

An analysis of the feedback structure driving water dynamics in the Dead Sea region

Preliminary results from the “Dead Sea” project

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systems research

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- Introduction to System Dynamics
- Causal-Loop Diagrams (CLD)
- Main types of system behaviour
- CLD: physical and socio-economic subsystem
- Why external correctives often fail
- Effects of delays in feedback loops
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The „Dead Sea“ project

- The overall objective is: to establish a scientific basis for a „more sustainable“ water and water-related land management
 - Divided in a physical, socio-economic and governance subsystems
 - Development of GIS-based database
 - Development of “realistic” scenarios till 2020
 - Development of a quantitative computer model
- System analysis as main approach
 - To analyse the system structure and behaviour
 - To calculate scenarios till 2020
- Modelling future development possibilities
 - “Real” complex systems have many uncertainties
 - “Real” complex systems have many possible developments
 - Scenarios are helpful to reduce uncertainty and visualize possible future trends

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Introduction to System Dynamics

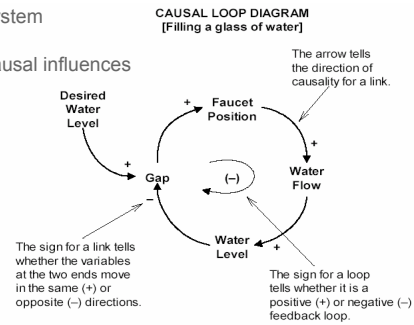
- Developed in the 60ies by J.W. Forrester at the MIT
 - Analysed oscillating production by General Electrics USA
 - Industrial Dynamic 1961, Principle of systems 1968
- Basic principles
 - Thinking in dynamical processes over time
 - Thinking in models / awareness of systems structure
 - Qualitative analysis of systems with Causal-Loop Diagrams
 - Quantitative computer modelling with Stock-Flow Diagrams
 - Steering of systems
- Applications
 - Club of Rome “World” model (Meadows et al. 1972)
 - Biology, ecology, economics, education, engineering, medicine, public administration and policy design etc.

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Causal-Loop Diagrams (CLD)

Elements

- Verbal description of the system
- System parameters
- Arrows and signs for the causal influences

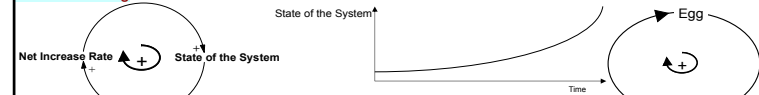


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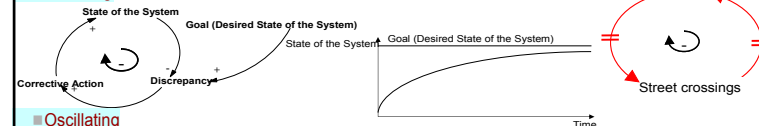
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Main types of system behaviour

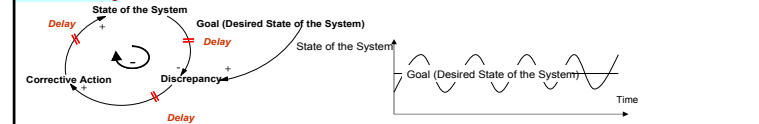
Reinforcing



Balancing



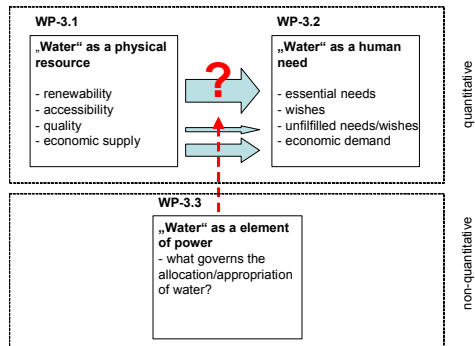
Oscillating



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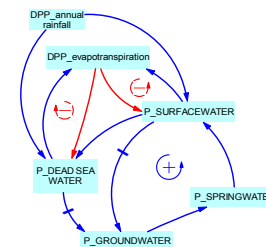
Subsystems of the Dead Sea Project



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CLD: physical subsystem



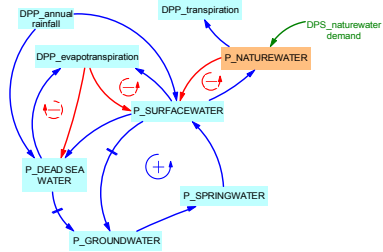
Legend:

