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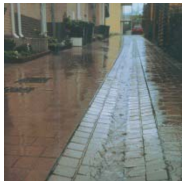
A mathematical approach to find long-term strategies for the implementation of resource orientated sanitation





University of Kaiserslautern
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siwawi

Focus and Background

- **Industrialised / developed countries**
  - High standard of water supply and disposal
  - (water) infrastructure already built
- **Urban Water Management**
  - regional water and nutrient cycle
  - technical aspects
- **Transformation of existing water infrastructures**
  - problems resulting e.g. from demographic and climate change cause a conceptual alteration in urban water management
  - from predominantly centralised end-of-pipe solutions
  - towards more resource orientated closed-loop systems

Focus and Background

- **How can sustainable drainage and sanitation devices be implemented in existing systems in an optimal way?**
  - extensive financial and construction efforts
  - a conversion can only be realised successively over a long period

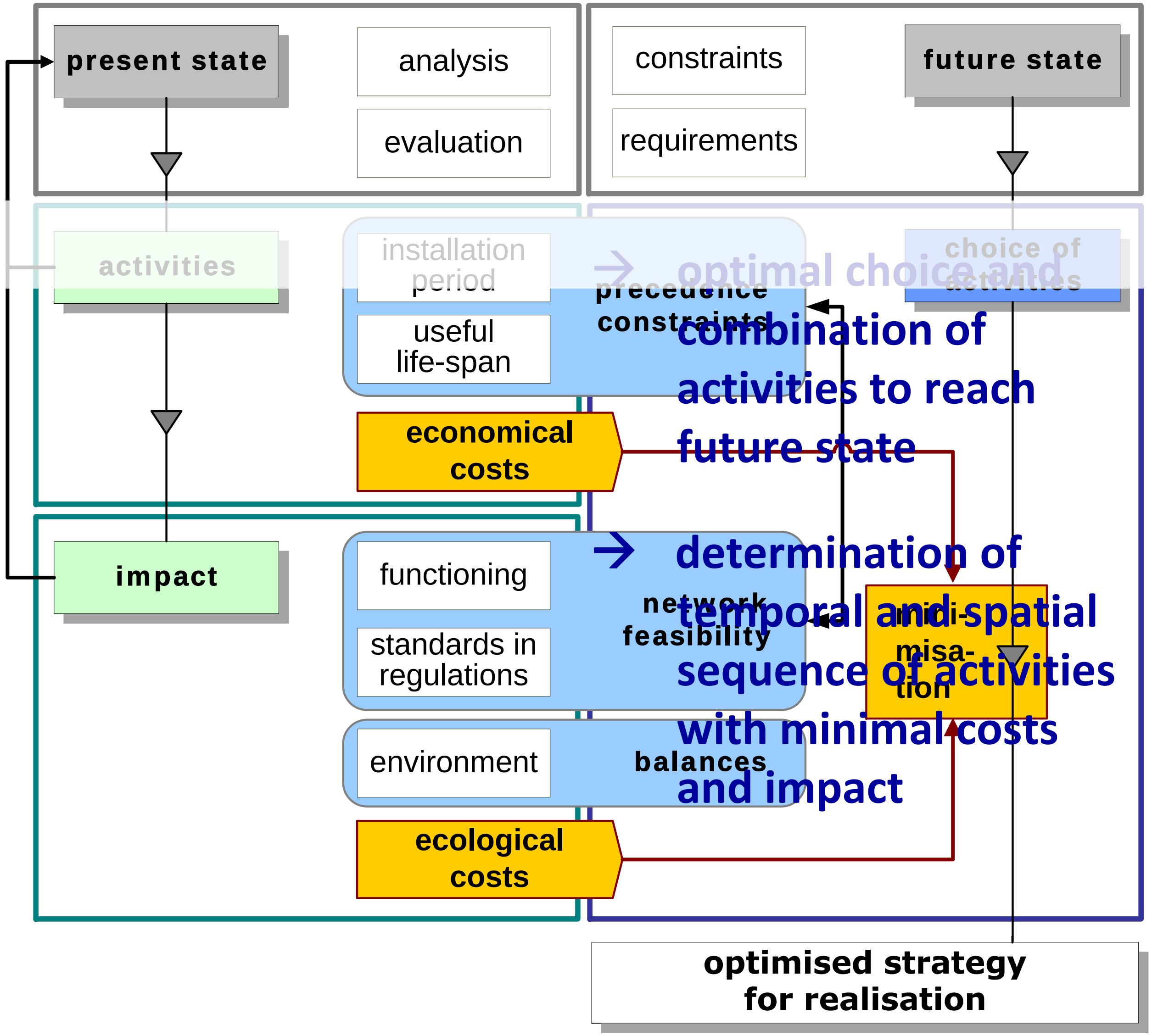
Development of optimised strategies for transformation → mathematical approach

