London/Ont., November 2004

Natural disasters:

holistic concept for recurring phenomena

Erich J. Plate
Universität Karlsruhe

Contents:

1. Disasters, vulnerability, and human security
2. Indices for vulnerability and human security
3. Long term development of human security
4. Planning to optimize human security
5. Conclusions

1 Disaster, vulnerability, and human security

A natural disaster occurs only if an extreme natural event strikes a vulnerable population. What is meant by vulnerability needs to be specified.

Definition: A natural disaster is a state, in which a population, population group, or individual is not able to cope, i.e. is not able to overcome the adverse effects of an extreme event, without outside help

When looking at extreme natural events, such as a flood, we find:

> **Whereas usually the primary cause of a flood is extreme rainfall or snow melt, i.e of natural origin, impact and magnitude of a disaster are determined by human influences.**

The definition of disaster as a state where people at risk can no longer help themselves conforms to the modern view of disaster as a social event, where the people at risk are vulnerable to the effect of a natural extreme event because of their social conditions.

According to this view, disaster management is not only a technical task, but should be a contribution to the general reduction of the vulnerability of people threatened by extreme events.

It is the purpose of this presentation to present a framework for analysis of disasters based on this view

Let us look at vulnerability. It needs to be defined:

Who is vulnerable?

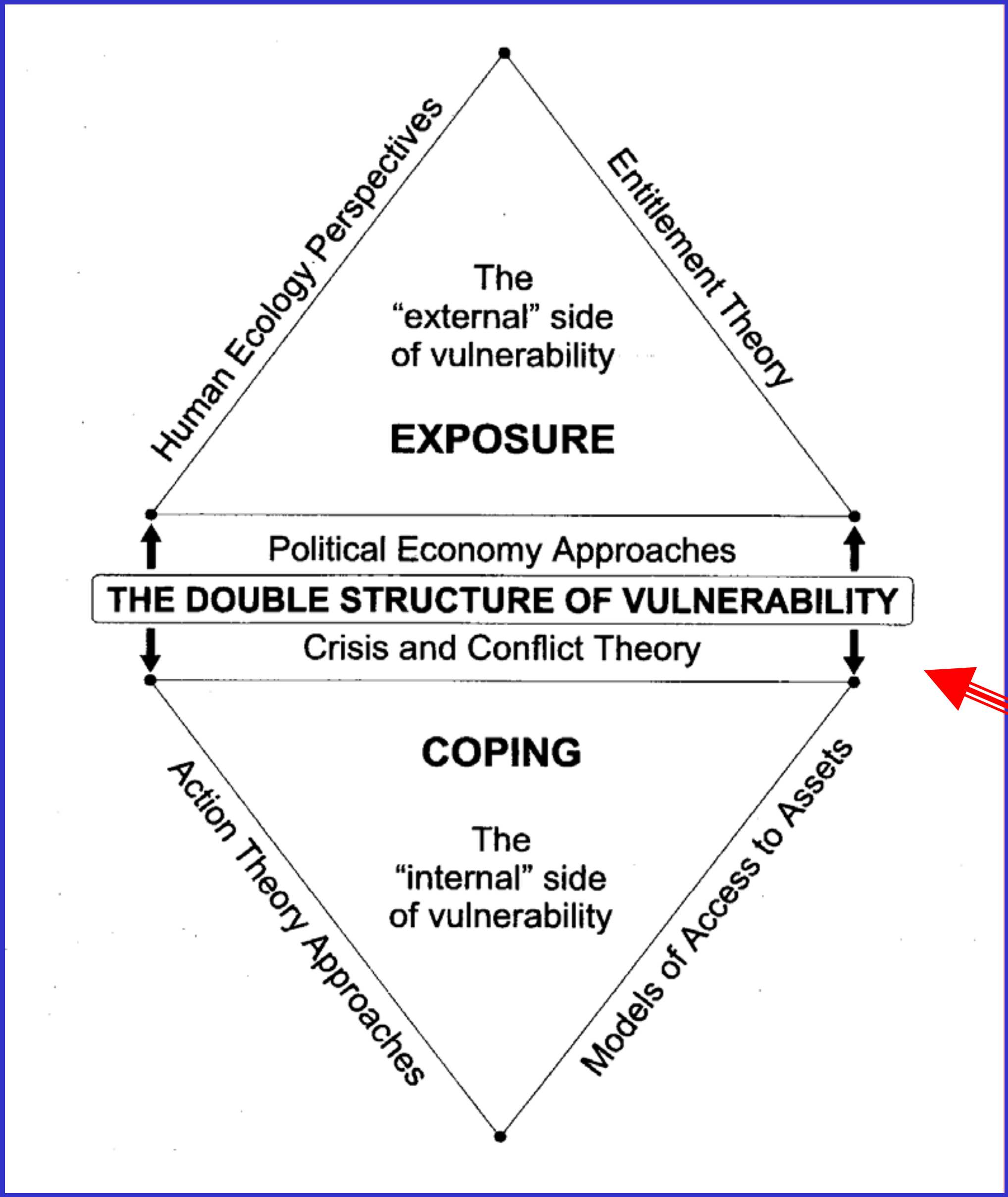
Objects or persons could be vulnerable. These are the elements at risk (EAR).

Types of vulnerability:

1. Monetary vulnerability: vulnerability can be expressed in terms of cost for reestablishing previous conditions

2. Social vulnerability is the condition of persons at risk

3. Environmental vulnerability: expresses the damage to the environment as it affects human security



Blaikie et al. 2001: Vulnerability is the characteristics of a group in terms of its capacity to anticipate, cope with, resist, and recover from the impact of a (natural) extreme event.

The double meaning of vulnerability has been made clear (Bohle, 2000)

perhaps better:

exposure = vulnerability

coping = resistance

Blaikie,P., T.Cannon, I.Davis, B.Wisner (2001): At risk: natural hazards, people´s vulnerability and disasters, Routledge, London

From these definitions, the social dimension of vulnerability becomes apparent. The term vulnerability consequently implies two aspects:

- **the resistance, i.e. the ability to cope with the disaster .**
- **the vulnerability in the narrow sense, i.e. the degree of being affected by an extreme event (exposure).**

A challenging task is to define factors (an index) that quantifies the impact on human vulnerability of natural disasters, and to obtain a quantitative basis for decision making. Let this factor be called the

„index of human security“

2. Indices for vulnerability and human security

Definitions: **(as in World Water Development Report 2003)**

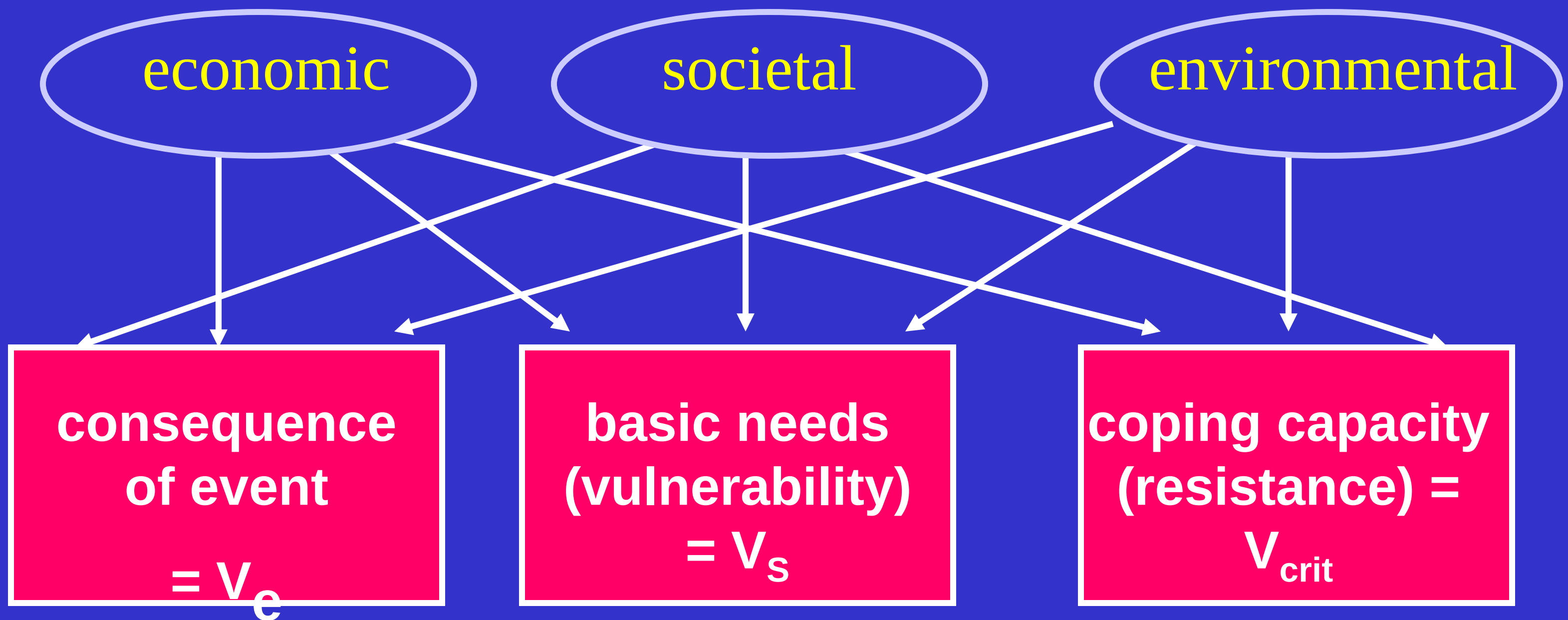
An indicator, comprising a single data point (or a single variable) or an output value from a set of data (aggregation of variables), is a quantity that describes a system or process such that it has significance beyond the face value of its components. It aims to communicate information on the system or process. The dominant criterion behind an indicator´s specification is scientific knowledge and judgement.

