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Social cost-benefit analysis in the context of regional adaptation planning

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Presentation structure

- Context of climate change, adaptation and infrastructure
- Cost-benefit analysis in brief
  - The basics and metrics
  - Valuation choices, duration, discount rate
  - Non-priced effects
  - Uncertainty
  - Distribution effects / fairness – market organisation
  - MCA and CBA
- Structuring a CBA
- Applications
  - incl. insurance aspects

The context

- **Climate change**
  - Processes of different pace and scale
  - Uncertainty, (ir)reversibility
- **Different types of adaptation**
  - Automatic/autonomous ; Reactive ; Proactive
  - Isolated vs. Integrated
- **Infrastructure**
  - Large size, indivisibilities, layers, network effects
  - Long lifetime, economic & spatial structuring
  - Public good features, implications of market organization

Climate change impacts – temporal profiles

Temporal profile of the unfolding of the change	Duration of the state resulting from the change*	
	Permanent	**Transient**
Mode I: Slow and fundamental	• Sea level rise (navigation effects, flood risks) • Retreat of sea ice (with annual fluctuations)	• Increased weather variability, notably worse winter conditions
Mode II: Slow underlying trends culminating in quick changes	• Exponential growth of algae in the Baltic Sea and in lakes (impacts or tourist travel) • Collapsing fish stocks (due to temperature change)	• Infrastructure collapse due to changes in hydrology and soil mechanics • Collapsing fish stocks (due to invasive species) • Drought and harvest losses
Mode III: Sudden and dramatic	• Polar navigation possibilities (?) •	• Floods (infrastructure planning / design, availability, materials, ICT, modal split) • Storms (infrastructure planning / design, availability, materials, ICT, modal split)

Categorising stages of adaptation

	Passive Adaptation - automatic in nature and economy - only ex post measures (no anticipation)	**Active Adaptation** - automatic in nature and economy - ex ante and ex post policies
Emission scenario dependent baseline (A1-T, B1, A2, etc.)	*Reference costs and benefits*	--
Selected baseline + adaptation policy	non-optimised 'wait and see approach'	*Rational adaptation policy – but disjunct from mitigation strategy*
Selected baseline + adaptation & mitigation policy (only relevant when assessment period goes beyond 2050)	even less optimised 'wait and see approach'	*Rational integrated adaptation & mitigation strategy*

From: Perrels et al 2005

Review of climate change effects in built-up areas (1)

Climate Driven Phenomena	Evidence for Current Impact/ Vulnerability	Other Processes/ Stresses	Projected Future Impact/ Vulnerability	Zones, Groups Affected
a) Changes in extremes				
Tropical cyclones, storm surge	Flood and wind casualties and damages; economic losses: transport, tourism, infrastructure (e.g., energy, transport), insurance (7.4.2; 7.4.3; Box 7.3; 7.5)	Land use/ population density in flood-prone areas; flood defences; institutional capacities	Increased vulnerability in storm-prone coastal areas; possible effects on settlements, health, tourism, economic and transportation systems, buildings and infrastructures	Coastal areas, settlements and activities; regions and populations with limited capacities and resources; fixed infrastructures; insurance sector
Extreme rainfall, riverine floods	Erosion/landslides; land flooding; settlements; transportation systems; infrastructure (7.4.2) (see regional Chapters)	As for tropical cyclones and storm surge, plus drainage infrastructure	As for tropical cyclones and storm surge, plus drainage infrastructure	As for tropical cyclones and storm surge, plus flood plains
Heat or cold-waves	Effects on human health; social stability; requirements for energy, water and other services (e.g., water or food storage), infrastructures (e.g., energy transportation) (7.2; Box 7.1; 7.4.2.2; 7.4.2.3)	Building design and internal temperature control; social contexts; institutional capacities	Increased vulnerabilities in some regions and populations; health effects; changes in energy requirements	Mid-latitude areas; elderly, very young, ill and/or very poor populations
Drought	Water availability, livelihoods; energy generation; migration,; transportation in water bodies (7.4.2.2; 7.4.2.3; 7.4.2.5)	Water systems; competing water uses; energy demand; water demand constraints	Water resource challenges in affected areas; shifts in locations of population and economic activities; additional investments in water supply	Semi-arid and arid regions; poor areas and populations; areas with human-induced water scarcity

Source: IPCC 4AR_2

Review of climate change effects in built-up areas (2)

Climate Driven Phenomena	Evidence for Current Impact/ Vulnerability	Other Processes/ Stresses	Projected Future Impact/ Vulnerability	Zones, Groups Affected
b) Changes in means				
Temperature	Energy demands and costs; urban air quality; thawing of permafrost soils; tourism and recreation; retail consumption; livelihoods; loss of melt water (7.4.2.1; 7.4.2.2; 7.4.2.4; 7.4.2.5)	Demographic and economic changes; land-use changes; technological innovations; air pollution; institutional capacities	Shifts in energy demand; worsening of air quality; impacts on settlements and livelihoods depending on melt water; threats to settlements/infrastructure from thawing permafrost soils in some regions	Very diverse, but greater vulnerabilities in places and populations with more limited capacities and resources for adaptation
Precipitation	Agricultural livelihoods; saline intrusion; tourism; water infrastructures; energy supplies (7.4.2.1; 7.4.2.2; 7.4.2.3)	Competition from other regions/sectors. Water resource allocation	Depending on the region, vulnerabilities in some areas to effects of precipitation increases (e.g., flooding, but could be positive) and in some areas to decreases (see drought above)	Poor regions and populations
Saline intrusion	Effects on water infrastructures (7.4.2.3)	Trends in groundwater withdrawal	Increased vulnerabilities in coastal areas	Low-lying coastal areas, especially those with limited capacities and resources

