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Checklist for building resilience

for Transport Infrastructure

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Overview of main steps in increasing resilience of infrastructure networks

- Hazards, climate variables & exposure
- Vulnerability
- Cascading effects
- Risk assessment
- Ambitions & measures

This requires:

- Overview of hazards & climate change
- Data collection & collation
- Analyses
- Decision making and taking action

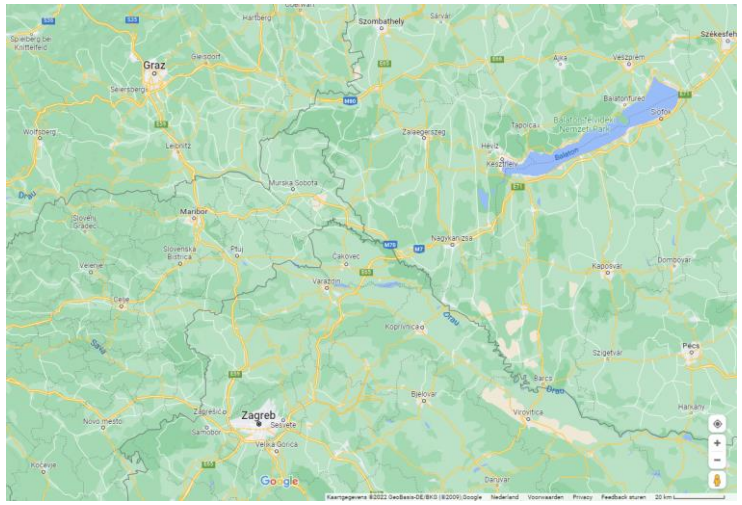
Overview of hazards & climate change

Identify relevant natural hazards & Collect data

Natural Hazard	Relation to climate change variable	Present in region of interest [yes/ no]	Expected change in climate variables	Return period or susceptibility map available	Unit on map	Source
Example: fluvial flooding	*Precipitation*	*Yes*	*Increase in 2050 by 15% increase in occurance*	*Maps with return period available (1:10y, 1:50y, 1:100y, 1:500y)*	*Flood depth [m]*	
Hydro-meteorological						
Pluvial Flooding	Precipitation	x, mainly lower ranked roads	Short duration precipitation events; maximum short term precipitation (IDF curves)	no maps present but there are IDF curves that provide return periods		Meteorological service, climate model data (extremes, max mm per hour, l/ sec)
Fluvial Flooding	Precipitation					l/ sec for river/ stream flows
Landslides (precipitation-induced)	Precipitation					
Coastal Flooding – storm surges and sea level rise	Sea Level Rise (global temperature)					
Heat waves	Temperature					
Wildfires	Temperature, Precipitation					
Water scarcity	Temperature, Precipitation					
Heavy snow fall	Temperature, Precipitation, (wind – snow drifts)					
Geophysical						
Landslides (seismic-induces)	-					
Earth quakes	-					
Tsunami	-					
Volcano	-					

Data collection & collation - roads

- Source of data: road owner (asset management system)
- Required road information
  - Location of roads (primary, secondary, tertiary)
  - Location of assets
  - Type of pavement
  - Number of lanes



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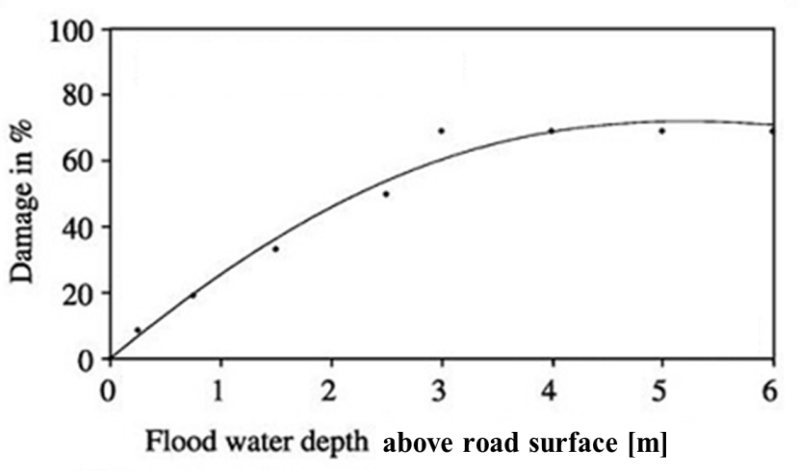
Data collection & collation – vulnerability curves