Mathematical Model

initial situation

mathema-tical model

aim



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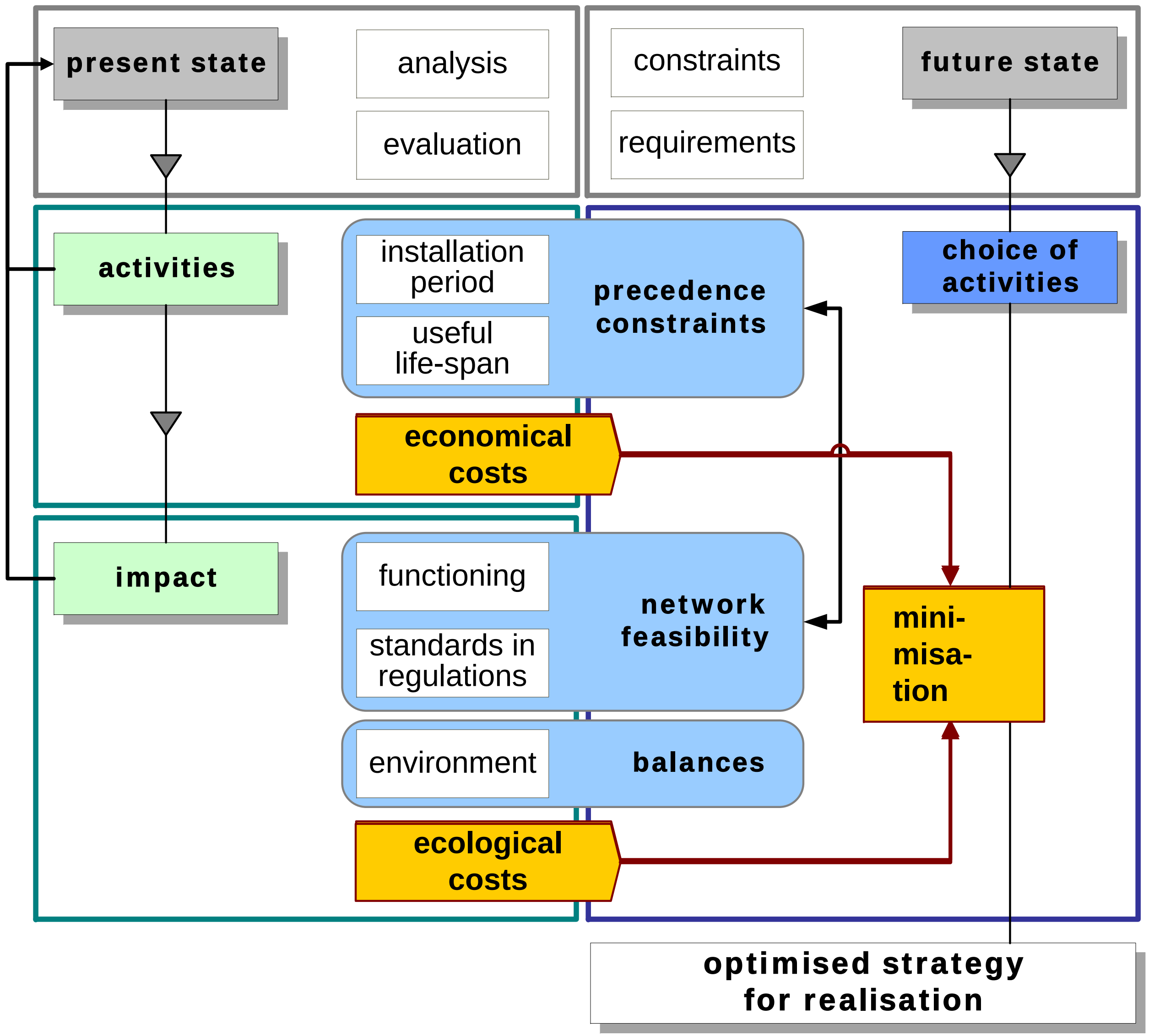
Mathematical Model

