Technological Design and Development

Early Indicators for Concern in Risk Assessment

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Arnim von Gleich, Bernd Giese

University of Bremen

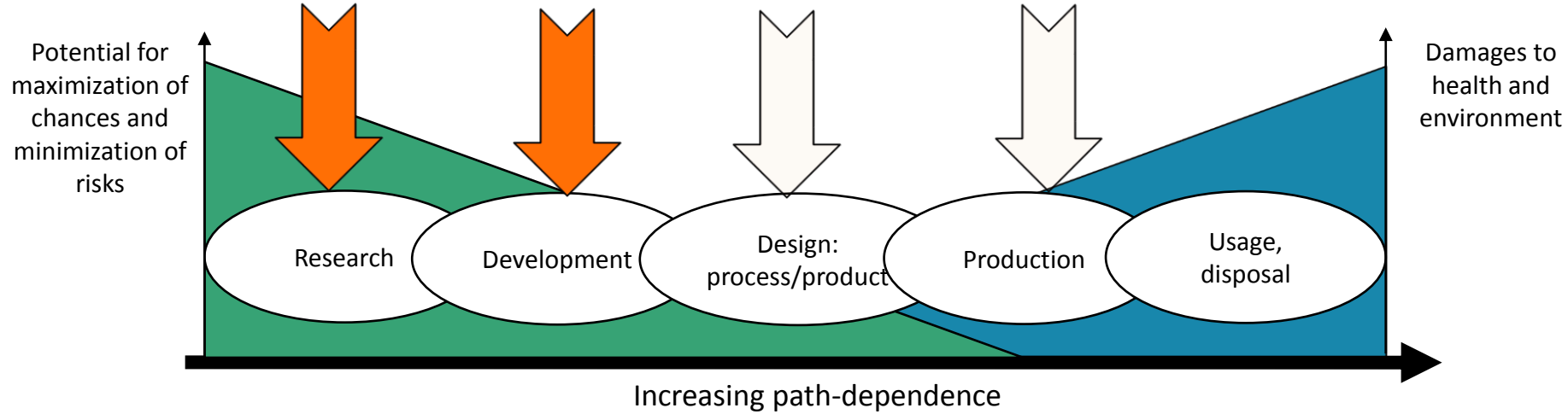
Fac. Production Engineering

Dep. Technology Design and Development

Early TA-Indicators for Opportunities and Risks and Starting Points for Precautionary Systems Design

1) Paradigms
2) Theoretical and practical abstractions (models, experiments)
3) New or improved functionalities
4) Benefits, hazards, exposure
5) Guiding design principles

=> Alternative development paths



Indicators in TA

Intentions
long term, short term

Aims, Visions

Actor/User

Intended use / misuse

Characteristics for Exposure-/Hazard-Potential

Amount of input
Mobility
Persistence
Self-Reproduction

Trigger
Technology
Intervention

Depth of Intervention
Power to induce effects
Novelty / Xenobiotic
Evolutionary approvednes

Vulnerability

Complexity
System Dynamics
Trajectory
Preliminary Tension

Affected System
ecologic, socio-technical
economic…

Carrying Capacities
Tipping Points
Weak Points
Resilience

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Precautinary (prospective) TA

Indicators for concern and methods to identify:

- **Exposure potential**: Capability of trigger/tech to induce high exposure
  => Characterization of trigger/tech (persistence, mobility, self-reproduction,…)
- **Hazard potential:** Capability of trigger/tech to induce adverse effects
  => Characterization of trigger/tech (depth of intervention, power, CMR, …)
- **Vulnerability of the affected system**: Systems capability to absorb perturbations
  => Perturbation oriented and structural vulnerability analysis (exposure, sensitivity, adaptive / carrying capacity, weak points, tipping points, …)

Exposure potential is gaining weight, even without concrete suspicion for adverse effects