An index is a mathematical aggregation of variables or indicators, often across different measurement units so that the result is dimensionless.

The purpose of an index is to provide compact and targeted information for management and policy development and decisions.

The problem of combining the individual components is overcome by scaling and weighting processes, which are not absolut, but reflect social preferences.

Indicators for event based human security

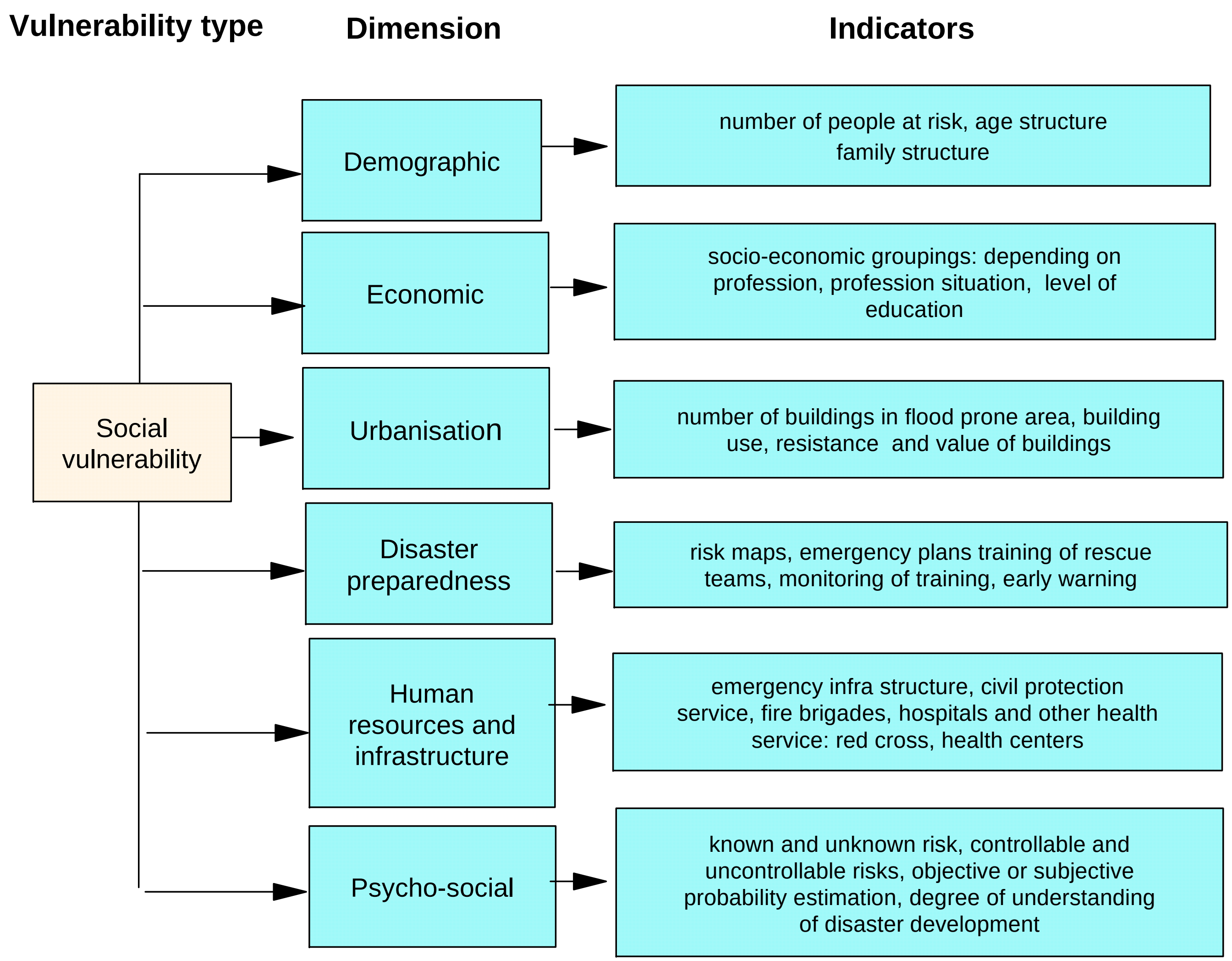


Each set of indicators produces a part of each of the indices. The sum of the partial indices, weighted by weights γ_{ij} yield indices V_e, V_S, and V_{crit}:

$$V_e = \gamma_{11} V_{eE} + \gamma_{21} V_{eS} + \gamma_{31} V_{eR}$$

$$V_S = \gamma_{12} V_{SE} + \gamma_{22} V_{SS} + \gamma_{23} V_{SR}$$

$$V_{crit} = \gamma_{13} V_{CE} + \gamma_{23} V_{CS} + \gamma_{33} V_{CR}$$



Source: de Almeida, A., C.Mmatias Ramos, M.A. Santos, T. Viseu (eds).(2003) Dam Break Flood Risk Management in Portugal,Laboratorio Nacional de Engenharia Civil, Lisbon, Portugal

To generate an operational measure for human security, let us assume:

----that the capacity of the people at risk to cope with general living conditions, including natural extreme events can be quantified by an index for resistance = V_{crit}

---- that an index V_s exists, with the same dimension as the resistance, which describes quantitatively the resources needed for maintaining adequate living conditions

---- that an index V_e exists which describes the resources needed for handling the consequences of the extreme event to life and property of the people at risk.