initial situation

mathematical model

objective functions

aim



Application

- Suburb of Kaiserslautern: KL-Siegelbach
  - Rural catchment of 90 ha area
  - 3,000 inhabitants
  - heterogeneous forms of housing / use
  - 70 % drained by combined sewer system (3 overflow devices), 30 % drained by (modified) separate sewer systems
  - wastewater is transported to central WWTP of Kaiserslautern (220,000 p.e.)

  → effects on WWTP not included in this study

future state

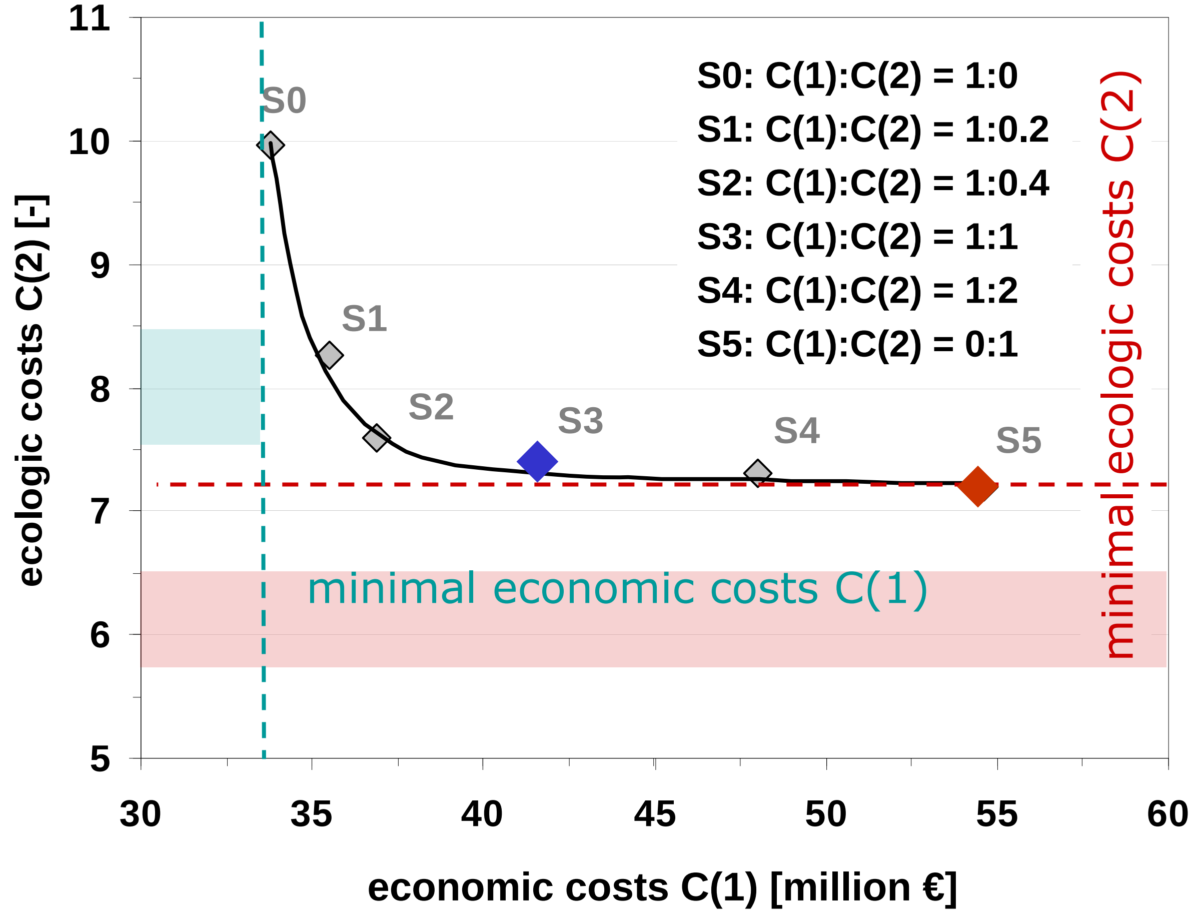
- **future state and conditions**
  - **example** of future state for implementation
    - **stormwater** runoff and wastewater should not be mixed any more,
      achieve natural stormwater management
    - decentralised treatment of **blackwater**
    - **greywater** should be treated centrally in WWTP