- Blue arrows: positive relations
- Red arrows: negative relations
- Green arrows: demand-wishes
- P... Pools (physical subsystem)
- DPP... Driving Parameter (physical)
- DPS... Driving Parameter (socio-economic)

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CLD: physical subsystem

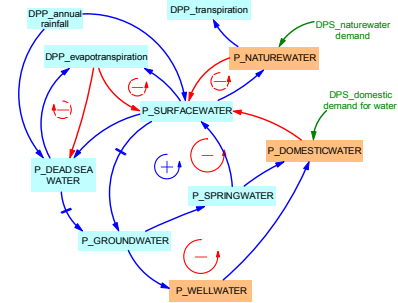


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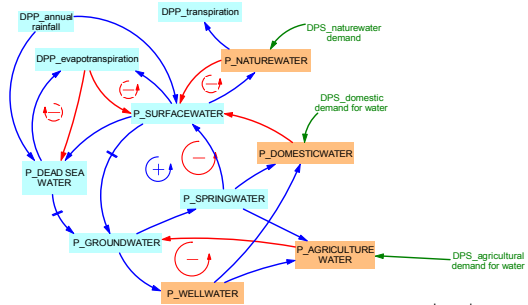


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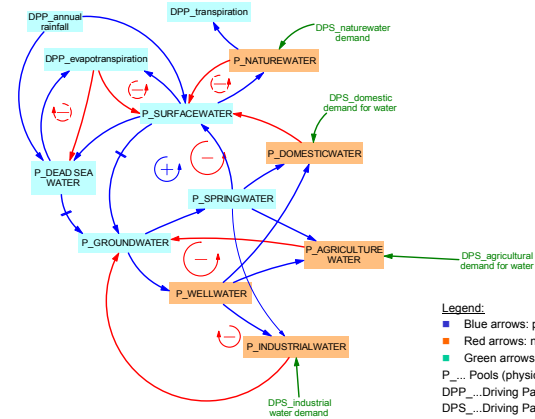


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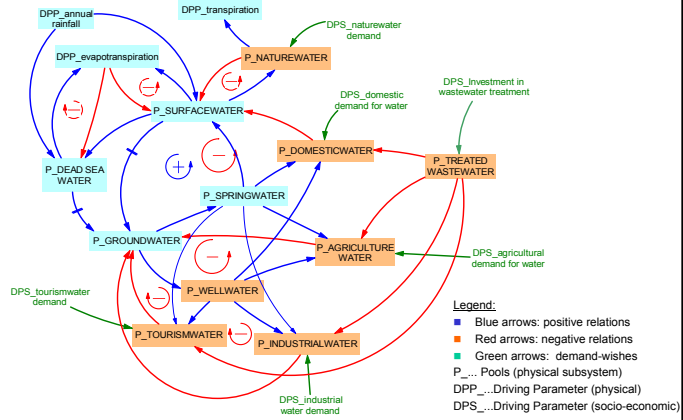


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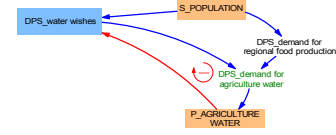
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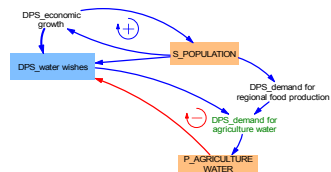
CLD: socio-economic subsystem



