

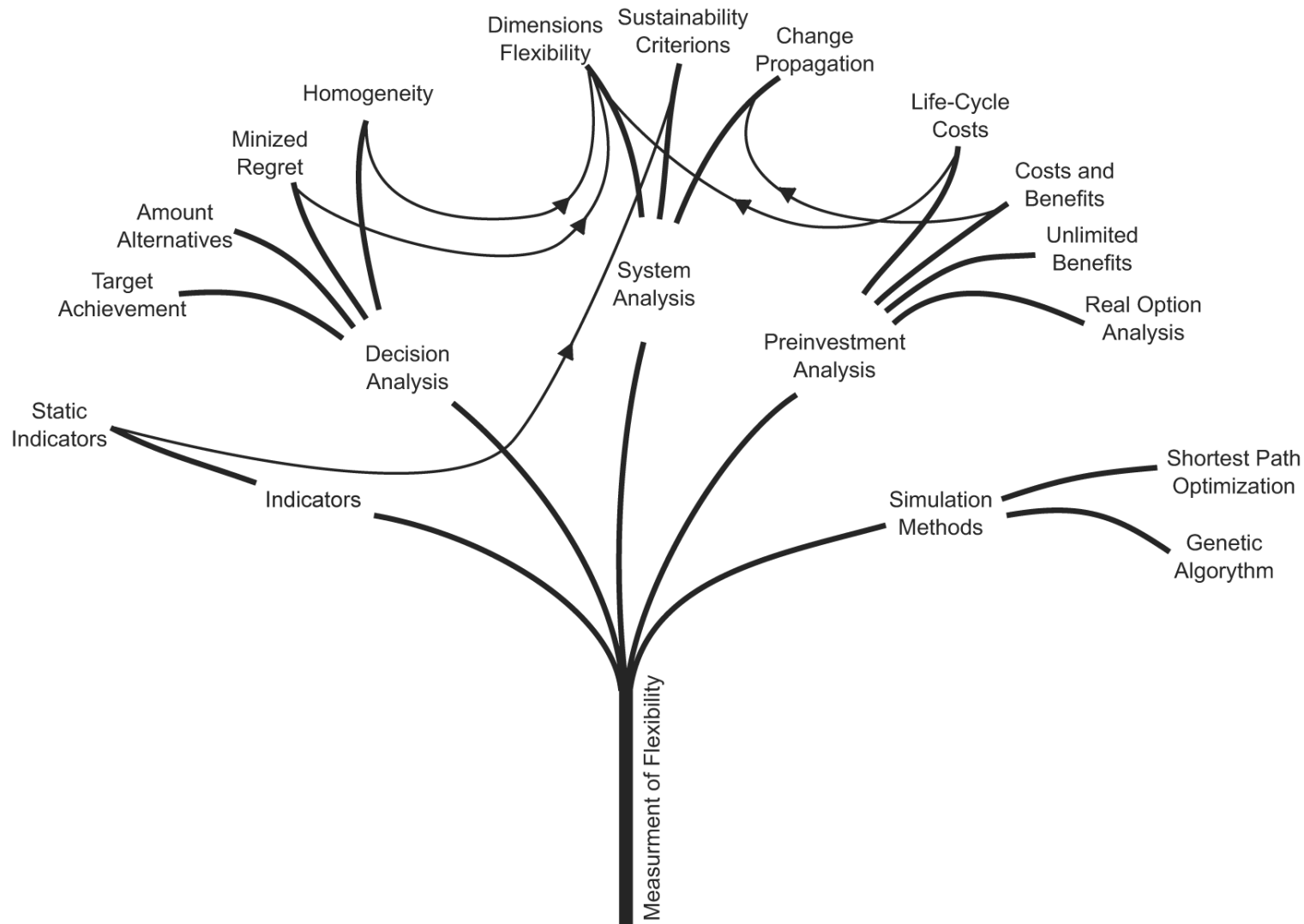
Measuring the Flexibility of Urban Drainage Systems

The Future of Urban Water - 24-26 January UNESCO Paris

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Measurement of Flexibility



Definition of Flexibility

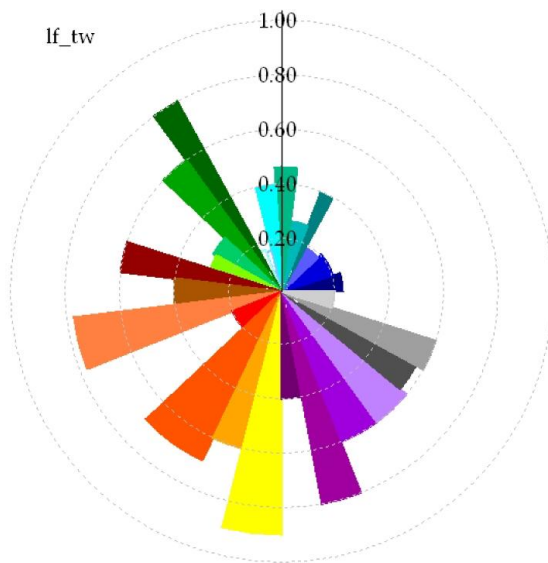
Flexibility is the ability of urban drainage systems to use their active capacity to act to respond on relevant alterations in a performance efficient, timely and cost effective way.

Deal with future
uncertainties

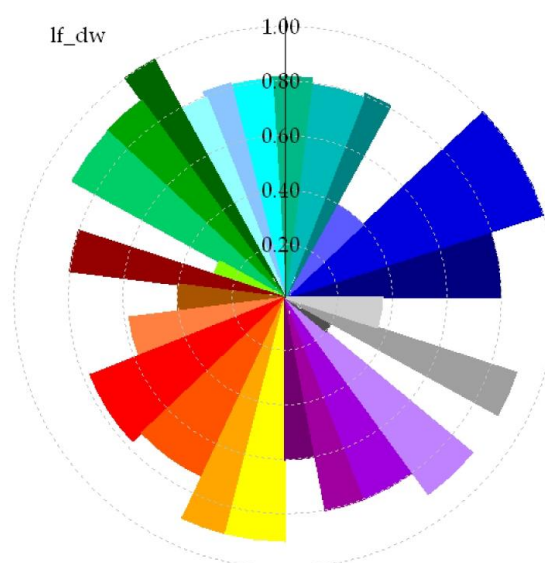
Capability for active
change of system

Characteristics of
the change process

Static Indicators



- 20-jähriges Hochwasser
- chem. Sauerstoffbedarf
- Phosphor
- Feuchgebiete
- Verdunstung
- Überlauf aus Retention
- Ressourcen/Energieeinsatz
- Funktionswert
- Flächenverbrauch