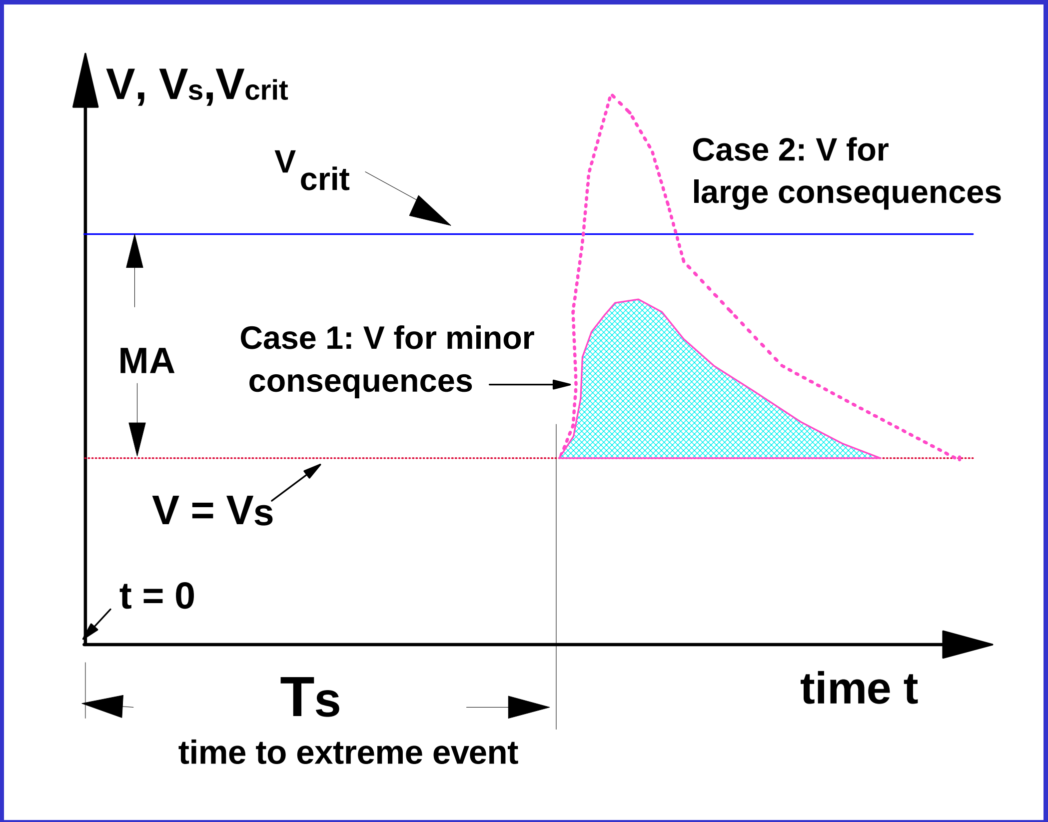
Index development for an extreme natural event

The vulnerability is defined as the total resources needed for meeting the demands of a natural extreme event, i.e.:

$V = V_s + V_e$

Consequently we can quantify the coping capacity by means of the „human security index MA“:

$MA = V_{crit} - V_s$



Condition for disaster: V exceeds V_{crit}

Example: As a first approximation, disaster mitigation can be addressed in economic terms. For each type of disaster, needed funds can be compared with available funds.

V_{crit} = total amount of money available for all purposes (the GNP/person),

V_s = "normal" vulnerability, the part of GNP/person needed for maintaining social standards.

MA = monetary value of human security, i.e. the distance between the two curves,

Then: effect of a natural disaster for a whole country is measured in terms of the fraction of the GNP that is lost due to a natural disaster

Disasters can have same financial consequences, but can have very different social consequences in different countries.

Example: **December disasters 1999 in France and in Venezuela.**

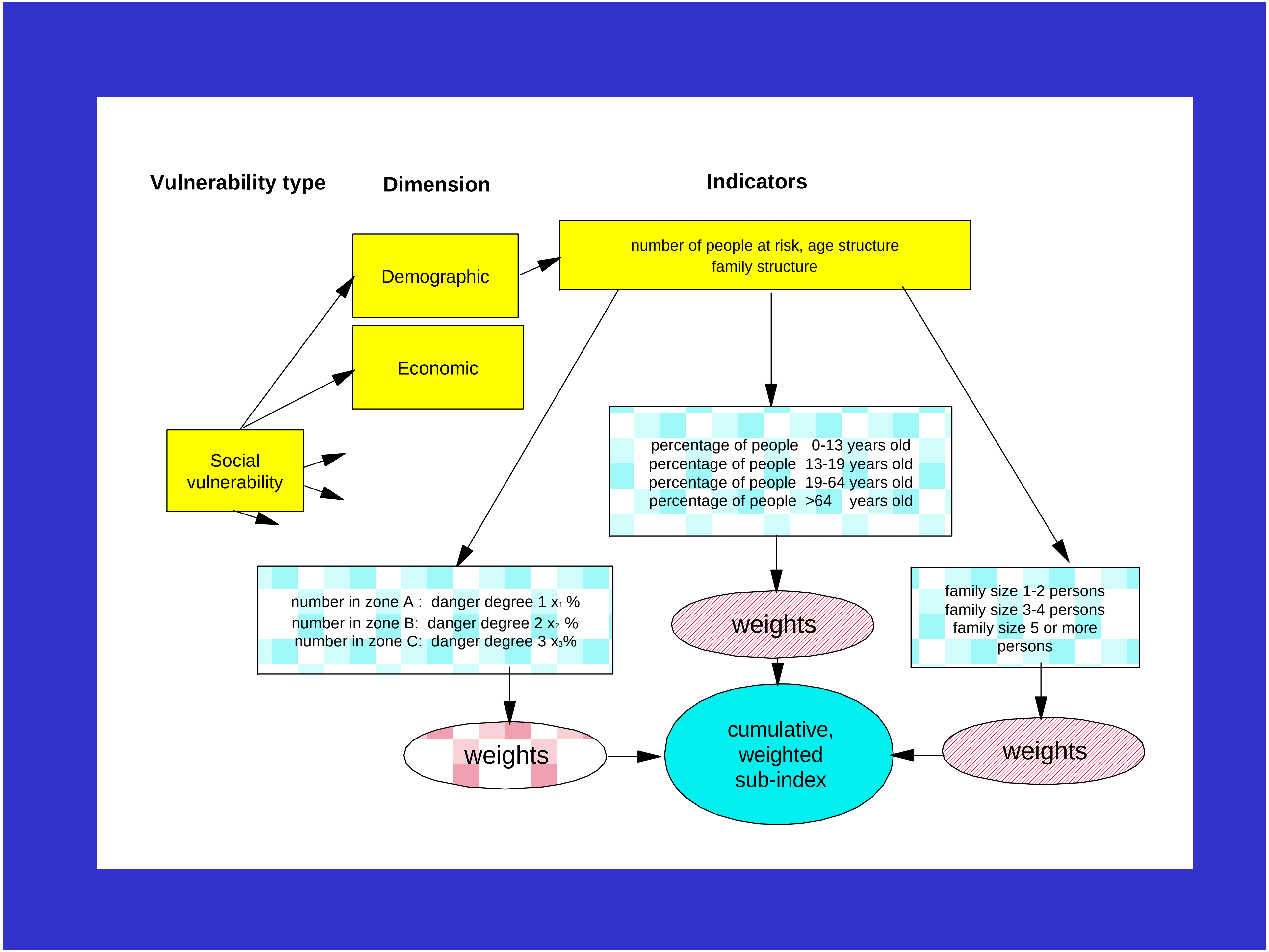
Land slides in Venezuela (1995 GNP: 143 Mrd US $) and

subtropical storm in France (1995 GNP: 1451 Mrd US $)

