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# Response to weather conditions and weather forecasts as a basis for assessing climate change adaptation

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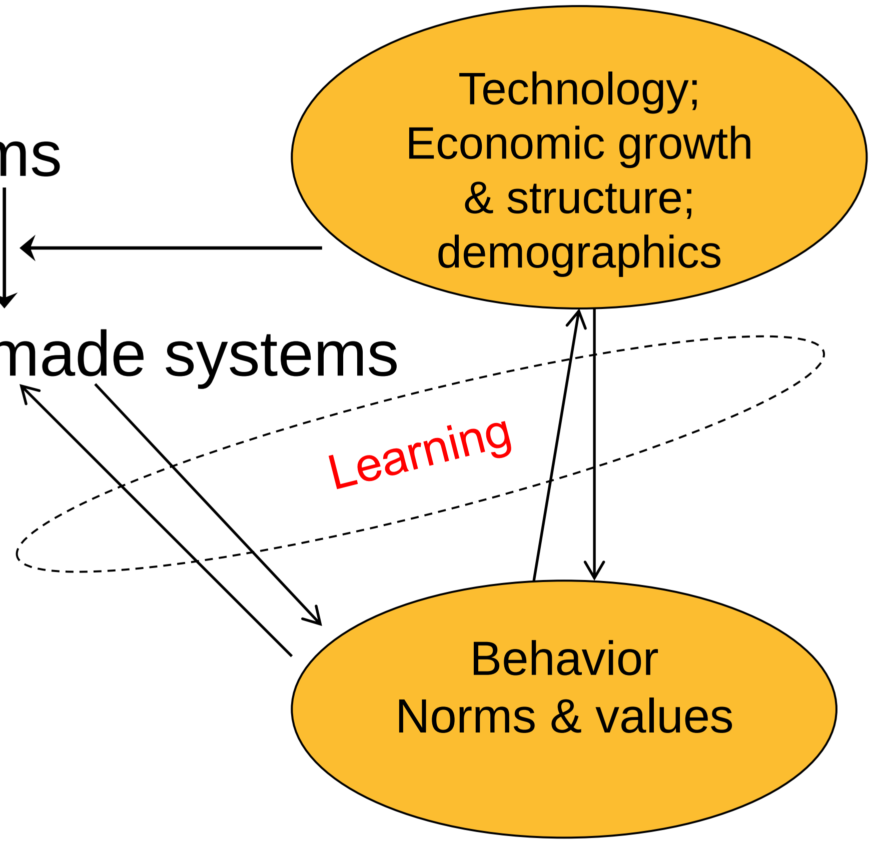
# Structure

- Decomposing change
- Learning from current responsiveness
- Co-evolution
- Illustration of effects
- Conclusions

# From climate change to economic impact

- Changes in climate
  - Effects on natural systems
    - Implications for man made systems



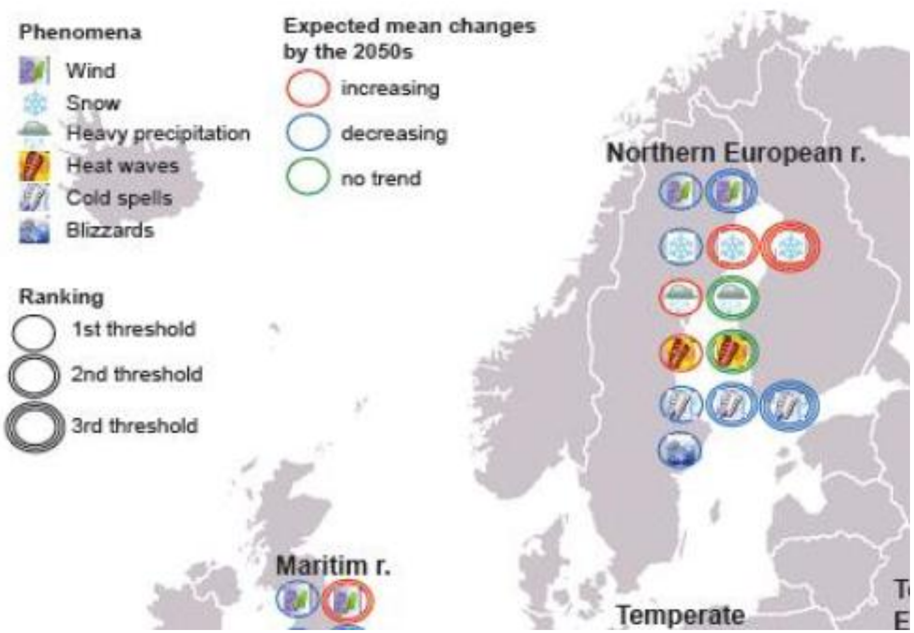
# Examples of impact decomposition - TOLERATE

