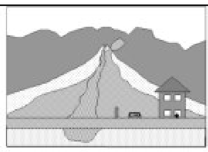
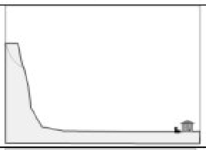
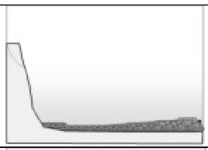
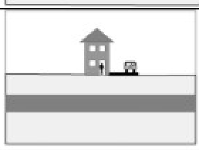
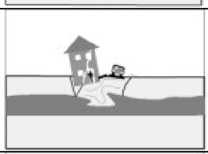
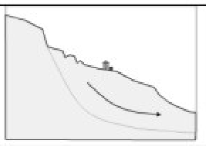
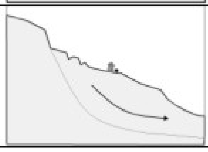


- **Maintenance level**. As discussed before poor maintenance weakens the building.
- **Location of doors and openings**: the location of openings will determine if and where flood waters can enter the building.
- **Presence of a basement**: the presence of a basement, and whether a basement has windows or not will determine the degree of damage even when the floodwaters are very low.
- **Height of the building**: the building height will determine how much of the building will be flooded. If the building consists of more storeys, the inhabitants will have distributed the content of the building over more floors, causing less damage when the lower floor is flooded. It also allows evacuation of people and valuable contents to higher floors.
- **Distance to the channel**: the proximity to a channel may determine whether the building will be undercut by a fast eroding stream, leading to the collapse of the building. Also the foundation of the building is relevant in this respect.
- **Presence of walls and other flood retaining structures**: the presence of walls around the building, or small levees will make that the building is flooded only at a later phase.

4.3.3 Building behavior under a landslide

Since there are so many different types of landslides, it is difficult to indicate what are the main building characteristics that determine the degree of loss to landslides, as indicated in figure 4.15. The type, velocity and volume of the movement will determine whether the building is only damaged or whether is will be completely destroyed. Also the distance of the building to the source of the movement will play a very important role, and the determination of the runout is therefore very relevant. The important building characteristics are more or less similar to those that are relevant for earthquakes, in particular the structural type, and the foundation type. The orientation of the building and proximity to other buildings are also very relevant, as a building may be in "the lee side or shadow" of other buildings which may take the main impact and reduce the damaging effect.

Figure 4.15: different ways in which a building might be affected by a landslide

Type	Before	After	Likely damage to elements at risk	Factors determining risk
Impact by large rockmass			**Buildings:** Total collapse likely **Persons in buildings:** Loss of life/ major injury likely **Infrastructure:** Coverage and obstruction / destruction of surface **Persons in traffic:** Loss of life/ major injury possible	• Volume of rockfall mass • Location of source zone • Distance to Elements at risk • Triggering factors • Local topography along track • Intermediate obstacles • Precursory events
Impact by single blocks			**Buildings:** Total collapse not likely. Localized damage **Persons in buildings:** Minor to major injury likely **Infrastructure:** Coverage and obstruction of traffic **Persons in traffic:** Loss of life/ major injury possible	• Volume of rockfall blocks • Number of rockfall blocks • Location of source zone • Distance to Elements at risk • Triggering factors • Local topography along track • Intermediate obstacles
Impact by landslide mass			**Buildings:** Collapse / major damage depending on volume **Persons in buildings:** None, persons are normally able to escape **Infrastructure:** Coverage and obstruction of traffic **Persons in traffic:** None, persons are normally able to escape	• Volume of landslide mass • Water content • Landslide material type • Triggering factors • Distance to Elements at risk • Local topography along track • Speed of landslide movement
Loss of support due to undercutting			**Buildings:** Collapse / major damage likely **Persons in buildings:** None, persons are normally able to escape **Infrastructure:** Complete destruction of road surface. **Persons in traffic:** None, persons are normally able to escape	• Volume of landslide mass • Water content • Landslide material type • Triggering factors • Retrogressive landslide • Cliff erosion • Speed of landslide movement
Differential settlement /tilting due to slow movement			**Buildings:** Tilted buildings with cracks. Normally no collapse **Persons in buildings:** None, slow movement. People not in danger **Infrastructure:** Tilting and cracks, traffic slowed down **Persons in traffic:** None, slow movement	• Volume of landslide mass • Water content • Landslide material type • Triggering factors • Speed of landslide movement • Amount of displacement
Impact by debris flow on slope			**Buildings:** Filled by mud, damage to contents **Persons in buildings:** Minor-major injuries. Depends on speed. **Infrastructure:** Coverage of road surface. Obstruction of traffic. **Persons in traffic:** Minor-major injuries. Depends on speed.	• Volume of landslide mass • Water content • Slope steepness • Local topography • Landslide material type • Triggering factors • Speed of movement • Size of blocks transported
Flooding by debris flow on alluvial fan			**Buildings:** Filled by mud, damage to contents **Persons in buildings:** None, persons are normally able to escape **Infrastructure:** Coverage **Persons in traffic:** None, persons are normally able to escape	• Volume of debris flow • Water & sediment content • Local topography of fan • Triggering factors • Distance from source • Distance from lahar channel • Speed
Impact by Sturzstrom			**Buildings:** Total collapse **Persons in buildings:** Loss of life **Infrastructure:** Total destruction **Persons in traffic:** Loss of life	• Volume of rockfall mass • Location of source zone • Distance to Elements at risk • Triggering factors • Local topography along track • Distance from source zone • Precursory events
Liquefaction			**Buildings:** Differential settlement, cracks **Persons in buildings:** Minor injuries or no-injuries **Infrastructure:** Differential settlement, cracks **Persons in traffic:** no-injuries	• Soil types • Soil strength • Grainsize distribution • Foundation types • Earthquake intensity • Water table
Deep seated creep movement			**Buildings:** Differential settlement, tilting, cracks **Persons in buildings:** Minor injuries or no-injuries **Infrastructure:** Differential settlement, cracks, broken pipes **Persons in traffic:** no-injuries	• Speed of movement • Local geological situation • Age of landslide • Seasonality of movement

4.3.3. Generating building attributes

Based on the three examples the following list of building characteristics is presented in Table 4.10. In this table the importance for a number of hazard types is indicated.

Table 4.10: Summary of importance of building characteristics for damage estimation for different hazard types. Red = very important, Yellow= less important, Green = not important.

Building characteristics	**Earthquake**	**Flooding**	**Landslides**	**Techno-logical**	**Cyclone**	**Fire**
Structural type						
Construction materials						
Building code applied						
Age						
Maintenance						
Roof type						
Building height						
Floor space						
Building volume						
Shape						
Proximity to other buildings						
Proximity to hazard source						
Proximity to vegetation						
Openings						

There are many items in the table that have to do with the quality of the construction. The structural type combined with the construction materials determine the strength of the building. But also the fact whether the building have been constructed according to a building code. The factor "age" can be used as a proxie to determine whether buildings are older or younger to the date when building codes where enforced in a given area. Age and maintenance also are indications for the current state of the building.
There are two factors that can be considered most important: **structural type** and building height. Table 4.11 gives a summary of the main structural types used in the HAZUS methodology for earthquake loss estimation. In the case of flooding and hurricanes, a more simplified classification of structural type and height of buildings is used. However, this classification of structural types can not simply be used in developing countries as they will often have far more buildings in the masonry class. Masonry buildings consisting of field stones, or adobe (mud blocks) are very common in developing countries. For instance figure 4.16 gives an example of a building classification used in the city of Lalitpur, Nepal.

Table 4.11: Building structure types used in the HAZUS methodology for earthquake loss estimation, combining structural types and height of buildings. Each combination has its own code, and is linked to vulnerability curves for that particular type. A description of each of the structural types can be found on http://www.conservationtech.com/FEMA-WEB/FEMA-subweb-EQ/02-02-EARTHQUAKE/1-BUILDINGS/D3-Bldg-types.htm

Main	**Building structure type**	**Low rise 1-2 stories**	**Mid rise 4-7 stories**	**High rise ≥ 8 stories**
Wood frame	Wood, Light Frame (≤ 5,000 sq. ft.)	1 (W1)	-	-
	Wood, Commercial and Industrial (> 5,000 sq. ft.)	2 (W2)		
Steel frame	Steel Moment Frame	3 (S1L)	4 (S1M)	5 (S1H)
	Steel Braced Frame	6 (S2L)	7 (S2M)	8 (S2H)
	Steel Light Frame	9 (S3)		
	Steel Frame with Cast-in-Place Concrete Shear Walls	10 (S3L)	11(S3M)	12 (S3H)
	Steel Frame with Unreinforced Masonry Infill Walls	13 (S3L)	14 (S3M)	15 (S3H)
Rein-forced concrete	Concrete Moment Frame	16 (C1L)	17(C1M)	18(C1H)
	Concrete Shear Walls	19 (C2L)	20 (C2M)	21 (C2H)
	Concrete Frame with Unreinforced Masonry Infill Walls	22 (C3L)	23 (C3M)	24 (C3H)
	Precast Concrete Tilt-Up Walls	25 (PC1)		
	Precast Concrete Frames with Concrete Shear Walls	26 (PC2L)	27 (PC2M)	28 (PC2H)
Masonry	Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms	29 (RM1L)	30 (RM1M)	-
	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms	31(RM2L)	32 (RM2M)	33 (RM2H)
	Unreinforced Masonry Bearing Walls	34 (URML)	35(URMM)	-
	Mobile Homes	36 (MH)		

Floorspace is another very important building factor required for loss estimation. It is used directly in combination with urban land use type to estimate the number of people in the buildings. Floor space should ideally be obtained from **building footprint maps**, or from cadastral maps. However, cadastral maps often show the various plots of land with different owners, which often do not coincide with building boundaries. Therefore, such maps are mostly made from high-resolution satellite images or airphotos, using on-screen digitizing. On-screen digitizing of building footprints can be a very labour intensive work. Literally thousand of individual polygons should be mapped. For instance, the RiskCity dataset that we are using is only for a part of the city, but it already contains around 30000 individual polygons. Sometimes it is possible to use already digitized building footprint maps. However, once should be careful with those, for several reasons. A common problem found is that there is no link between non-spatial data (e.g. housing data) and spatial data (e.g. building footprints).They might be in a data format like AutoCad DXF, which doesn't have topology, and which has a complete segment around each polygon. To edit this for so many polygons is very difficult. The other caution is that the map might not be up to date. This is illustrated in Figure 4.17 where an existing building footprint map from 1998 was updated with image interpretation from an Ikonos image. Also efforts have been made to automatically extract buildings from InSar, Lidar and IKONOS.