Vpvb substances in REACH

Nanoparticles passing the blood-brain barrier

'Contamination' of ecosystems with GMOs

⇒ Hygiene as precautionary approach

⇒ Effect independent (exposure related) precautionary strategy

Character of technology affects the extend and type unknowns

Known unknowns as well as unknown unknowns (surprise, black swans) can be induced

Example: Cooling agents – CFCs vs. propane, butane

Indicators for high exposure potential:

- High production volumes (quantitative)
- Persistence, bioaccumulation (qualitative)
- Long half-life values (qualitative)
- Mobility – gaseous, dusty, nano-scale, active migration, … (qualitative)
- Self-replication (qualitative)

Intensity and Depth of Intervention Inducing Unknowns and Leading to Precautionary Measures

Character of Trigger	Consequences	Risk Minimization
Intensity of Intervention **High Quantity** Dimension/Amount/ Frequency substantial, mechanical, energetic	**Power to induce mainly local effects** energetic/mechanical/chemical/toxic e.g. explosion, noise, bucket wheel excavator/acid/acute poison	Low quantity/gradually rising: **High Adjustability** known unknowns easy to estimate, unknown unknowns rather low reversibility rather high Effects mainly local and correctable e.g. quick loss of hazardous qualities by dissipation, degradability etc. **Trial-and-Error-Strategy justifiable**
Depth of Intervention **Specific Character/ Quality** manipulating control structures atoms/molecular structures/genes	**Power to induce long-range effects** extremely long chains of causes and effect in space and time persistence/mobility, extreme half-life self-replication e.g. CFCs, radioactive nucleotides, release of GMO	High depth of intervention and power: **Adjustability low** known unknowns high, unknown unknowns high irreversibility dislimitation of hazard and/or exposure potentials is reason for high concern **Far reaching precautionary strategy necessary**

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Precautionary Design

Amount of known and unknown unknowns

Intensity / Depth of intervention
Power of Trigger high

Precautionary Design:
- Containment
- Lower intensity / depth of intervention
  e.g. quick degradability, safety strains, …
- Higher resilience of intervention, fail-safe

Amount of known and unknown unknowns

Vulnerability / Resilience of Affected System

Precautionary design:
- Lower exposure, sensitivity
- Higher adaptive capacity
- Higher resilience through
  storage, buffering, redundancy

Design Elements of Resilient Systems

Resilience: Capability to obtain system services even in turbulent environments and massive inner failure

Capabilities of system

- **Resistance**
  protective measures against external perturbations – e.g. dykes
- **Adaptation**
  inner flexibility and self-repair, e.g. synthetic immune system
- **Improvisation**
  flexible use of different resources
- **Innovation**
  making use of opportunities by rebuilding the system

System structures

- **Variety / diversity of compounds and resources**
- **Redundancy of central elements**
- **Modularity**
- **Subsidiarity**
  appropriate relation of centrality and decentrality
- **Interconnectedness with flexible forms of coupling**
- **Feedback loops**
  balanced relation of positive and negative fbl
- **Storage and buffers**
- **Dampers and friction**
- **…**