Source: IPCC 4AR_2

Cost-benefit analysis – the basics 1

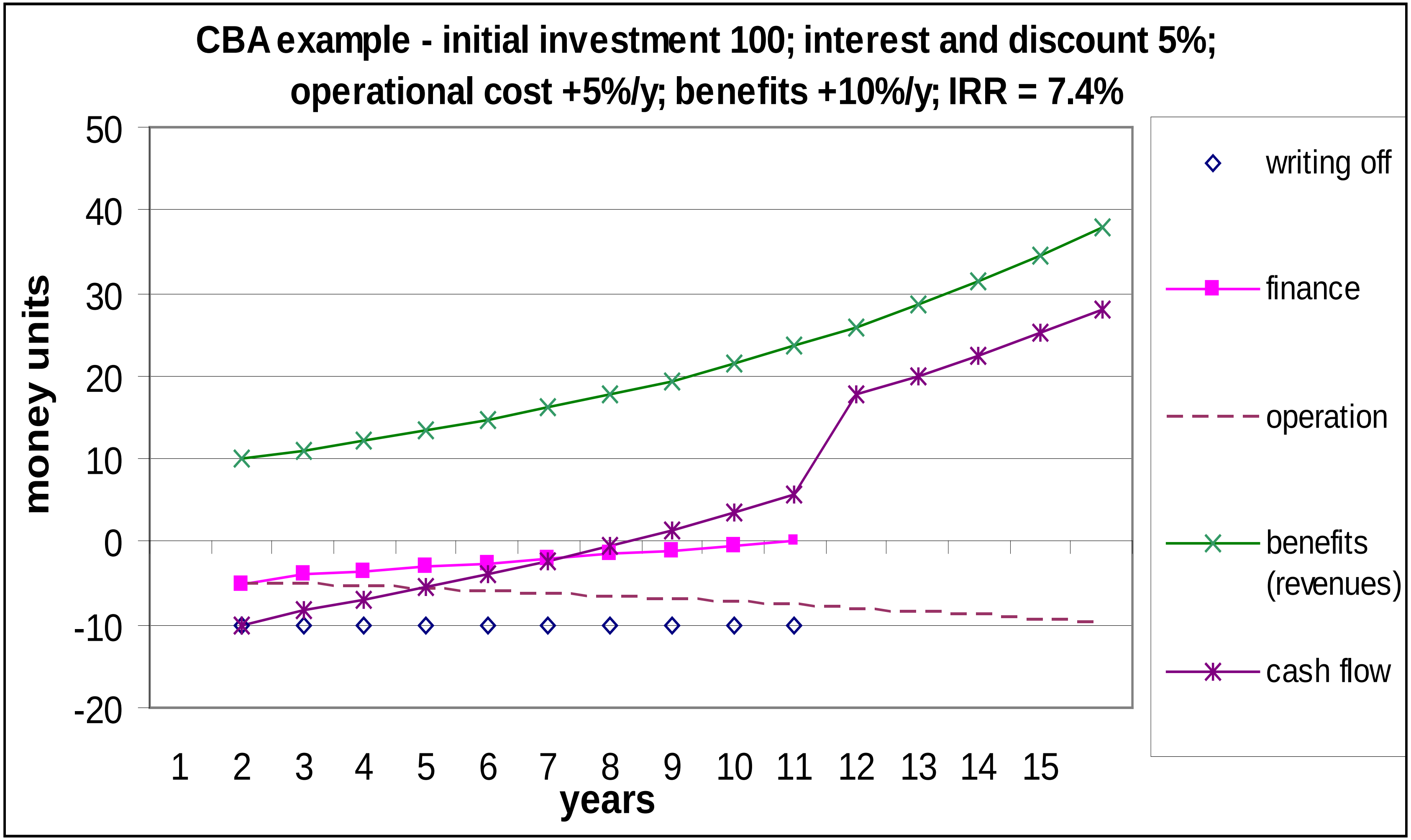
- **CBA:**
  - assess for the estimated lifetime of a project the annual expenditures (investment funding cost, operational cost, etc.) and the annual revenues
  - consider an appropriate discount rate and assess NPV (net present value), IRR (internal rate of return), and net cash flows
  - rank alternatives by score level
- **SCBA**: social CBA – total benefits -/- total costs *for society*, in this case benefits and costs often don't accrue (entirely) to the same organisation due to the public nature of a project (CBA can be subset of SCBA)
- **CEA:** cost-effectiveness analysis – this is used if for (a part of) the intended impacts no (shadow) price can be established (or when that is contentious)

Cost-benefit analysis – the basics 2

- **Metrics:**
  - Net present value (NPV) : $$\mathrm{NPV} = \sum_{t=0}^{n} \frac{(x_t - y_t)}{(1+r)^t}$$
  - Internal Rate of Return (IRR): r = r* such that NPV = 0
  - Benefit-Cost Ratio (B/C ratio): $$\mathrm{BC-ratio} = \sum_{t=0}^{n} \frac{y_t}{(1+r)^t} \Big/ \sum_{t=0}^{n} \frac{x_t}{(1+r)^t}$$
  - Macro-economic criteria (Δ%GDP; Δ% employment; etc. in case of very large or very effective projects)
- **NB!** Different metrics may produce different rankings for the same set of projects
- Above listed indicators are only straightforward in case of *priced* effects and assuming limited and tractable uncertainty
- Above list of indicators provides no clue of *redistribution* effects, nor of implications of m*arket organisation* alternatives

Cost-benefit analysis – the basics 3

Simple example: despite positive IRR still cash flow challenge years 1 - 8



Valuation principles – consistent choices!