Figure 4.16: Example of the number of buildings per homogenous unit for 4 different structural types of building in Lalitpur, Nepal: Adobe, Brick in Mud (BM), Brick in Cement (BC) and Reinforced Concrete Buildings (RCC). (Source: ITC MSc Jeewan Guragain, 2004.

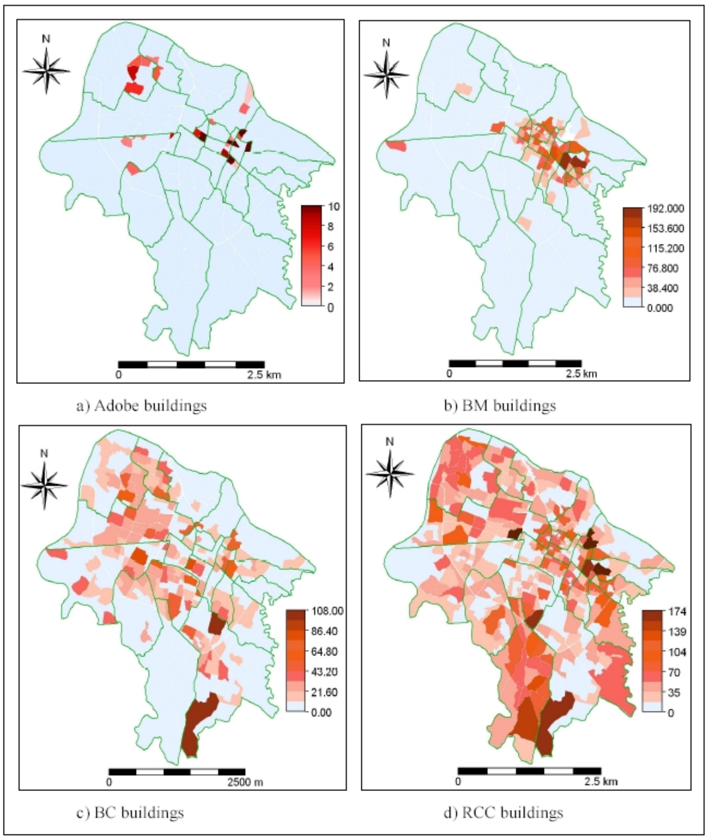
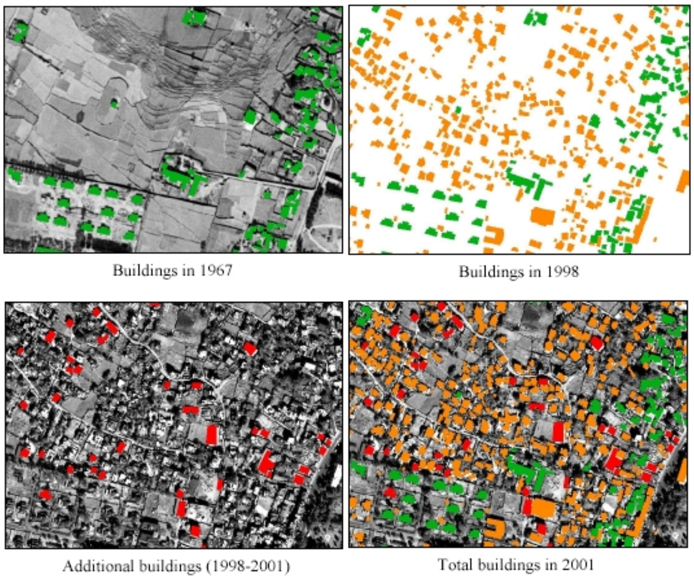


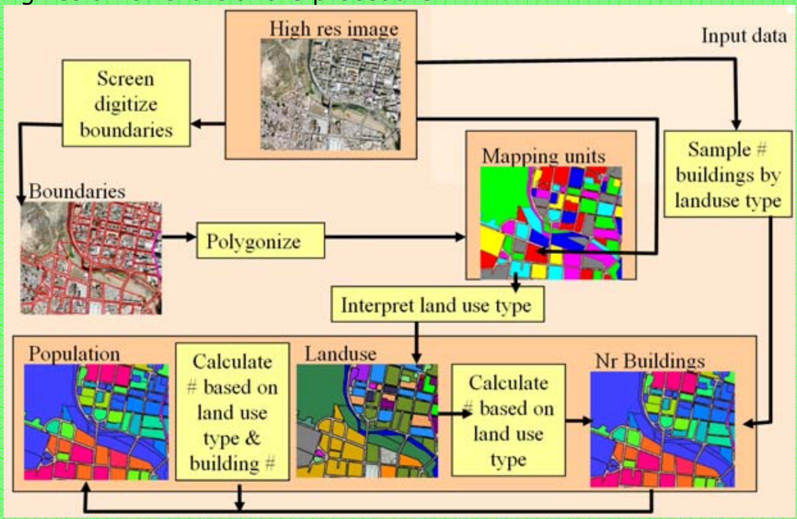
Figure 4.17: Illustration of the use of multi-temporal imagery for building mapping in Lalitpur, Nepal. A Corona image was used for 1967, and existing building footprint maps for 1998, and an Ikonos image for 2001.



Attempts have been made to generate building footprint maps automatically from high resolution images using Object Oriented Analysis with image segmentation techniques (e.g. using the software Definiens). The results are promising, especially when also height information on buildings can be used in the analysis. However, still a lot of manual editing is needed, and currently the technique is not a substitute yet for manual interpretation.

Task 4.8: RiskCity exercise: Generating an element at risk database from scratch (duration 3 hours)

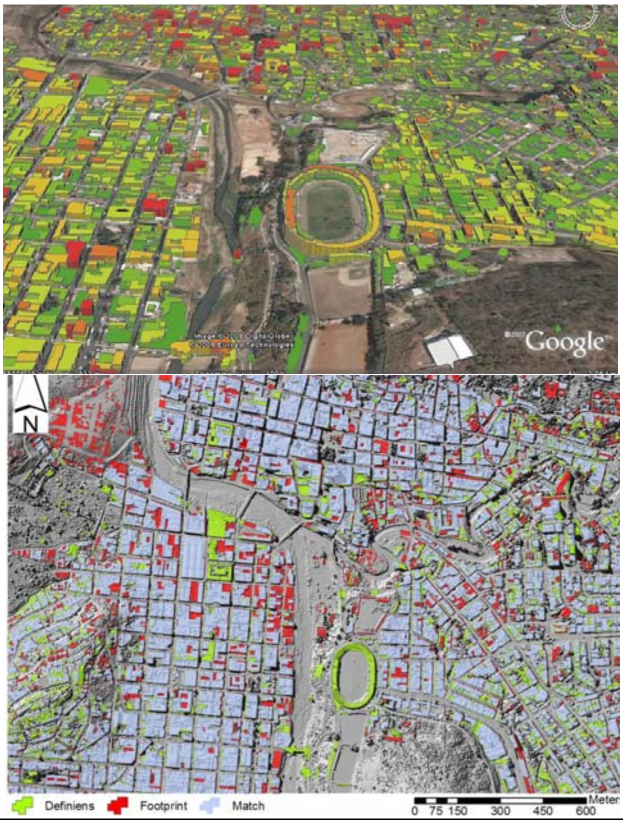
This is a good moment to pause the theory part and continue with the RiskCity GIS exercise number 4A: Generating an elements at risk database from scratch.
This exercise gives several methods for the generation of a database for the elements at risk within RiskCity, focusing on buildings and population. First it is assumed that no detailed building information is available, and the number of buildings has to be estimated based on the urban land use type and the average floorspace of buildings per land use type. Population estimates are made based on the building floorspace.
The basic unit for risk assessment we will use in this exercise is the so-called mapping unit. It consists of a number of buildings, and can be compared with a city block, or a census tract.
In this exercise you first generate mapping units by on-screen digitizing, and then you will collect attribute information on urban land use, number of buildings and population density.
The figure below gives a flowchart of the procedure



Building height

Another very important building attribute is height. It is needed to evaluate the vulnerability to earthquakes and flooding, and it is needed together with the area of the building footprints to calculate the total floorspace of the buildings within a mapping unit, or the building volume. Traditionally building height is very difficult to obtain over a large area. It is normally mapped in the field on the basis of house-by-house surveys. Another option is to use photogrammetry with airphotos or high resolution satellite imagery (e.g. Cartosat 1). However the best technique available is the use of Airborne Laser scanning (LiDAR). LiDAR data is used as point clouds with multiple returns, to determine the top of buildings, and the overall building altitude. This is converted to the number of floors based on the average height of one floor derived from a sample of the buildings. Object Oriented Analysis has proven to be quite successful for building footprint mapping from Lidar data (see comparison with original building footprints in figure 4.18).

