Maurizio Indirli

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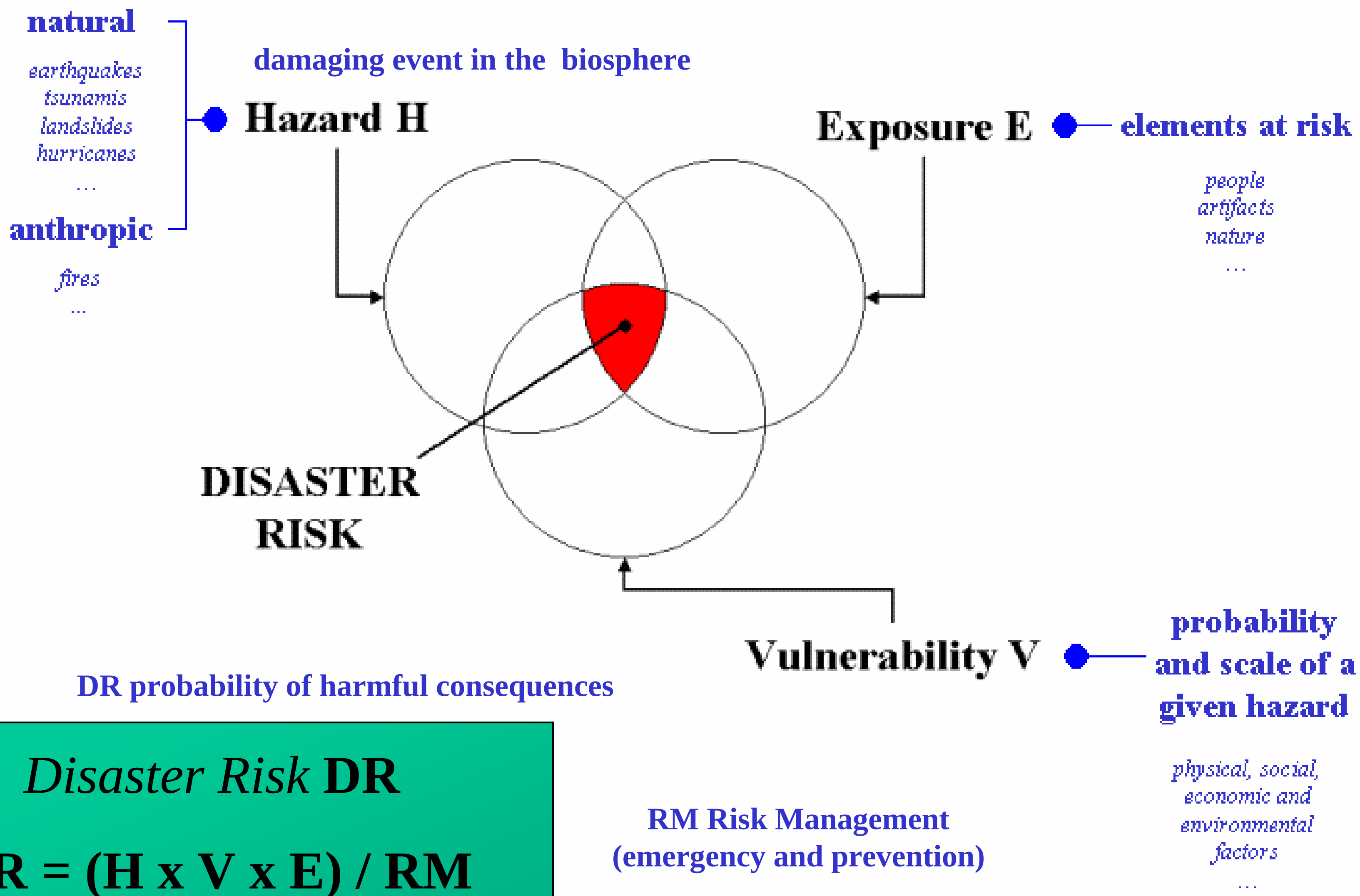
Energy and Environment, Italy**

OVERVIEW ON RISK ASSESSMENT APPROACHES FOR NATURAL HAZARDS

- **introduction**
- **a brief summary on risk assessment**
- **research and projects**
- **conclusions**

introduction

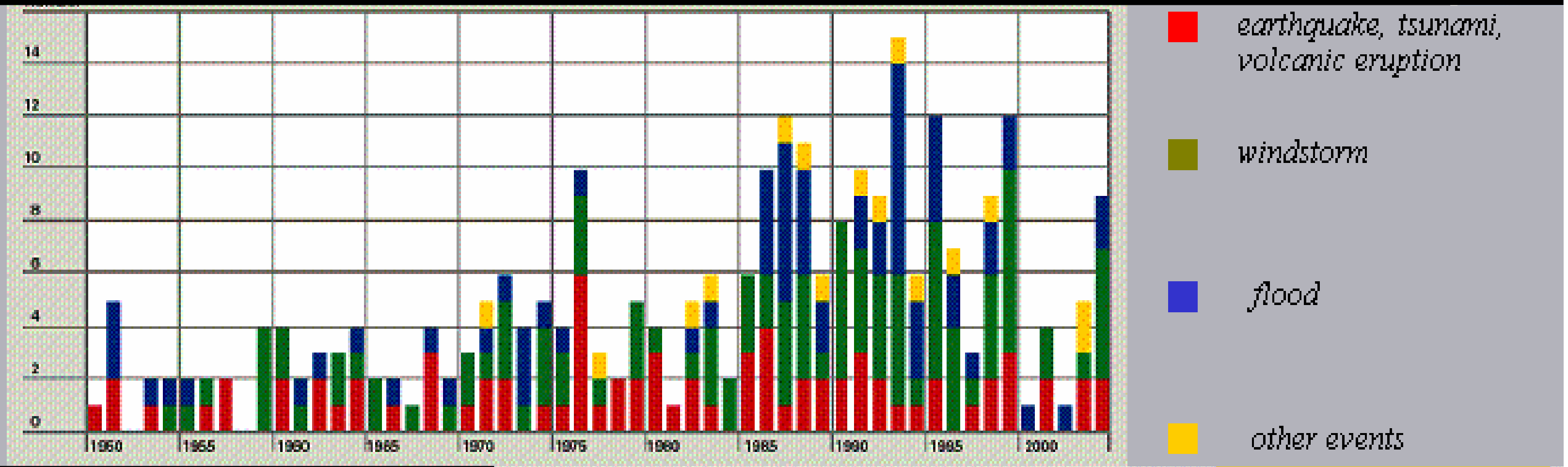


Disaster Risk **DR**

$$DR = (H \times V \times E) / RM$$

Risk Management **RM**

Risk Assessment (RA) is an estimate of the social and economic impact that hazards can have on people, buildings, services, facilities and infrastructures.