- **Where** to measure?
  - Production
  - Consumption → welfare/wellbeing (the ultimate issue)
  - Potential vs. actual impacts (e.g. real estate)
- **What** to measure?
  - Stocks (e.g. real estate) *or* flows (production, income)
  - From direct cost to overall economic impact
  - Market / non-market
  - Baseline / automatic adaptation/ planned adaptation
- Beware of **double counting** (stocks-flows; costs-transfers)
- Uncertainty / Risk / Volatility

Duration of alternatives

- If project alternatives have different duration → normalize on common duration by:
  - Defining follow-up for shortest project(s) up to length of longest project or..
  - Such that total duration of follow-up + amortization free period of long alternative end at same time
- Lack of harmonization makes NPVs incomparable
- Formally summarized, e.g.:

$$\sum_j NPV_{i_j} = \sum_j \left[\sum_{t=0 \dots t_j} \frac{(x_{t_j} - y_{t_j})}{(1+r)^{t_j}} \right]$$

- Where project i_1 runs from t_0 to t_1 and project i_2 from t_1 to t_2

The discount rate

- The discount rate (r) in the NPV calculation needs to be chosen

$$\mathrm{NPV} = \sum_{t=0}^{n} \frac{(\mathrm{x_t} - \mathrm{y_t})}{(1+\mathrm{r})^{\mathrm{t}}}$$

- If a project is (predominantly) commercial a bank interest rate can be used and nominal prices to allow for inflation effects
- For SCBA a real interest rate (i.e. no inflation) is used
  - if economic lifetime < ~25 y. → norm rate (often ~ 5%)
  - If economic lifetime > ~50 y. → lower rate depending on envisaged time horizon and uncertainty (Barro, 2009; Weitzman, 1998)

Non-priced effects 1

- Some costs and benefits don't have an (explicit) price, e.g.
  - Environmental effects
  - Pure public goods (e.g. a dyke; the police force)

Infer a *shadow price* – this can be based on:

- Unit-cost (e.g. based on public sector accounting)
- Replacement cost (of damaged nature)
- Willingness to pay (WTP; to compensate loss or prevent a project)
  - *Survey* based or *proxy/analogy* based
- Eco-system service(s) infer a unit value via:
  - differential impact on priced effect (e.g. harvest volume)
  - comparison with engineering alternative
- Quasi-market for tradable permits

Non-priced effects 2

- The explicit price is not necessarily the right social price:
  - The price of a good does not account for *external costs*, e.g. environmental damage or damage to third parties (e.g. congestion, road safety, traveller security)
  - The price of a good does not account for *external benefits*, i.e. avoided damage to nature or third parties (e.g. extra safety in new cars, careful road design)
- **Internal vs. external effect**
  - **Internal**:
    - those costs & benefits that remain in the studied system or accrue to the same agent that created them
    - often the price is either explicit or can be estimated
  - **External**:
    - those costs & benefits that end up outside the studied system or accrue to other agents than the creating agent
    - usually the price is not explicit and may be hard to estimate

Uncertainty 1

- Different kinds and 'levels' of uncertainty:
  - **Aleatory** and **epistemic** uncertainty
    - **Aleatory**: uncertainty due to *variability*
    - **Epistemic**: uncertainty due to *lack of knowledge*
- Distinction by level of the analytical process
  - **Paradigm level**: e.g. long term evolution in societal value systems and prioritization structures
    - scenario choices; delineation; (model type choice)
  - **Conceptual level**: understanding of the causal structure
    - Model (type) choice; model structure; data sources/needs
  - **Model level**: sufficiently adequate representation of the causal structure and orders of magnitude of influence factors
    - Model validation; data quality
  - **Parameter level**: adequate estimates of parameters in selected functions in the models

Are we focusing on the right issues?

Uncertainty 2

Are we using the right frameworks?
Identify & acknowledge where best to reduce uncertainty

- **Natural science related**: e.g. limitations to downscaling of modeled future climate features, inherent chaotic processes underlying weather & climate
- **Social science related**: e.g. responsiveness to measures, projections of key economic and social variables, actual location of growth and decline
- **Time related**: for ever longer time frames uncertainty is abounding ever more
- **Interaction with other sub-systems**: (e.g. impact of changes in trade flows)
- **Data quality; parameter quality**, etc. for a particular application

Uncertainty 3 – (partial) remedies

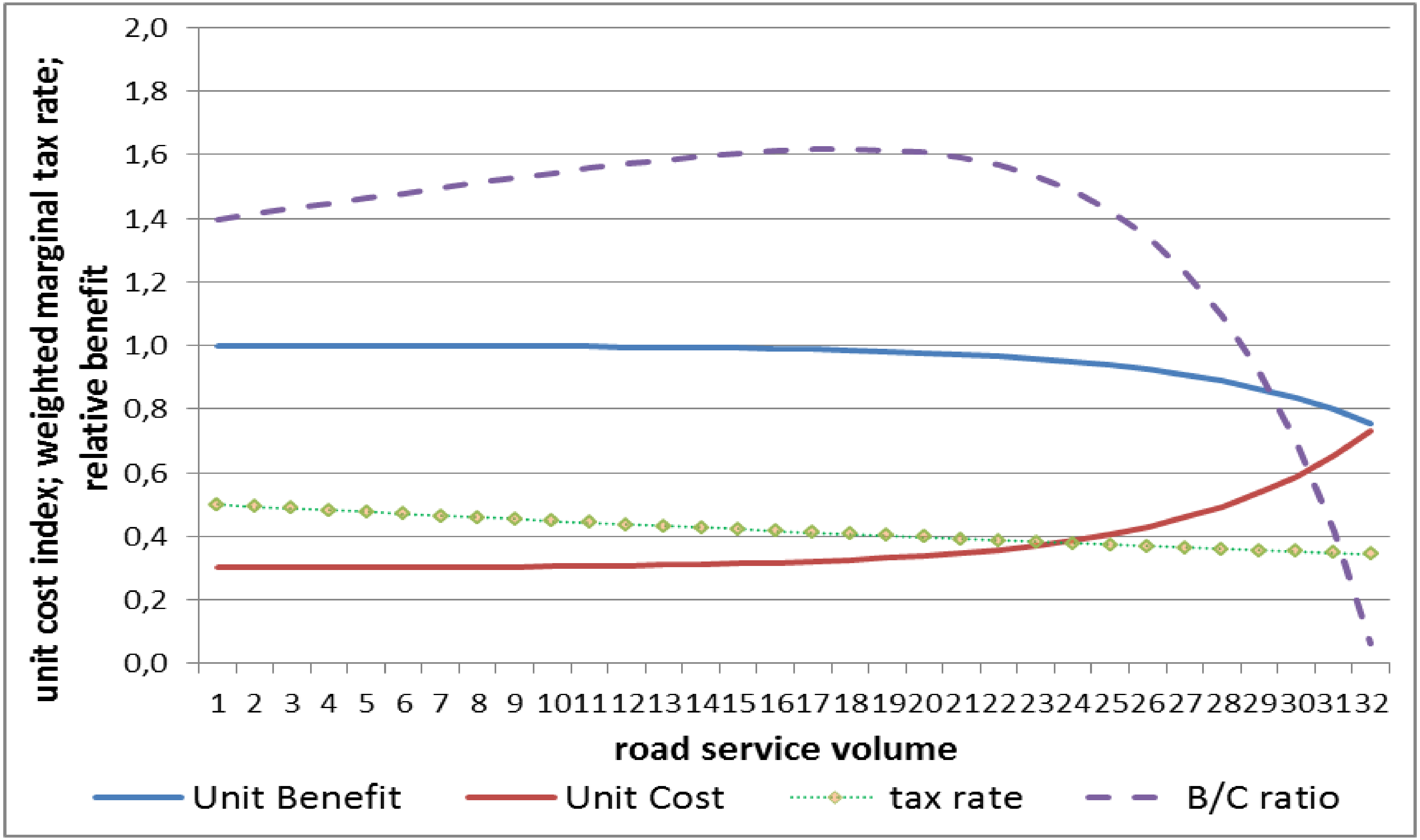
- **Retrospective** and **prospective** approaches
- (statistical) *sensitivity analysis* (data; parameters)
- *error propagation analysis* (how deviations develop in a model)
- *benchmarking* (accuracy compared to other models & realizations)