System resources

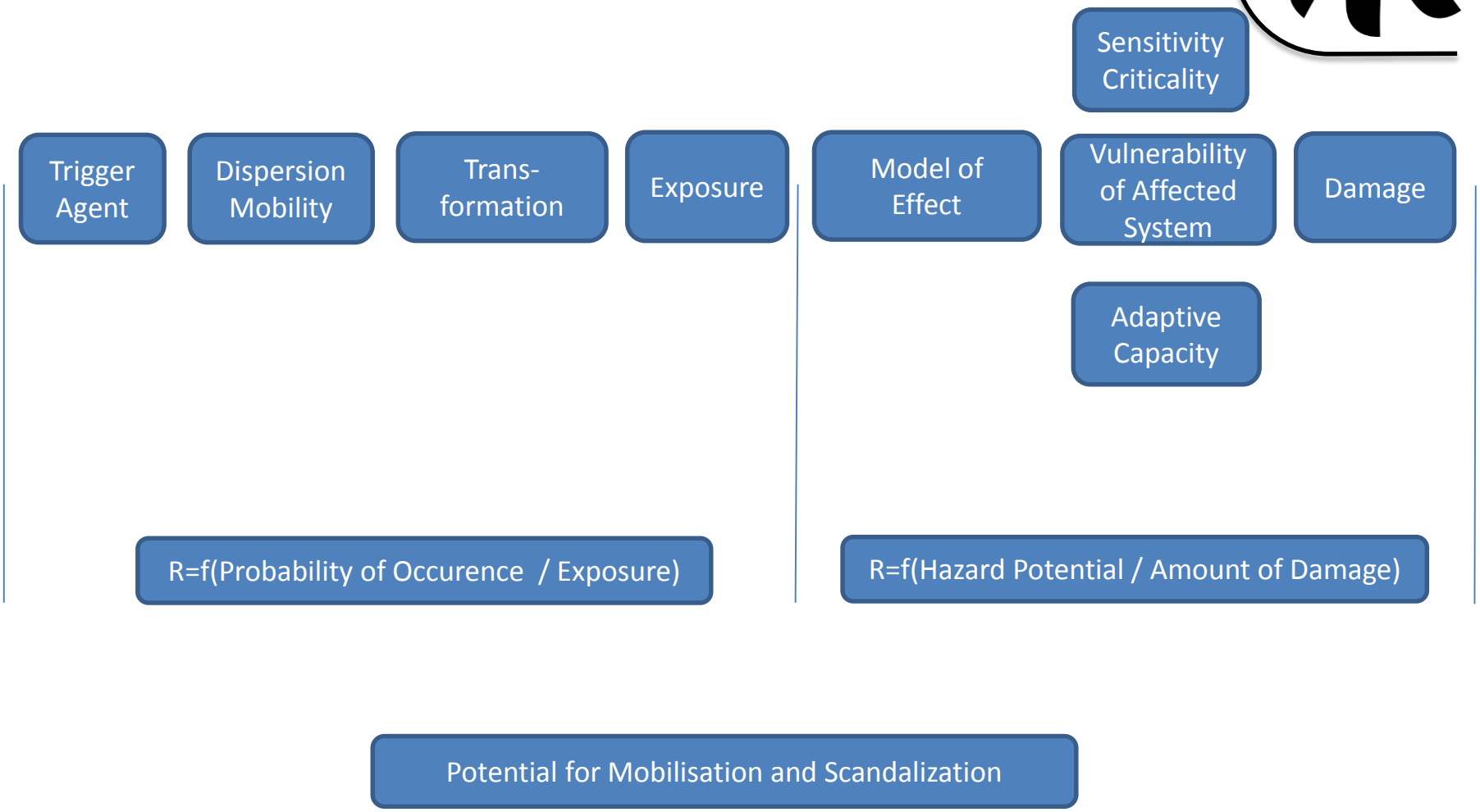
(preferably diverse)

- **Energy**
- **Material**
- **Information**
- **Time**
- **Institutions**
- **Finance**
- **Creativity / Ideas**
- **…**

Conclusions

- In early stages of innovation: concentration on triggers/ technologies/functionalities => Indicators regarding ‘character’ Later: on affected systems => Indicators regarding ‘vulnerability’
- Character of trigger/technology induces type and extend of unknowns (known and unknown unknowns)
- Weight of indicators and severity of precautionary measures depends on expected range of consequences (up to global and irreversible)
- Step from TA-Indicators to design principles necessary (resilient systems)

Concepts and Aspects in Risk Chain



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Uncertainty

Indicators for concern should be identifiable and based on evidence, and

- they refer to something else
- they 'indicate' the potential to produce threats

Uncertainty may occur in a) determination of actual value of indicator and – even more - in b) its capability to indicate concern

Example:

Characteristics of chemicals: vp/vb in REACH

a) Operations to determine persistence (resp. biodegradation)
   => OECD Guidelines

b) What does vp/vb indicate for?
   => High potential for exposure