- mittleres Hochwasser
- abfiltrierbare Stoffe
- Kupfer
- Kleinklima
- Nutzbarkeit Ressourcen
- Investitionskosten
- Personaleinsatz
- Präsenz
- Kleinräumigkeit

- mittleres Niedrigwasser
- Stickstoff
- Blei
- Grundwasserneubildung
- Verfahrensvielfalt
- Betriebskosten
- Nutzwert
- Möglichkeiten der BB
- Planungshorizont

$$Hom = \begin{cases} 1 - \frac{\sigma}{tUV} & \text{where } \sigma \leq tUV \\ 0 & \text{where } \sigma > tUV \end{cases}$$

$$\sigma = \sqrt{\sum_{i=1}^n w_i (pUV_i - tUV)^2}$$

Real Option Analysis

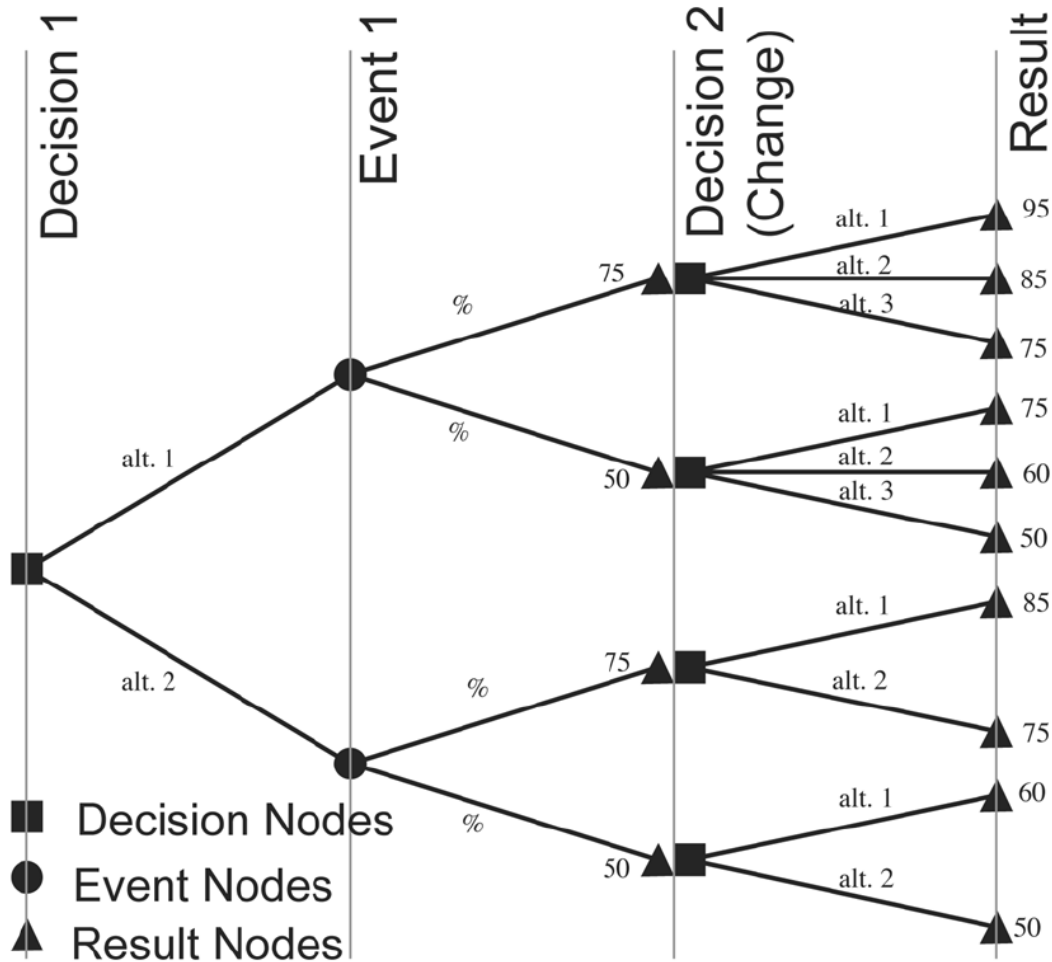
Originating from the financial options used on stock markets

An option is the right but not the obligation to buy a product at a certain point of time with a price agreed in advance -> comparable with flexibility

Use equations for option analysis to calculate the value of flexibility

$$c = S_0 \cdot \Phi(d_1) - X e^{-rT} \cdot \Phi(d_2)$$

Decision Analysis (Decision Tree)

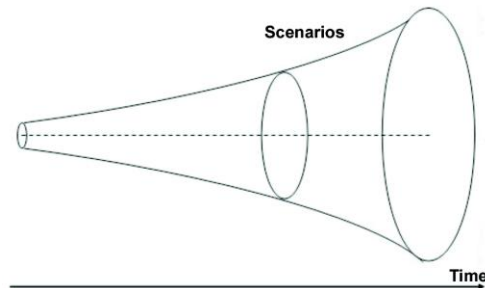


$$exHom = \begin{cases} 1 - \frac{\sigma_{ex}}{mtUV} & \text{where } \sigma_{ex} \leq mtUV \\ 0 & \text{where } \sigma_{ex} > mtUV \end{cases}$$