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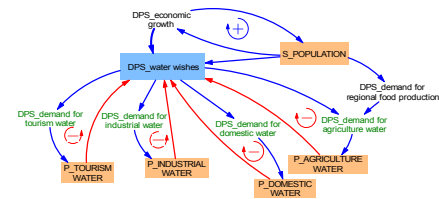
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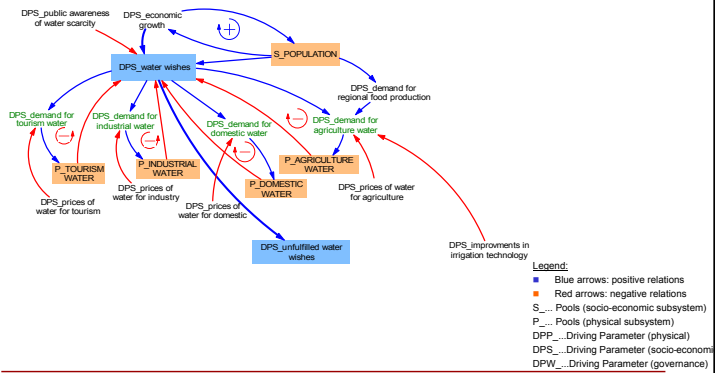
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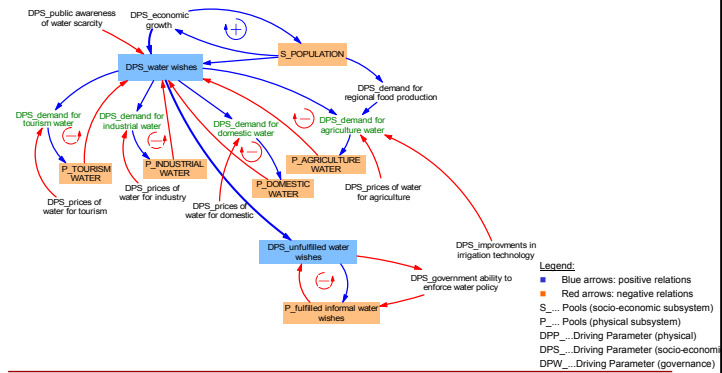
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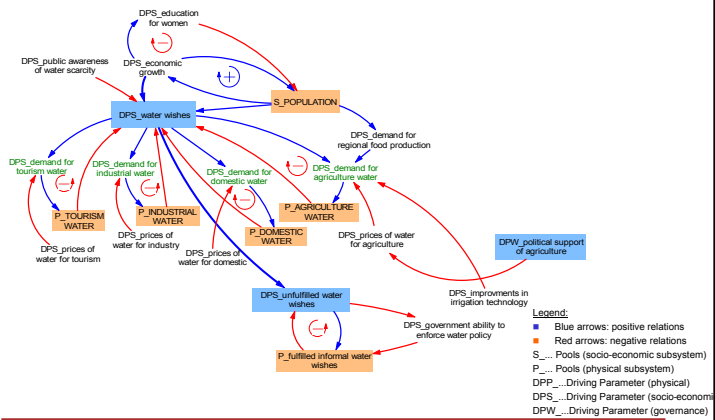
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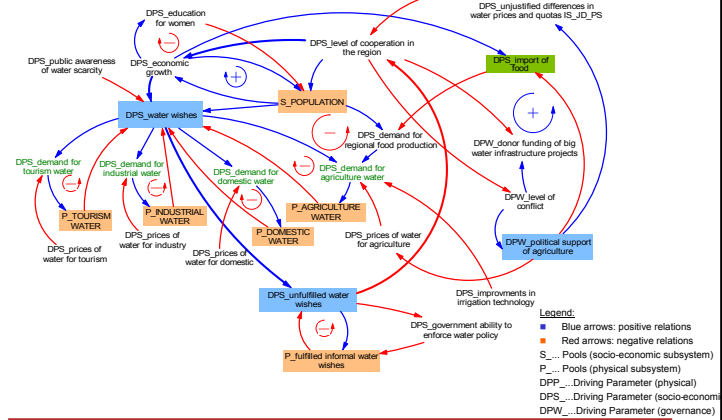
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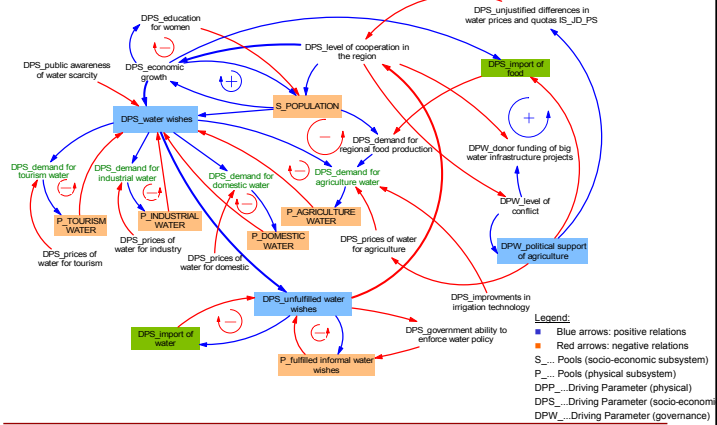
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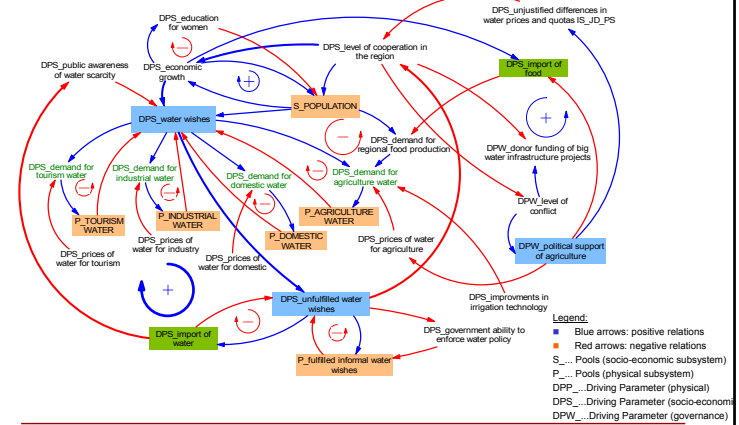
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Why external correctives often fail

