WATCH

WATer management for road authorities in the face of climate CHange

CASE STUDY

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ROD-IS

Case study

- M10 Denmark
- Major existing road leading into Copenhagen
- One of the ROADAPT high risk locations from the case study

The DRD and climate change adaptation

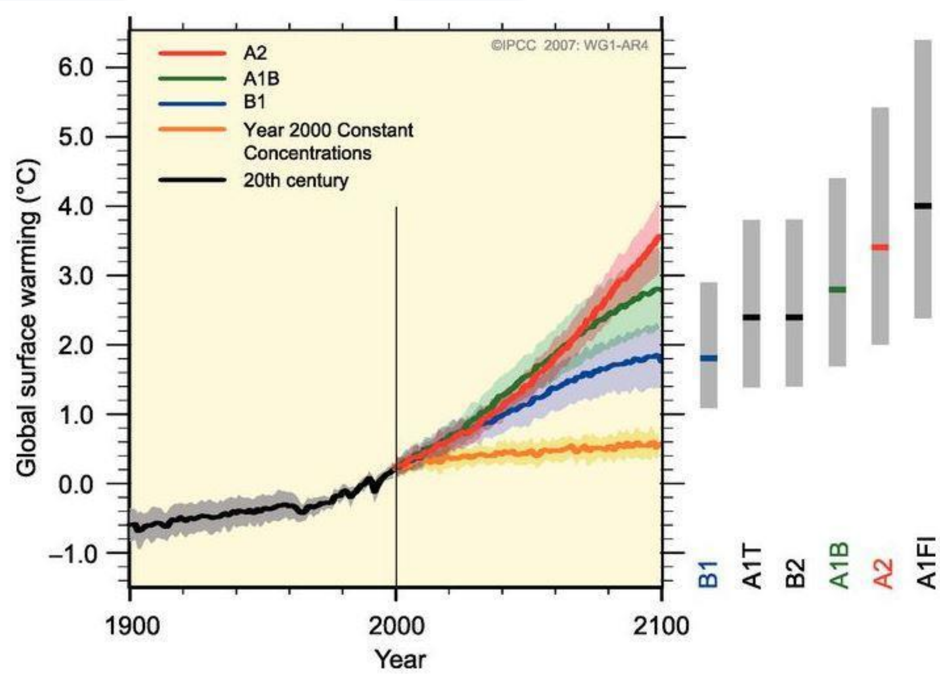
- A strategy on climate change was implemented in 2013.
- Still, not all roads are adapted fully to cope with climate change.

1. Managing flooding when it occurs
   a. *having call-out services ready*
   b. *informing road users about the flood*
   c. *clearing up quickly*
   d. *being part of the strategic road network*
2. Improving and adapting roads where possible
   a. *analyzing the event*
   b. *creating a database of events*
   c. *implementing improvements*
   d. *cooperating with the relevant authorities*
3. Preventing where possible
   a. *screening for particularly vulnerable sections*
   b. *participation in legislative work relevant to the management of rainfall on roads*
   c. *exercising prudence in the planning and construction phase*
   d. *considering climatic adaption in connection with carriageway widening*
   e. *focusing on research, and developing methods and knowledge about climatic adaption*
   f. *international cooperation and information-sharing in the field*

Case study

The DRD and climate change adaptation

- The Danish government, and thereby the DRD, has opted to follow the A1B IPCC-scenario.