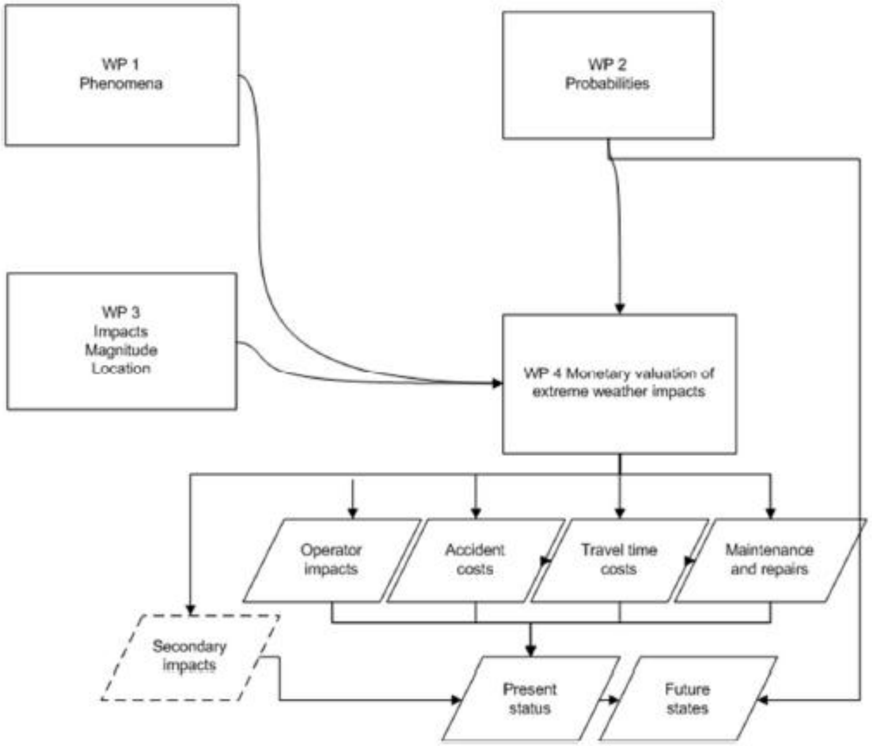
Expected cost of R50 flood 2005-2050:

- approx. € 65 mln. - *current* climate & building stock
- +15% ~ +20% when accounting for future climate
- +40% ~ +50% when accounting for economic growth
- -10% ~ +10% owing to urban (land use) planning and regulation

Source: Perrels et al., 2010

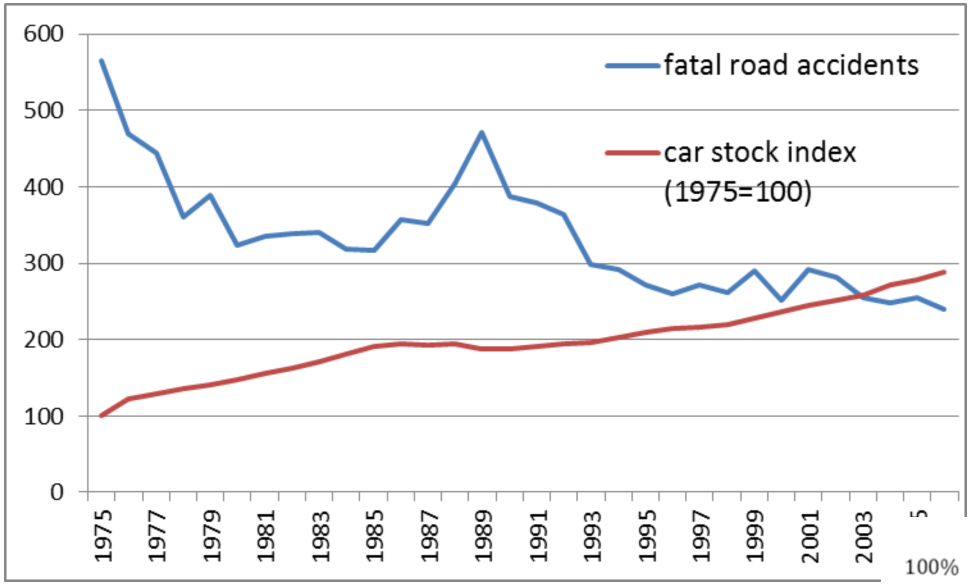
# Examples of impact decomposition - EWENT