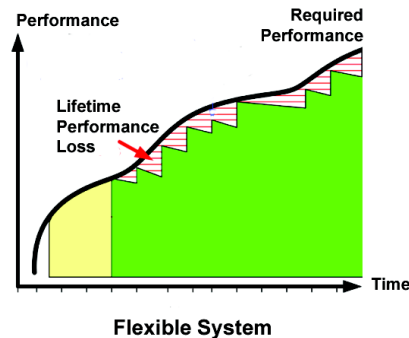
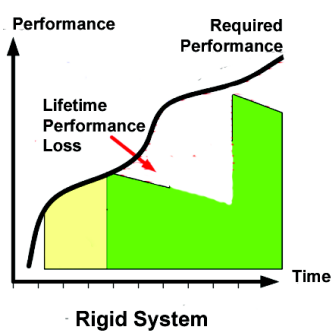
$$\sigma_{ex} = \sqrt{\frac{1}{m} \sum_{j=1}^m (tUV_j - mtUV)^2}$$

$$mtUV = \frac{1}{m} \sum_{j=1}^m tUV_j$$

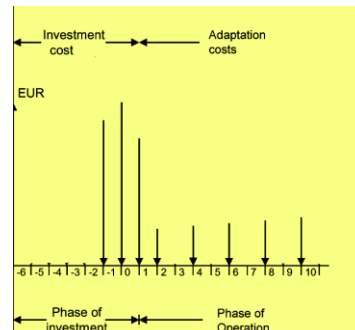
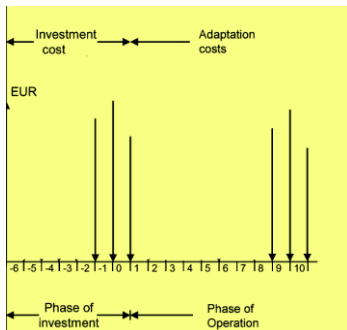
System Analysis (Dimensions of Flexibility)