Figure 4.18: Above: Visualization of building footprints in Google Earth in 3-D using Lidar height data. Below: Automatically derived building footprint map from LIDAR using OOA



Task 4.9: RiskCity exercise: Generating an element at risk database with available data (duration 3 hours)

We will now look at the RiskCity GIS exercise number 4B: Generating an elements at risk database with available data.
Now we assume that we have good data available for generating the elements at risk database:
- A LIDAR dataset which will allow us to calculate building heights
- A building footprint map which will allow us to calculate exact floorspace areas, and
- Census data which will improve the population information.

The aim of this exercise is to use this data to generate the required building attributes for the elements at risk mapping: number of floors, number of buildings per mapping unit, and day and nighttime population.

Building costs

In order to estimate the cost of building one can differentiate the following source:
- Real-estate agencies, which represent the market price ("real"). Of course the market prices of buildings fluctuate depending on the economic situation.
- Cadastres in most developing countries, which indicate the ratable price ("fictitious") which is used as the basis for taxation.
- Engineering societies, which use the construction price ("replacement").
- Insurance companies, which use the insured amount for the building, if it is possible to have a building insurance against natural disasters,

In practice the costs of buildings are often based on the available data for either one of these sources. It is sometimes difficult to get hold of the building values as used by the cadastres, whereas it is easier to use the values from real estate agencies. Samples are taken from each type of building in the various land use classes. In some countries building societies produce a monthly index that allows to update property prices. Risk assessment can be carried out by using the replacement value or the market value. It is important to specify which one was used in the risk calculation.

An aspect that should be taken into account is the depreciation possibility. In some countries real estate is constantly growing in market value, provided that the maintenance to the building is adequate. The growth in value might be as high as 10 % a year, especially in economically positive periods, when there is considerable demand for real estate. In bad economic times and when the property is not maintained and the value of the building will go down rapidly as indicate in figure 4.19.

Figure 4.19: Depreciation: with age a building will loose its value due to deterioration.

A common problem with obtaining values of buildings is related to inflation. For instance, the monthly rise in prices of building materials is not always proportional to monthly inflation. If cadastral prices are reliable but the valuation was carried out a few years back, it is difficult to update the property price.

Apart from building costs also the content costs are very relevant, especially for those hazards that have less structural damage such as flooding. Figure 4.20 gives an idea of the damage of the costs (building and content) increase with increasing flood level.

Figure 4.20: Percentage of losses of the total value of the property due to increasing flood level, starting at -2.5 when basement is flooded. (Source: Fabio Luino)

Real estate value:
€ 240.000

Height H (m)	Damage %	Loss
+1,0	24	€ 57.600
+0,8	20	€ 48.000
+0,6	16	€ 38.400
+0,4	12	€ 28.800
+0,2	7	€ 16.800
0	5	€ 12.000
-0,5	4,5	€ 10.800
-1	4	€ 9.600
-1,5	3	€ 7.200
-2,0	2	€ 4.800
-2,5	0	0

4.3.4 Collection information on buildings: example of Turrialba, Costa Rica

This part shows an example of an elements at risk database for the city of Turrialba, located in Costa Rica. A series of color aerial photographs with a scale of 1:40,000 were scanned with high resolution and combined with a Digital Elevation Model and a series of ground-control points for the generation of an orthophoto-map (See Figure 4.21). On the orthophoto all buildings within the city and its direct surroundings were digitized, as well as the land parcels, the roads and other infrastructures. This resulted in a digital parcel map, consisting of 7800 polygons. Each polygon was described in the field by a team of investigators, making use of checklists for the collection of data on hazard and vulnerability. For each parcel the following attributes were described:

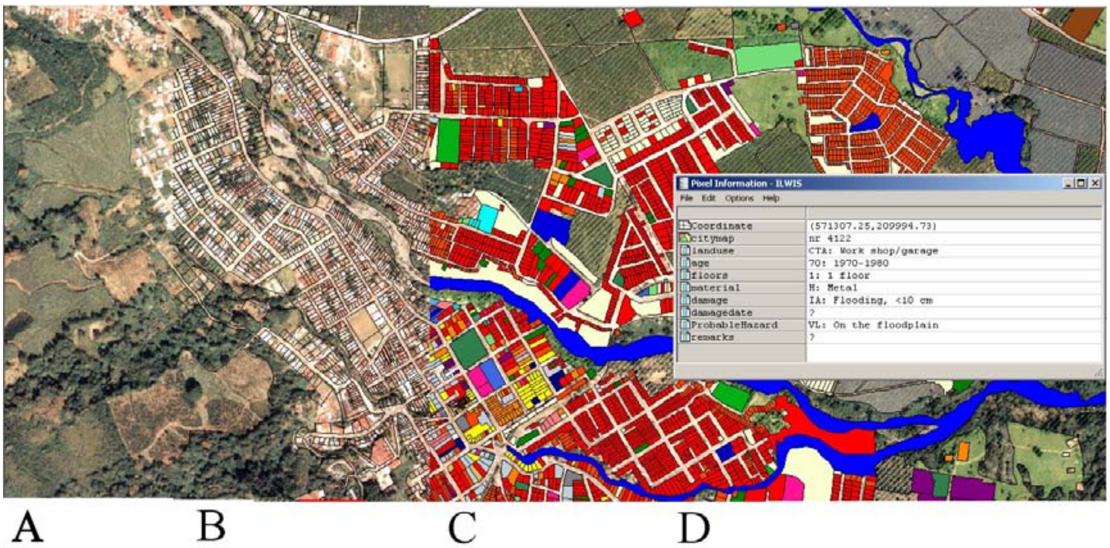
- **Use**: land use, with main division in residential, institutional, commercial, industrial, recreational, agricultural and others
- **Material**: material of the building, in order to estimate the vulnerability
- **Age**: age of the building, obtained through interviews
- **Value_building**: estimation of the replacement value of the building
- **Value_contents**: estimation of value of contents of building
- **Number of floors**
- **Hazard**: the hazard as observed or inferred by the experts in the field
- **Damage**: reported damage due to natural or human-induced hazardous events

Historical information on the occurrence of previous disastrous events was collected by interviewing elderly people, newspaper searches, and through the damage reports available in the INS (National Insurance Institute). Based on this information a database was generated, which is linked to the parcel database in GIS, and which allows for the generation of thematic maps on each of the above-mentioned parameters.

The database was used to generate vulnerability maps for the city. In the case of flooding, vulnerability functions were used to relate flooding depths with expected degrees of damage, using information for the construction of the buildings and for the contents of each building separately. On the basis of historical information, flood depth maps were generated for different return periods. These were combined with the vulnerability values and the cost information for the generation of cost maps. These were combined with the probability information in order to derive annual risk maps.

For the vulnerability reduction in the city by different hazards, the city map will be very helpful for the preparedness and disaster management. Besides this the map will be of great use for the municipality to find suitable areas for the further expansion of the settlement areas and also to relocate the people living in hazard prone areas. As the system is not only designed for disaster management, but serves as a multi-purpose tool, the municipality is using the orthophoto and the database for updating its land-ownership database in order to improve the tax collection system.

Figure 4.21: Different views of the large-scale database for the city of Turrialba. A: orthophoto, B: vector overlay of parcels, C: polygons displaying landuse type, D: reading information from the attribute database.



4.4 Population

The population in urban areas has both static and dynamic characteristics.
- The **static** characteristics relate to number of inhabitants, the densities of the population and the age compositions;
- The **dynamic** characteristics relate to the activities patterns of the people, and the distribution of the population in space and time. One of the most important socio-cultural vulnerability indicators is the time-distribution of the population.

For population characteristics, data from the national censuses can be used. Data collected at household level e.g. age, gender, income, education and migration.
Census data is the only consistent source for demographic data with a wide geographic scope. It is the most reliable and detailed information for describing local areas: neighborhoods, cities, counties. They are also used as benchmark data for studying population changes (trend/direction), and are key input for making projections concerning population, household, labour force and employment. Census data is the basis for government development programmes at district levels, and policy development, management and evaluation of programmes in fields of: education, literacy, employment and manpower, family planning, housing, maternal child health, rural development, transportation and highway planning, urbanization and welfare.
Census data is costly to collect. In the US the 2000 census was calculated to cost around 56 US $ per house. Census data is also confidential data and as it contains private information it is normally only available at an aggregated level.
Cadastres and censuses are very important inputs for risk assessment. However the classification of building types tends to be unsuitable, and the census tracts or enumeration districts may change from one census to the next.
HAZUS uses census data to estimate direct social loss due to displaced households, and casualties. The Census Bureau collects and publishes statistics about the people of the United States based on the constitutionally required census every 10 years, which is taken in the years ending in "0" (e.g., 1990). The Bureau's population census data describes the characteristics of the population including age, income, housing and ethnic origin. See table 4.12 for a list of the fields obtained from the census data, and how they are used. The population information is aggregated to a census tract level. Census tracts are divisions of land that are designed to contain 2500-8000 inhabitants with relatively

Table 4.12: Census data available for the US which is used in HAZUS for shelter need calculation (S), casualty estimation (C) and occupancy class estimation (O).