objective functions

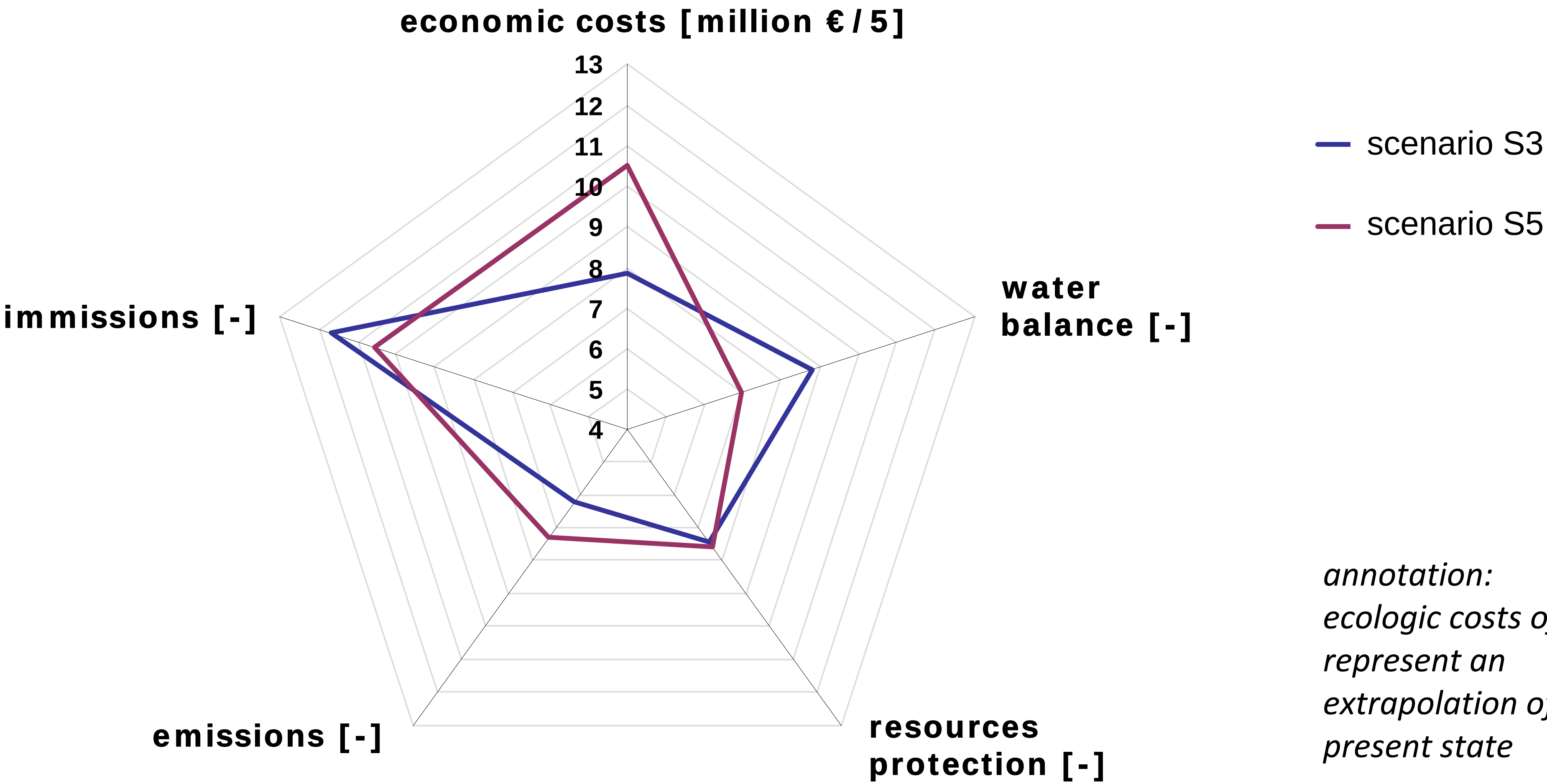
- **period of consideration**
  - 50 years of conversion + 30 years of ‘maintenance’
  - total project costs with 3 % interest rate
  - budget 2.5 million € / time step (5 years)
- **weights objective functions**
  - weight economic costs C(1) : ecologic costs C(2)
    - Scenario 0 1 : 0
    - Scenario 1 1 : 0.2
    - Scenario 2 1 : 0.4
    - Scenario 3 1 : 1
    - Scenario 4 1 : 2
    - Scenario 5 0 : 1