Capability for change: Range of future states which could be managed

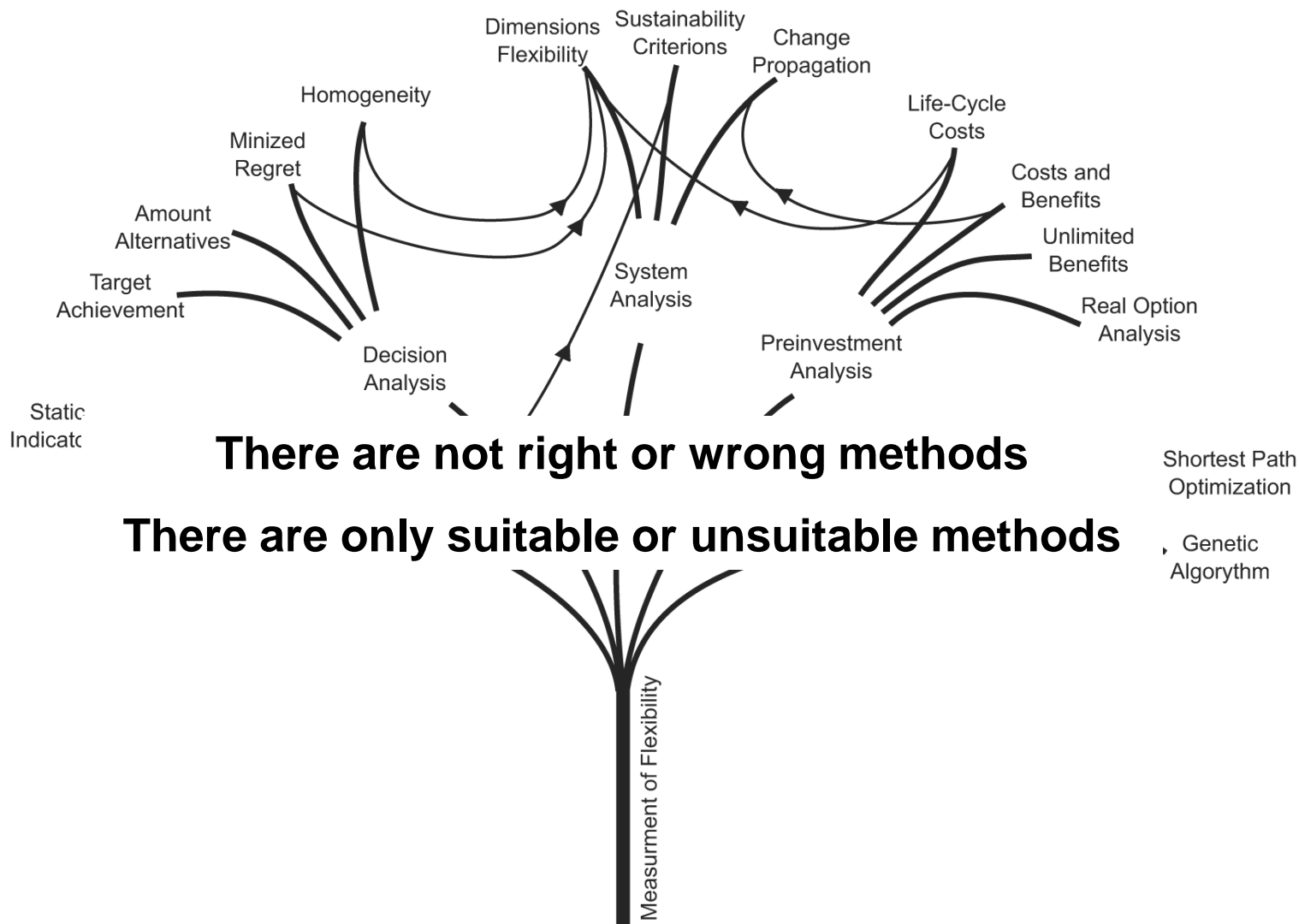


Uniformity: Homogeneity system performance for altering conditions

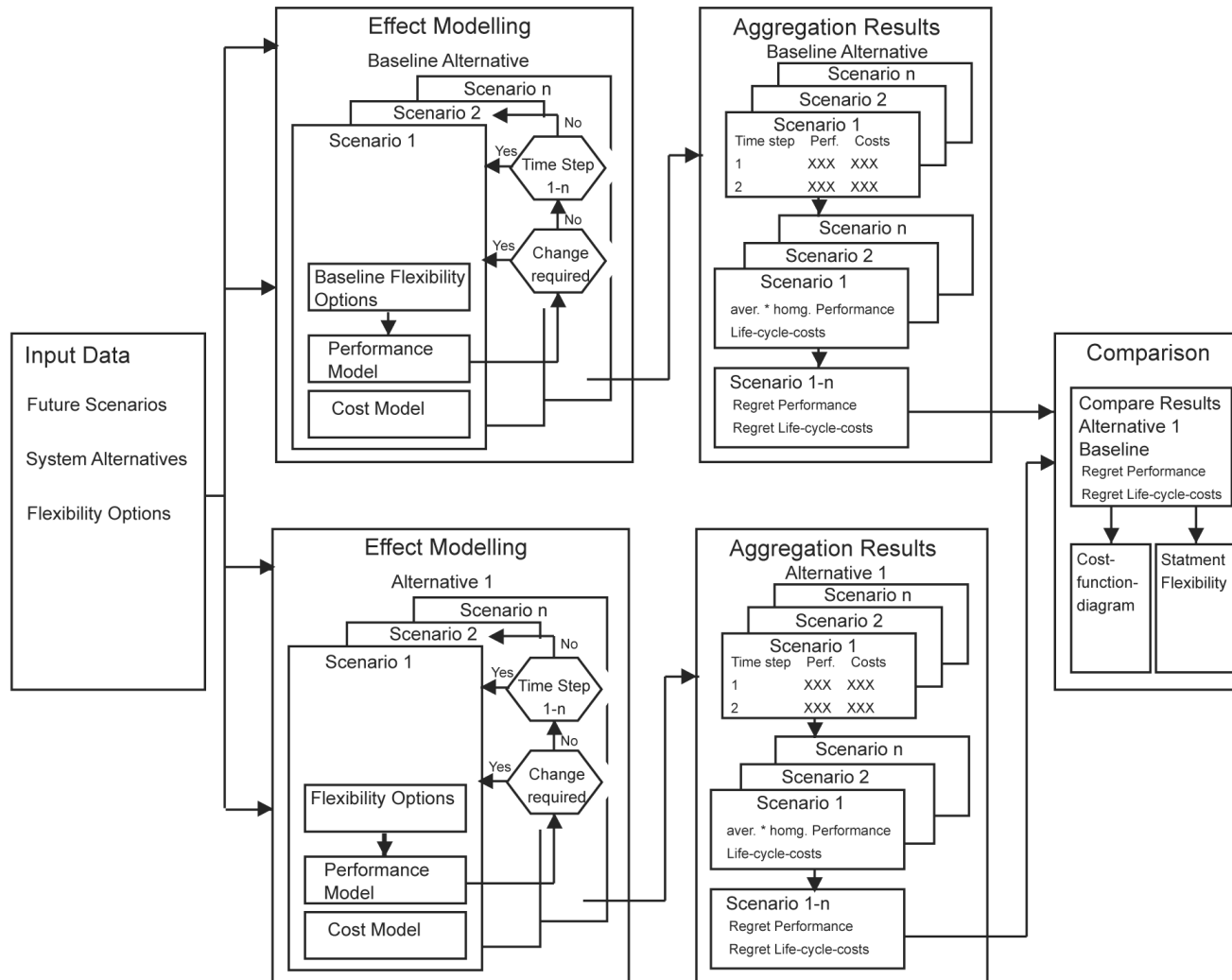


Effort of change: Cost of change, duration of change etc.

Measurement of Flexibility



Detailed Approach for Measurement of Flexibility



Case Study

- real but anonymised case study
- residential area with 400 living units
- total area 17 ha
- 60% impervious area
- MsC thesis Beatriz Sepulveda