- **Improve learning capabilities** of planning and analytical processes
  - Adaptive management approaches
  - Better / systematic monitoring – full evaluation cycles
  - Experience and data sharing (e.g. Adaptation Clearinghouse for Europe ACE) ..speeds up learning by more *concurrent* efforts
- At the output side (adaptation solution alternatives):
  - What are the hedging alternatives next to (heavy) investments?
    - Risk sharing instruments: insurance, derivatives, options, etc.?
    - Information systems (early warning, etc.)?
    - Localized/staggered improvements?

Distribution effects & market organization 1

- For publicly funded infrastructure there is often no link between use and payment (via taxes) → consequence:
  - the distribution of the benefits of the infrastructure not necessarily reflects the distribution of the tax payments (by person, region, etc.)
  - If the deviation of the distributions of costs and benefits coincides with differences in income levels (or profitability levels for business) the mismatch is not 'only' a matter of principles, but also has macro-economic implications – meaning that it denotes not only a transfer but to some extent also a production or income effect
  - For (road) infrastructure this ties in with alternative approaches for determining desirable service levels per segment/region:
    - **Output equality**: same service level throughout the system
    - **Input equality**: same value-for-money ratio throughout the system

Net benefit redistribution of road services: hypothetical example



Distribution effects & market organization 2

- External effects may have significant distributional aspects, e.g. traffic noise and low air quality are often pronounced in poorer neighborhoods or notably affect children & elderly (‘**environmental justice**’)
- The way the provision of infrastructure services is organised affects the distribution of benefits and costs of measures/investments
  - extent of integration or separation of infrastructure capacity service, mobility service, and actual shipment/delivery:
    - ease of substitution and share in the value added chain
  - degree of outsourcing of maintenance, construction, and design tasks:
    - cost minimization vs. quality targets
    - responsibility & motivational attachment/detachment to targets of Road Authority

CBA and MCA

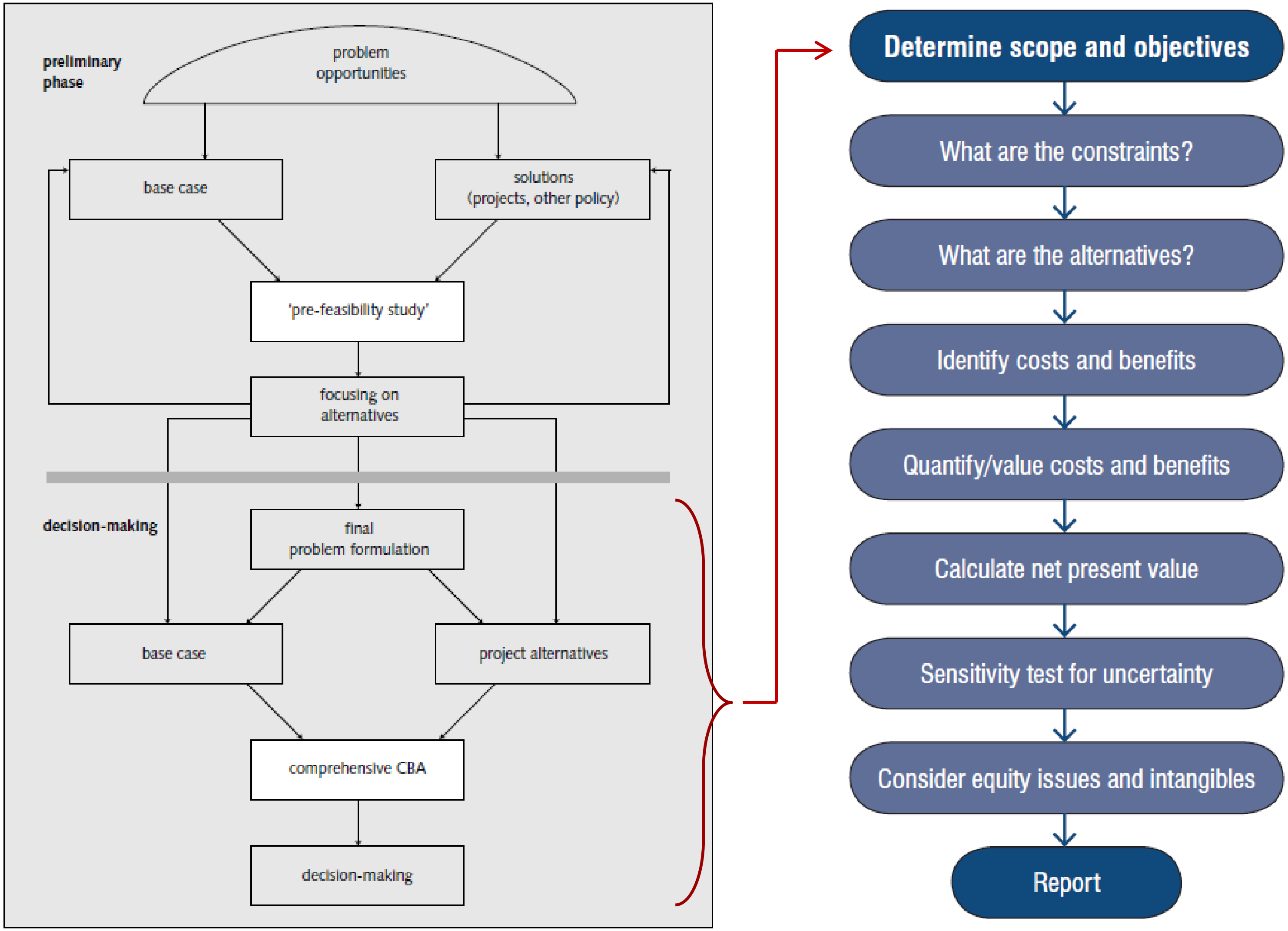
- Quite some scholars favour an exclusive choice for either CBA or MCA (multi-criteria analysis), ..
- … however combined (embedded) use is possible (e.g. Sijtsma 2006)
    - the economic performance of a project can be selected as one criterion among others in a MCA, or …
    - … prices and volumes of effects can be weighed (like in MCA)
    - embedding is complicated due to risks of duplicate & conflicting representation of effects