■ Examples

- Import of water through Red-Dead or Med-Dead connections
 - Consumer habits might change even from the day of construction decision on
 - Long construction time (10-15 years)
 - Strong disturbance of system (ecosystem)
 - Shift of burden: Short-term advantages may cause long-term disasters
- Increase of wastewater treatment
 - Willingness to use the water in agriculture is essential
 - Negative influences to groundwater from wastewater (delay in effects)
- Increase of water price for agriculture
 - Informal use; leaky pipelines; clientilism-nepotism
 - Growing population needs more food
 - Level of regional cooperation strongly influences role of agriculture (import-export)

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Effects of delays in feedback loops

- Shower in a hotel: mixing warm and cold water
 - Short-term: faucet changes show no effects → more and more is changed
 - Mid-term: water turns to hot or to cold
 - Long-term: oscillating system around individual optimum level
- Blocking of Inflows to Dead Sea
 - Short-term: no visible consequences
 - Mid-term: sinkholes, groundwater level and quality changes
 - Positive feedback induces exponential growth (increased dynamic)
 - Corrective measures also have delays before effects can be seen
 - Long-term: possible irreversible destruction of ecosystem
- Import of water Med-Dead, Red-Dead
 - Short-term: decision of construction influences behaviour of actors
 - Mid-term: increase of water availability creates additional water wishes, external dependence (water from outside)
 - Long-term: unpredictable changes for the system

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Conclusion

■ General

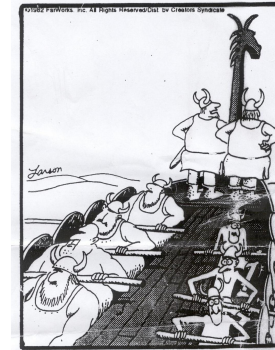
- System dynamic approach provides insight in structure of system
- Causal-Loop Diagrams help to visualize system and system behaviour
- Structure shapes behaviour
- Delays hide cause-effect relations
- Within unknown complex systems: it is often better to set small changes and analyse effects (wait for the feedback)
- Complex systems can only be managed in an adaptive way
 - Monitoring of key parameters and indicators is necessary

■ Insights for the Dead Sea water management

- More systemic investigations of the system structure and behaviour are necessary
- Short-term solutions have to be analysed more deeply for consequences
- Actors have to be involved in system analysis as well as in management decisions
 - Insights in system behaviour creates acceptance for necessary decisions
 - Actors have to understand in general what their actions cause (feedbacks)
- Measures like increasing price for water might have not the intended effects → development of integrated management measures

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"I also have it, Sven -- this silly feeling, that we are driving in a circle!"

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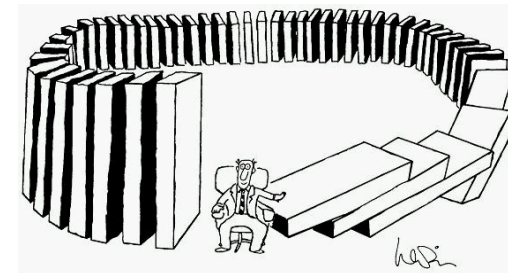
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