Step 1: Alternative Solutions for Drainage



Sewers

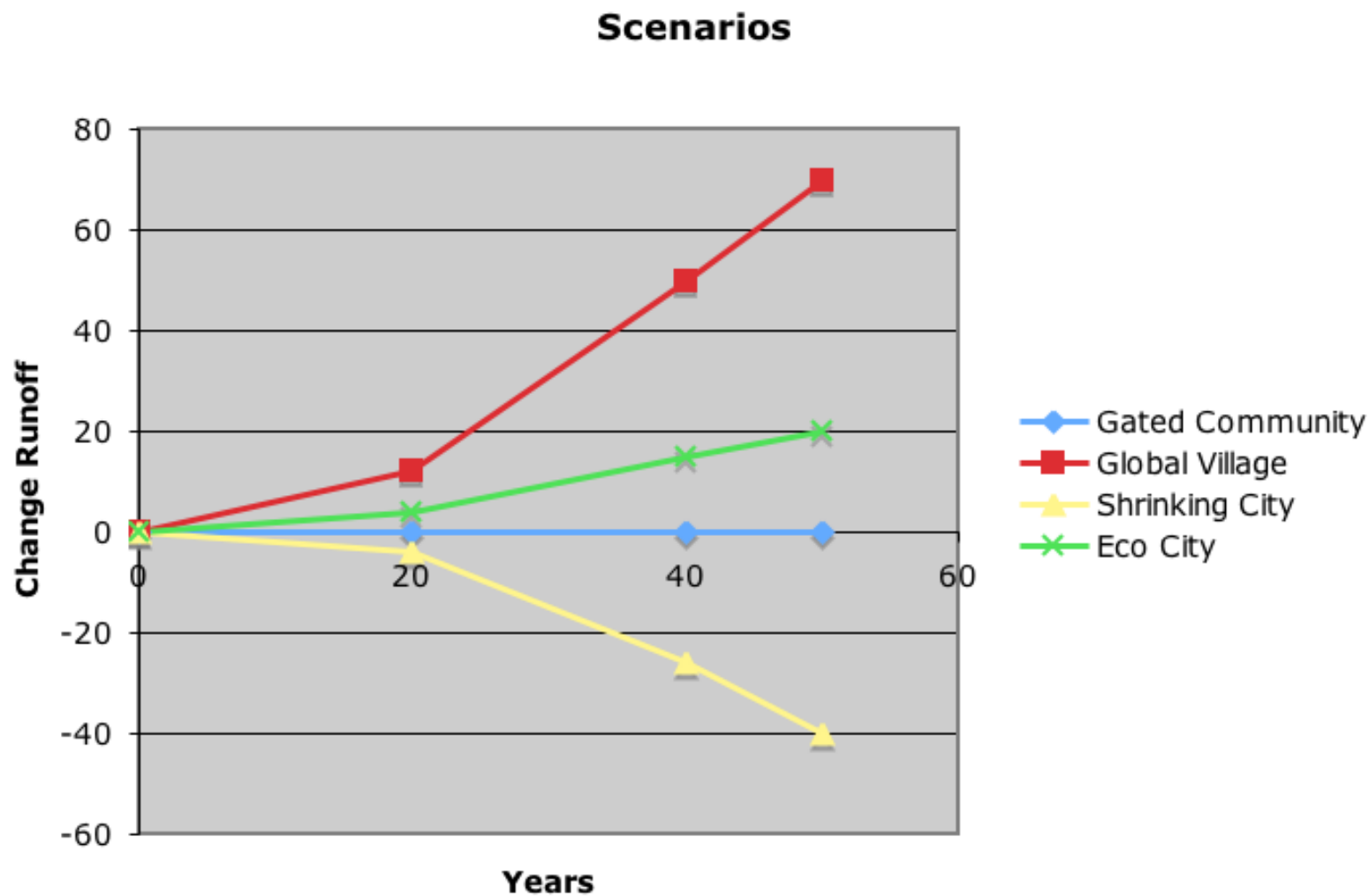


SUDS I

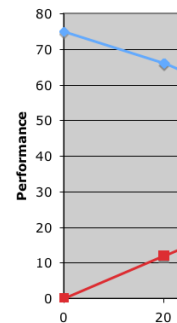
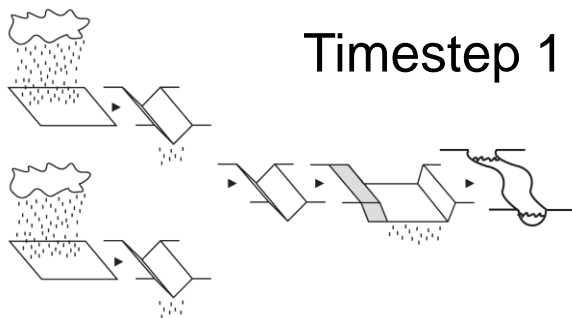


SUDS II

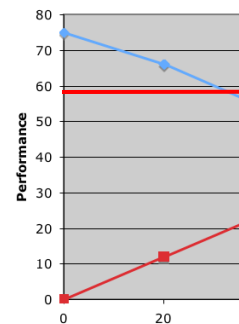
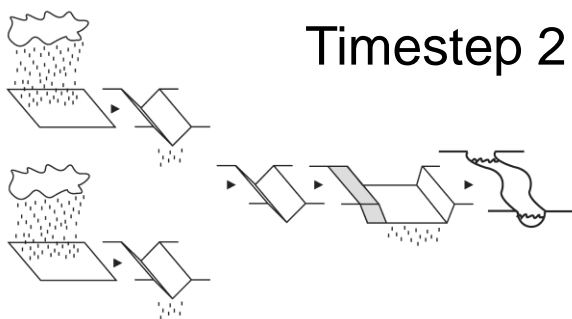
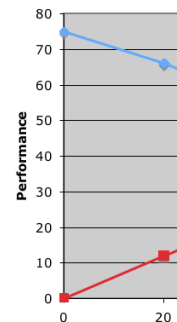
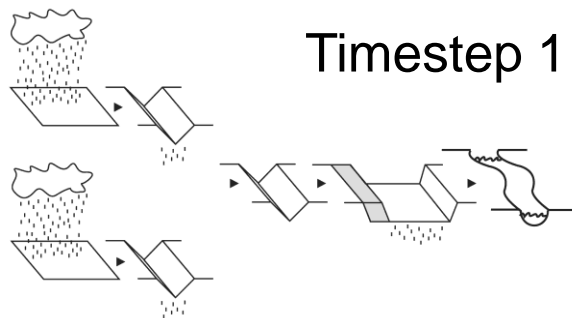
Step 2: Future Scenarios



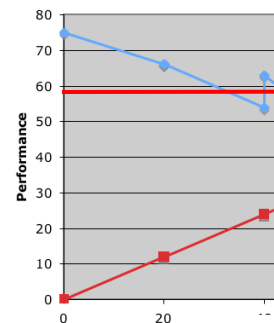
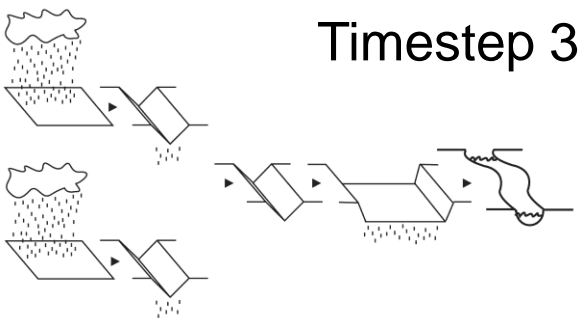
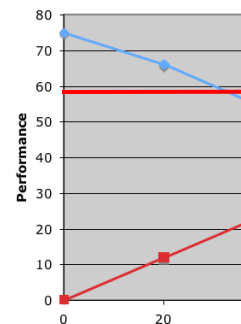
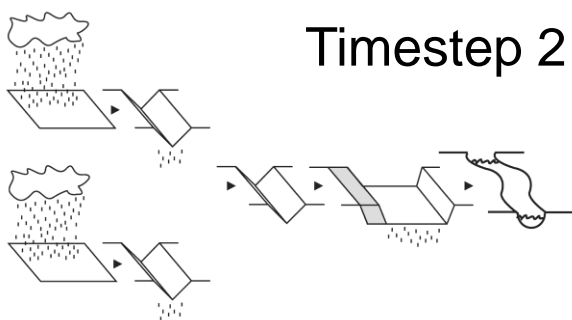
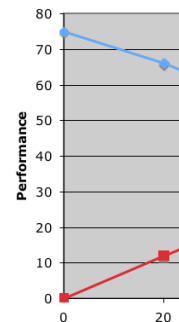
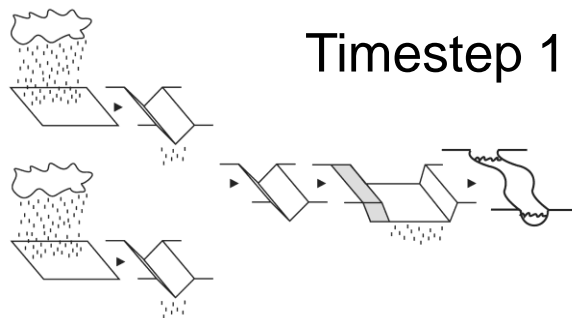
Step 3: Modelling the Effects