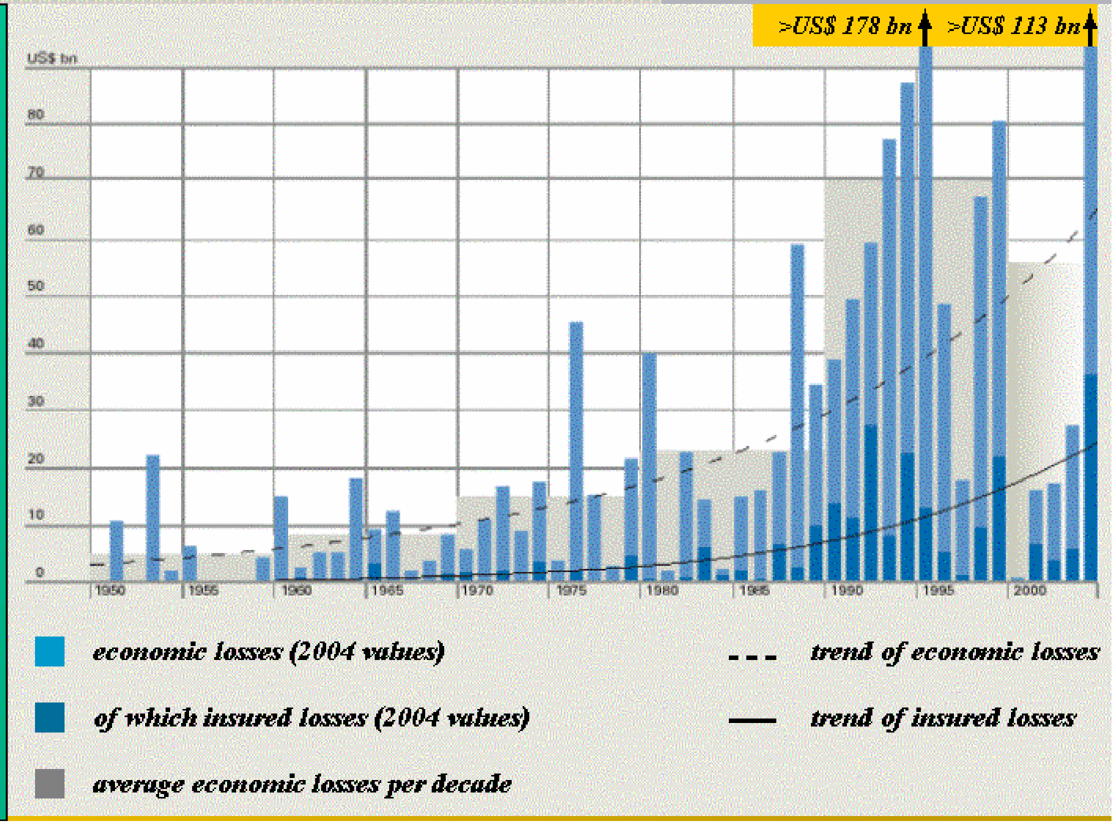


The economic cost

of disasters

have been increased

over decades



impact of natural disasters on urban habitat

earthquake and fire:
San Francisco 1906, Valparaiso 1906,
Messina & Reggio Calabria 1908

earthquake:
Loma Prieta 1989, Northridge 1994,
Kobe, 1995, Izmit 1999

historical centers

buildings, services, facilities and infrastructures

earthquake:
Molise 2002

schools

impact of natural disasters on urban habitat

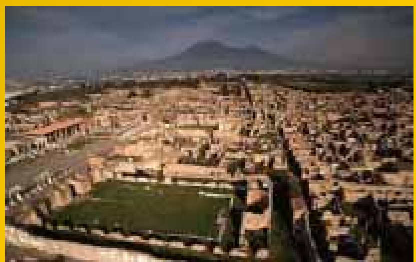
earthquake:
Reggio Emilia-Modena 1996, Marche-Umbria 1997-98,
Molise 2002, Bam 2003, Indonesia 2006

cultural heritage

impact of natural disasters on urban habitat


flood:
Florence 1966, Prague 2002

landslide and flood:
Vajont 1963

hurricane:
Katrina 2005

tsunami:
Venice and Trieste 1511,
Indian Ocean 2004

volcanic eruption:
Pompeii 79, Stromboli 2007

urban habitat

WHAT TO DO AGAINST NATURAL DISASTERS

disaster prevention

- hazard models and maps
- vulnerability studies
- building inventory
- mitigation programmes
- citizenship preparedness

emergency

- understand well and quickly each disaster process
- provide damage assessment
- address civil defense interventions

post-disaster activities

- reconstruction and rehabilitation programmes

tools for an integrated risk management

urban habitat and cultural heritage

Radenci, 1998:

Declaration on the protection of cultural heritage in emergencies and exceptional situations

(ICBS, International Committee of the Blue Shield)

Kobe, 2005:

World Conference on Disaster Reduction

(UNESCO, ICCROM, Japan Orgs …)

- **urban habitat and cultural heritage are particularly at risk in the period following natural and antropic catastrophes**

- **often emergency response and post-emergency activities are not much sensitive to protection of urban habitat and cultural heritage**

needs to better integrate protection into the whole disaster management process

innovative tools for urban habitat and cultural heritage protection

GEOMATICS

a conglomerate of measuring, mapping, geodesy, satellite positioning GPS, photogrammetry, computer systems and graphics, remote sensing RS, geographic information systems GIS, environmental visualization, laser scanner

disaster prevention

GIS and RS are used to manage the wide volume of data needed for hazard and risk assessment

(early warning systems, emergency planning, hazard mapping, vulnerability evaluation, building inventory, etc.)

post-disaster preparedness

GIS and RS provide quantitative damage assessment with speedily, cost effective and free from subjectivity techniques

(catastrophe survey, emergency activities, loss estimation, etc.)