Description of Field	S	C	O
Total Population in Census Tract	*		
Total Household in Census Tract	*		
Total Number of People in General Quarter	*		
Total Number of People < 16 years old	*		
Total Number of People 16-65 years old	*		
Total Number of People > 65 years old	*		
Total Number of People - White	*		
Total Number of People - Black	*		
Total Number of People - Native American	*		
Total Number of People - Asian	*		
Total Number of People - Hispanic	*		
Total # of Households with Income < $10,000	*		
Total # of Households with Income $10 - $20K	*		
Total # of Households with Income $20 - $30K	*		
Total # of Households with Income $30 - $40K	*		
Total # of Households with Income $40 - $50K	*		
Total # of Households with Income $50 - $60K	*		
Total # of Households with Income $60 - $75K	*		
Total # of Households with Income $75 - $100K	*		
Total # of Households with Income > $100k	*		
Total in Residential Property during Day		*	
Total in Residential Property at Night		*	
Hotel Occupants		*	
Vistor Population		*	
Total Working Population in Commercial Industry		*	
Total Working Population in Industrial Industry		*	
Total Commuting at 5 PM		*	
Total Number of Students in Grade School		*	
Total Number of Students in College/University		*	
Total Owner Occupied - Single Household Units	*		*
Total Owner Occupied - Multi-Household Units	*		*
Total Owner Occupied - Multi-Household Structure	*		*
Total Owner Occupied - Mobile Homes	*		*
Total Renter Occupied - Single Household Units	*		*
Total Renter Occupied - Multi-Household Units	*		*
Total Renter Occupied - Multi-Household Structure	*		*
Total Renter Occupied - Mobile Homes	*		*
Total Vacant - Single Household Units			*
Total Vacant - Multi-Household Units			*
Total Vacant - Multi-Household Structure			*
Total Vacant - Mobile Homes			*
Structure Age <40 years			*
Structure Age >40 years			*

homogeneous population characteristics, economic status and living conditions.

Table 4.13: Population distribution data used in RiskCity exercise. This is a major simplification of reality.

Land use class	People/ building	AVG floor space M2	Day time	Nightt ime
Com_business	20	20	1	0
Com_hotel	100	12	0.1	1
Com_market	1000	10	1	0
Com_shop	10	23	1	0
Ind_hazardous	10	1000	1	0
Ind_industries	25	400	1	0
Ind_warehouse	20	2000	1	0
Ins_fire	25	64	1	1
Ins_hospital	800	38	1	1
Ins_office	100	16	1	0
Ins_police	50	32	1	1
Ins_school	300	33	1	0
Pub_cemetery	0	0	0	0
Pub_cultural	200	13	0	1
Pub_electricity	0	0	0	0
Pub_religious	500	10	1	0
Rec_flat_area	0	0	0	0
Rec_park	0	0	0	0
Rec_stadium	20000	3	0	0
Res_large	5	90	0.2	1
Res_mod_single	6	17	0.2	1
Res_multi	20	13	0.2	1
Res_small_single	6	11	0.2	1
Res_squatter	7	5	0.3	1
River	0	0	0	0
unknown	0	0	0	0
Vac_car	0	0	0	0
Vac_construction	0	0	0	0
vac_damaged	0	0	0	0

In the absence of census data static population information is generally derived through the building footprint map, where the land use type and the floorspace will determine the number of people present in a particular building. Standard values of population per area are used. Table 4.13 gives the general population values for RiskCity that will be used in the first exercise that deals with the generation of an element at risk map from scratch. In this method the population is estimated by mapping unit. For each mapping unit the number of buildings is estimated. Also the land use is given for each mapping unit. Table 4.13 then gives the general number of people present in a building of a particular land use type. These data are very general and do not incorporate the actual size of the building. For most of the residential areas this will be more or less adequate, as the 5 classes can also be fairly well linked with the average household size. For other land use types, such as schools, or hospitals this method might lead to wrong results, as it doesn't take into account the floorspace. In the second exercise that generates an elements at risk database using existing data such as building footprints, and LiDAR data, it is possible to estimate the floorspace for each building. In that case it is possible to calculate the number of persons per building by multiplying the average floorspace per person per land use type with the floorspace of the building. It is

	2:00 a.m.	2:00 p.m.	5:00 p.m.
Residential	0.99(NRES)	0.80(DRES)	0.95(DRES)
Commercial	0.02(COMW)	0.98(COMW)+0.15(DRES)+0.80(AGE_16)	0.50(COMW)
Industrial	0.10(INDW)	0.80(INDW)	0.50(INDW)
Commuting	0.01(POP)	0.05(POP)	0.05(DRES)+ 1.0(COMM)

where:
POP is the census tract population taken from census data
DRES is the daytime residential population inferred from census data
NRES is the nighttime residential population inferred from census data
COMM is the number of people commuting inferred from census data
COMW is the number of people employed in the commercial sector
INDW is the number of people employed in the industrial sector.
AGE_16 is the number of people 16 years of age and under inferred from census data (used as a proxy for the portion of population located in schools)

Table 4.14: Distribution of population for different periods of the day according the HAZUS methodology.

difficult to obtain general values for the average floorspace per person. Such type of information should be collected using participatory mapping, taking stratified samples for each land use class. For each sample the number of people in a building should be then related to the size of the building (See table 4.13). Table 4.14 shows the manner that HAZUS uses for estimating the dynamic population density in different land use types and different periods of the day. Note that all information on the required population estimates is coming from the census data (table 4.12). In the absence of census data the dynamic population can be estimated using day time and night-time factors as indicated in table 4.13

Participatory mapping for estimating population density and activity pattern

Participatory mapping can be a very useful tool for the generation of a population database, when detailed census data is lacking. Based on mapping of individual buildings together with interviews of local population it is possible to establish household activity patterns. An example of such a study is shown in Figure 4.22. Showing the daily distribution of household in their residence over the course of a day, for weekdays, sundays and holidays.

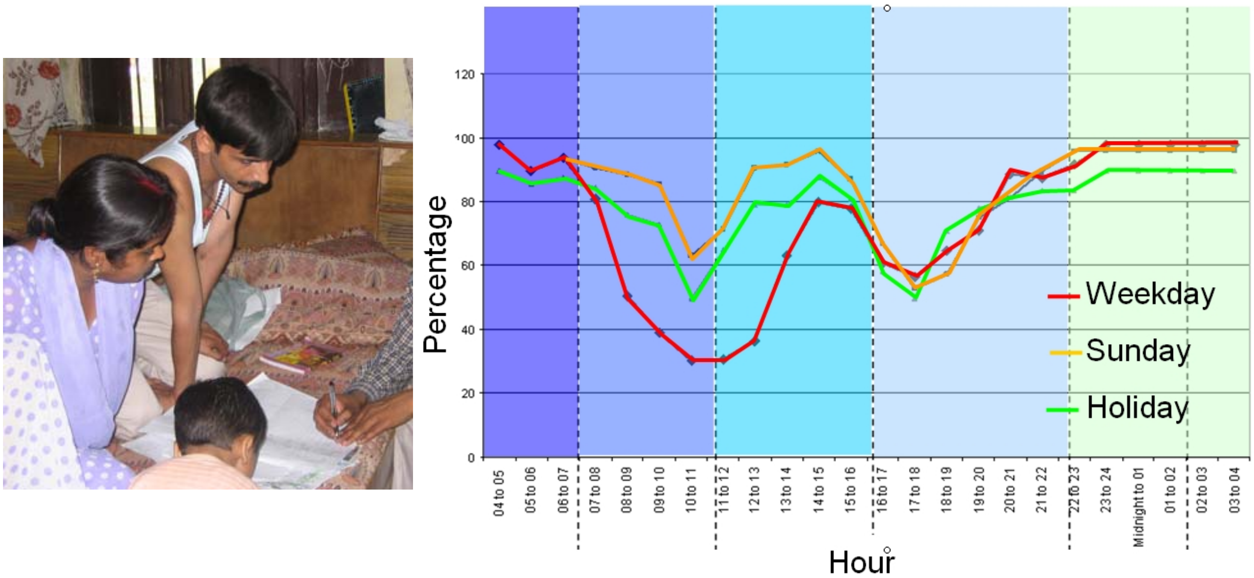
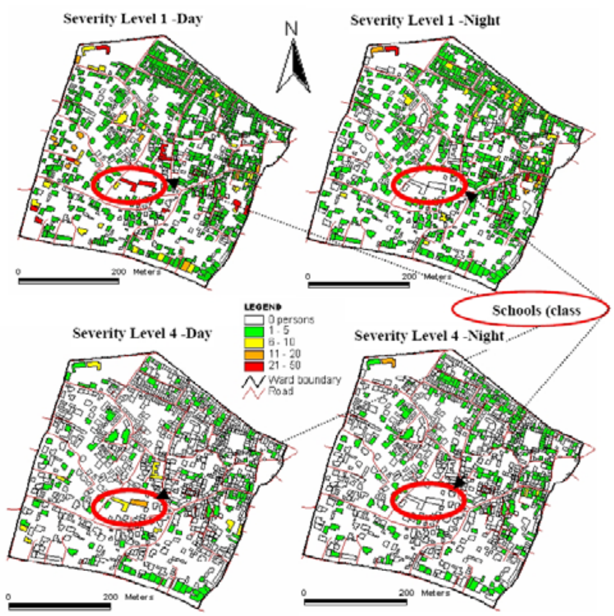


Figure 4.22 : Community based Household Activity Pattern Survey in Dehradun, India. Right: resulting activity pattern of households over a day.