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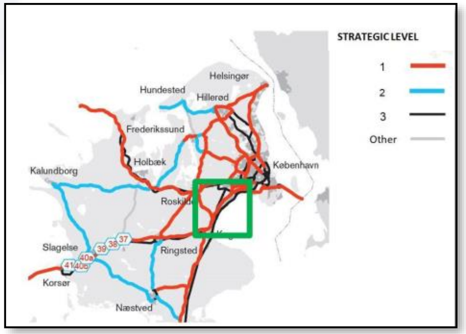
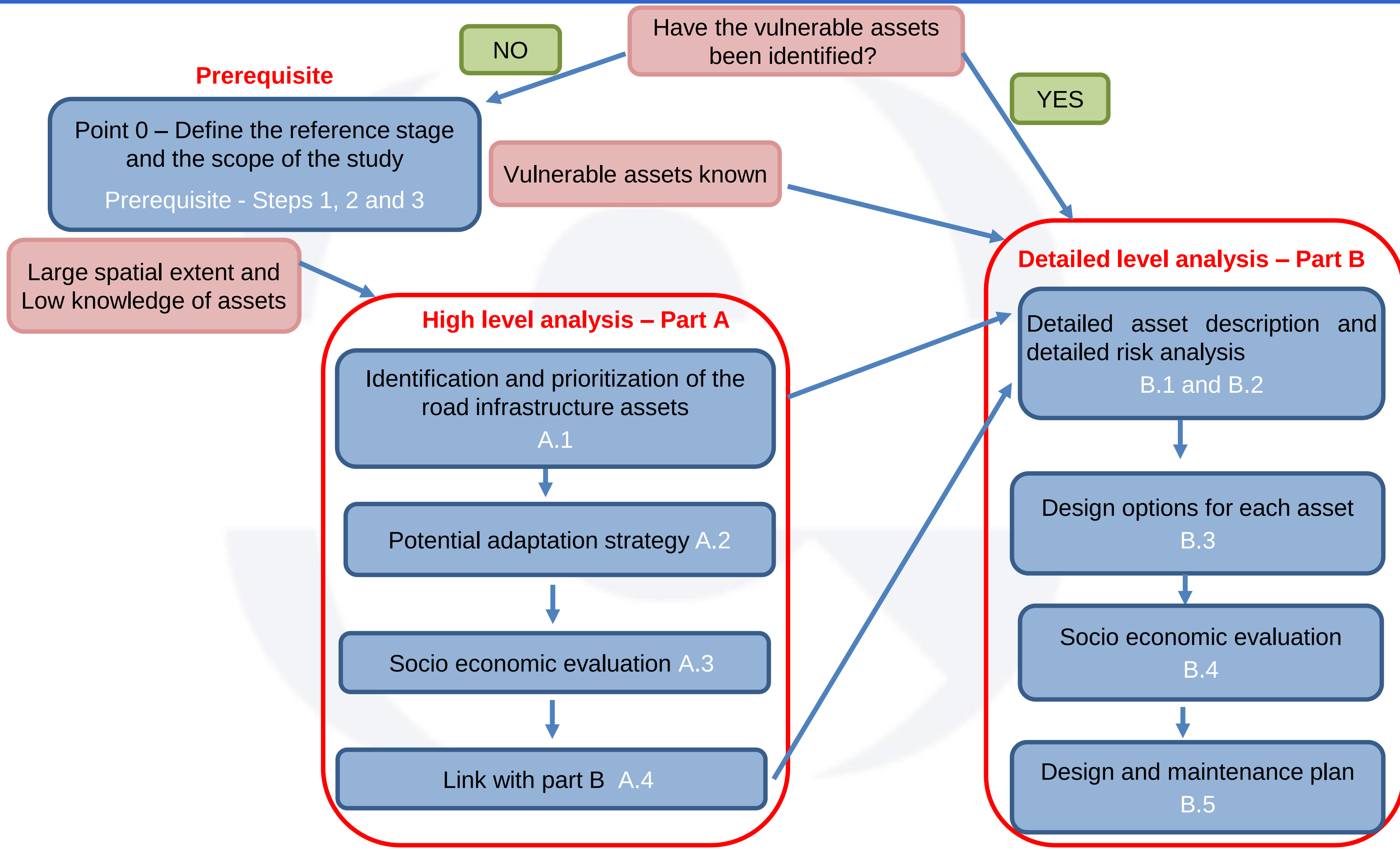
Case study

- To demonstrate how the WATCH manual and can be applied by NRAs on a single project/road
- Most heavily used road in Denmark with an AADT of approximately 120,000.
- Highest strategic importance of all road types



Manual


Have the vulnerable assets been identified?
NO
YES
Prerequisite
Point 0 – Define the reference stage and the scope of the study
Prerequisite - Steps 1, 2 and 3
Vulnerable assets known
Large spatial extent and Low knowledge of assets
High level analysis – Part A
Identification and prioritization of the road infrastructure assets A.1
Potential adaptation strategy A.2
Socio economic evaluation A.3
Link with part B A.4
Detailed level analysis – Part B
Detailed asset description and detailed risk analysis B.1 and B.2
Design options for each asset B.3
Socio economic evaluation B.4
Design and maintenance plan B.5