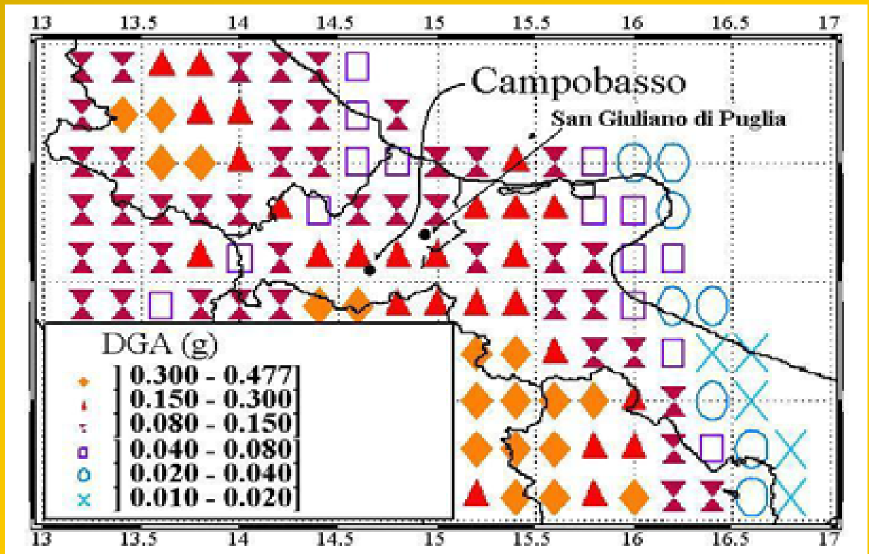
- **the situation outline is very inhomogeneous**
- **traditional methods coexist with advanced skills (especially in archaeology)**

innovative tools for urban habitat and cultural heritage protection

EARTHQUAKE AND TSUNAMI HAZARD MAPPING

cultural heritage: 100% save

preventive definition of seismic input with high accuracy



Deterministic map of seismic input for the Molise Region; source: University of Trieste and ICTP

- **earthquake scenarios**

  (algorithms for space-time medium terms forecasting, not only acceleration peak values)

- **deterministic models**

  (realistic simulation of ground shaking, not only probabilistic earthquake return periods)

- **microzoning advanced methodologies**

  (local ef fects due to soft soil)

- **sea waves propagation**

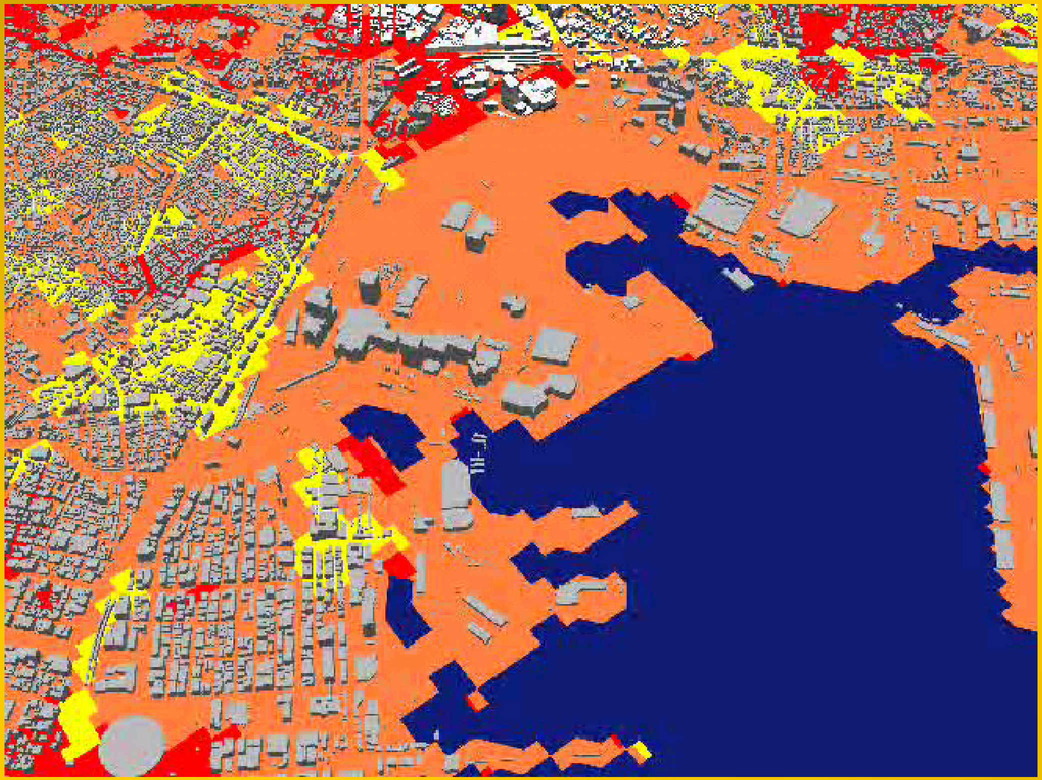
  (monitoring and accurate analytical models)

UNESCO-IUGS-IGCP Project 414

“Realistic Modeling of Seismic Input for Megacities and Large Urban Areas”

innovative tools for urban habitat and cultural heritage protection

GIS APPLICATION AND DEVELOPMENT



Seismic Hazard and Risk Maps; source: S. Midorikawa, 3rd International Workshop on Remote Sensing for Post-Disaster Response, 2005, Chiba, Japan