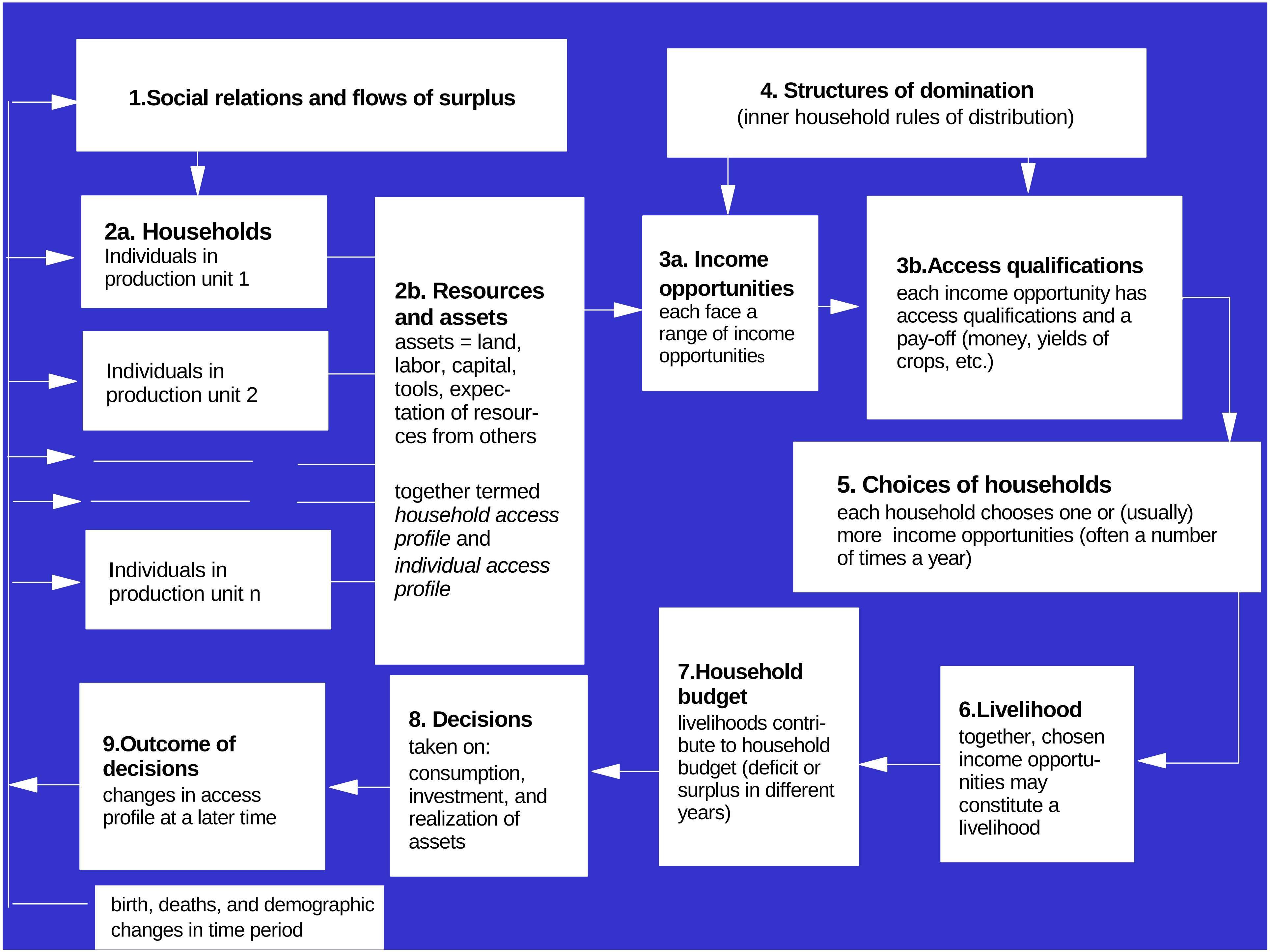
both caused damage valued at roughly 10 Mrd US $

but: 123 casualties and 0.7% GNP in France,

versus: 30,000 casualties and 7% GNP in Venezuela!



Vulnerability type
Dimension
Indicators
Demographic
Economic
Social vulnerability
number of people at risk, age structure
family structure
percentage of people 0-13 years old
percentage of people 13-19 years old
percentage of people 19-64 years old
percentage of people >64 years old
number in zone A : danger degree 1 x1 %
number in zone B: danger degree 2 x2 %
number in zone C: danger degree 3 x3%
family size 1-2 persons
family size 3-4 persons
family size 5 or more persons
weights
weights
weights
cumulative, weighted sub-index


1.Social relations and flows of surplus
4. Structures of domination
(inner household rules of distribution)
2a. Households
Individuals in production unit 1
Individuals in production unit 2
Individuals in production unit n
2b. Resources and assets
assets = land, labor, capital, tools, expectation of resources from others
together termed household access profile and individual access profile
3a. Income opportunities
each face a range of income opportunities
3b.Access qualifications
each income opportunity has access qualifications and a pay-off (money, yields of crops, etc.)
5. Choices of households
each household chooses one or (usually) more income opportunities (often a number of times a year)
6.Livelihood
together, chosen income opportunities may constitute a livelihood
7.Household budget
livelihoods contribute to household budget (deficit or surplus in different years)
8. Decisions
taken on: consumption, investment, and realization of assets
9.Outcome of decisions
changes in access profile at a later time
birth, deaths, and demographic changes in time period

An important indicator is the resilience of the elements (people) at risk. There exist different definitions of resilience.

The best definition is:

> Resilience is the ability of a population or population group to recover from an abnormal adverse condition and to return to the normal state.

A measure of resilience is the rate based on the time it takes to return to normal:

Example: let the recovery be expressed through an exponential function. Here k_e may be termed the recovery factor.

$$V_e = V_{e0} \cdot e^{-\frac{t}{k_e}}$$

$$\frac{dV_e}{dt} = -\frac{V_{eo}}{k_e} \cdot e^{-\frac{t}{k_e}}$$

3. Long term development of human security

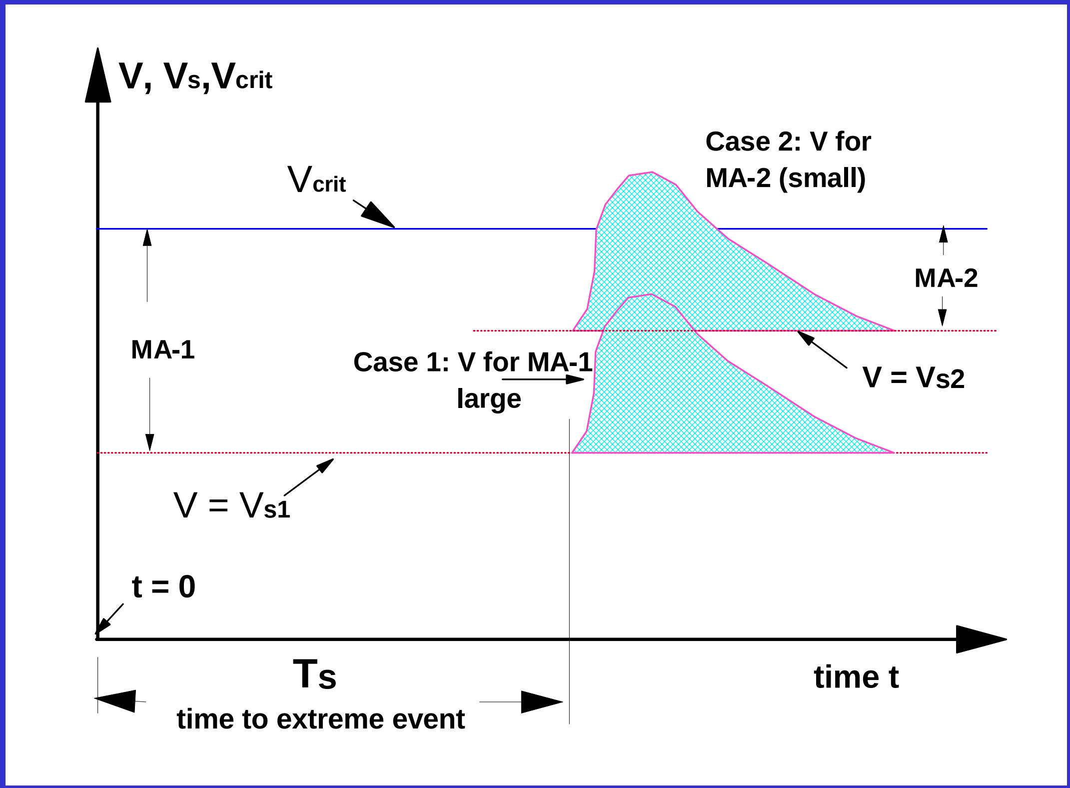
The challenge: For development needs of the future:

- for allocating limited resources within a country
- for allocating resources to the most needy locations in developing countries

we must learn to describe the change with time of disaster potentials.

For this, we need indices to quantify the long term effect of natural disasters!

Rapid onset disasters are superimposed on deteriorating conditions of a society.