MAX (NPV$_i$)

$$NPV = \sum_{t=0}^{n} \frac{(x_t - y_t)}{(1+r)^t}$$

$$MIN(S) = \sum_{j=1}^{n} \sum_{i=1}^{m} \left[w_{ij} \cdot \beta_{ij} \cdot f_{ij}(X_i) \right]$$

Structuring a CBA 1



Source: Eijgenraam et al 2001

Source: Commonwealth of Australia 2006

Structuring a CBA 2

Macro-economic full scale SCBA by effect type and source

welfare estimate / causal estimate		Project country				foreign countries
		priced effects		non-priced effects		
		redistribution	efficiency	efficiency	redistribution	
direct effects	operators	*operating profits*		*uninsured risks*		*journey time*
	users	*cheaper transport*		*journey time profits, safety*		*profits*
	third parties			*air pollution, noise*		*air pollution*
indirect effects		*effects on other modes*		*congestion*		*congestion*
		strategic effects		*regional inequality*		*exchange rate effect*

Source: Eijgenraam et al 2001

Applications

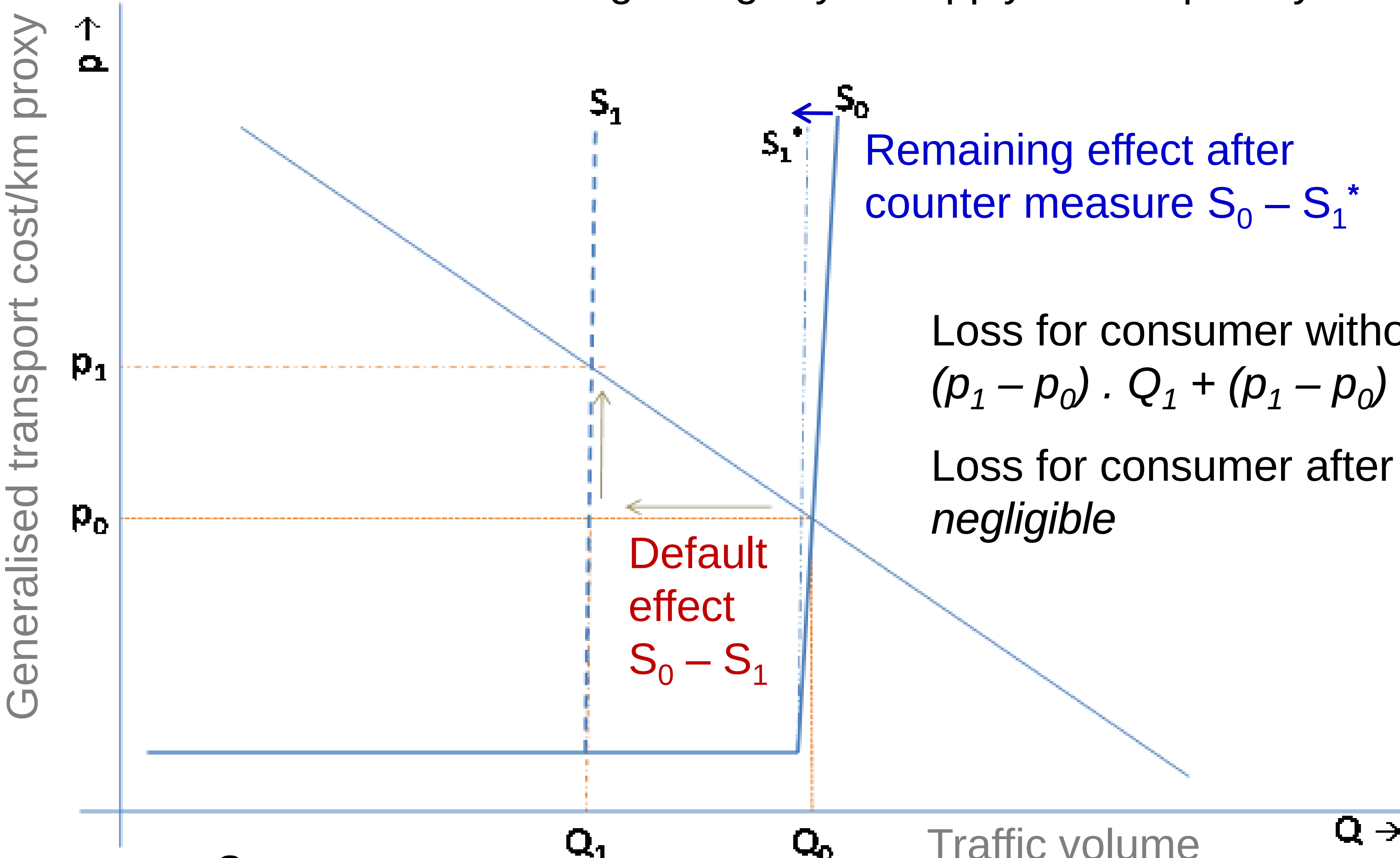
- Assessing climate change enhanced weather effects on road infrastructure
  - traffic safety
  - road maintenance
  - traffic capacity