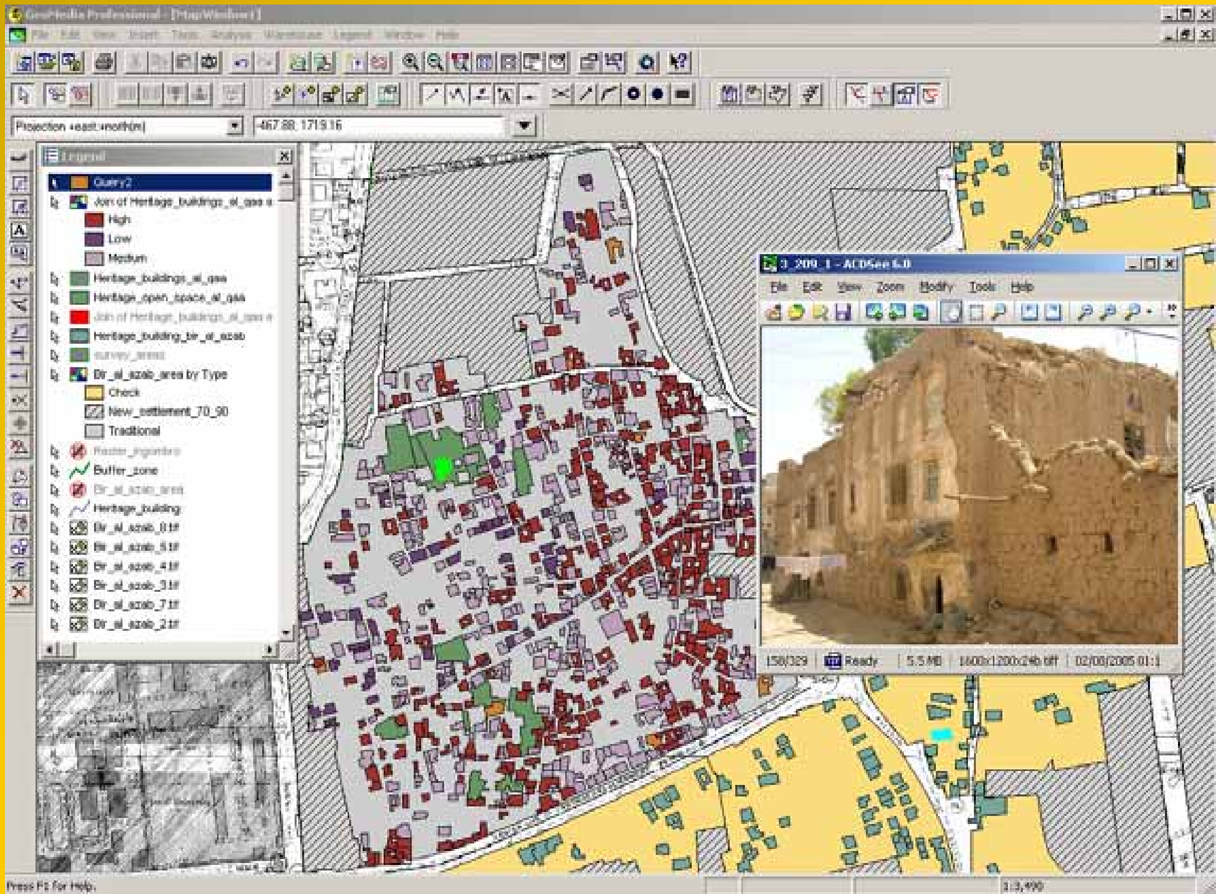
- **detailed geo-referred maps**
- **in-field surveys**
- **RS image processing**

joining hazard and vulnerability data into maps which must identify house by house, giving a sharp classification of danger

- **virtual reality tools for education activities**

innovative tools for urban habitat and cultural heritage protection

BUILDING VULNERABILITY INVENTORY



Building vulnerability inventory, an application to the Old City of Sana'a (Yemen); source: University of Ferrara, Department of Architecture

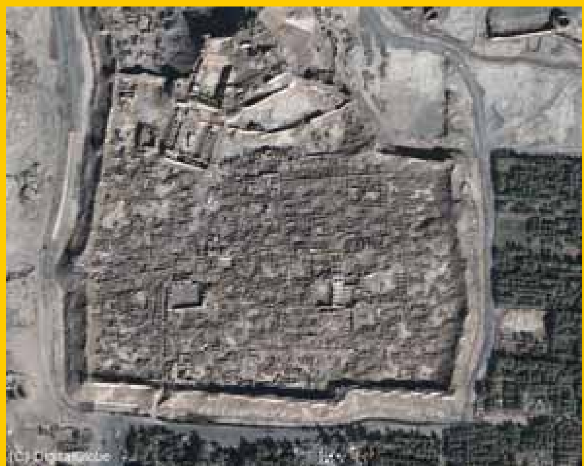
- **GIS platforms**
  with different levels of "depth"
- **urban planning**
- **architectonic description**
- **structural features**
- **vulnerability functions**

ICOMOS
Washington Charter
"Charter for the Conservation of the Historic Towns and Urban Areas"

innovative tools for urban habitat and cultural heritage protection

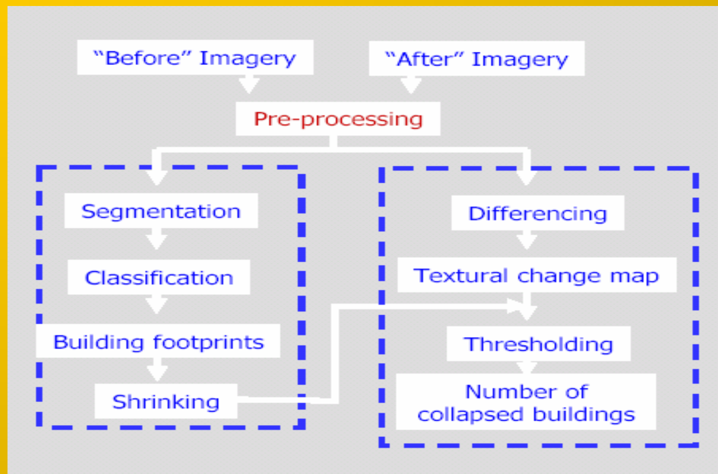
DAMAGE ASSESSMENT AND BUILDING CLASSIFICATION

Bam (Iran) before (up) and after (down) the 2003 earthquake, source: QuickBird satellite images



RS high resolution imagery

- **very rapid comparison, "before" and "after" the event, for large areas**
- **classification algorithms of the built-up texture**



Damage classification procedures from RS imagery, source: S. Midorikawa

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FINAL GOAL

- MULTILAYER RISK MAPS

- DETAILED BUILDING INVENTORIES

RISK

- **global risk factor for a given area (or building)**
- **reliable combination methods and algorithms**

MAP

- **from wide areas to local scale**
- **highlighting single buildings**
- **attract the citizen's interest on his own risk**

INVENTORY

- **social and historic information**
- **vulnerability data (materials, techniques, …)**
- **damage data**
- **reconstruction, rehabilitation, city planning**

a brief summary on risk assessment

risk assessment

	PROCESS		***OUTPUTS***
STEP 1	➢ definition of the study region	identify hazards	➢ study region
	➢ creation of a base map of the region		➢ base map
	➢ identification of hazards of interest		➢ list of hazards of interest
STEP 2	➢ hazard database construction	profile hazards	➢ updated and completed hazard profiles
	➢ performing a data gap analysis		➢ maps of hazard areas
	➢ profile and priority of hazards		➢ hazard priority list
STEP 3	➢ inventory database construction	inventory assets	➢ inventory data tables and maps
	➢ performing a data gap analysis		➢ inventory data
			➢ data source list
STEP 4	➢ construction of estimate losses scenarios and risk assessment tools	estimate losses and risk assessment tools	➢ loss/exposure for the study region
	➢ evaluation of the results		➢ risk assessment outputs
			➢ tables and maps
STEP 5	➢ mitigation options identification	consider mitigation options	➢ mitigation options list
	➢ mitigation options verification		