- Vulnerability curves: relationship damages/ down time & hazard intensity
  - Sometimes available
  - Sometimes make use of neighbouring countries
  - In case of susceptibility maps create function based on estimated amount of damage per event
- If no vulnerability curvers are present: make them yourself!
- Repair costs and duration of disruption, from e.g.
  - Road asset management system
  - Historical records
  - Other
- Who has records of such events and their consequences?
  - Preferably make use of large database – source(s)?
  - Otherwise use local expert knowledge



Data collection & collation – criticality/ importance of road stretches

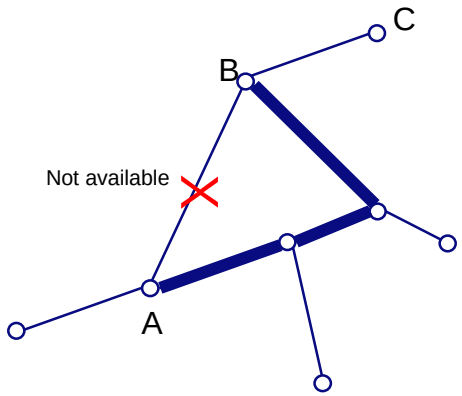
Depending on approach (quantitative vs semi-quantitative), for each road stretch:

Fully quantitative (EAD, EAL):

- Usage of all road stretches, from e.g.
  - Traffic counts & Value of time
- Additional costs of alternative route
  - Road network, single link disruption
- Source: road authority, …

Semi-quantitative:

- Multicriteria analysis, making use of
  - Stakeholder input



Calculate for all road stretches

	Weight	Corridor														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
International	3.61	12.7	5.0	12.2	13.6	12.4	11.5	11.5	11.4	6.6	6.2	10.6	13.3	7.6	10.7	13.4
Industry	2.19	5.3	3.7	5.5	8.0	7.0	6.9	4.7	4.1	4.1	3.6	6.2	5.5	5.2	5.0	5.4
Harbour	3.10	8.2	4.0	6.7	11.8	10.4	7.4	5.7	7.4	4.2	3.8	7.3	6.6	5.1	10.0	5.2
Tourism	3.04	10.1	6.9	6.6	11.9	12.8	8.9	7.6	9.8	6.0	3.6	4.8	7.4	6.7	8.3	13.0
Agriculture	2.52	5.3	4.7	5.7	8.2	9.1	7.5	7.0	5.9	5.2	6.5	7.9	7.1	5.5	5.3	7.7
Evacuation*	3.33	12.5	10.0	8.0	10.5	14.0	16.0	14.0	13.1	12.5	11.1	11.1	12.2	11.0	11.3	14.1
Summation		41.6	24.2	36.7	53.4	51.7	42.2	36.5	38.5	26.1	23.6	36.7	40.0	30.1	39.2	44.8