Next pages (EWENT)

- Assessing flood risks in cities
  - TOLERATE: From climate modeling to appraisal of counter measures
  - IRTORISKI: Extended event-tree analysis

Road capacity effects of weather & CC

Changes in the supply curve caused by extreme weather conditions while accounting for rigidity of supply in transport systems



Loss for consumer without measure:
$(p_1 - p_0)\ .\ Q_1 + (p_1 - p_0)\ .(Q_1\text{-}Q_0)/2$

Loss for consumer after measure:
negligible

Source:
Nurmi and Perrels, 2011 (forthcoming)

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Example: TOLERATE

river flood risk enhanced by:

- climate change
- economic growth

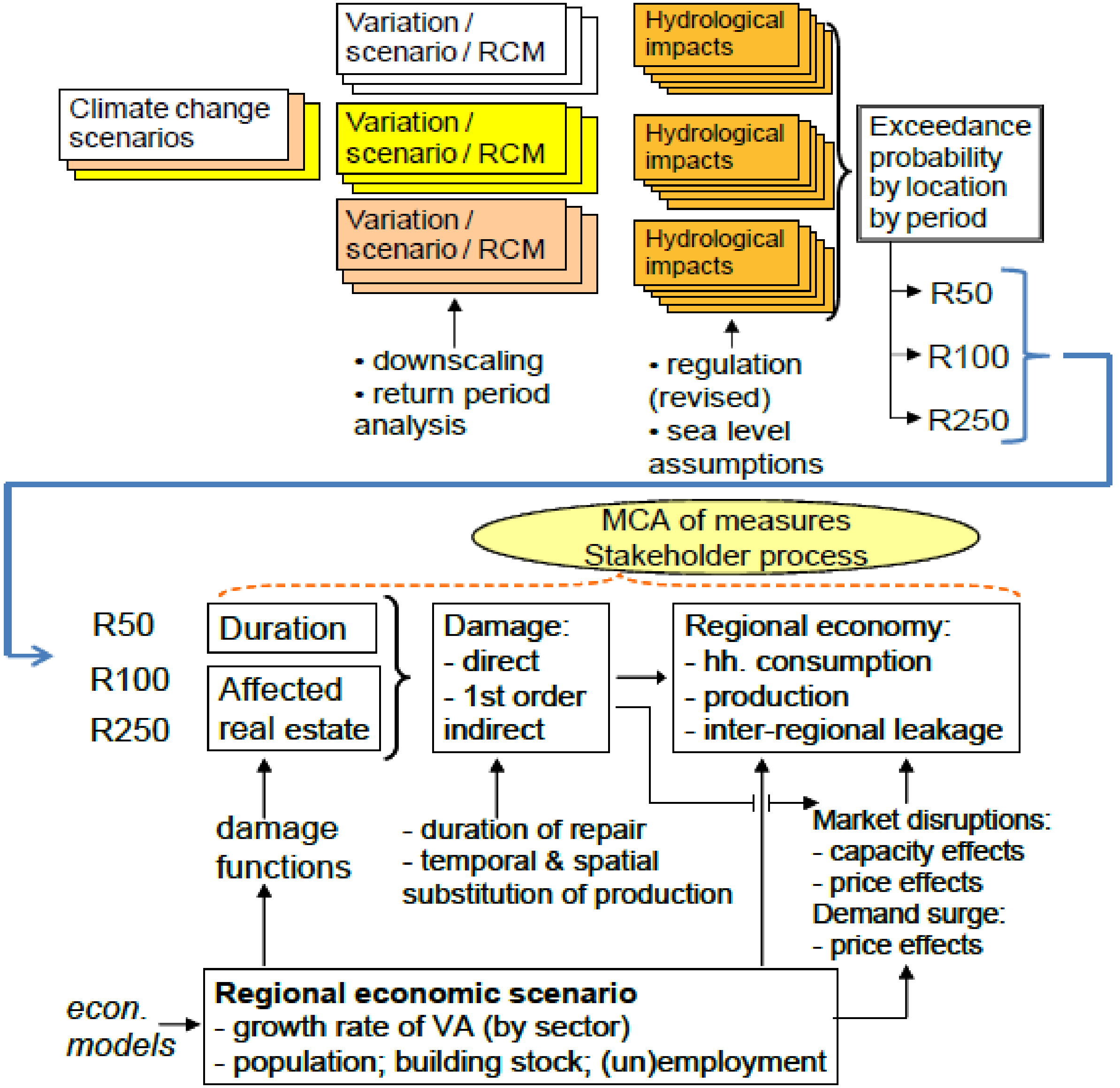


Figure 1. *TOLERATE study structure, Rnn refers to a return time of a flood in years*