FEMA 386-2 2001

STEP 1 **identify hazards**

- **avoid omission**
- **consider full range of potential hazards**
- **investigate carefully:**
  - *historical information*
  - *newspapers and Internet sites*
  - *experience of modern events*
  - *technical information*
  - *experts' opinion*
  - *review of existing plans and reports*
- **focus most prevalent hazards**
- **hazard grouping**

- **hazard grouping is a crucial point**
  (links between primary and secondary hazards)

- **the identification of global hazard factors is a difficult step to carry out**
  (inhomogeneous methods)

- **earthquake and tsunami**
- **landslide and mudslide**
- **subsidence**
- **hurricane and tornado**
- **flood**
- **coastal storm and erosion**
- **volcanic eruption**
- **drought**
- **wildfire**
- **winter storm (ice and snow)**
- **avalanche**
- **…**

STEP 2 **profile hazards**

- some hazards (floods) occur in predictable areas and can be easily mapped
- other hazards (tornadoes) can occur anywhere: they can be profiled recording the maximum potential wind speed
- great attention must be paid to compare and prioritize hazards

• create GIS platforms

• identify clearly hazard level areas

- hazard event: specific occurrence
- frequency: how often
- probability: likelihood (statistical measure)
- duration: how long an event lasts
- magnitude: severity (technical measure)
- intensity: effect of an event at a particular place
- hazard areas: geographic areas within the study region

STEP 3 **inventory assets**

- **demographics (population, employment, housing)**
- **building stock (residential, commercial, industrial)**
- **essential facilities (emergency operations centers, hospitals, schools, shelters, police/fire stations)**
- **transportation systems (airways, highways, railways, waterways)**
- **lifeline utility systems (potable/waste water, oil, gas, electric power, communication systems)**
- **high potential loss facilities (dams/levees, nuclear facilities, military installations)**
- **hazardous material facilities (facilities housing industrial/hazardous materials)**
- **cultural heritage (historical centers, archaeological remains, monuments, museums)**

- **inventory assets organize a huge amount of data**
- **critical buildings, facilities (and…) must be classified separately**

STEP 3

inventory assets

Sample Data Resources

General Building Stock
- Square Footage
- Building Count
- Occupancy to Model Building Type Schemes
- Building Characteristics

Economic
- Building Valuations
- Content Valuations
- Inventory Valuations
- Repair Times
- Business, Personal and Rental Income
- Disruption Costs
- Lifeline Valuations
- Indirect Economic Data

Flood Hazard
- Topography
- Shorelines
- Dunes
- Hydrology
- Runoff
- Soil Permeability
- Basin Storage
- River Reaches
- Water Sheds
- Stream Gauge Locations
- Discharge
- Forest Cover
- High Elevation Indices
- Precipitation
- Temperature

Transportation
- Highway
  - Roads
  - Bridges
  - Tunnels
- Railway
  - Tracks
  - Bridges
  - Tunnels
  - Facilities
- Light Rail
  - Tracks
  - Bridges
  - Tunnels
  - Facilities
- Bus Facilities
- Ports & Harbors
- Ferry Facilities
- Airport Facilities and Runways

HAZUS-MH by FEMA

STEP 3

inventory assets

Building Classification System

5 Major Structural Classes

- Wood
- Steel
- Concrete
- Masonry
- Manufactured Housing

33 Occupancy Classes

- Residential
- Commercial
- Industrial
- Agricultural
- Religion/Nonprofit
- Government
- Education

HAZUS-MH
by FEMA

STEP 3 **inventory assets**

information

- **building-specific**
- **hazard-specific**

• the system can be implemented depending on the features of the country

• for Europe, specific categories can be defined for cultural heritage assets and historical centers

• vulnerability factors can be calculated with particular regard to existing (masonry, etc.) buildings, by including specific algorithms and procedures

(hybrid approach by Kappos, FAMIVE by D'Ayala, VULNUS by Bernardini, C-SISMA by Valluzzi-Modena, etc.)

STEP 3 **inventory assets**

• building-specific

- ➢ **building size**
- ➢ **replacement value to pre-damaged conditions**
- ➢ **content value**
- ➢ **function use or value**
- ➢ **displacement cost due to hazard**
- ➢ **occupancy or capacity**
- ➢ **… ???**

STEP 3

inventory assets

• hazard-specific

	flood	*earthquake*	*tsunami*	*tornado*	*coastal storm*	*landslide*	*wildfire*	*… ???*
➢ type/type of foundation	x	x	x	-	x	-	-	
➢ code design level/construction date	x	x	x	x	x	-	x	
➢ roof material	-	-	-	x	x	-	x	
➢ roof construction	-	-	-	x	x	-	x	
➢ vegetation	-	-	-	-	-	-	x	
➢ topography	x	-	-	-	x	x	x	
➢ distance from the hazard zone	x	-	x	-	x	x	x	
➢ lowest floor elevation	x	-	-	-	x	-	-	
➢ base floor elevation	x	-	-	-	x	-	-	
➢ … ???								

STEP 4 **estimate losses**

- **building types: concrete, pre-cast concrete, reinforced and unreinforced masonry, steel, wood, etc.**
- **building occupancies: residential, commercial, industrial, education, agriculture, religion, government, etc.**
- **essential facilities: emergency operations centers, hospitals, schools, shelters, police/fire stations, etc.**
- **transportation systems: airways, highways, railways, waterways, etc.**
- **lifeline utility systems: potable/waste water, oil, gas, electric power, communication systems, etc.**
- **high potential loss facilities: dams/levees, nuclear facilities, military installations, etc.**
- **hazardous material facilities: facilities housing industrial/hazardous materials, etc.**
- **cultural heritage: historical centers, archaeological remains, monuments, museums, etc.**

- **in this analysis, the information must be provided together with the data of all the previous steps (=> *vulnerability functions*)**
- ***building damage* (structural, content, use and function) is a reliable indicator of risk and can be used to rank risks from various natural hazards and estimate risk in absolute terms**

STEP 5 — **mitigation options**

regulatory measures	➢ **legislation which organizes and distributes responsibilities to protect a community from hazard**
	➢ **regulations that reduce financial and social impact of hazards through measures (insurances, new/updated design and construction codes, new/modified land use and zoning regulations, incentives for mitigation)**
repair and rehabilitation of existing structures	➢ **removal or relocation of structures in high hazard areas**
	➢ **repair and strengthening of essential and high-potential-loss facilities**
	➢ **repair and strengthening of cultural heritage**
protective and control structures	➢ **deflect destructive forces from vulnerable structures and people**
	➢ **erect protective barriers (safe rooms, shelters, vegetation belts, etc.)**