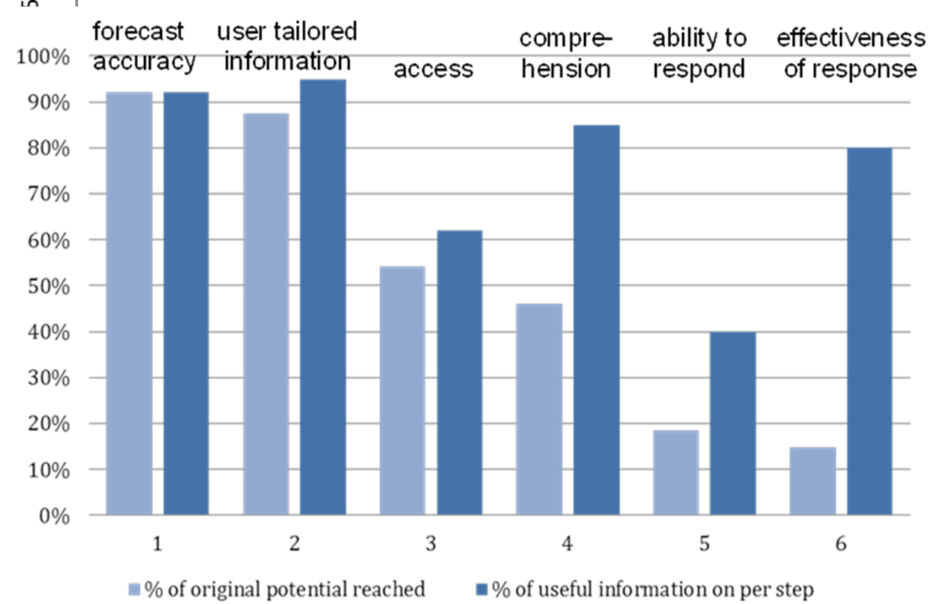




Source: Nokkala et al, 2012

# Learning from current responsiveness (1)




Source: Finnish Transport Administration




Source: Nurmi et al 2012

**WSCA**

# Learning from current responsiveness (2)

Weather service pay-off matrix (assuming ideal information uptake)

| ***Action*** | **Adverse weather** | **Not adverse weather** |
|---|---|---|
| **Protection** | **C** | **C** |
| **No protection** | **L** | **0** |

| | ***forecast* weather conditions** | | |
|---|---|---|---|
| ***realized* weather conditions** | **A = 0** | **A = 1** | climate based probabilities |
| **A = 0** | $p_{00}$ | $p_{01}$ | 0.800 ($p_{c\_0}$) |
| **A = 1** | $p_{10}$ | $p_{11}$ | 0.200 ($p_{c\_1}$) |
| forecast likelihoods | 0.800 ($p_{f\_0}$) | 0.200 ($p_{f\_1}$) | |

$$Value\ \ of\ weather\ \ service := (p_{c\_1}.L) - \left((p_{c\_1}.C) + (p_{c\_0}.p_{10}.L) + (p_{c_0}.p_{01}.\gamma.M)\right)$$

Source: Perrels et al forthcoming

# Learning from current responsiveness (3)

**Weather Service Chain Analysis (WSCA)**

| | Information filtering steps | Present qualities and room for improvement |
|---|---|---|
| 1 | weather forecast accuracy | Accuracy levels good, 92% or 19 out of 21 bad weather days were predicted (Sihvola et al. 2008, in Finland) |
| 2 | information/message customer orientation | Road weather warnings are well understood by drivers – about 90% of people understand what is meant by “normal” “poor” or “very poor weather” (Quantis 2010), Sihvola et al. |
| 3 | access to weather information | high availability, user rates however only about 62 % (Sihvola et al. 2008, in Finland) messages needed about current road weather conditions including in-car systems and road sings (WIST 2002) |
| 4 | comprehension of the information | People mostly use personal observations over real weather information (Pisano and Nelson 1997), bad judgements about current conditions However weather information makes the judgement about current conditions more accurate (Sihvola and Rämä 2008) – 85% |
| 5 | ability to respond timely and effectively | the frequency of bad weather warnings sufficient for timely responds (Lazo 2002) but too high threshold for adjustments (Pisano & Nelson 1997), education needs about driving in bad weather conditions and the use of weather information – only 20% of all drivers change their decisions, however people with weather information make changes more often than other drivers, circa 40%. More study needed on this area. |
| 6 | actual effectiveness of responses | mostly right responses: (earlier departure from home, lower driving speeds, cancellations of trips and different routes used), however changes happen with too low magnitude: speed reductions too low, only 2% lower volume on road traffic when bad weather warning issued (Quantis in Finland) – we give numerical value of 80% |
| 7 | incidence of the costs and benefits of the response | awareness on who is eventually benefitting is important to understand; part of the benefits to vehicle drivers due to lower costs of driving, network analysis needed to estimate mode substitution |