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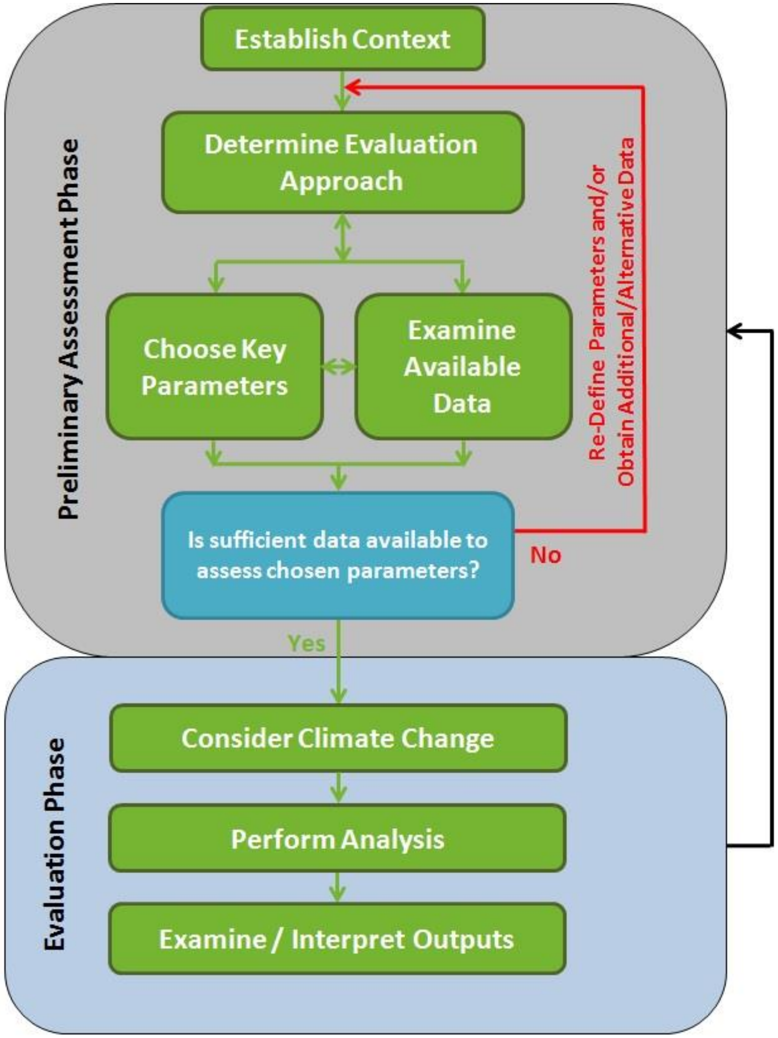
Socio-Economic Analysis



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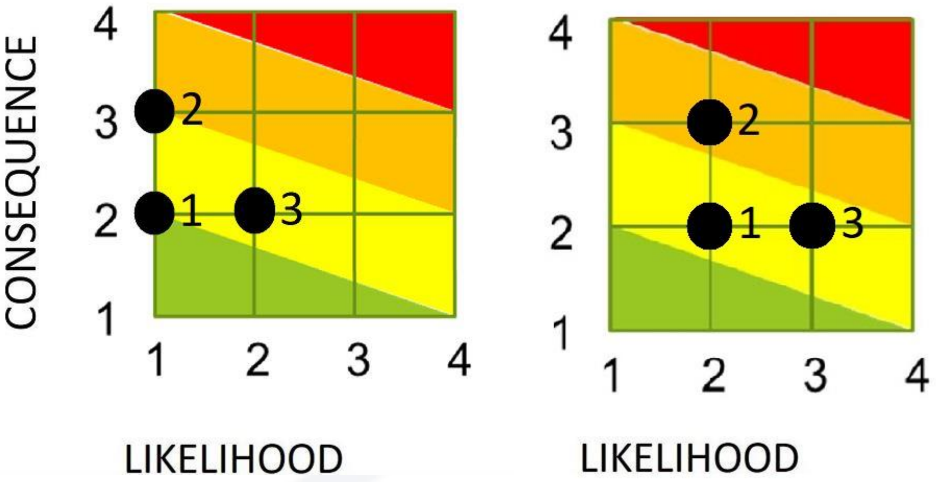
Part A
High-Level Analysis

High level risk analysis

- ROADAPT quickscan method
- Used to identify the assets that may have an unacceptable risk level

1. Retention systems
2. Culverts
3. Pumps



High level risk analysis

- Methodology from step A.1 of the manual
- Analysis of
  - Threat
  - Vulnerability (intrinsic and extrinsic)
  - Consequences (link with SEA)