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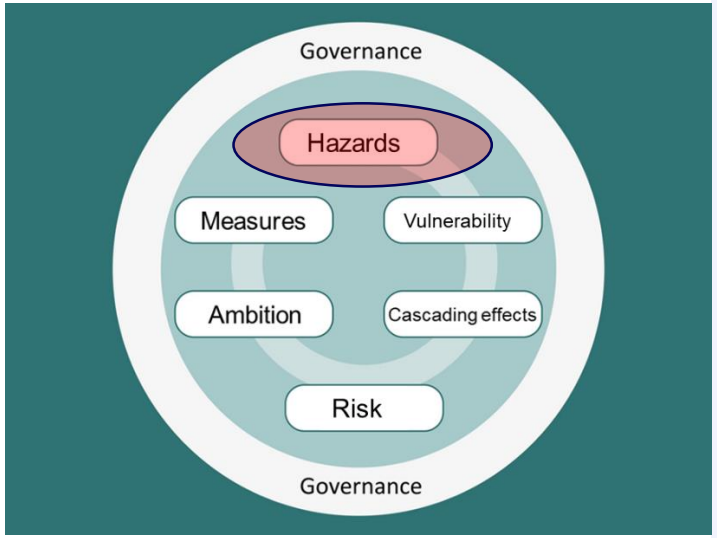
Analyses: fully quantitative vs semi-quantitative

Based on available information and ambition and capabilities of stakeholder, choose analysis/ approach:

	Remodel the hazard (making use of the climate data directly)	**Change in probability of occurrence based on statistics. Only possibility for precipitation related events (based on rainfall statistics and return periods)**	**Based on climate data and expert judgement: Identify a range of expected changes in occurrence and/or intensity**
	Intensity + probability of occurrence changes	Probability of occurrence changes	Probability of occurrence changes
i. Hazard maps with different return periods with models	X	X	X (less accurate)
ii. Hazard maps with different return periods without models		X	X (less accurate)
iii. Susceptibility map with susceptibility without intensity and return period			X

	Road Usage/ Traffic data	**Value of time**	**Network criticality/Extra distance**	**Duration of disruption**
i. Fully quantitative	Traffic model output specified per type of road user per road stretch. Or traffic counts at segment level.	Specified by type of road user or value per vehicle	Time delay when a road stretch is disrupted and a detour has to be taken. This is expressed in hours (or in distance translated to time)	Hours per type of natural hazard and hazard intensity (when intensities are available)
ii. Semi-quantitative	Traffic counts at large corridor level or alternatively based in stakeholder meetings	During stakeholder meetings define the network criticality based on economic importance per corridor and divided in different categories (e.g. ports, agriculture, tourism, industry, hub connection, evacuation etc.)		

Hazard, climate variables and exposure



Goal of step:

- Identify relevant natural hazards
  - Available hazard information (e.g. ThinkHazard)
  - Local experience

Sub steps:

1. Create overview of natural hazards
   a. Identify which natural hazards potentially affect the road infrastructure in your country/ region
   b. Identify which climate variables are relevant to these natural hazards
2. Collect data
3. Overview of current variability in current climate
4. Overview of trends in climate change
5. Define the approach on how to translate the change in climate variable to a change in natural hazard
6. Geographic data collection
7. Exposure analysis

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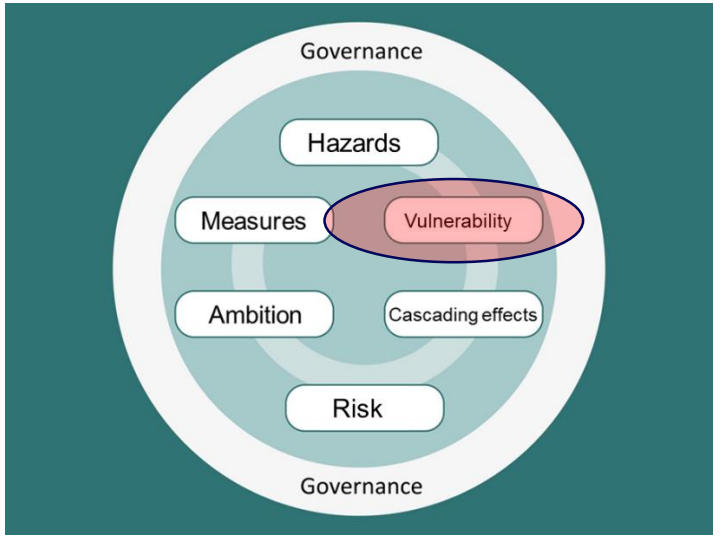
Vulnerability