Source: Nurmi et al 2012

# Learning from current responsiveness (4)

**WSCA:**

$$Q_{mt} = \prod_{s=1}^{7} \{P_{ms_t}\}$$ where $0 \leq P_{ms} = f_{ms}(x_{s_i}; \dots; x_{s_{i+n}}) \leq 1$

$$B_{mt} = Q_{mt} . \gamma^{\alpha(1-Q_{mt})} . B_{m,t}^{max}$$

$$P_{ms} = \frac{\left[\sum_{j=1}^{M} \sum_{i=1}^{N} p_{j,i}\right]}{M.N}$$

$$p_{j,i} = \frac{e^z}{1+e^z}$$

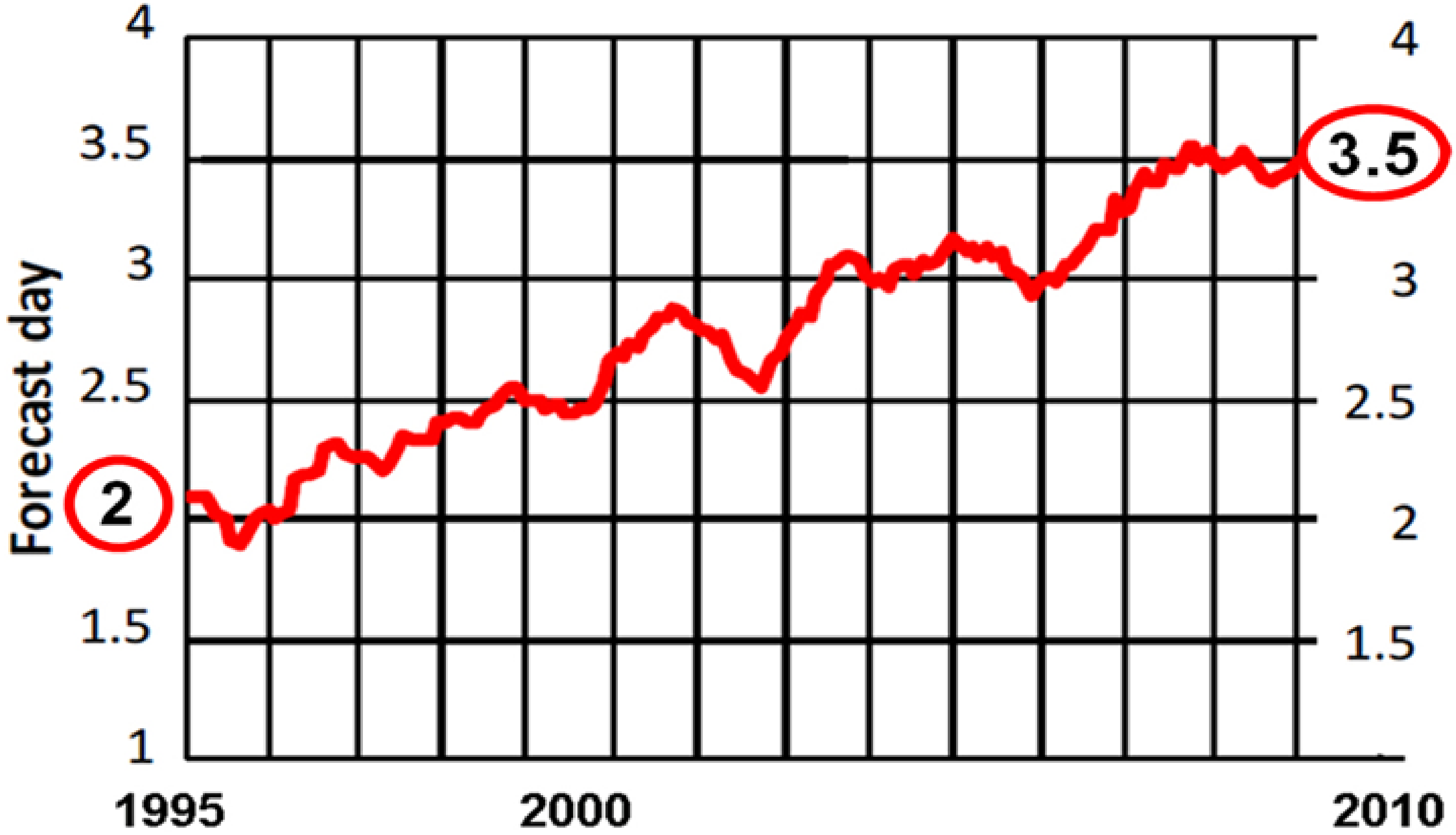
$$z = \beta_0 + \sum_{i=1}^{n} \beta_i x_i$$