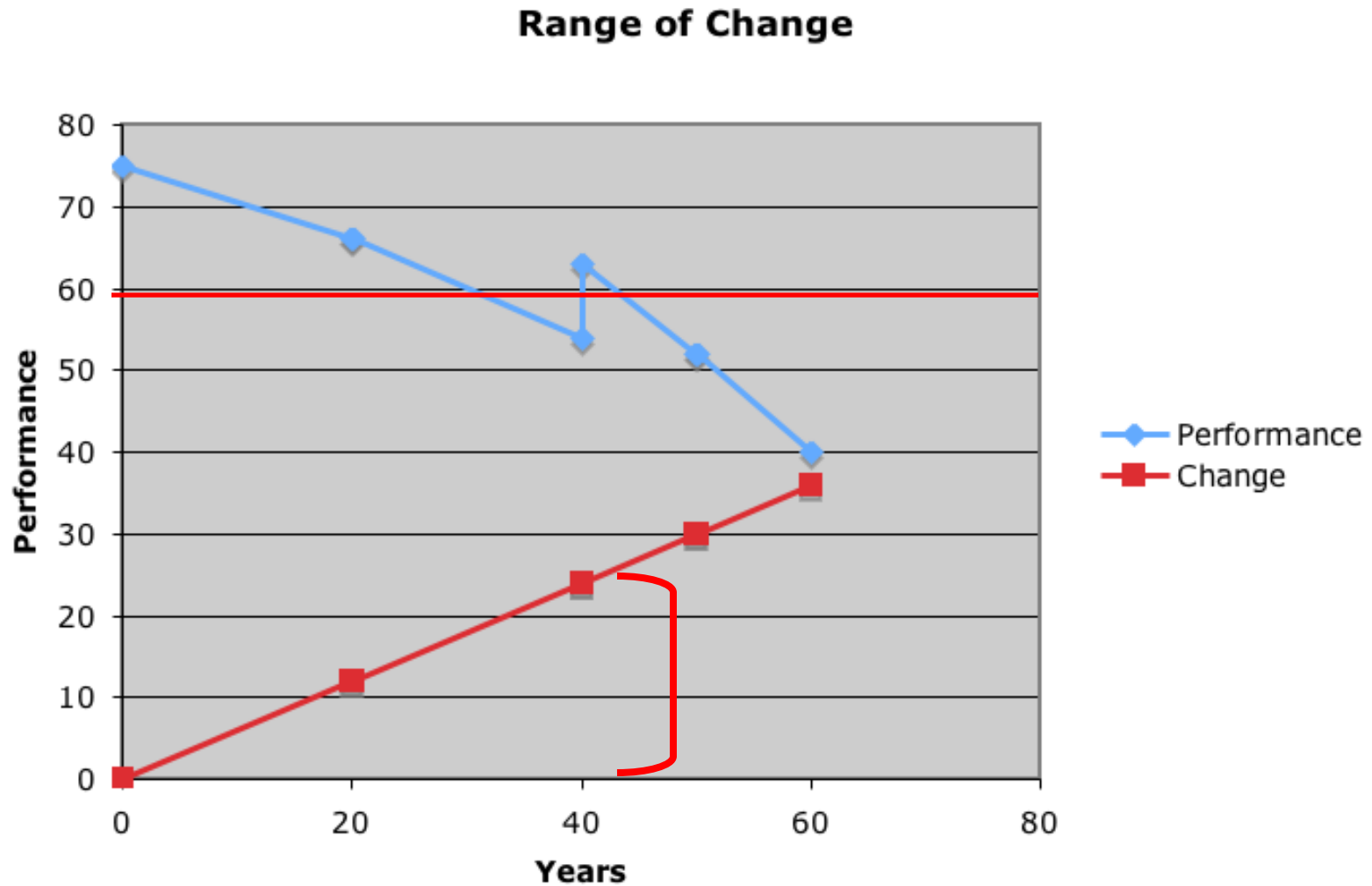
Step 3: Modelling the Effects



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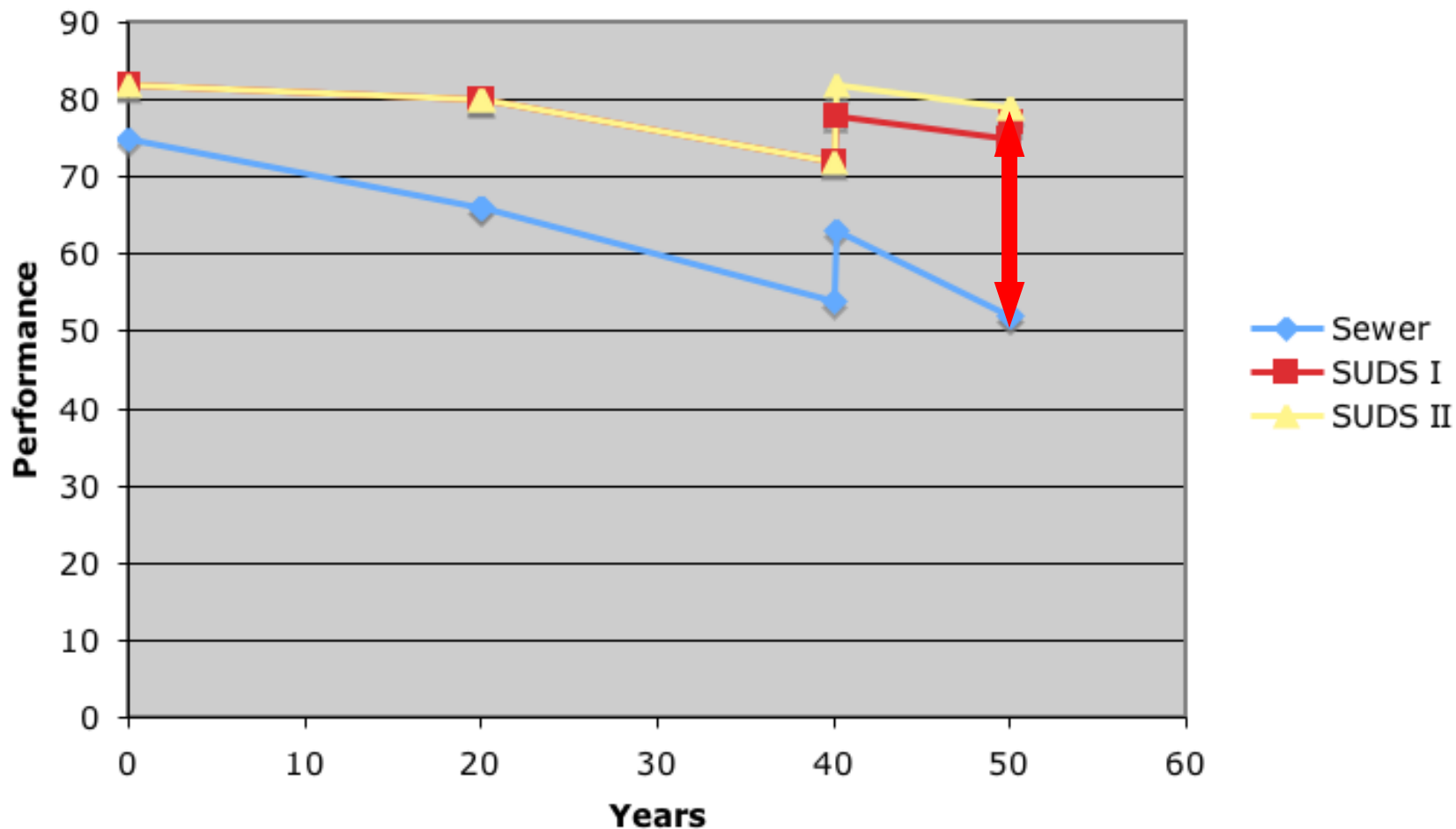