Apart from people being present in buildings (by living/working/studying) there are also people who come from outside which stay for a while in the study area (e.g. for shopping, visiting, work or going to school). Based on similar activity studies for other urban land uses (school, shops, office etc.) it is possible to compute the population per building and per land use type for each period of the day, using a formula such as the one shown below. It should be noted that there is a considerable variation in commuting patterns and this type of formula should be calibrated.

$$\text{Hourly Presence of People} = \sum_i^1 \begin{array}{l} [\text{No of Households per building}] \ *(\text{Average Hourly Number of Persons}) \\ [\text{No of Shops}] * (\text{Average Hourly Number of Persons}) + \\ [\text{No of Schools}] * (\text{Average Hourly Number of Persons}) + \\ [\text{No of Other Units}] * (\text{Average Hourly Number of Persons}) \end{array}$$

Figure 4.23: Example of population losses due to earthquakes for different perods of a day and different earthquake scenarios (Source: Jimee, Van Westen and Botero, 2008)



This community based information can then be used for population loss estimation, based on earthquake scenarios for different periods of the day. Figure 4.23 Shows an example for a ward in the city of Lalitpur, Nepal. The large differences between night and daytime scenarios can be observed especially in the school areas.

4.5 Participatory GIS for Disaster Risk Assessment

For the generation of information at the local level it is important to work together with local communities, and learn from their local knowledge. Local or indigenous knowledge is often critical in understanding the vulnerabilities and capacities of an area, but is rarely available on maps and even less so in a format that can be entered into a GIS. However, this information is crucial as the local population has the best knowledge on the hazard events that they have experienced; their local causes and effects, and the way their community had to cope with them. This information is essential for land use planning, conflict management, and for disaster risk management. After all, disaster risk reduction aims at reducing the risk of the people against disaster events, and for the implementation of sustainable disaster risk management policies the support and collaboration of local people is essential.

4.5.1 Local Knowledge

In a participatory approach the knowledge of local people is not simple "tapped" by the outside people involved in a risk assessment study. This can of course also be done, but then the local community is considered an information source, and not a partner in the risk management. Local people have a vast amount of knowledge on hazards, vulnerability, and risk. However not all of this knowledge is readily available. It is often "**tacit knowledge**", of which they were not directly aware as they normally do not communicate this to outsiders. Therefore there has to be a process of "**eliciting the knowledge**", making them formulate it, and interact with them. This cannot be done in a fast and unpersonal manner. There has to be an atmosphere of confidence between local people and the risk investigators, before people are willing to formulate this type of knowledge. Local knowledge can consist of many components:

- Knowledge of historical disaster events, and the damages they have caused.
- Knowledge on the elements at risk, and how they value them.
- Knowledge on the factors contributing to vulnerability.
- Knowledge of their coping strategies and capacities to confront disasters.
- Knowledge about commuting patterns

However, local knowledge is often not recognized as an important source of information by investigators working in disaster risk projects in developing countries, especially those that are controlled by higher authorities. The knowledge is often perceived as non-scientific and often discarded at the favor of probabilistic models for risk assessments. Local knowledge is also perceived as difficult to retrieve, difficult to be expressed in quantitative terms or to be converted into spatial formats. The goal of participation is to give at risk communities ownership, the ability to express themselves, to learn from them, and ultimately to empower them through the acknowledgement of their skills, abilities, and knowledge. Participation improves the self–confidence and capacities for risk management of local communities and municipal authorities. They become aware of local knowledge as an asset they have in their own territories and hands and therefore need less external human, technical and economical assistance.

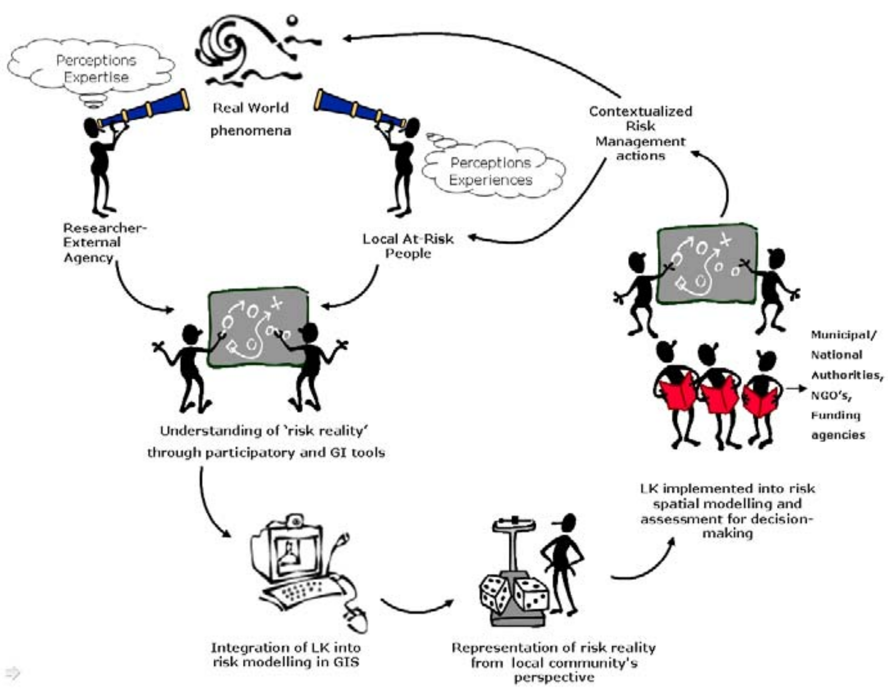


Figure 4.24: Local knowledge in participative risk assessment (source: Peters, 2008).

4.5.2 Tools for traditional community based Disaster Risk Management

Over the past decades many community-based methods have been developed as a diagnostic process leading to a common understanding of a community's disaster risks. The size of the hazard-related problems as well as the resources and opportunities to cope with these are identified and analyzed. Community risk assessment has four components: a) Hazard assessment; b) Vulnerability assessment; c) Capacity assessment and d) People's perception of the risks.
The tools commonly used employ methods such as workshops, (semi structured) interviews, transect walks in which the situation is discussed, focus group discussion, problem tree analysis, community mapping, ranking of problems and solutions, etc.
The information is assembled through tools such as Capacity and Vulnerability Assessment (CVA), Hazards, Vulnerability and Capacity Assessment (HVCA), and Damage, Needs and Capacity Assessment (DNCA). The typical information that can be gathered by these means is related to:

- Analysis of disaster management activities and practices at the community level.
- Community risk perception.
- Determination of the needs and expectations of the communities in relation to hazard mitigation and loss minimization.
- Assessment of their levels of preparedness.
- Methods to enhance their capacity and options for more effective responses to reduce vulnerability
- Community-based hazard management plans.

Figure 4.25: Examples of traditional CB methods for risk assessment using transets and sketchmaps (Source: Peters, 2008)

The Vulnerability and Capacity Assessment tool (VCA) is a practical and diagnostic method mostly used by NGOs for planning and evaluating projects. The VCA is aimed to help practitioners to understand the nature and level of risk that communities face, where the risk comes from; what and who will be worst affected; what assets are available at different levels to reduce the risk; and what capacities need to be further strengthened. Many toolkits have been developed, by organisatons such as IFRC, OXFAM, ADPC, ActionAID, Tearfund etc. For a good overview of the various methodologies please visit the webpage of the ProVention consortium: http://www.proventionconsortium.org/?pageid=43

Task 4.10: Video on Community based approaches (duration 30 minutes)
To understand better the community-based approach to disaster risk management at local level, it is good to watch one of the following videos on Youtube:
IFRC Preparing for Disaster: A community based approach
http://www.youtube.com/watch?v=AWS4s6E5ock
Building Community resilience to Disasters
http://www.youtube.com/watch?v=gmc3CoiCfKo

4.5.2 Focusing on spatial information in local risk assessment

The conventional methods for community based disaster risk assessment also collect and use spatial information, for example in the form of community mapping (See figure 4.25). However the product obtained through such processes, which are often also rather time consuming, remain where they are, or at best end up in a report, or are put on the wall of the community center. The spatial information is not maintained, and will be lost after a while. The spatial information is also not properly georeferenced so that it can be utilized in a GIS. Another problem is that such information is difficult to incorporate in the risk management planning of the local authorities. Where local authorities, who are responsible for the safety of the population living in the area of their jurisdiction, are not motivated or able to be involved in risk management, it is left up to the local communities to deal with the problem themselves. That is why there is such a large focus on these techniques by (international) NGO's working with low-income people in disaster prone areas. However, where the local authorities recognize their responsibility and are involved in risk assessment, it is crucial that the local information is incorporated into their plans.
Therefore it is surprising that there are not more applications of Participatory GIS or participatory mapping to hazard identification and risk mapping. Local people's direct experience or historical 'folk memories' of floods, water-logging, landslides, avalanches, storm damage, coastal inundation, etc., also of pest outbreaks, vulnerability to earth movements, etc., should be essential inputs to scientific assessments of the extent of hazards and the degree of risk. P-mapping and PGIS are excellently suited to the needs for incorporating local knowledge, participatory needs assessment & problem analysis, local prioritising, and understanding responses and coping strategies.

PGIS is a useful tool for extracting lay (indigenous) knowledge, perceptions of environmental problems and hazards, and presenting and communicating it to environmental scientists and local authorities.