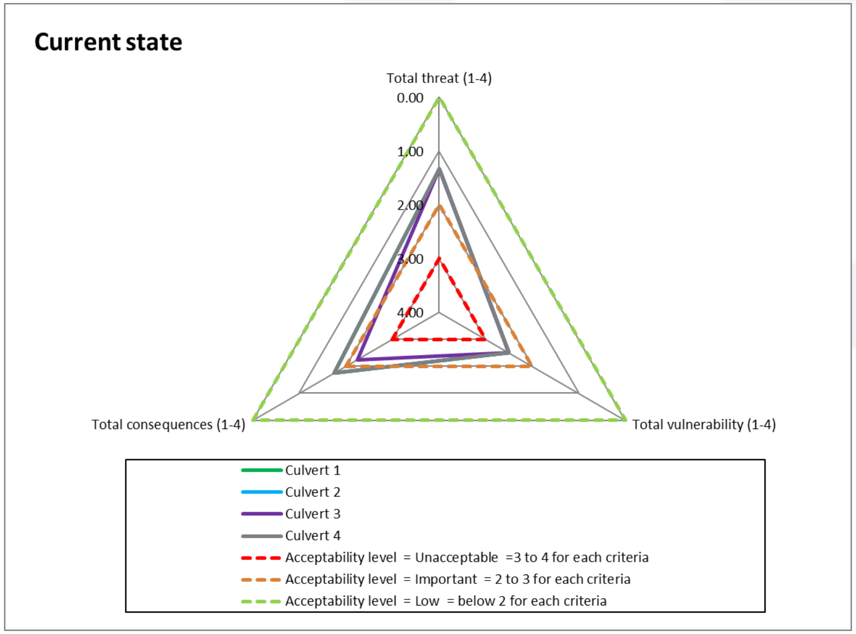
Identification and prioritization of the road infrastructure assets
A.1

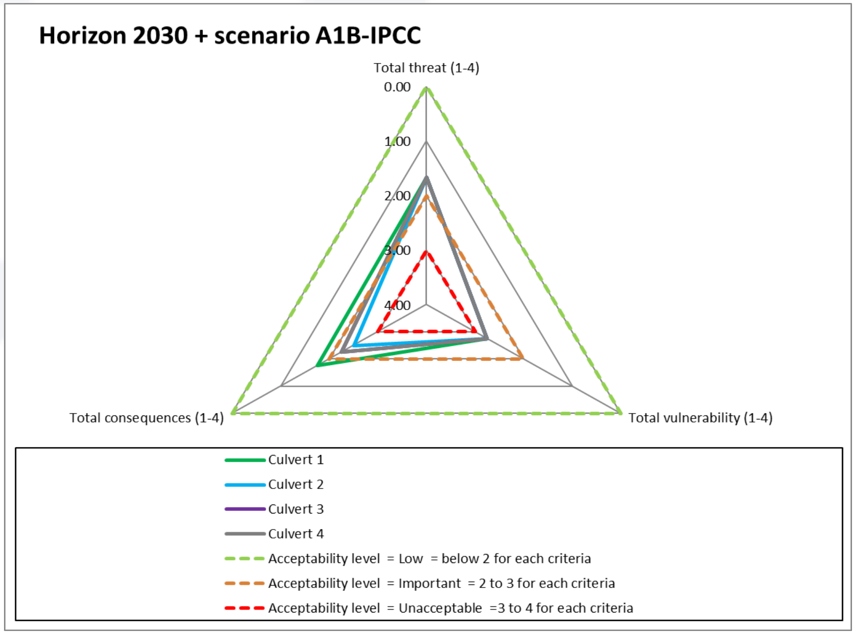
				1.2.1 Elements to score the criteria				
Risk component		**Relevant criteria**	**Comments**	**Low impact (1)**	**medium impact (2)**	**high impact (3)**	**very high impact (4)**	**Comments**
Threat		Hazard : extreme rainfall events		improvement (decrease of extreme rainfall events)	stability	highly aggravation	very high aggravation	
		Likelihood		very seldom Less frequent than dimensionned for	seldom As dimensionned for	can occur More frequent than every 10 years	very likely More frequent than every 5 years	
		Exposure		very minor exposure (very low duration < hours and very local event)	minor exposure (low duration < 1 days and local event)	moderate exposure (moderate duration < 1 week and regional event)	high exposure (long duration > weeks and large event)	
Vulnerability	**Intrinsic factor of vulnerability**	Sizing return period		> 50 yrs	25 yrs	10 yrs	<10 yrs	
		Structure age		< 10 yr	10-25 years	25-50 years	> 50 yrs	
	Extrinsic factor of vulnerability	Traffic volumes		< 1 000 veh/j	1000 to 10 000 veh/j	10 000 to 50 000	> 50 000 veh/j	to adapt according to the area
		Road network redundancy		several other road available	equal road available	one smaller road available	no other road available	
Consequences		Maintenance & Serviceability Issues (i.e. repair costs)	Directs costs for maintenance and repair costs	less than 25 k€	between 25 and 100 k€	between 100 and 500 k€	above 500 k€	Direct costs
		Environmental costs : flooding of an agricultural land, floating debris…	Impact on the surroundings environment	no vulnerable area upstream	medium vulnerable area upstream (natural area)	high vulnerable area upstream (agricultural area)	very vulnerable area upstream (industrial area with possible pollution due to flooding)	Indirect costs
		Societal Impacts & Requirements (effect, costs) : flooding of a urban area, operation organisation image…	Impact on social surroundings (urban area, road network, reputation…) linked to the economic importance of the area	no vulnerable area upstream	medium vulnerable area upstream (natural, agricultural area) or very flat area	High vulnerable area upstream (urban area upstream, low road upstream)	very vulnerable area upstream (urban area, industrial area with possible pollution due to flooding….)	Indirect costs
		Safety Constraints & Impacts	linked to fill height above the culvert	Insignificant: No remarquable consequence assessed fill height > 2 m	Noteworthy As dimensioned for fill height : 80 cm to 2 m	Very significant: Substantial traffic disruption and potential overload of adjoining roads Fill height : 50 cm to 80 cm	Catastrophic Causing significant material damage and/or human injury / fatalities fill height :< 50 cm or low point in the vicinity	Direct costs