$$CV = V.Q_{mt}$$

$V = B_{m,t}^{max}$ (?; depends on assumptions)

Source: Perrels et al forthcoming

# Co-evolution




Evolution of the predictability of surface precipitation, 1995-2010, by the ECMWF numerical weather prediction model (after © ECMWF)

Source: Nurmi et al 2012

# Co-evolution through service innovation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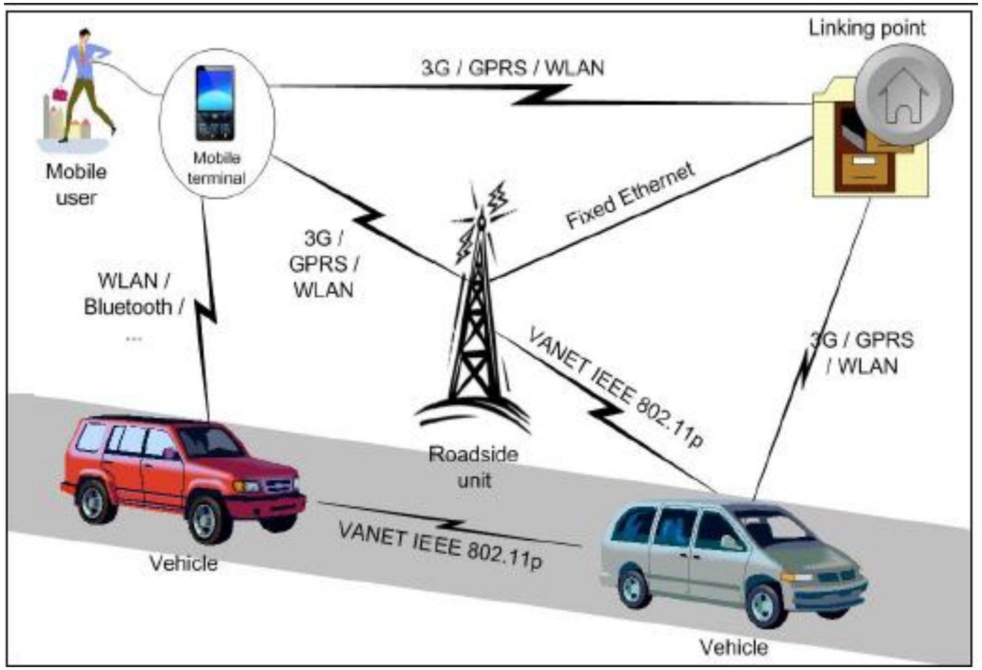