Participatory GIS can be used for:

- Reconstructing historical hazardous events by obtaining eye-witness information from the local people in the affected communities.
- Obtaining information on the characterization of elements at risk at the local level. A considerable amount of information is not publicly available and can only be collected locally, with the help of the local communities.
- Understanding the coping mechanism that households in local neighborhoods employ with respect to the frequently occurring hazardous events like flooding.
- Understanding the factors that determine the level of vulnerability of the households in local communities, and their capacities.
- Evaluating the possible risk reduction measures that are suggested by local communities,
- Allowing interaction between local communities and Non-governmental organizations, as well as with local authorities.
- Post disaster damage mapping

It should be kept in mind that PGIS is not only about collecting information from the local communities, but rather about collecting information with them, and interact with them as they have local knowledge that is indispensable for reducing the risk.

Figure 4.26: Participatory mapping in action (Source: Peters, 2008)

4.5.3 Tools for Participatory mapping: Mobile GIS

In a participatory mapping approach basically the same tools can be used as in the traditional approaches mentioned before. More emphasis is given, however, to the representation of the spatial related information in a format that can be used in a GIS and can be updated and shared with other stakeholders. There is a wide range of non-digital techniques for participatory mapping, such as the generation of community maps on top of a large scale airphotos or satellite images. It is surprising how well local people are able to recognize their daily environment on such detailed images. Other techniques are the generation of simple scale models in 2-D or even in 3-D as people are much better at identifying features when they can refer to the terrain as they see it in three dimensions.
However the use of digital techniques for information collection are preferred, as this speeds up the process of data collection, and avoids the lengthy conversion of information into digital form. With the use of Mobile GIS it is possible to directly collect the spatial information, based on a high resolution image that can be uploaded into the palmtop computer, and link it with attribute information that is collected in the field. High resolution images can be compressed up to 25 times using software such as MrSid. Some of the most used tools for Mobile GIS are:

ArcPad
ArcPAd is one of the products of ESRI designed in combination with the ArcGIS suite, which allows users to make their own interface for data collection using a handheld device with a GPS connection. The data is collected in the format that can be directly applied in ArcGIS.

Cybertracker
CyberTracker software creates data entry templates to use on Windows PocketPC or PalmOS handheld computers to gather and map locally-generated, spatial knowledge. Connected to a GPS, CyberTracker instantly geo-references data. "CyberTracker's unique design allows users to display icons & text which makes data collection faster. It allows field data collection by non-literate users and school children". CyberTracker has been applied to local spatial knowledge in post-disaster relief operations. CyberTracker, Cape Town, South Africa. http://www.cybertracker.org/index.html

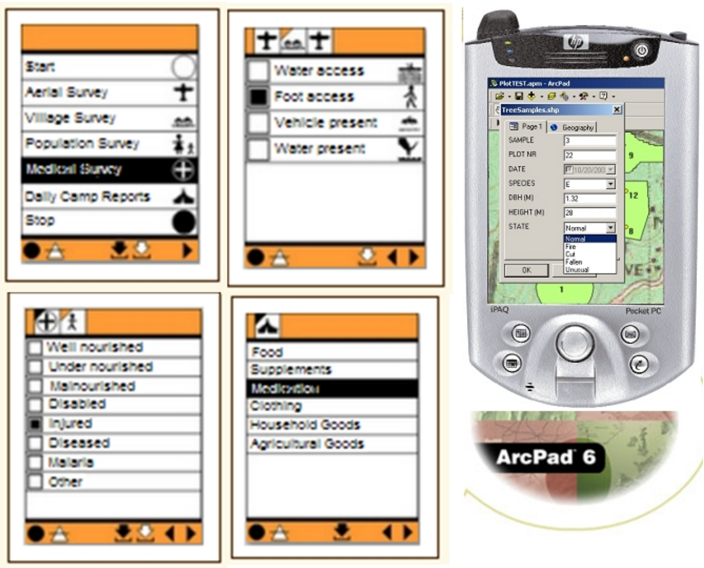


Figure 4.27: Left: Cybertracker input windows for a survey of disaster relief using simple icons. Right: View of ArcPad software installed on a hand held device.

Mobile GIS can be used for many of the steps involved in disaster risk management. Figure 4.28 shows an example for landslide mapping. Landslides are interpreted from stereoimages, and the interpretation is digitized and converted to the mobile GIS together with an orthoimage. In the field the boundaries are checked and the landslide attributes recorded. Figure 4.29 shows an example of mobile GIS developed for rapid mapping of building damage after a disaster (e.g. earthquake). In such cases there is a need for a rapid survey of many buildings, and a classification should be made in order to indicate if the building is still inhabitable.

Although mobile GIS has become a standard tool in many data collection projects, and is now also very affordable, it also has a number of limitations. There is always the danger that data might be lost if the device is stolen, damaged, or if data is accidentally deleted. Working with mobile device with small screens can also be rather problematic, especially in conditions of direct sunlight. Furthermore there is a danger that the operation of the device takes more time than the discussion with local people.

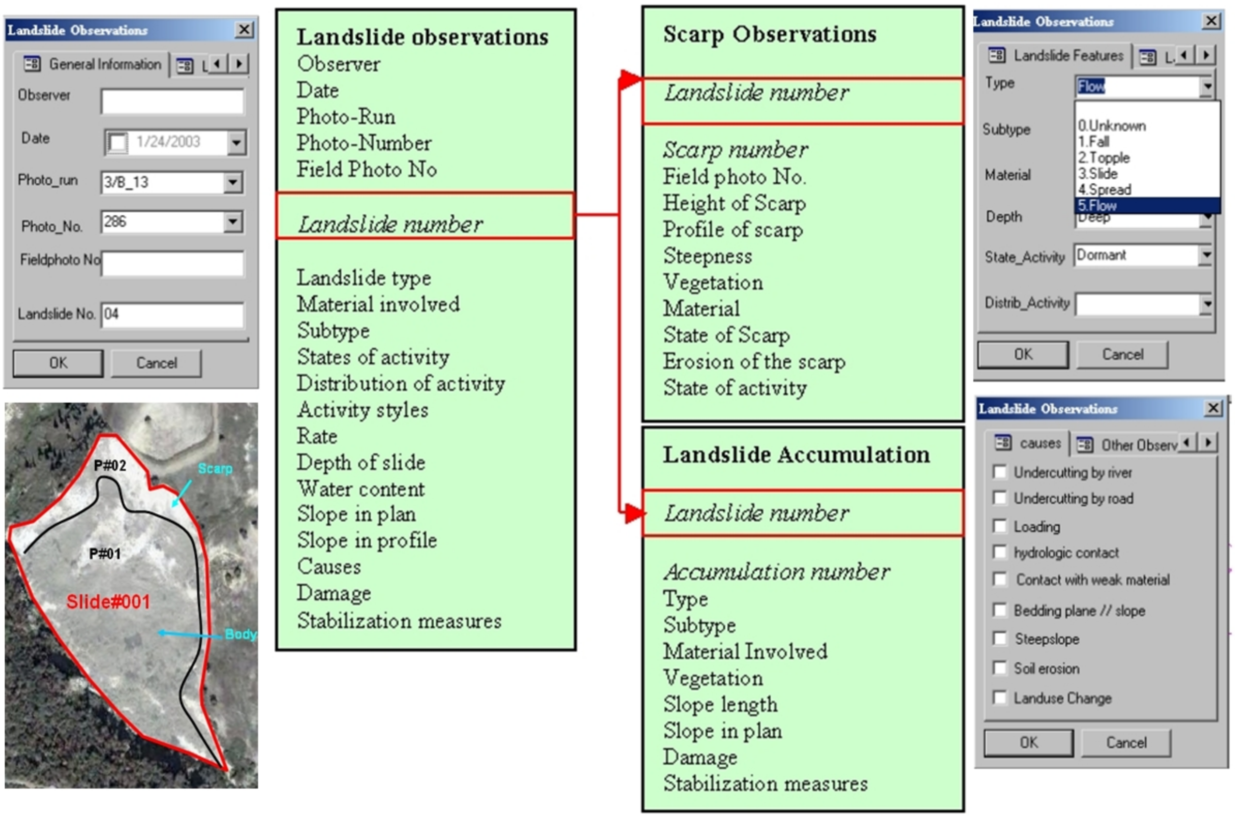


Figure 4.28: Mobile GIS for landslide inventory mapping. An example of the part of the database structure (center), input screens (left and right) and the interpreted landslide from a high resolution image, which is checked in the field.