Risk component		Relevant criteria	Culvert 1	Culvert 2	Culvert 3	Culvert 4	Culvert 1	Culvert 2	Culvert 3	Culvert 4	Comments
Threat		Hazard : extreme rainfall events	2	2	2	2	2	2	2	2	
		Likelihood	1	1	1	1	2	2	2	2	climate change
		Exposure	1	1	1	1	1	1	1	1	
Total threat (1-4)			**1.33**	**1.33**	**1.33**	**1.33**	**1.67**	**1.67**	**1.67**	**1.67**	
Vulnerability	**Intrinsic factor of vulnerability**	Sizing return period	2	2	2	2	2	2	2	2	
		Structure age	1	1	1	1	2	2	2	2	increase of age of assets
	Extrinsic factor of vulnerability	Traffic volumes	4	4	4	4	4	4	4	4	
		Road network redundancy	3	3	3	3	3	3	3	3	
Total vulnerability (1-4)			**2.50**	**2.50**	**2.50**	**2.50**	**2.75**	**2.75**	**2.75**	**2.75**	
Consequences		Maintenance & Serviceability Issues (i.e. repair costs)	2	2	2	2	2	2	2	2	
		Environmental costs : flooding of an agricultural land, floating debris…	1	1	1	1	1	4	1	1	construction of an industrial area for example
		Societal Impacts & Requirements (effect, costs) : flooding of a urban area, operation organisation image…	1	1	3	1	1	1	3	3	construction of a urban area for example
		Safety Constraints & Impacts	3	3	3	3	3	3	3	3	
Total consequences (1-4)			**1.75**	**1.75**	**2.25**	**1.75**	**1.75**	**2.50**	**2.25**	**2.25**	

High level risk analysis

- Conclusion
  - All culverts are 'important' to further investigate
  - Method does not discriminate between culverts
  - Culverts need more detailed analysis (Part B)





Adaptation strategies - MCA

Potential adaptation strategy A.2

- Strategies
  - As is (current state)
  - Allocate Additional Resources for updating
  - Updating or bypassing the strategy for service level