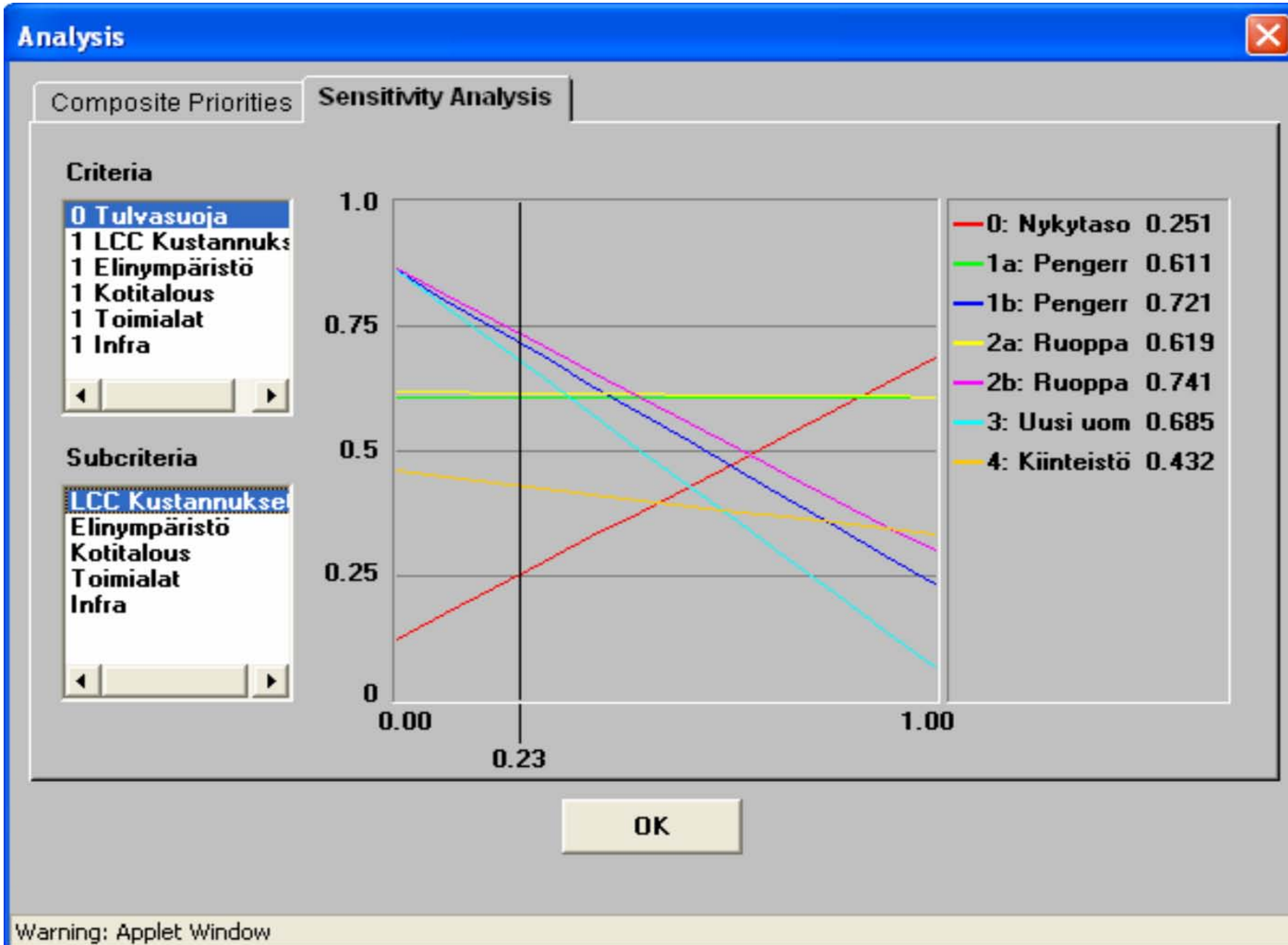
Source: Perrels et al, 2010

TOLERATE: Direct cost summary

- Expected value of direct damage for R50 and R250 both approx. 60 ~ 70 mln.€ for the period 2005-2050 with 2005 building stock and no economic growth
- Economic growth share +50% - the figure depends strongly on the estimated growth rate and the time span
- Climate change share +15% ~ +20% - depending on how to weigh in different return times (+ unsure aspect of (revision of) river-lake system regulation)
- Building stock share -10% ~ +10% - depending on how spatial plans and building spatial planning technology are developing, this factor seems harder to quantify;

TOLERATE: Regional impacts – different displacement rates

TOLERATE: Embedding CBA in decision making by means of Group Decision Support System (MCA)



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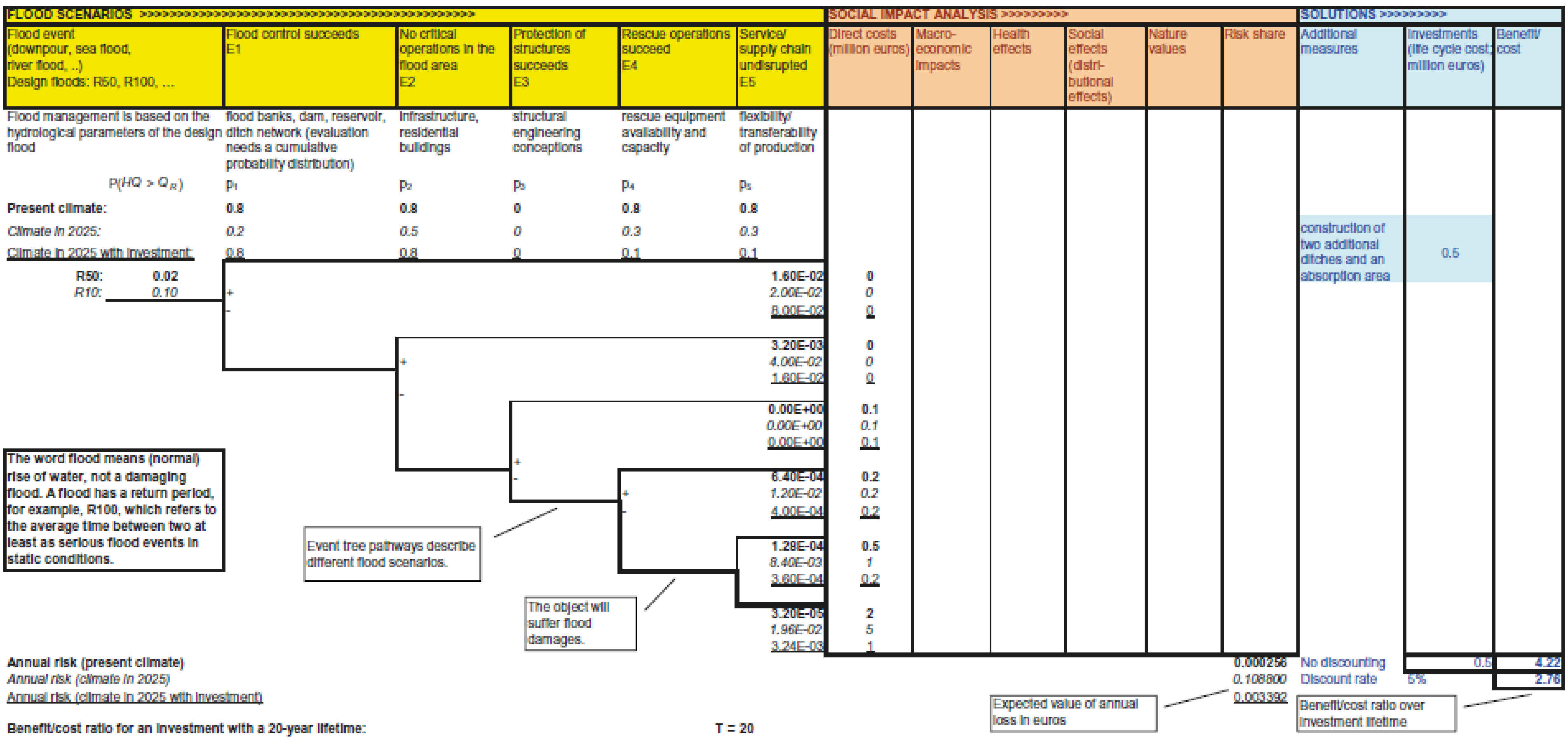
IRTORISKI – extended event tree analysis