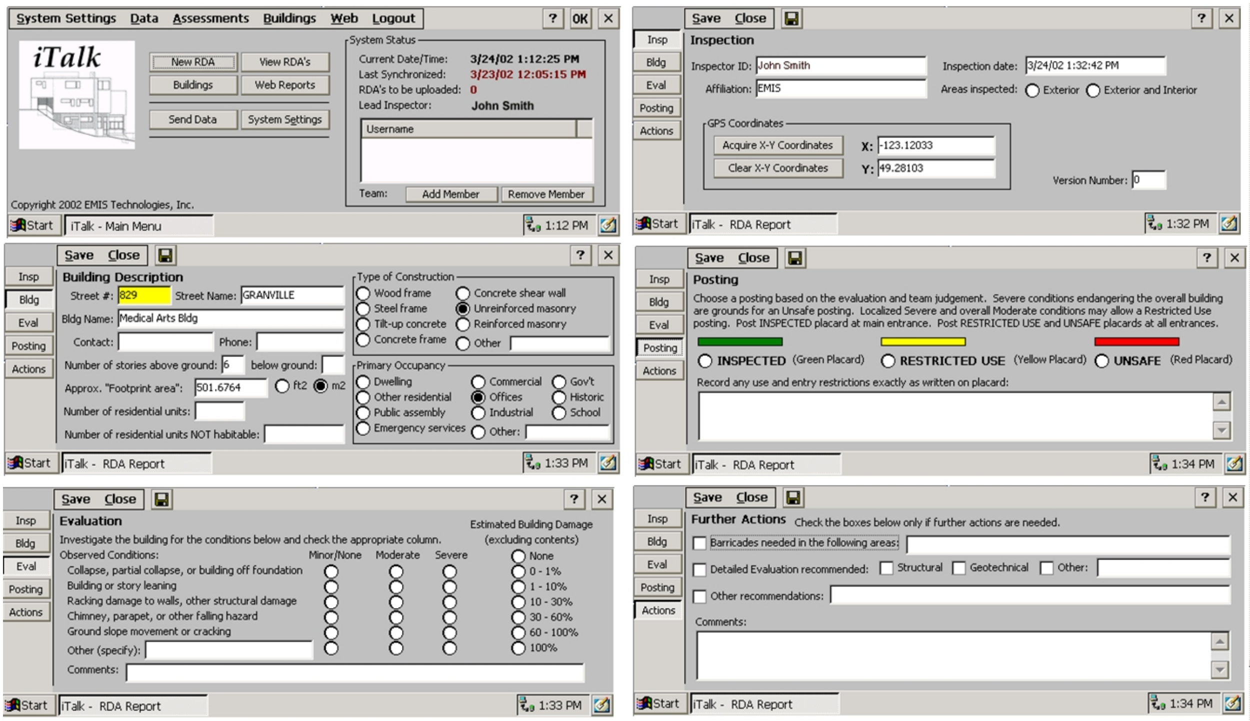


Figure 4.29: Example of a tool for the use of Mobile GIS for rapid damage assessment after a disaster (e.g. earthquake): iTalk. Source: http://www.emistech.com)

4.5.3 Participatory mapping in hazard assessment.

The use of participatory mapping is a very important tool in hazard assessment, for:

- The **reconstruction of historical disaster events** with respect to the extension, severity, and frequency of these events. Often it is also possible to reconstruct historical scenarios. These can then also be used in combination with modeling results, either as input in the models (e.g. terrain parameters, flood marks) as well as for validating models (e.g. validating flood models for particular scenarios with the result of community maps made for the same events.)
- The **mapping of damage** caused by these historic events. Even though the events may have happened some time ago and the damages might not be visible anymore, local communities can still identify where, what and how much was damaged. Furthermore they indicate how much they were affected in terms of their livelihood, access to basic services etc.
- The manner in which they **perceive** the various hazard events that have happened. It may not always be very straightforward to link the magnitude of the hazard events with the degree of manageability, which is an indication how the local communities experienced and perceived the severity of the event. For instance small events that happened close to each other might have caused more problems than larger event that happen less frequently. For example, figure 4.30 shows the manageability classes that were derived together with local communities regarding the flood threat in their area. Classes were made not of water depth or duration, but these were combined into manageability classes based on community-derived criteria.
- The **coping strategies**: the way in which local people dealt with the effects of the event.

The use of participatory mapping for hazard assessment also has a number of drawbacks which should be taken into consideration:

- Local knowledge is local: people have best knowledge on their own small area. The reliability decreases when they are asked about situations in nearby locations where they don't go regularly.
- Local knowledge of historical events is limited. If there is a series of hazard events that have affected them (e.g. landslides, floods), it will be difficult to remember them in the correct way. They become often mixed, and merge into one picture, which makes it difficult to analyze the effect of events with different magnitude. Normally the largest event is remembered for the longest period.
- The local knowledge might be ambiguous and different people might give quite varying opinions on past hazard scenarios. Therefore the investigator has to corroborate the information by interviewing many people, or organize workshops where the information is discussed with a whole group.
- It is not possible to use local knowledge to evaluate events that have not happened before, or that happened so long ago that the local communities do not have a clear memory of. For instance the effect of a 1/200 year earthquake is very difficult to evaluate with the local community if the last one has happened more than 60 years ago.

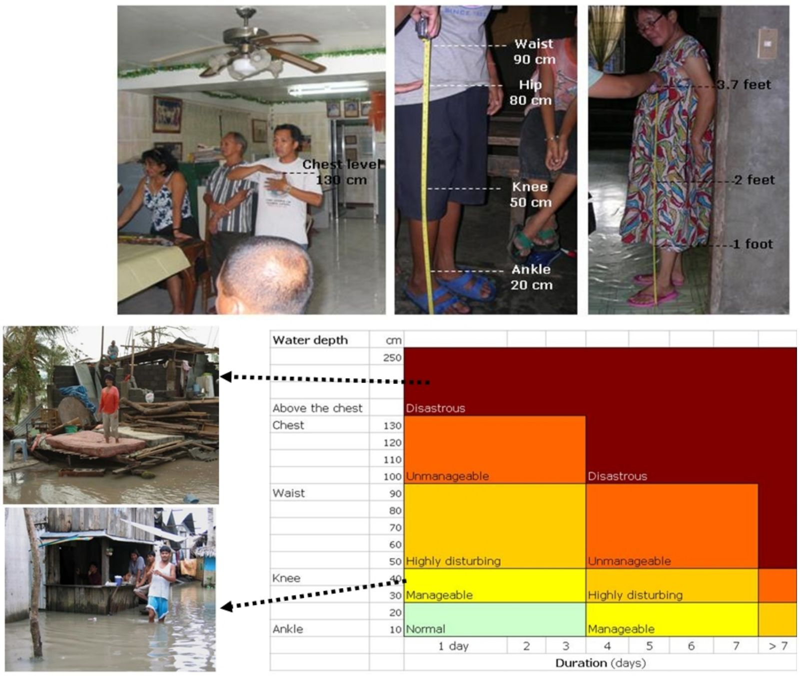


Figure 4.30: Hazard maps are based on the criteria that the community indicates regarding their perception of the severity of the hazard, in so-called "manageability" classes.

4.5.4 Participatory mapping of elements at risk

This session dealt with a number of aspects related to elements at risk mapping. Although elements at risk information may be derived from existing data sources such as cadastral and census data, there is always a need to collect additional information to characterize the elements at risk for vulnerability assessment. Furthermore in case existing data are not available it is actually the primary source of elements at risk information for mapping the following aspects:

- **Buildings:** Correct delineation of buildings from image interpretation is difficult, even when using high resolution images. Figure 4.32 gives an example of the difficulty to delineate individual buildings in dense urban areas. For collecting information on building types, construction materials, land ownership, and the checking of urban land use, normally stratified samples are taken, as it is often too time consuming to do a complete house-by-house survey. Figure 4.32 also shows the input screen used in Mobile GIS for building mapping.
- **Population characterization:** mapping of population characteristics such as socioeconomic status, livelihood, income level, dependency ratio (ratio between income earners and rest of the household), family size, commuting patterns.
- **Basic infrastructure:** access to drinking water, sanitary facilities, but also community services such as health (hospitals and health centers) institutional (neighborhood offices), educational (schools), religious (churches, mosques and temples), areas for recreation and open spaces which can be used for evacuation purposes.
- **Mapping of environmental problems:** waste disposal situation, the presence of environmental problems like stagnating water, polluted areas etc.

Participatory mapping covering large areas can also be done by selected people from the local community, which are trained to do the survey, or by involving students from a nearby university. However, care should be taken in that case that the quality of the survey is constant, and a system of quality checking should be built in.

Block_id	Element_id	Use	C.mater_wl	Concret_ht	C.mater_rf	C.mater_fl	No_fl
z2b19	z2b1915	Residential:low income	concrete-wood	30-50cm	Iron sheets	concrete	1 floor
z2b19	z2b1917	Residential:mid-low income	concrete-wood	50-100cm	Iron sheets	concrete	1 floor
z2b19	z2b1916	Residential:mid-low income	concrete-wood	50-100cm	Iron sheets	concrete	1 floor
z2b19	z2b1918	Residential:mid-low income	concrete-wood	50-100cm	Iron sheets	concrete	1 floor
z2b19	z2b1919	Residential:mid-low income	concrete bricks	not applicable	Iron sheets	concrete	1 floor
z2b19	z2b1920	Residential:low income	concrete-wood	50-100cm	Iron sheets	unkown	1 floor
z2b19	z2b1922	Residential:middle income	concrete bricks	not applicable	Iron sheets	unkown	1 floor
z2b19	z2b1923	Other services	concrete bricks	not applicable	Iron sheets	concrete	1 floor
z2b19	z2b1921	Residential:middle income	concrete bricks	not applicable	Iron sheets	concrete	1 floor
z2b19	z2b1924	Residential:middle income	concrete bricks	not applicable	Iron sheets	concrete	1 floor
z2b19	z2b1925	Residential:middle income	concrete bricks	not applicable	concrete	concrete	1 floor

Figure 4.32: Example of the use of mobile GIS for building mapping. The buildings have been digitized before on a high-resolution image, and the boundaries are checked in the field. With ArcPad a number of input screens have been defined for the collection of the attribute data. For each attribute a selection can be made from a list of possibilities, and estimations on percentages are checked to avoid errors in data input. The lower part shows the output table that will be linked

Task 4.11: RiskCity exercise on the use of Participatory mapping information (duration 3 hours)
At this point it is good to go back to the RiskCity case study and have a look how Participatory mapping can be used in the context of RiskCity. Of course in the framework of this course it is not possible to collect this type of information yourselves. Therefore we have done this already for you in two neighborhoods of the city. One that is flood prone and the other which is landslide prone. You can select which one of the two aspects you would like to work on.