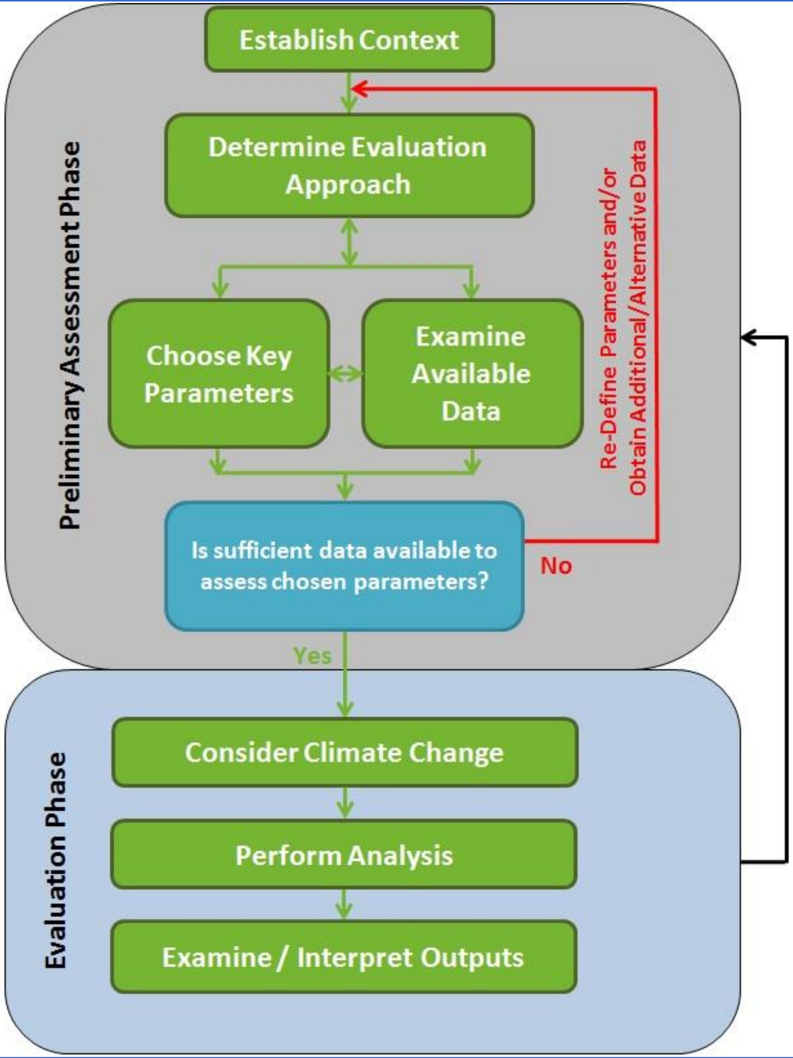
Socio-Economic Analysis Framework

Socio-economic analysis essential for implementation of the WATCH outcomes

- Provide arguments whether actions need to be taken
- Choose optimum solution

Evaluation approaches

- Multi Criteria Analysis
- Life Cycle Costing
- Cost Effectiveness Analysis
- Cost Benefit Analysis



Adaptation strategies - MCA

Socio economic evaluation A.3

- Strategies
  - As is (current state)
  - Allocate Additional Resources for updating
  - Updating or bypassing the strategy for service level

- Use of an MCA to identify best strategy
- Key parameters
  - Maintenance & Serviceability Issues
  - Environmental issues
  - Societal Impacts & Requirements
  - Safety Constraints & Impacts

Adaptation strategies - MCA

Category	Cost, C, in €
-2	C ≥ 500,000
-1	100,000 ≤ C < 500,000
0	Neutral/N/A
+1	25,000 ≤ C < 100,000
+2	C < 25,000

Impact Level	Climate Change Impact
-2	Increase in Frequency and severity of Flooding events such that threat of culvert failure is inevitable
-1	Increase in Frequency and severity of Flooding events such that threat of culvert failure is likely
0	Neutral/N/A
+1	Increase in Frequency and severity of Flooding events such that culverts are operating at full capacity
+2	Increase in Frequency and severity of Flooding events such that culverts are operating with a reasonable margin of safety against failure

Adaptation strategies - MCA

Impact Level	Maintenance & Serviceability Issues	Environmental issues	Societal Impacts & Requirements	Safety Constraints & Impacts
-2	Significant repairs	Significant impact on environment, untreated water flowing into sea, crossing streams	Re-routing of traffic/use of alternative transport mean due to road closures	Multiple Casualties/severe injuries
-1	Repairs above routine maintenance	Significant clear up on road, Environmental impact assessment possibly required	Significant delays due to lane closures (e.g. 6hr standstill)	Casualties/severe injuries
0	Neutral/N/A	Neutral/N/A	Neutral/N/A	Neutral/N/A
+1	Minor repairs in line with routine maintenance	Normal Clear up over greater area of road required	Minimal delays/congestion, no rerouting required, road operational	Minor injuries
+2	Minimal/no repairs	Minimal impact on the environment, normal clear up in localised area, untreated water on the road only	No delays/congestion, no rerouting required, road operational	Material Damage