- **mitigation options must be hazard targeted**

STEP 5 **mitigation options**

the adoption of updated building and safety codes is mandatory

- **earthquake: the adoption of revised set of rules by several Government Authorities is a step already achieved**

example: **Italian seismic classification and building codes after the 2002 Molise earthquake**

- **hurricane: the main recommendations (both for flood and wind) include updated building codes**

example: **the USA after the hurricane Katrina**

IBC, International Building Code

IRC, International Residential Code,

NFPA 5000, Building Construction and Safety Code

ASCE 7 & 24, American Society of Civil Engineers

FEMA 550 (Federal Emergency Management Agency)
Recommended Residential Construction for the Gulf Coast:
Building on Strong and Safe Foundations

STEP 5 **mitigation options**

- **collect/compare codes and recommendations of different countries**

***vertical approach*: targeted on single hazard**

***horizontal approach*: compare and harmonize for different hazards**

research and projects

the EU-MEDIN portal: research on natural disasters

the EU-MEDIN (European Mediterranean Disaster Information Network) aims at improving the research synergy in the field of natural disasters mitigation

main fields of activity:

- **seismic risk**
- **volcanic risk**
- **landslides and avalanches**
- **floods and storms**
- **forest fires**

many research projects on multi-hazard approach are described in the portal

identify common procedures and methodologies from a big "puzzle"

the EU-MEDIN portal (http://www.eu-medin.org/)

earthquakes: *3F-CORINTH, EOLES, NEDIES, SEADOME, 3HAZ CORINTH, EPSI, , ESPON_HAZARDS, OPTSEDT, SEISLINES, ARMONIA, EU-MEDIN, ORCHESTRA, SEISMIC CYCLES, COMSHELFRISKS, EURACTIVE ROOFER, PATCH_IRPINIA, SESAME, CORSEIS, EUROSEIS-RISK, PREPARED, SPICE, CRONUS-EU, GEOWARN, PRESAP, SPIDER, DGLAB-CORINTH, GO, PROHITECH, TomAve, DISWAL, HYDRAMED, RELIEF, VAST-IMAGE, E-RUPTIONS, I-GET, RETINA, EERWEM, ISFEREA, RISK-UE, EMICES, LessLoss, S.A.F.E*

volcanoes: *ARMONIA, Exploris, ORCHESTRA, TomAve, DORSIVA, GEOWARN, Pre-Erupt, TomoVes, E-RUPTIONS, LABVOLC2, RETINA, VOLCALERT, ERUPT, MULTIMO, SPICE, VOLUME, ESPON_HAZARDS, NEDIES, TERN, WEIRD, EU-MEDIN, NOVAC, TMFSV*

landslides & avalanches: *3HAZ CORINTH, ENSEMBLES, IMIRILAND, OASYS, ALARM, ENVASSO, IRASMOS, ORCHESTRA, ARMONIA, ESPON_HAZARDS, LessLoss, RETINA, ASSIST, EU-MEDIN, LEWIS, SAFERDRILL, COMSHELFRISKS, EUROSEIS-RISK, MITCH, SLIDE2FLOW, Concerted action on landslide and avalanche risks, GALAHAD, MUSCL, THARMIT, DAMOCLES, GLACIORISK, NEDIES*

floods and storms: *ACTIF, EDEN IW, FLOOD RELIEF, NEDIES, ADC-RBM, EFFS, FloodMan, ORCHESTRA, AFORISM, ELDAS, FLOODSite, OSIRIS, ARMONIA, ELLA-ELBE-LABE, FRAMEWORK, PRUDENCE, AUTO-HAZARD PRO, ENSEMBLES, HYDROMET, RAMFLOOD, CARPE DIEM, EOLES, IMPACT, RAPHAEL, CLIFF-A, ESPON_HAZARDS, MANTISSA, SPHERE, CLIFF-B, EU-MEDIN, MICE, SWURVE, CLOUDMAP2, EURAINSAT, MITCH, THARMIT, COMSHELFRISKS, EUROTAS, MUSIC, WRINCLE, EcoFlood, FAME PROJECT, NATURAL HAZARDS*

forest fires: *A GIS decision support system, EOLES, FOFIRECO, ORCHESTRA, ACRE, EPOC0040, FOMFIS, PHOTON FIRE DETECTOR, AFFIRM, ERAS, FORFAIT-A, PPFAS, ARMONIA, ESPON_HAZARDS, FORFAIT-B, PREVENTION OF FIRES, AUTO-HAZARD PRO, EU-MEDIN, Formidable, PROMETHEUS, CARICA, EUFIRELAB, GEIS, PROMETHEUS SV, CLIFF-A, FFP-PB, HORACE, RAPSODIE, CLIFF-B, FFR, INFLAME, RISCOFF, Collecting and recycling forest waste, FIERS, LIS, RISK SENSORS, COMETS, FIMEX, MEFISTO, SALTUS, CONTROL OF FOREST FIRES, FIRE EROSION, MEGAFIRES, SHAEP, CONTROL-FIRE-SAT, FIRE STAR, MICE, Simulation des incendies de forêts, DEDICS, FIRE TORCH, MINERVE, SPREAD, DELFI, FIREGUARD, MINERVE 2, WARM, EFAISTOS, FIREMEN, NATURAL HAZARDS, WEIRD, ENSEMBLES, FIRES, NEDIES* http://www.fema.gov/hazus

EARTHQUAKE • WIND • FLOOD

the HAZUS-MH procedure

- **the Hazards U.S. Multi-Hazard (HAZUS-MH) is a risk assessment standardized methodology and software program that estimates potential losses from floods, hurricane winds and earthquakes**
- **HAZUS-MH was developed by the Federal Emergency Management Agency (FEMA) under contract with the National Institute of Building Sciences (NIBS).**
- **in HAZUS-MH, current scientific and engineering knowledge is coupled with the latest geographic information systems (GIS) technology to produce estimates of hazard-related damage before, or after a disaster occurs**
- **the development of further additional tools is foreseen**

the database should be flexible, freely available for use by any country and organization through Internet access, open-source, encouraging the worldwide community to participate to its development and validation