Source: Virta et al, 2011

Insurance

Insurance is a ***risk sharing*** instrument alongside:

- Mutual funds
- State support

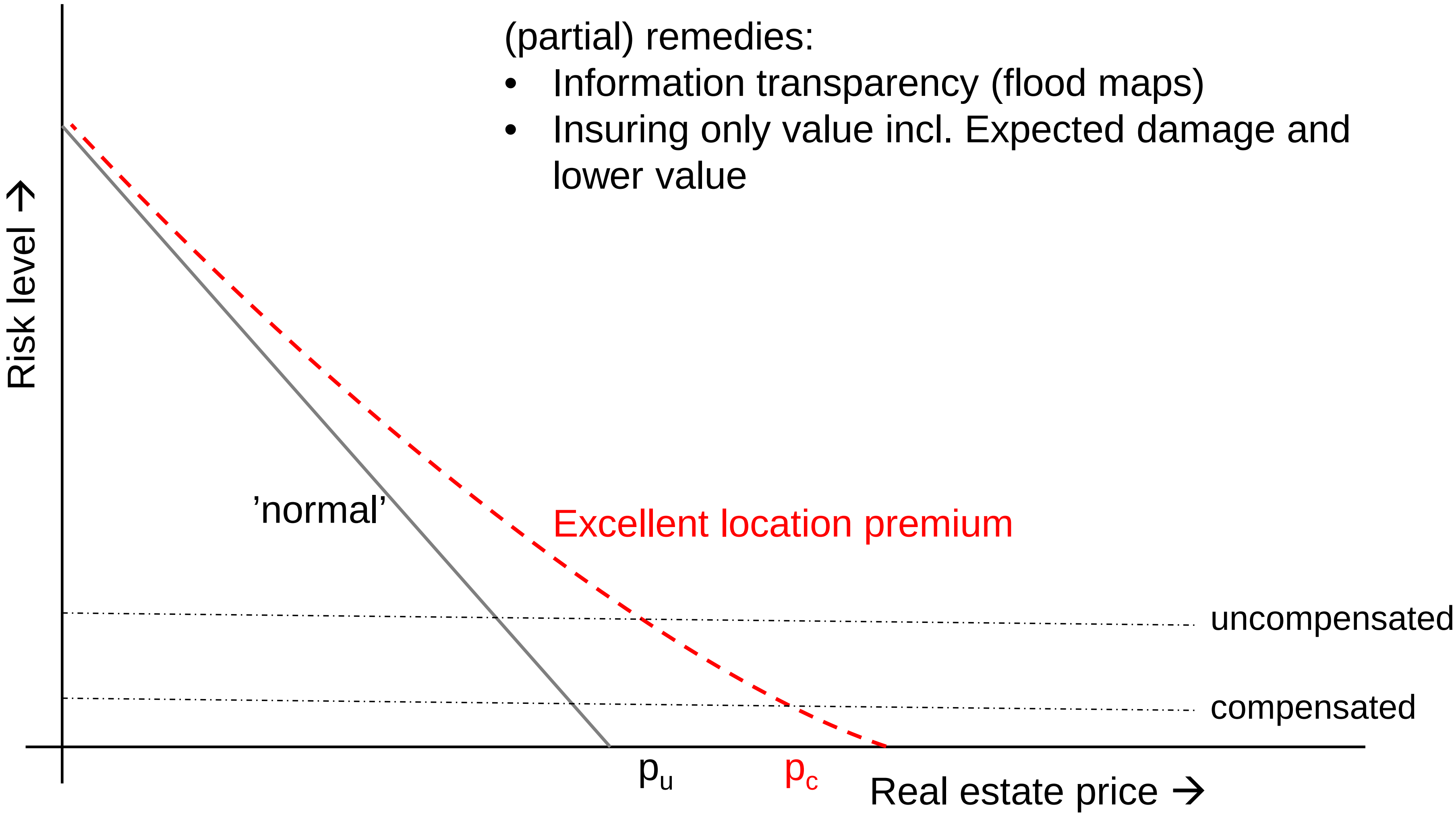
Requires:

- Non-systemic (stochastic) risks
  - Residual risks may be insurable after adequate risk reducing measures, if residual risk assessable
- Avoidance of *moral hazard*
- Avoidance of *adverse selection*
  - At client side for commercial viability
  - At insurer side for social viability

Insurance - moral hazard

(partial) remedies:

- Information transparency (flood maps)
- Insuring only value incl. Expected damage and lower value



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Thank you

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