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Adaptation strategies - MCA

Strategy	Maintenance & Serviceability Issues	Environmental Issues	Societal Impacts & Requirements	Safety Constraints & Impacts	Averaged Total
As is (current state)	-2	-1	-2	-1	-1.5
Allocate Additional Resources for updating (Enlarge Culvert)	1	1	1	2	1.25
Updating or bypassing the strategy for service level	0	-1	-2	-1	-1

Strategy	Direct Cost	Averaged Parameters	Climate Change Impact	Total
As is (current state)	2	-1.5	-1	-0.5
Allocate Additional Resources for updating (Enlarge Culvert)	-2	1.25	1	0.25
Updating or bypassing the strategy for service level	1	-1	-1	-1

Part B
Detailed Analysis

Detailed assessment

- Part B
  - Detailed resilience assessment
  - In case study no design calculations have been made and no alternatives measures have been studied
  - CBA used to identify whether enlarging culverts is appropriate

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Detailed assessment - CBA

Current climate

Strategy	Construction cost in €			Yearly maintenance cost per culvert in €	Total average yearly cost in €
	Construction cost	Service Culvert	Average yearly construction cost		
As is /No action	0	On average. 30 years old as is and designed for 50 years	0	4,500	4,500
Enlarging capacity of culverts	2,500,000	50 years	97,521	5,000	102,521

Strategy	Maintenance & Serviceability Issues in €	Environmental effects in €	Societal Impacts & Requirements in €	Safety Constraints & Impacts in €	Total impact in €	Return period of threat	Annual average expected impact in €
As is / No action	190,000 per flooding caused by culvert failure	65,000 per flooding caused by culvert failure	1,500,000 For a 6h standstill on M10 due to flooding	10,000	1,765,000	0.1/year	176,500
Enlarging capacity of culverts	190,000	65,000	1,500,000	10,000	1,765,000	0.02/year	35,300

Strategy	Yearly construction and maintenance cost in €	Annual average expected impact in €	Annual expected cost in €
As is / No action	4,500	176,500	181,000
Enlarging capacity of culverts	102,521	35,300	137,821

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Detailed assessment - CBA

Future (2030) climate

Strategy	Construction cost in €			Yearly maintenance cost per culvert in €	Total average yearly cost in €
	Construction cost	Service Culvert	Average yearly construction cost		
As is / No action	0	On average. 30 years old as is and designed for 50 years	0	4,500	4,500
Enlarging capacity of culverts	2,500,000	50 years	97,521	5,000	102,521

Strategy	Maintenance & Serviceability Issues in €	Environmental effects in €	Societal Impacts & Requirements in €	Safety Constraints & Impacts in €	Total impact in €	Return period of threat	Annual average expected impact in €
As is / No action	190,000 per flooding caused by culvert failure	65,000 per flooding caused by culvert failure	1,500,000 For a 6h standstill on M10 due to flooding	10,000	1,765,000	0.2/year	353,000
Enlarging capacity of culverts	190,000	65,000	1,500,000	10,000	1,765,000	0.03/year	52,950

Strategy	Yearly construction and maintenance cost in €	Annual average expected impact in €	Annual expected cost in €
As is / No action	4,500	353,000	357,500
Enlarging capacity of culverts	102,521	52,950	155,471

Detailed assessment - CBA

Strategy	Net Annual Benefit in €	B/C ratio	Net Annual Benefit in €	B/C ratio
Time Period	Present Climate	Present Climate	2030	2030
Enlarging capacity of culverts	43,179	1.44	202,029	3.08

Case study

- Results show that
  - Many major and minor assets can improved with the WATCH approach for improved holistic water management
  - CBA provides new and/or more elaborate way of assessing and ranking parameters
  - The manual and CBA improve basis for optimum decision making, e.g. on assessing environmental issues when installing SuDS features, such as retention basins
  - Improving data gathering, storing and streamlining, e.g. for optimum risk analyses, was highlighted as a particular result focus area for improved water management

Thank you for your attention

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