Therefore, an event may be manageable (without leading to disaster) if the distance between V_s and V_{crit} is large enough

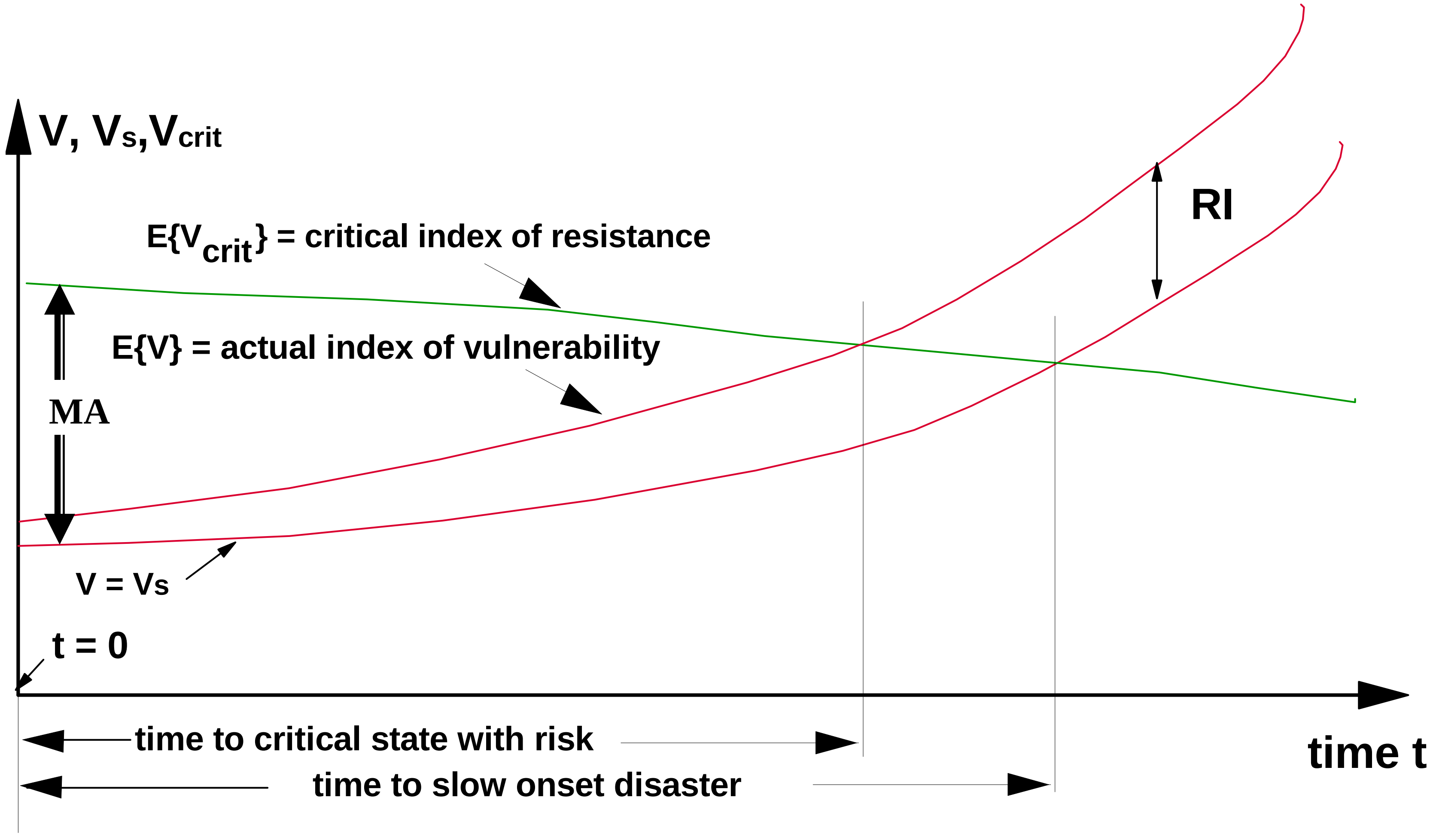
the same event may cause a disaster at a later time, when the distance has decreased due to (either deterioration of V_{crit}, or) increase of V_s

Note 1: looking at future developments involves large uncertainties: therefore V and V_{crit} are random variables, and their means E{V} and E{V_{crit}} are expected values in the sense of statistics.

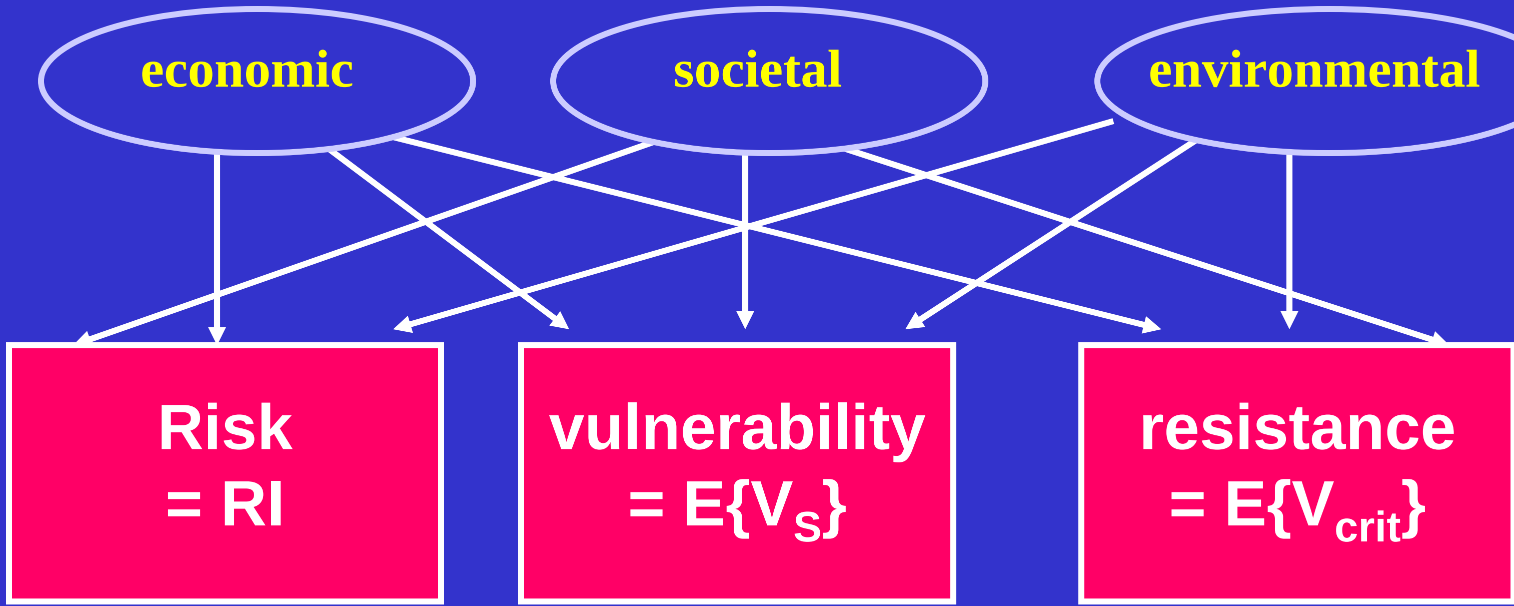
Note 2: under these conditions E{V} = E{V_s} + E{V_r}.

Note 3: E{V_r} = RI as expected value of the consequences of the exrtreme event (consequences expressed by means of a function K(u|D)

Time development of vulnerability with and without risk



Set of indicators for risk management:



Each set of indicators produces a part of each of the indices. The sum of the partial indices, weighted by weights γ_{ij} yield indices Ri, $E\{V_S\}$, and $E\{V_{crit}\}$:

$$Ri = \gamma_{11}\, Ri_E \quad + \quad \gamma_{21} Ri_S \;+\; \gamma_{31}\, Ri_R$$

$$E\{V_S\} = \gamma_{12}\, E\{V_{SE}\} \;+\; \gamma_{22} E\{V_{SS}\} + \gamma_{23}\, E\{V_{SR}\}$$

$$E\{V_C\} = \gamma_{13}\, E\{V_{CE}\} \;+\; \gamma_{23} E\{V_{CS}\} + \gamma_{33}\, E\{V_{CR}\}$$

Example: Defining a long term index of human security:

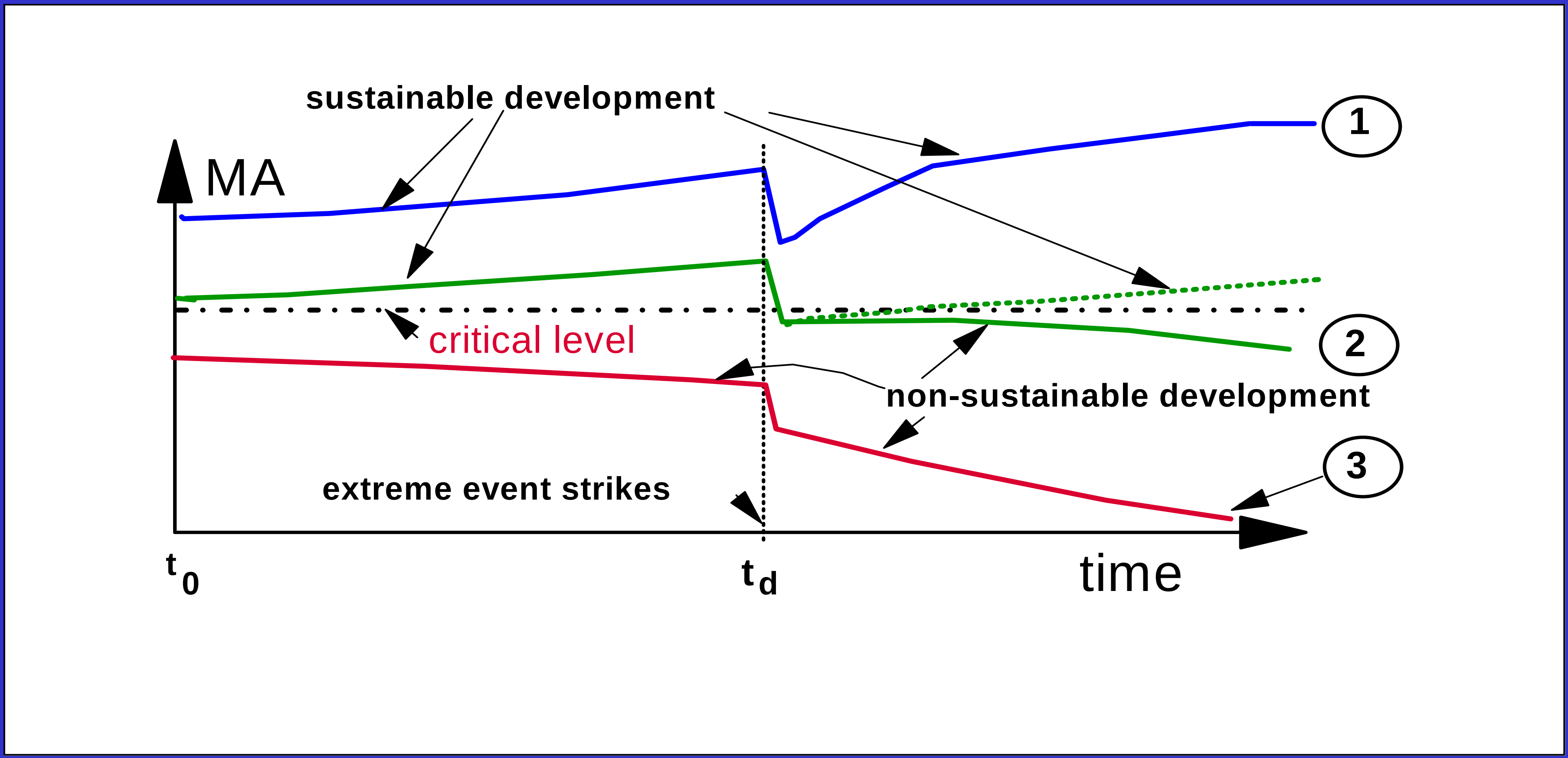
The long term index IV of human security is an estimate based on expected values E{.}:

$$IV = \frac{Ri}{MA}$$

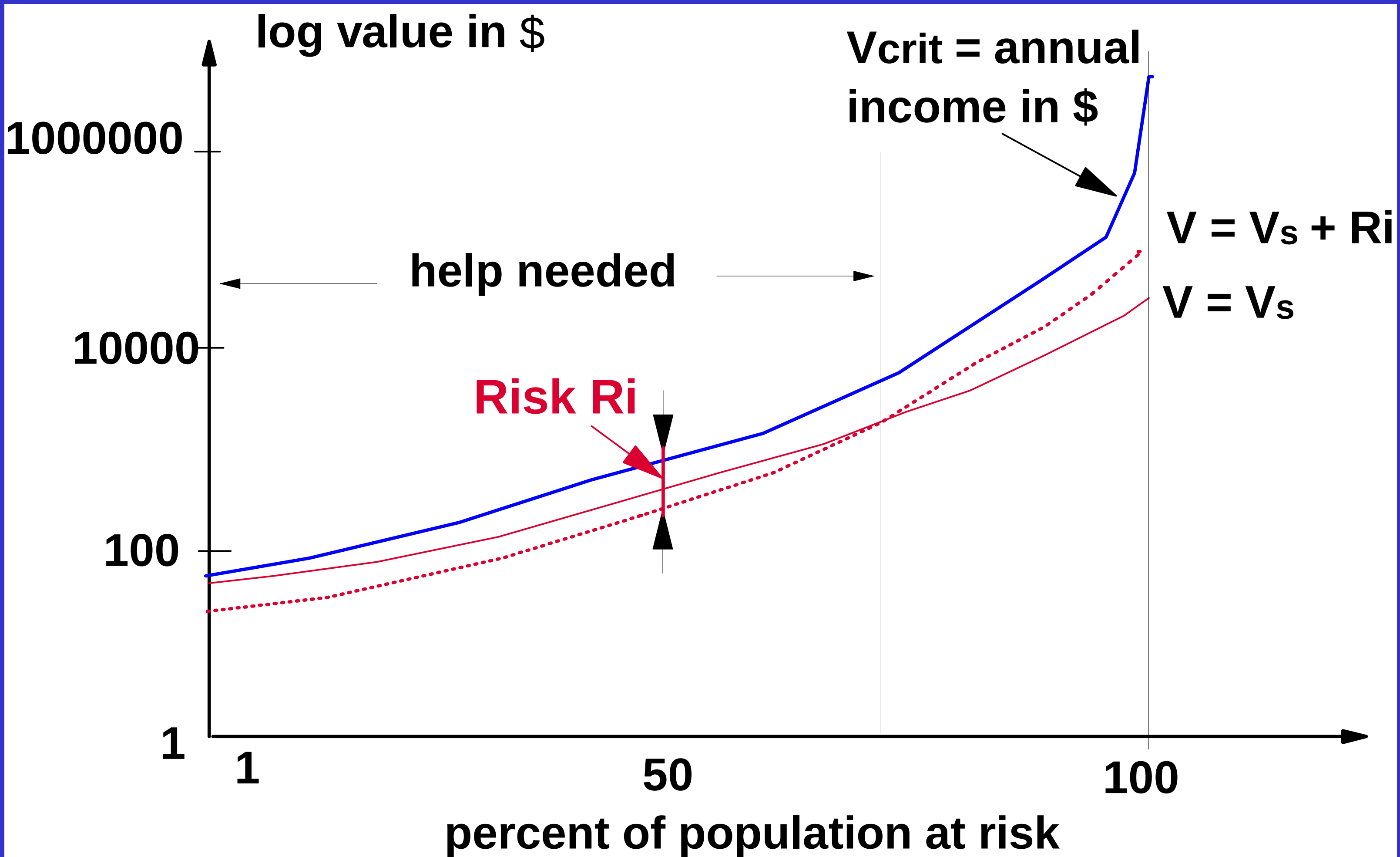
where: $MA = E\{V_{crit}\} - E\{V_s\}$

i.e. we associate the total available resources with $E\{V_{crit}\}$, identify $E\{V_s\}$ as the resources needed to cover living conditions, whereas $E\{V_e\}$ is the expected value of the consequemce of a natural extreme event.

Note: $E\{V_e\}$ is identical to the classical expression for the risk Ri!



Time development of human security index MA
as measure of sustainability of a city or society group



The social structure of human security
(in monetary terms)

Example: A homeowner has a house valued at W \$, on which he owes S \$. He also has availble capital K \$. The home is insured for v·W \$ (all expected values).