Chile – Manejo de riesgos en Valparaiso

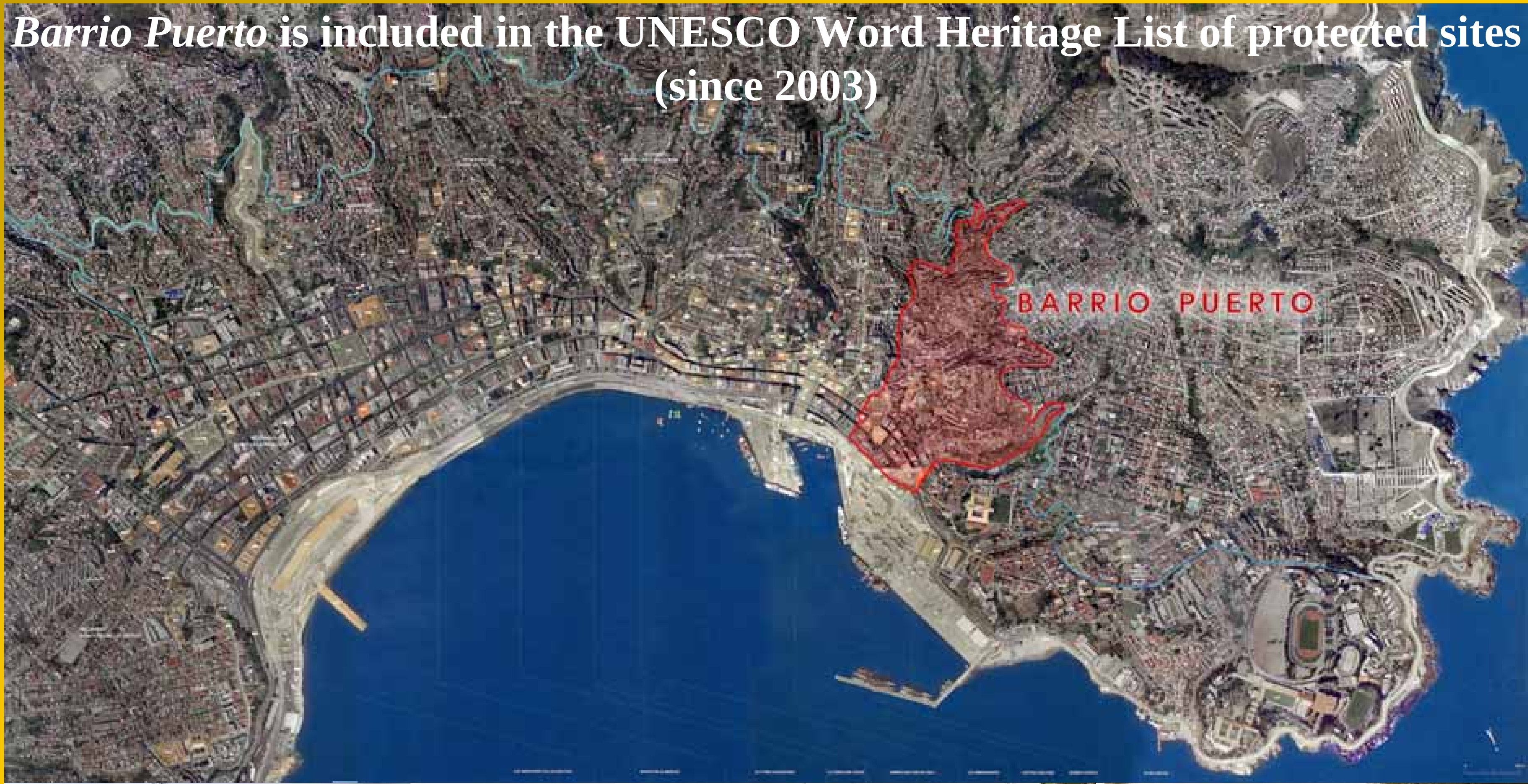
project agreement between Inter-American Development Bank and ENEA

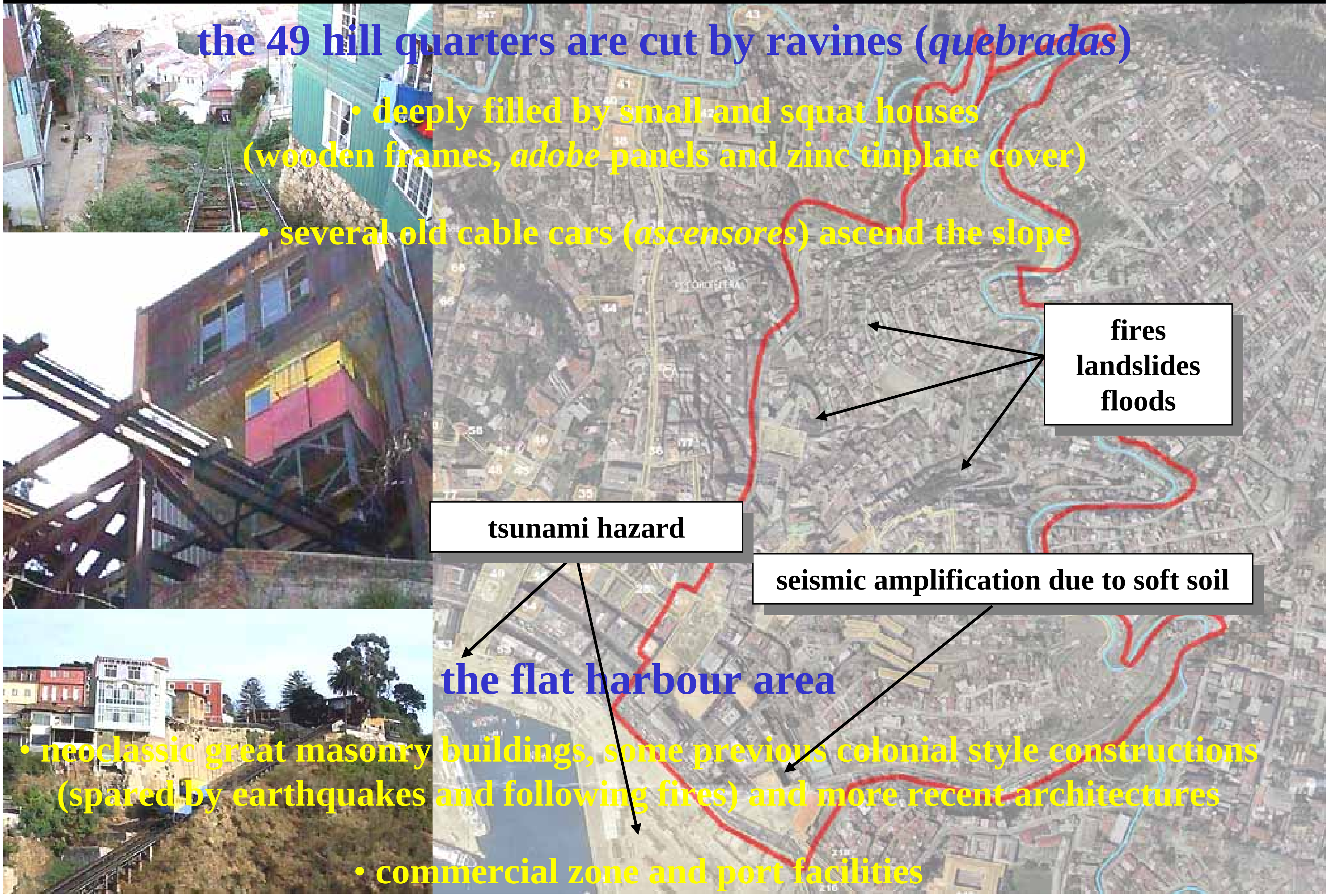
never-ending story of a tight interaction between society and environment

city is subjected to various hazards (earthquakes, tsunamis, landslides, fires)