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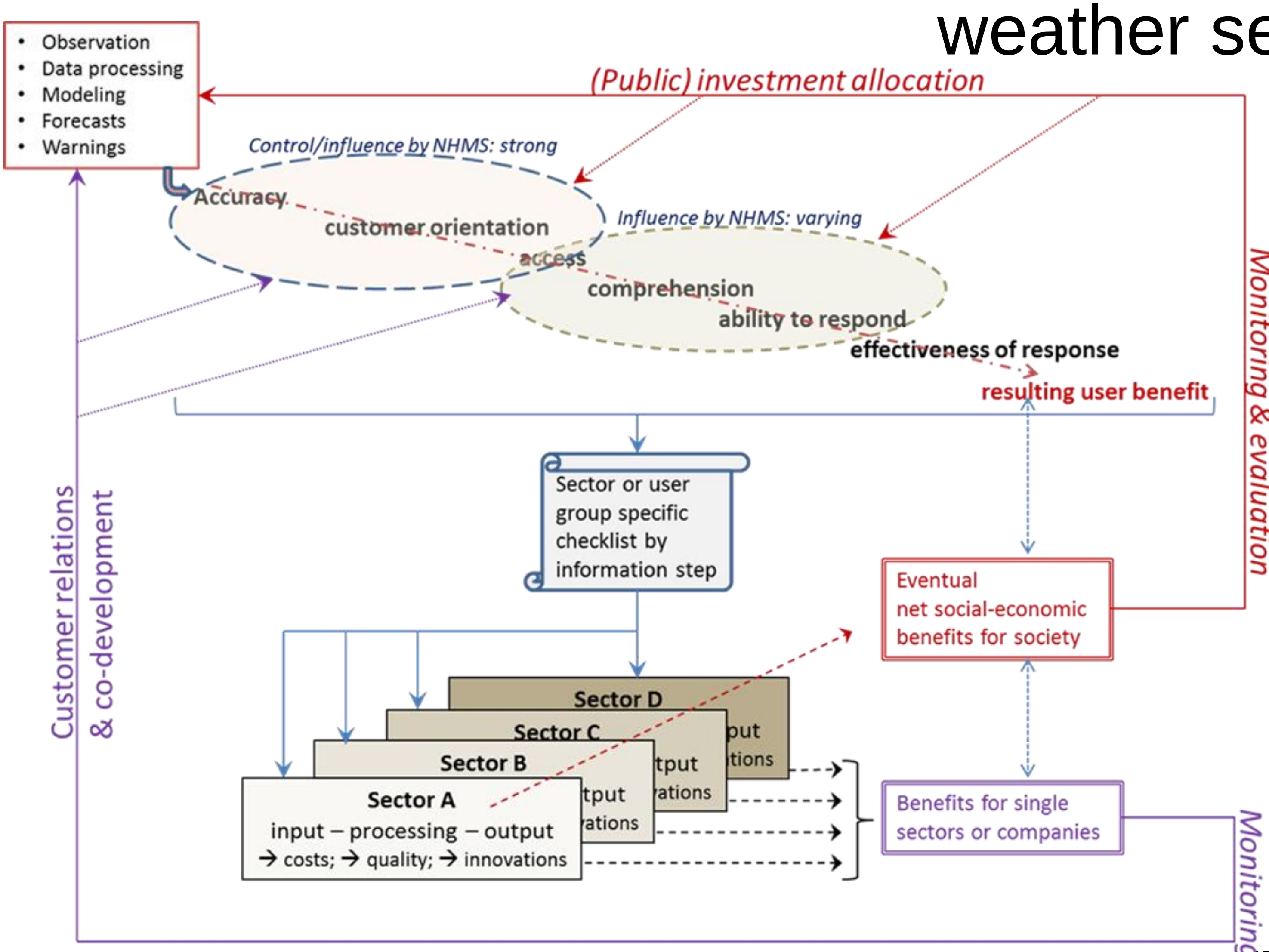
# Co-evolution through service innovation – weather services



# Accounting for co-evolution

$$V = (p_{c\_1}.L) - \left((p_{c\_1}.C) + (p_{c\_0}.p_{10}.L) + (p_{c_0}.p_{01}.\gamma.M)\right)$$

Weather service innovati on;

Technology;
Growth & Structure;
Behaviour

Weather service chain innovation

$$Q_{mt} = \prod_{s=1}^{7} \{P_{ms_t}\}$$

$$B_{mt} = Q_{mt}.\gamma^{\alpha(1-Q_{mt})}.B_{m,t}^{max}$$

# Accounting for co-evolution – hypothetical example

- Current level of *prevented* road traffic damage due to weather in Finland ~ € 36 mln.
  - Ageing of population ?
  - Economic growth:
    - Car stock ↑ e.g. +10% more cars
    - Car value ↑ e.g. +20% more valuable
    - Car safety ↓ e.g. 25% less accident prone
  - Weather service innovation:
    - Prediction accuracy ↓ e.g. +3%
    - Service chain effectiveness ↓ e.g. +20%
  - Damage potential -3 mln €; prevented damage + 8 mln €

# Conclusions

- In impact assessment and even more so in adaptation cost and benefit assessments do not account for co-evolution
- Co-evolution alludes to technical, social and institutional changes affecting exposure, vulnerability and resilience
- Co-evolution can result in lower (remaining) adaptation cost and benefits, but it may also entail maladaptation
- Current understanding of responsiveness to weather services combined with identification of service improvement potentials can assist to estimate a part of co-evolution effects

# Thank you

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