Consequently, his financial resistance (coping capacity) is:

$$E\{V_{crit}\} = v \cdot W - S + K$$

The house is expected to be partly destroyed by extreme events , leaving a value r·W. Furthermore, he may suffer additional damage Sch, yielding a risk cost of :

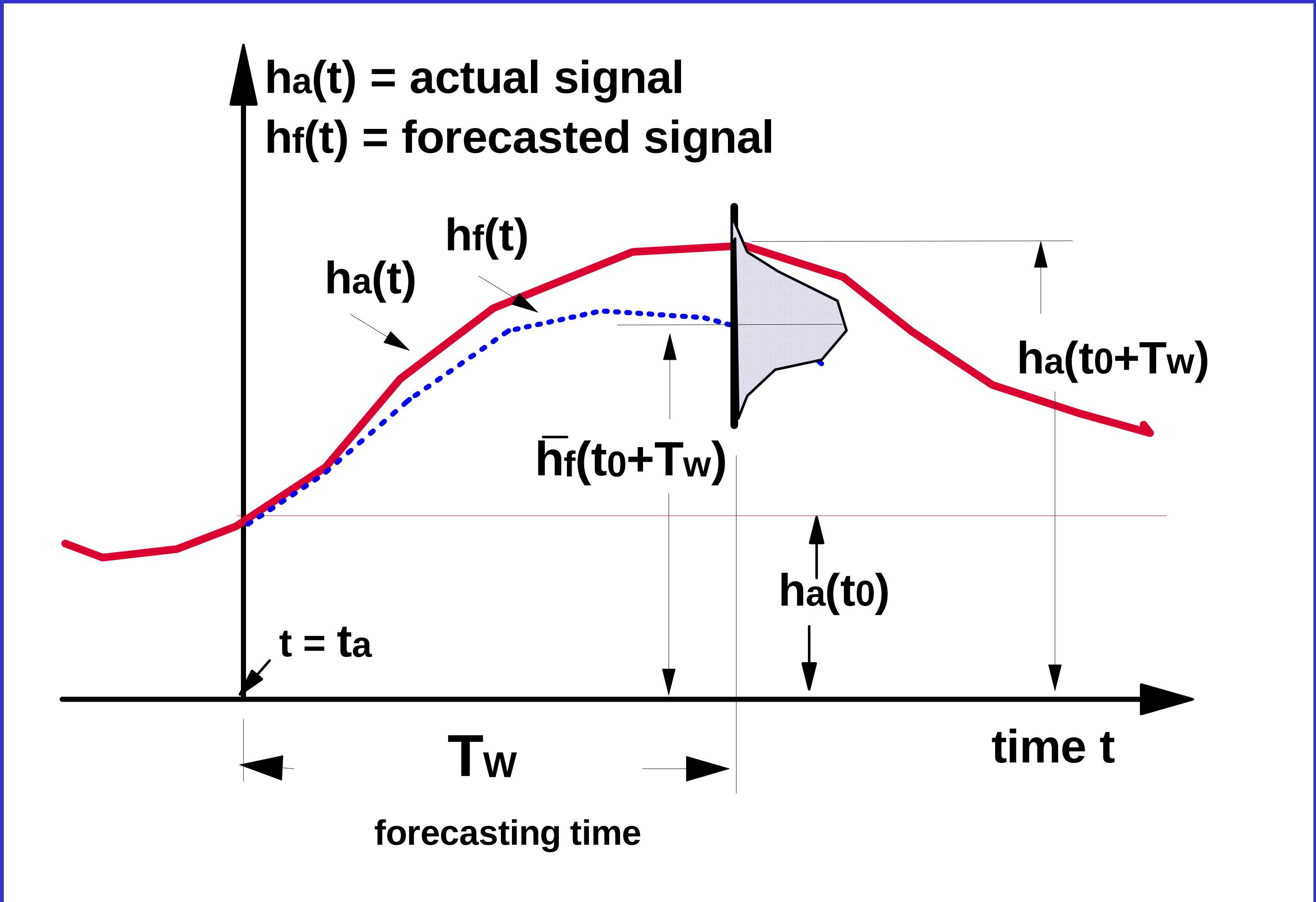
$$Ri = (1-r)W + Sch.$$

Therefore, his expected vulnerability is:

$$E\{V\} = Ri + E\{V_s\} = (1-r) \cdot W + Sch + E\{V_s\}$$

Consequently, his IV is: $\dfrac{K + (v-1+r) \cdot W - (S+Sch + E\{V_s\})}{v \cdot W - S + K}$

Translation of the concept needs forecasts for future development of all indices. Uncertainty analysis of the forecast is needed



If only h_t is known the best predictor for h_{t+T} is h_t, .
Let $h_{f,t+T}$ be the forecasted value for time t + T_W, and
let $h_{a,t+T}$ be the actual value at t+T_W.
Then we can define the following quantities:

$$\sigma_f^2 = \frac{1}{n}\sum_n (h_{a,t+T} - h_{f,t+T})^2 \quad (1)$$

and:

$$\sigma_a^2 = \frac{1}{n}\sum_n (h_{a,t+T} - h_{a,t})^2 \quad (2)$$

n = number of forecasting steps for time of forecast,
t = time for each time step, and
T = forecasting time T_W to peak.

These can be combined to yield a factor FB which describes the quality of the forecast, where the sums have to be taken over m forecasts:

$$FB = \frac{\sum_m \sigma_{fm}^2}{\sum_m \sigma_{am}^2} \quad (3)$$

Further insight can be gained by writing:

$$h_{f,t+T} = \overline{h}_{f,t+T} + h'_{f,t+T}$$

Where $\overline{h}_{f,t+T}$ is deterministic, and $h'_{f,t+T}$ is the random part. The variance then is:

$$\sigma_f^2 = \tilde{\sigma}_f^2 + \sigma_f'^2$$

with

$$\tilde{\sigma}_f^2 = \frac{1}{n}\sum_n (h_{a,t+T} - \overline{h}_{f,t+T})^2 \qquad \sigma_f'^2 = \frac{1}{n}\sum_n (h'_{f,t+T})^2$$

We define:

$$DF = \frac{\tilde{\sigma}_f^2}{\sigma_f'^2}$$

= INDEX OF DETERMINATION

4. Planning to optimize human security

For improving human security with respect to disasters, appropriate mitigation measures must be developed or improved, based on the recognition of changes both in vulnerability and in resistance.

There are three distinct ways of disaster mitigation:

- We can reduce the vulnerability
- We can increase resistance.
- We can reduce the impact

In principle, it is an optimization problem, to be solved by means of operations research methods.

$$Z = \sum_{t=1}^{T} \frac{1}{(1+e)^t} \left(V_{crit}(t) - V_S(t) - V_e(t) \right) \Big|_D$$

T = design life time in number of years,

t = time index in number of years,

e = rate of return

D = decision variable for the alternative considered

Solution 1: modify V_s and V_{crit} so that Z is positiv or ~ 0

Solution 2: reduce V_r = RI so that Z stays positiv

Best solution: the one that accomplishes the objective of obtaining Z > 0 at minimum cost.

Note that all quantities must be statistical expectations, expressed in the same numerical units!