The most disruptive earthquake happened in 1906 (8.3 Richter) destroying and burning down a large part of the city

Barrio Puerto is included in the UNESCO Word Heritage List of protected sites (since 2003)




the 49 hill quarters are cut by ravines (*quebradas*)
• deeply filled by small and squat houses
(wooden frames, *adobe* panels and zinc tinplate cover)
• several old cable cars (*ascensores*) ascend the slope
fires
landslides
floods
tsunami hazard
seismic amplification due to soft soil
the flat harbour area
• neoclassic great masonry buildings, some previous colonial style constructions
(spared by earthquakes and following fires) and more recent architectures
• commercial zone and port facilities

• Valparaiso City is a paradigmatic study case about multi-hazard mitigation
• risk factors must be very well evaluated during the future restoration phases

ENEA convinced the Municipality about the necessity to improve multiple risk evaluation and structural safety, in particular in the historical part

the project agreement has been recently signed between ENEA and IADB/BID

it foresees the collaboration with Ferrara and Trieste Universities, ICTP, Chile universities and the Chilean Navy Oceanographic and Hydrographic Service

• to perform topographic (DGPS) and 3D Laser-Scanner surveys

• to provide studies on seismic, tsunami and coastal erosion hazards

• to realize vulnerability analyses of the main structural typologies in Valparaiso (with particular regard to Barrio Puerto)

• to carry out an urban classification from high definition satellite images

• to make available the results inside a GIS system

• to approach a multiple natural risk assessment

• to suggest guidelines for future interventions

• to produce multimedia activities and accomplish training and bursary programs

conclusions

- Risk Assessment in case of natural hazards can be managed by using innovative and integrated tools (like vulnerability/loss estimation methodologies and GIS-based software) implemented in digitized databases, also provided by huge inventories and interactive import-export capabilities
- these systems can be implemented depending on the features of the countries; specific methodologies have to be defined for existing buildings, cultural heritage and historical centers

innovative tools for multi-hazard mitigation

- geomatics, building inventory, digitized databases, etc.
- advanced seismology, innovative engineering, etc.

"state-of-the-art"

- EU-MEDIN portal
- HAZUS-MH
- ………

conclusions

proposal for the construction of a multi-hazard pilot database in the framework of the COST ACTION C26

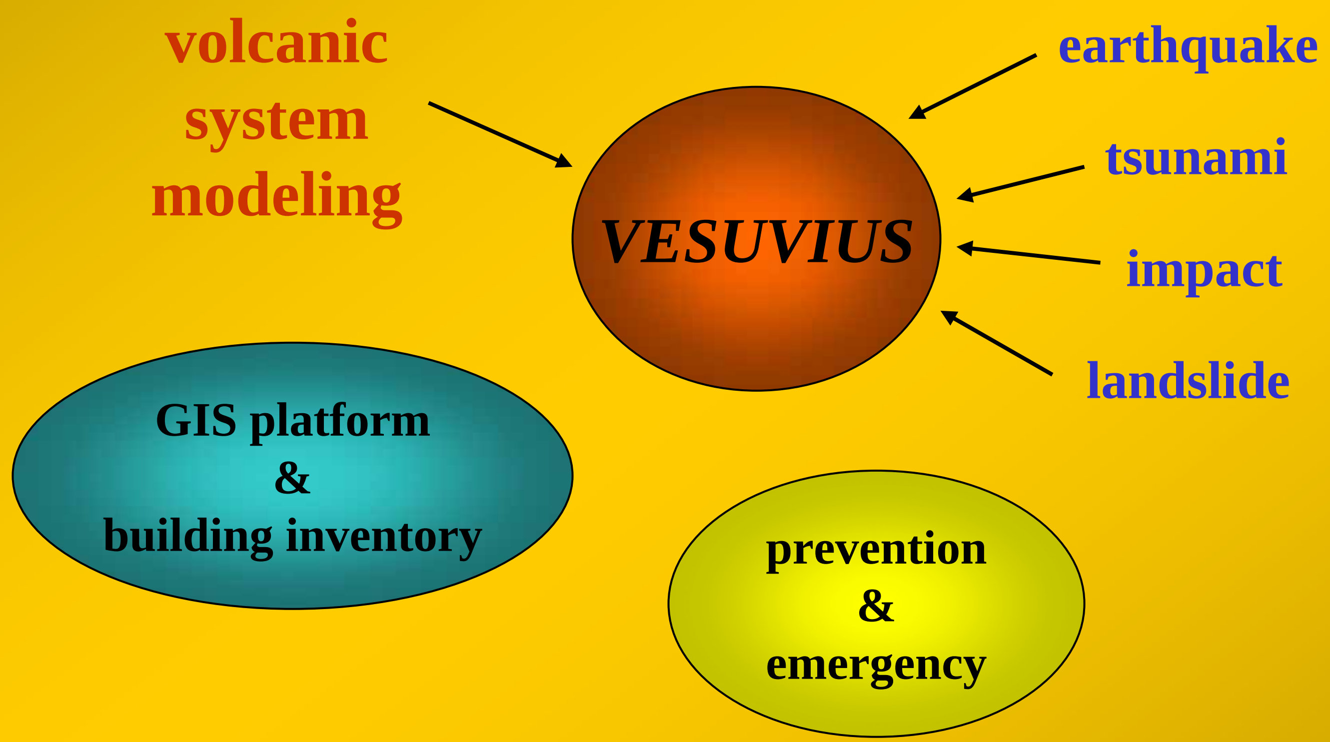
- **identification a representative study-case**
- **acquisition of the most advanced experiences**
- **collaboration in the framework of the EU-MEDIN portal**
- **involvement of Public Authorities and Civil Defense Departments**

definition of alliances for future EU projects

THANK YOU FOR THE ATTENTION

conclusions

JUST AN IDEA …



THANK YOU FOR THE ATTENTION