Results – objective function values

- ecologic costs C(2)
  - **different criteria (at present 11) count to these costs**
  - **main fields of criteria**
    - adaption of natural water balance
    - resources protection
    - emissions
    - immission
  - **each criterion is scaled to an interval from 0 (no detriment) to 1 (highest detriment)**

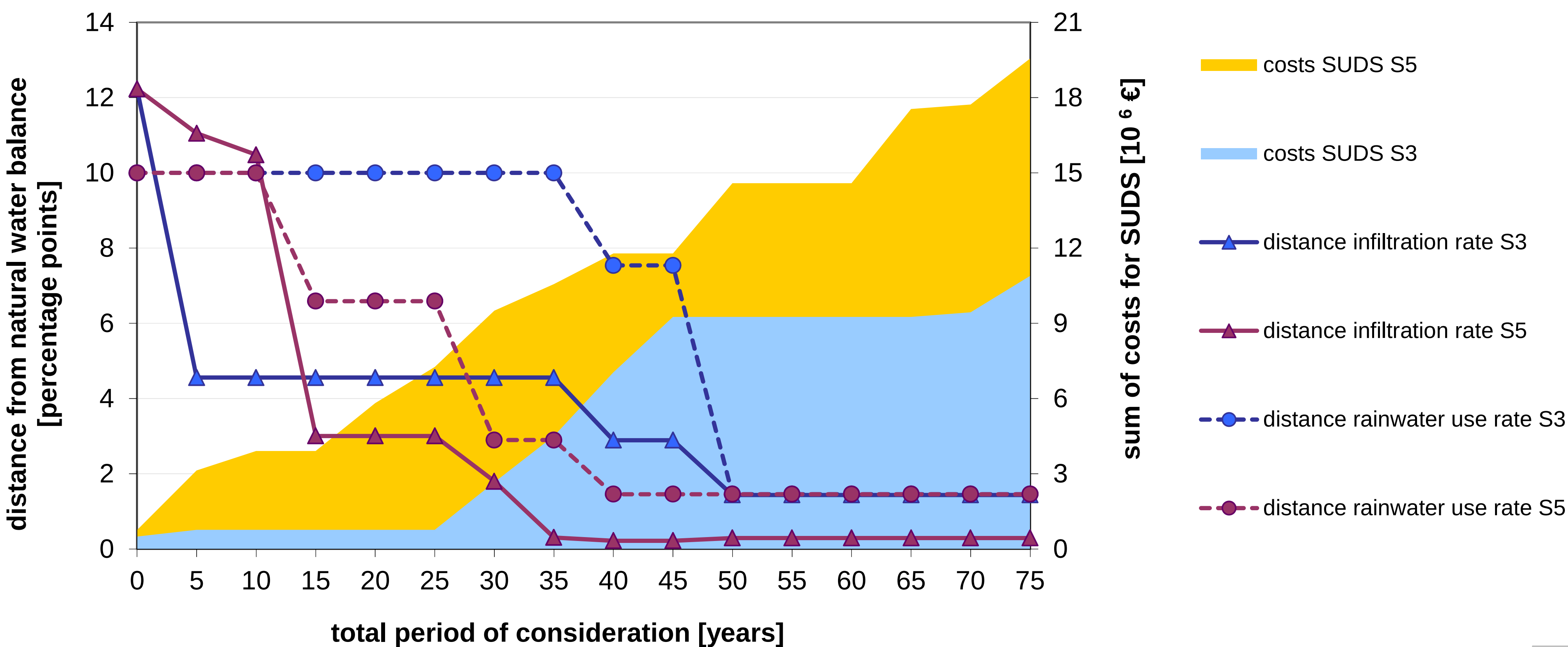


Results – portions $C_i(2)$ of $C(2)$

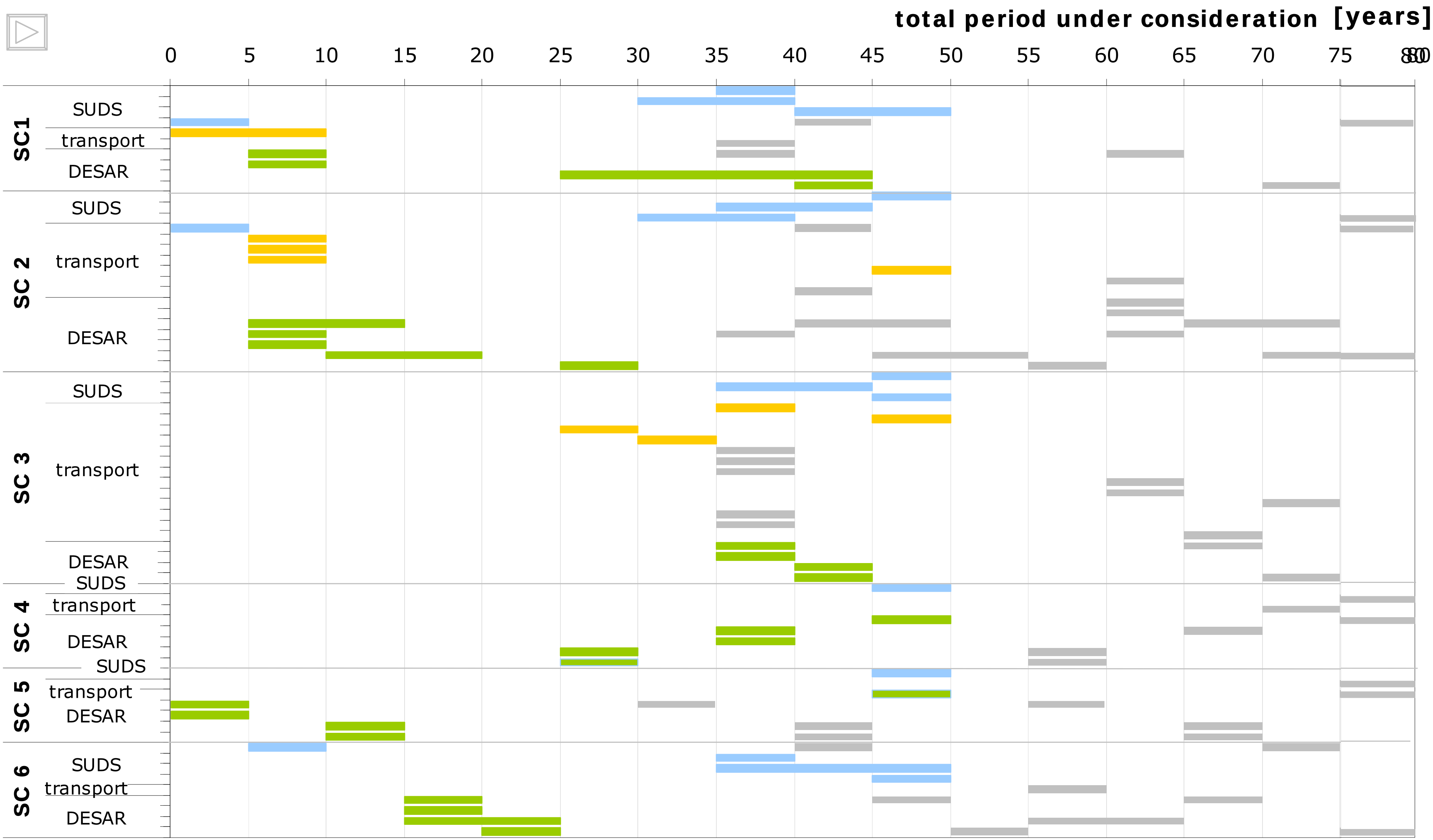


annotation:
ecologic costs of 16 would represent an extrapolation of the present state

Results – portions of C(2)



Results – time schedule



Conclusions and Outlook

- **to reach one future state many different optimal strategies are possible:**
  - the subjective weighting of the two costs is essential
  - it is also essential to specify which impact in C(2) has to be considered for an optimal transformation strategy
  - only the discussion of local deciders with engineers can lead to definite choice of solution (→ difficult!)

→ **potential of the approach in making possible to show all impacts in detail when calculating different scenarios**

→ **big potential for complex systems!**