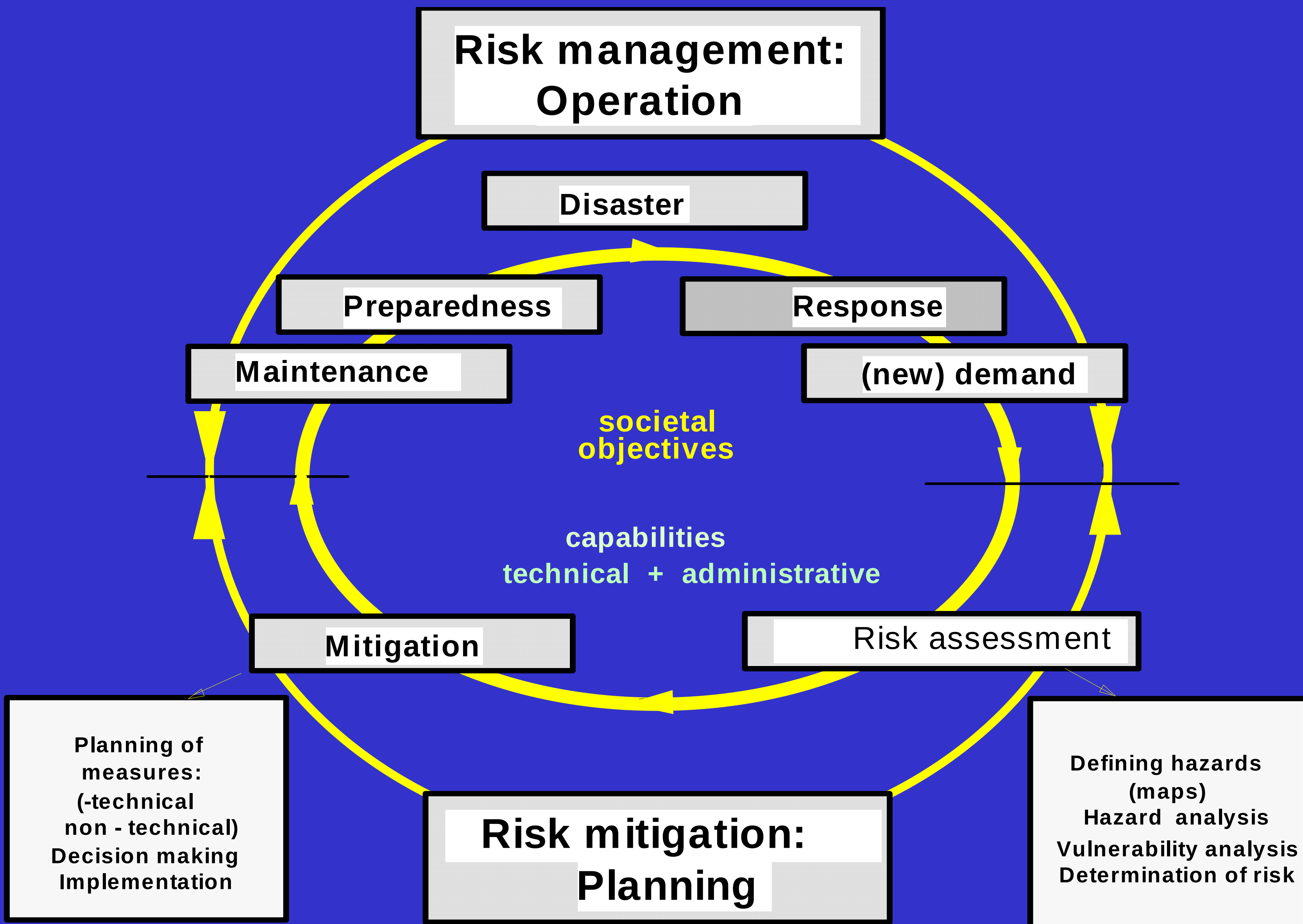
The effect of these processes must be investigated, quantified, and incorporated into mitigating concepts.

However, modification of V_s and V_{crit} is a long term task, requiring socio-economic efforts which need strong political support.

Short term solution: Reducing the risk RI

The method to be used is risk management.

The risk management cycle



Risk definition.

$$RI(\vec{D}) = \int_0^{\infty} K\left(u \middle| \vec{D}\right) \cdot f_u\left(u \middle| \vec{D}\right) \cdot du$$

u is the event (i.e flood stage), with pdf $f_u(u)$

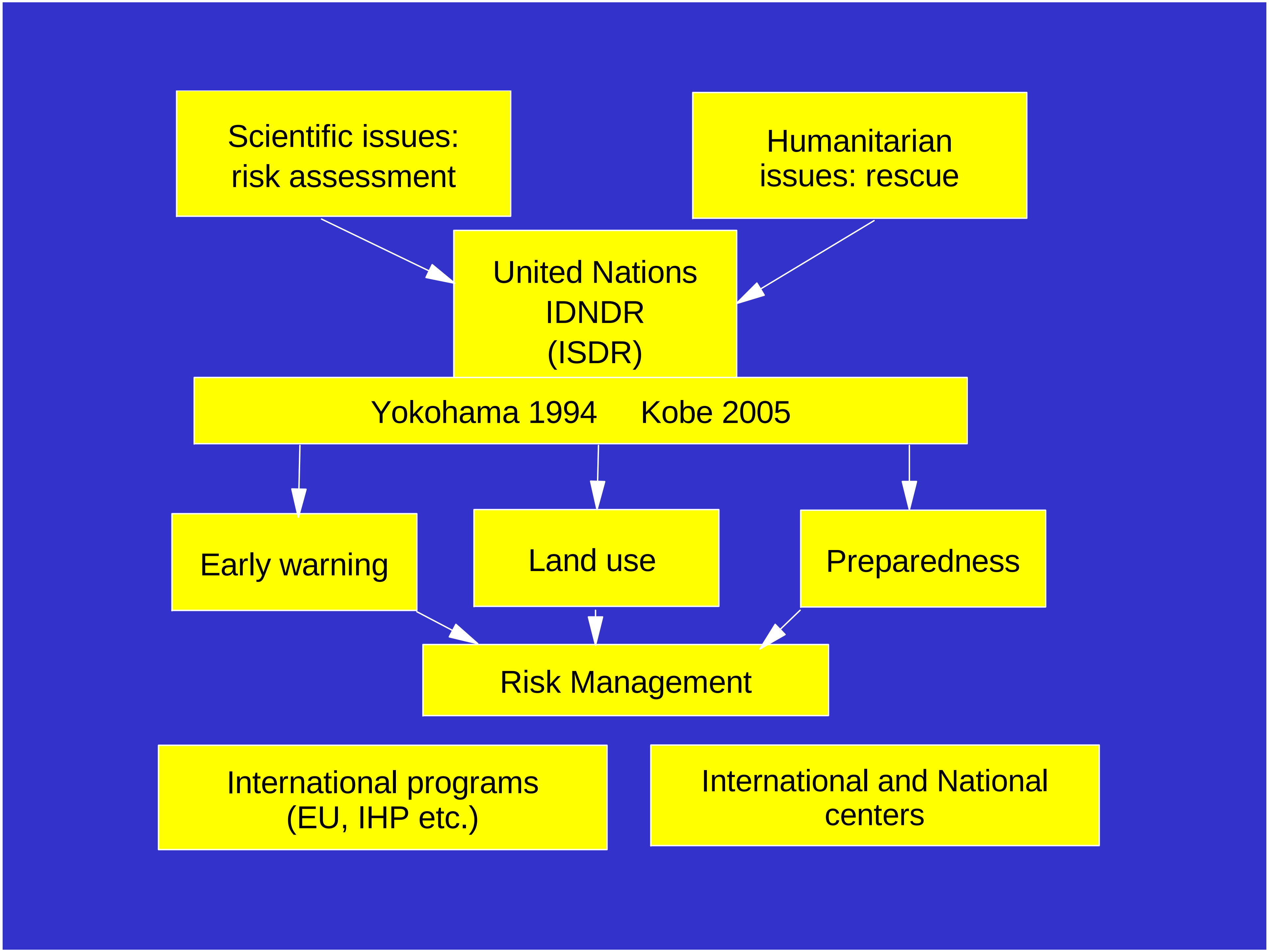
K(x|D) is the consequence function, to be determined through a vulnerability analysis.

The analysis must yield quantitative measures of the socio-economic and ecological consequences for each possible planning decision D.

5.Conclusions:

In order to translate these concepts into an useful tool, it is necessary to:

- identify the indicators that combine to yield the index of vulnerability
- develop a technology to assign weights to the indicators and thus to the indices
- forecast the future development of the numerical indicators and give their uncertainty bands
- determine the best approach for the improvement of resistance and reduction of vulnerability by means of a comprehensive planning process based on risk management.


Scientific issues:
risk assessment
Humanitarian
issues: rescue
United Nations
IDNDR
(ISDR)
Yokohama 1994 Kobe 2005
Early warning
Land use
Preparedness
Risk Management
International programs
(EU, IHP etc.)
International and National
centers

Thank you!

Factors combine to generate vulnerability

ROOT CAUSES	DYNAMIC PRESSURES	UNSAFE CONDITIONS	DISASTER	HAZARDS
Limited access to:	**Lack of:**	**Fragile physical environment:**		
-power -structures	-local institutions -training	-dangerous locations -unprotected buildings and infrastructure		Earthquakes High winds (cyclone/ hurricane/typhoon)
-resources	-appropriate skills -local investments	**Fragile local economy:**		Flooding
	-press freedom -ethical standards in public life	-livelyhoods at risk -low income levels	**Risk = Hazard +Vulnerability**	Volcanic eruption
	Macro-forces: -rapid population growth	**Vulnerable society:** -special groups at risk	**R = H + V**	Landslide
Ideologies:	-rapid urbanization	-lack of local institutions		Drought
-political systems -economic systems	-arms expenditure -debt repayment schedules -deforestation	**Public actions:**		Virus and pests
	-decline in soil productivity	-lack of disaster preparedness -prevalence of endemic disease		