Step 4. Indicators Flexibility



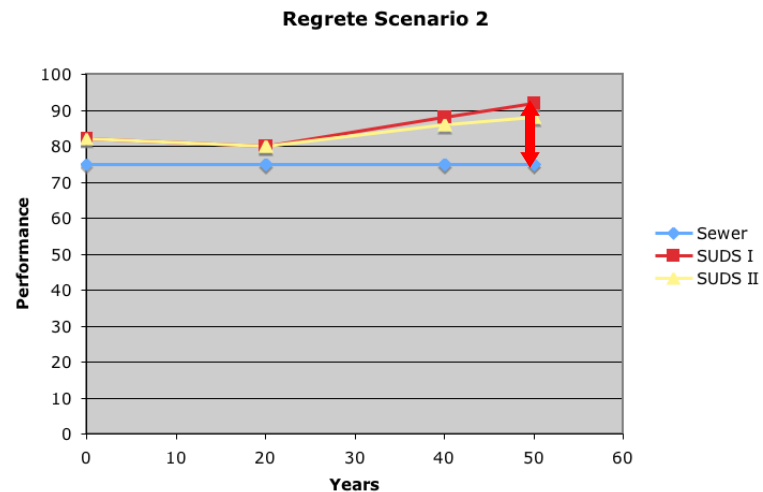
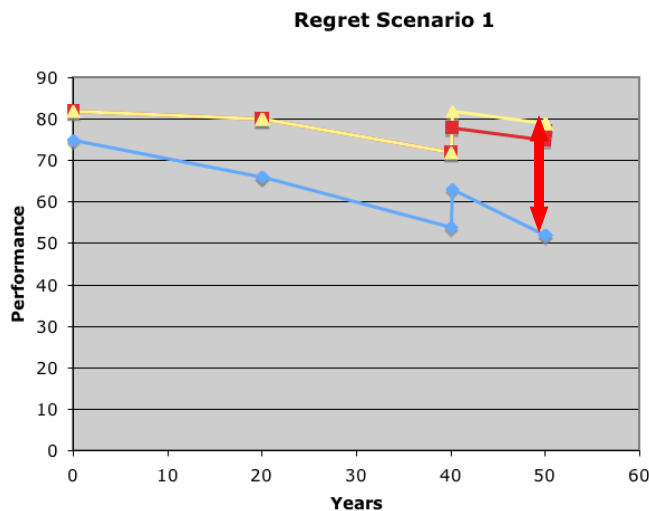
Step 4. Indicators Flexibility