Carry out the RiskCity exercise on Participatory mapping.

4.5.5 Participatory mapping in vulnerability and capacity assessment

In this section we will not expand too much on the aspects related to vulnerability and capacity, as this is the topic of the following session. We just would like to indicate here that the vulnerability and capacity analysis is the core of the community-based approaches, as the type of information that is needed to investigate this can only be obtained by dialogue and discussion with the local communities. Table 4.15 gives a summary of the information that was collected in a study on flood risk management for two neighborhoods (barangays) in the flood prone area of Naga city in the Philippines.

Table 4.15 Summary of the information that was collected using participatory mapping for a flood risk study in the Philippines (Source: Peters, 2008)

Components of the conceptual model for flood risk assessment		**Logical model: Elements and indicators used to spatially represent the conceptual model**	
Geo-Hazard	Flood	Water depth Duration Velocity	-Group/individual experiences about past events -Hydrological modelling
Vulnerability	*Exposure*	Location	-Surface elevation of the terrain -Location in relation to nearby elevated areas -Location in relation to elements susceptible to strong winds (antennas, large/robust trees, advertisement boards)
		Quality of the built environment	-Building types -Development level
		Quality of the Natural environment	-Waste management -Presence and origin of stagnated waters
	Resistance	Socioeconomic status	-Household composition -Occupations (type of activity, location) -Number of working people -Dependency ratio -Access to basic services (health, education, water, sanitation) -Access to resources during 'normal' times (land, goods and savings) -Access to resources during 'crisis' times (warnings, evacuation, relief)
	Coping	Mechanisms for risk management according to daily life aspects	-Coping mechanism before, during and after flooding related to : housing, livelihood, food, health, sanitation, safety of belongings, mobilization and overall safety.
Risk		Past, present and future scenarios for flood events with different return periods	- Flood scenarios for different events - Vulnerability of the elements under analysis - Implementation of socioeconomic development scenarios

4.5.6 Participatory mapping for disaster relief support

The last aspect covered here is the use of GIS for disaster relief. There are a number of initiatives in this field:

- **MapAction**, http://www.mapaction.org/index.html is a UK-based charity, staffed by specialist volunteers, whose core role is supporting humanitarian operations through provision of spatial data collection and mapping capabilities in the field. Large-scale maps focused on specific relief requirements through sectoral overlays, maps formatted to specific needs of aid agencies, Interactive GIS technology on web based servers, enabling on-line queries, enhance existing baseline maps in the field through computer-linked GPS/GIS systems.

- **GISCorps** is since 2003 an URISA program and operates entirely on a volunteer basis. GISCorps volunteers reside in different states across the USA and use a twiki site to work collaboratively. Emergency & relief work in: Andaman Islands., India Tsunami. and with Global MapAid, post-tsunami; Katrina USA MI & LA, Afghanistan. http://www.giscorps.org/
- **Global MapAid**, a non-profit organization, was initiated with a view of supplying specialist maps to emergency & humanitarian aid workers. The group consists of experienced aid workers, GIS analysts, web developers, and core volunteers from Stanford University. The focus is to map humanitarian crises hotspots by capturing data to assist predominantly in slow onset disasters such as food security, drought, HIV monitoring and orphanage survey refugee programs but also when necessary in rapid onset disasters such as floods. GMA's mission is to assist aid efforts by providing and assisting in the provision of mapping and corresponding communications systems for aid agencies, e.g. UN World Food Program. http://www.globalmapaid.rdvp.org/

Task 4.12: Summary on the use of Participatory mapping for disaster risk assessment (duration 15 minutes)

After reading this session and after you did the RiskCity exercise on the use of Participatory mapping information, it is good to make a summary of what you have learned.
Please do that by filling in the following table, and explain briefly your choices.

Hazard type	Location as point	Spatial extent	Historical events	Frequency	Causes	Damage	Vulnerabi lity
Floods							
Landslides							
Earthquake							
Volcanic eruptions							
Bush fires							
Township fires							
Storms							
Pest outbreak							
Drought							

Finally, please note down the advantages and disadvantages of Participatory mapping

Selftest

In order to evaluate whether you have understood the concepts that were presented in this session. Please make the following test, and check the answers in Blackboard.

Question 4.1: Spatial data for elements at risk
Which minimal spatial information is required in order to make an estimation of the vulnerability of buildings?
A) Building footprints
B) A high-resolution image (e.g. Ikonos)
C) Mapping units
D) Wards

Question 4.2: Elements at risk
Which of the following statements is relevant for <u>high potential loss facilities</u>?
A) A park can be used as an evacuation area
B) Hazardous chemical industries might produce an additional disaster once they are damaged by a hazard event.
C) Restaurants might have more people during a small period in the week.
D) Residential areas might have a higher number of casualties during the night.

Question 4.3: Participatory GIS
Participatory GIS for disaster risk assessment has the following advantages and disadvantages:
A) It involves community participation, but may not capture all possible hazard scenarios, due to the limited historical time-span of collective knowledge of the community.
B) It leads to the extraction of local (indigenous) knowledge, but unfortunately doesn't display this in the right projection system, and therefore cannot be used in GIS.
C) It allows the inclusion of local interests and priorities, but unfortunately doesn't formalize this information, so it might get lost soon.
D) It is a nice method to collect information from the population, which an expert can use to validate his scientific models, but it is not reliable.

Question 4.4: Elements at risk : urban land use
In order to make a good risk assessment, the classification of urban land use is important because:
A) It determines the types of buildings, and their vulnerability
B) It determines the population density
C) It determines the population distribution, during different time periods
D) All of the above.

Question 4.5: Elements at risk
Which attribute related to buildings is most important for the risk assessment, and why?
A) Urban land use, because from this attribute you can derive several other attributes, especially related to the density of population in day and nighttime scenarios.
B) The building contents because that is important in order to determine structural damage
C) The number of floors, because this determines the vulnerability of the population
D) The roof type, because that can be observed using satellite imagery.

Further reading:

Elements at risk classification.

- We recommend you to read the technical manual of HAZUS related to the inventory of assets for loss estimation. This manual is provided on the background directory of session 4 on the course DVD or blackboard site.

Some ITC PhD theses on this topic are:

- A.L. Montoya, I. Masser (Promotor), N. Rengers (Promotor), H.F.L. Ottens (Promotor) (2002) Urban disaster management : a case study of earthquake risk assessment in Cartago, Costa Rica . PhD thesis Utrecht University. document http://www.itc.nl/library/Papers/MONTOYA.pdf
- Botero Fernandez, V., Ottens, H.F.L. (promotor) , van Westen, C.J. (promotor) and Sliuzas, R.V. (promotor) (2009) Geo - information for measuring vulnerability to earthquakes : a fitness for use approach. Enschede, Utrecht, ITC, University of Utrecht, 2009. ITC Dissertation 158, 191 p. ISBN: 978-90-6164-272-5. http://www.itc.nl/library/papers_2009/phd/botero.pdf
- Peters Guarin, G., Frerks, G. (promotor) , van Westen, C.J. (promotor) and de Man, W.H.E. (promotor) (2008) Integrating local knowledge into GIS based flood risk assessment, Naga city, The Philippines. Wageningen, Enschede, Wageningen University, ITC, 2008. ITC Dissertation 157, 352 p. ISBN: 978-90-8585-295-7. http://www.itc.nl/library/papers_2008/phd/peters.pdf

Other related literature:

- Ebert, A., Kerle, N. and Stein, A. (2009) Urban social vulnerability assessment with physical proxies and spatial metrics derived from air- and spaceborne imagery and GIS data. In: Natural hazards : journal of the international society for the prevention and mitigation of natural hazards, 48 (2009)2, pp. 275-294. http://intranet.itc.nl/papers/2009/isi/kerle_urb.pdf
- Montoya L. Geo-data Acquisition through Mobile GIS and Digital Video: an Urban Disaster Management perspective (2003) In: Environmental Systems and Software, 18(10) Elsevier, pp. 869-876

Participatory GIS

- *For a good overview of the various methodologies please visit the webpage of the ProVention consortium: http://www.proventionconsortium.org/?pageid=43*
  This is a well-organised, annotated overview of Community Risk Assessment (CRA) approaches and methods, many of which are highly relevant to PGIS issues, applications and methods. This 'Guide to Handbooks and Guidelines' reviews the products of many agencies and NGOs, including Asian Disaster Preparedness Centre (ADPC); Oxfam, ActionAid; Centre for Disaster Preparedness Philippines, International Hurricane Research Centre, Florida; South Pacific Disaster Reduction Programme of the UN Dept of ESA; and the Philippines National Red Cross Society. Likewise there is a cross-indexed user-friendly guide to PRA and other survey tools for community spatial information, including hazard mapping; resource mapping; risk mapping; and gendered risk mapping. (NB of course the term 'mapping' in this context does not always mean just representation of geospatial information) The website also includes many case studies.

- A good overview of publication related to PGIS for disaster risk assessment, prepared Mike McCall can be found in ***:***
  http://www.proventionconsortium.org/themes/default/pdfs/CRA/PGIS_Sept08.pdf