Regret Scenario 1



Step 4. Indicators Flexibility

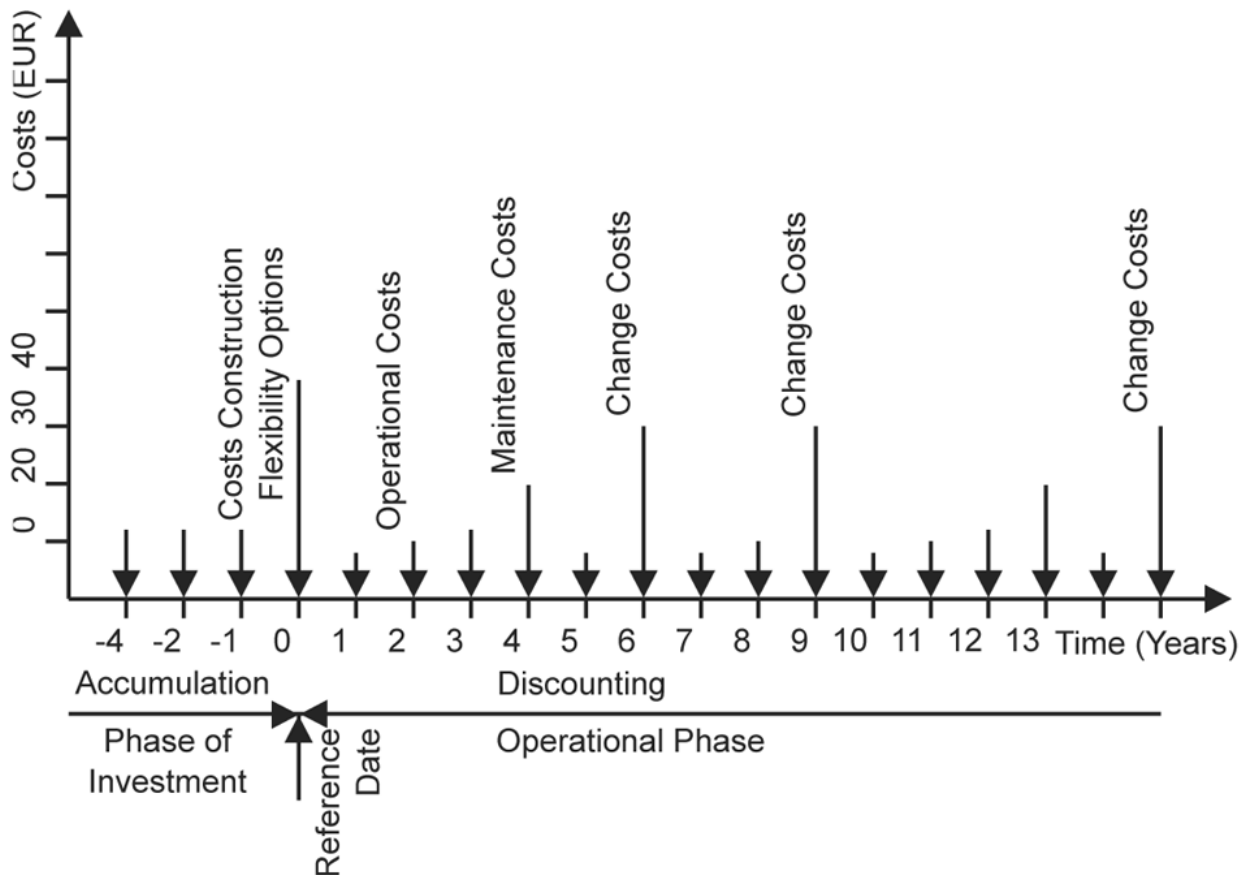
Minimax Regret for different scenarios



	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Sewer	30	16	20	32
SUDS I	5	0	2	0
SUDS II	0	4	0	1

Step 4. Indicators Flexibility

Life Cycle Costs



$$NPV = I_i + \sum_{t=1}^{t=EoP} \frac{CF_t}{(1+r)^t}$$

With: NPV: Net Present Value

I_i : Initial Investment

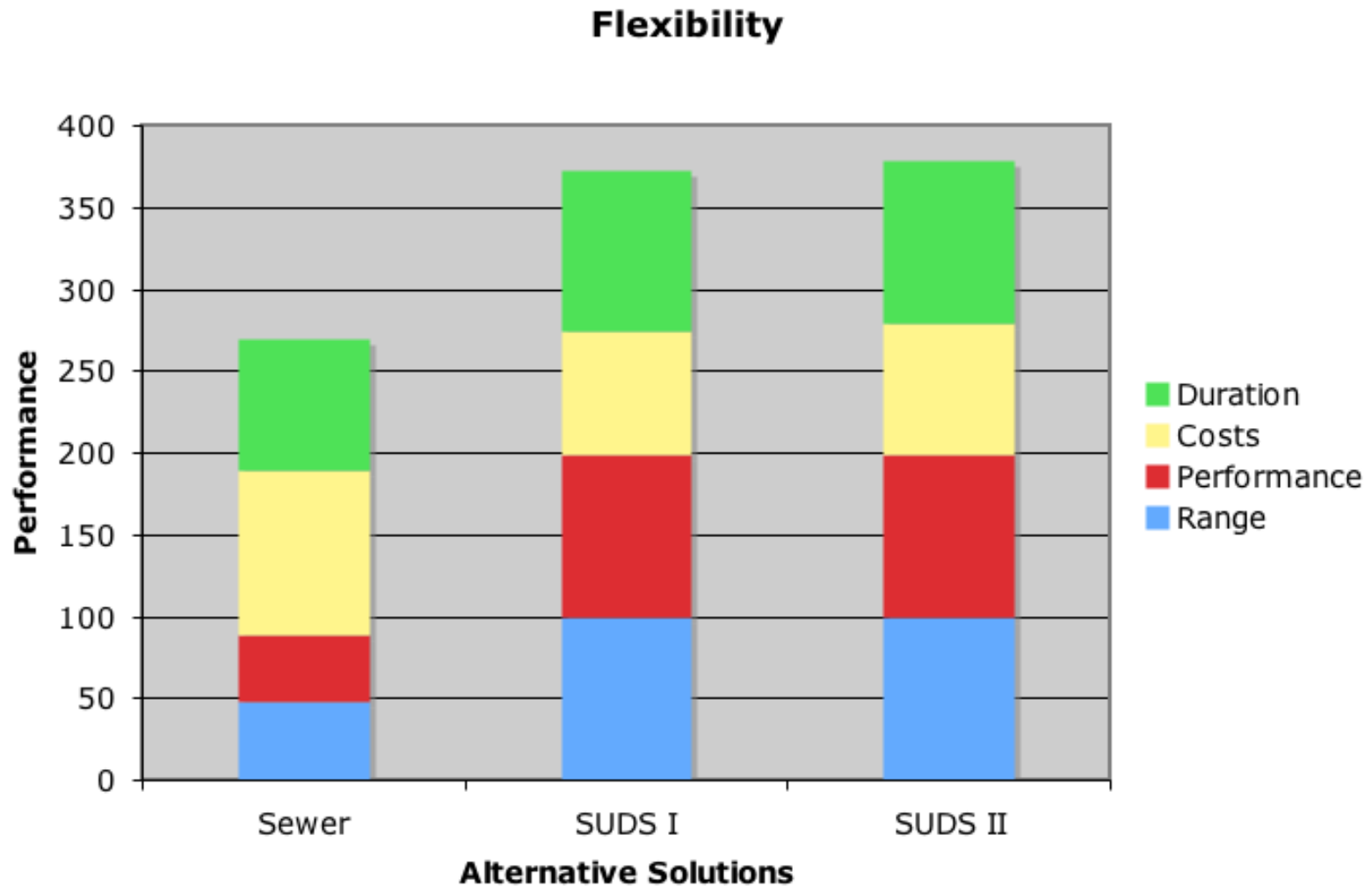
EoP: End of Project

Step 4. Indicators Flexibility

Duration of Change

Value	Description
0	The duration of change of the flexibility option is longer than the remaining constructional life span of the system.
20	For the implementation of the flexibility option a very long period is required.
40	For the implementation of the flexibility option a long period is required.
60	For the implementation of the flexibility option a medium period of time is required.
80	A quick implementation of the flexibility option is guaranteed.
100	A very fast implementation if the flexibility option is guaranteed. Or no change of the system is required

Step 5. Comparison Flexibility of Alternatives



Conclusions

- Measurement approach represent characteristics mentioned in definition of flexibility
- Precise description of flexibility
- Approach requires high amount of work
- Flexibility is recommended as decision criterion for the design of urban drainage systems.