Goal:

- Estimate potential damages that could occur as a result of the natural hazards

Sub steps:

8. Identify or create historical records of previous road damages
9. Identify or create vulnerability curves



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Cascading effects

Goal:

- Estimate the effects for road users i.e. socio-economic losses due to disruption of the road network

Options:

8. Fully quantitative (highest data need)
9. Semi – quantitative (more stakeholder input)

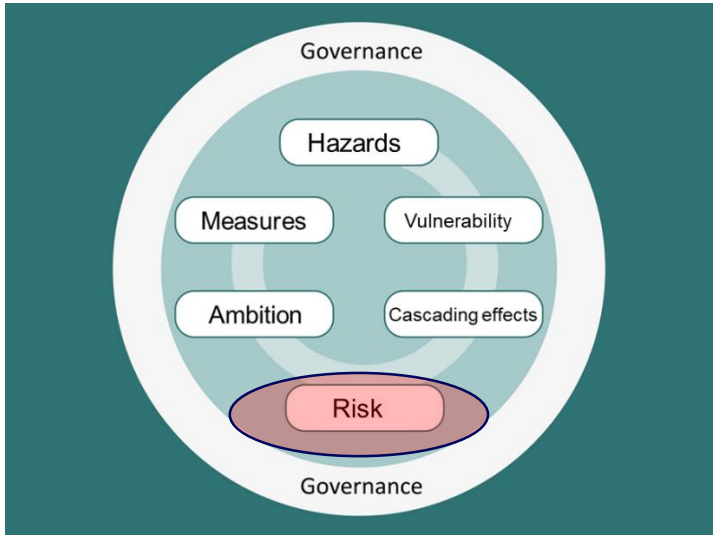
Risk Assessment

Goal:

- Determine the severity of the combined effects of natural hazards on the road network (damages and socio-economic losses)

Sub steps:

12. Risk assessment
13. Taking climate change effects into account
14. Prioritize for interventions



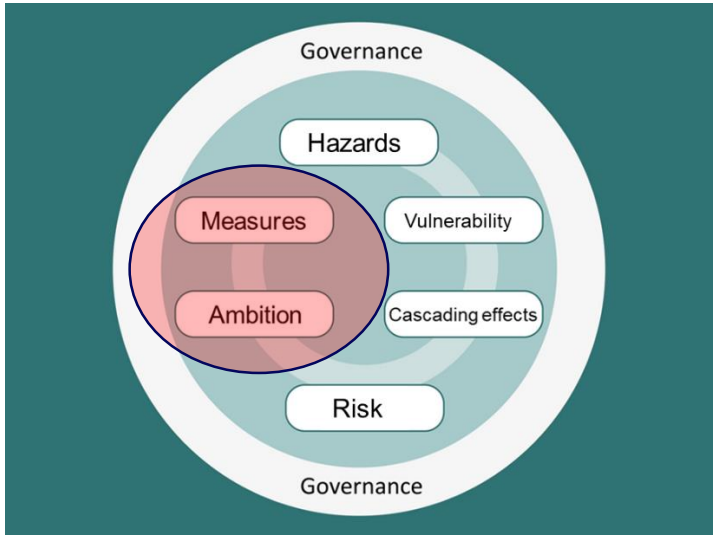
Ambitions and measures

Goal:

- Determine which measures could be taken to achieve the desired level of resilience

Sub steps:

15. Determine ambition
16. Identify measures
17. Formulate an adaptation strategy



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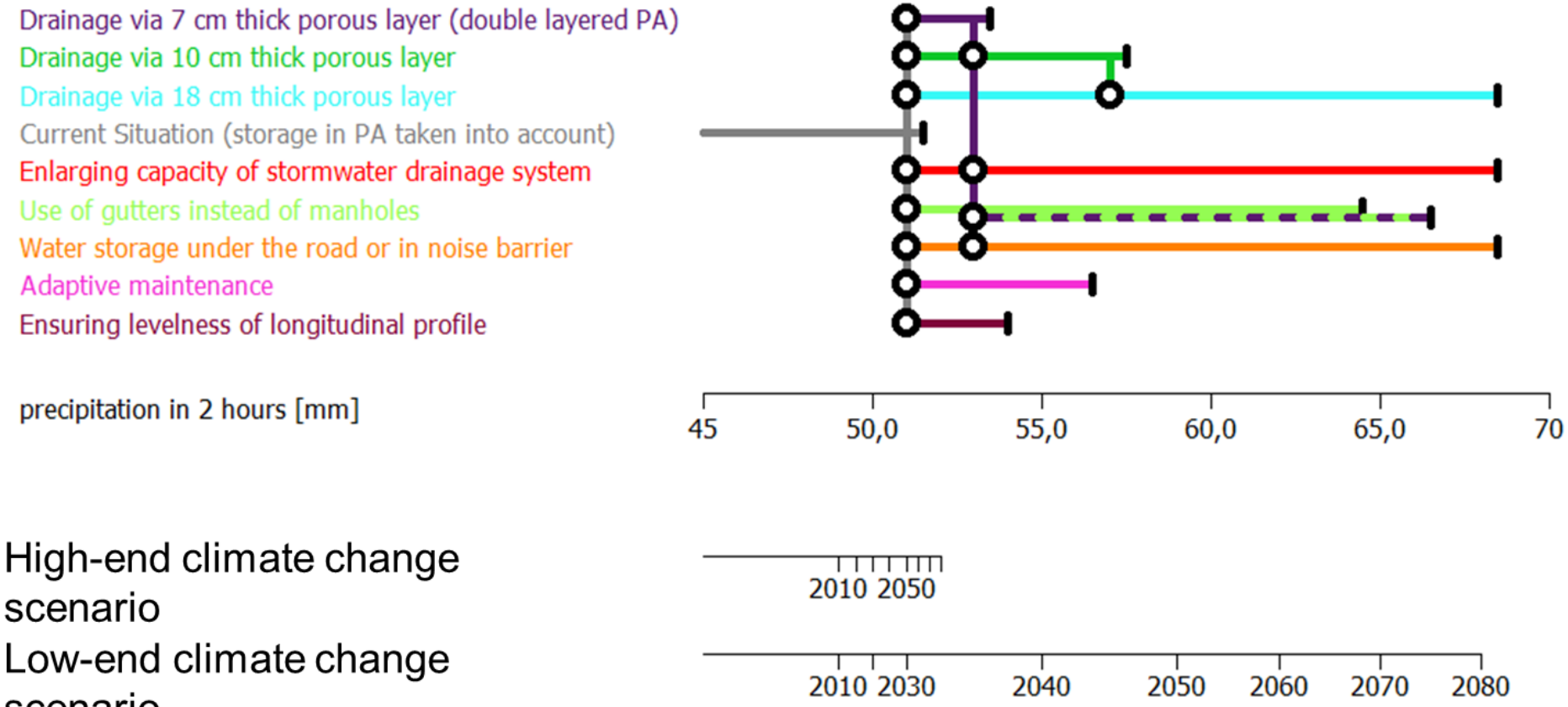
Decision making and taking action

- Determination of ambition:
  - *When is the situation no longer acceptable? And how much may improving the situation 'cost'?*
  - *often difficult to determine; in relation to climate change even more difficult*
  - This is often a difficult step
  - Stakeholder (Road owner, government) need to formulate this
- Identify measures
  - Make use of available lists (e.g. ROADAPT), local knowledge
  - Understand mechanism/ what you are trying to achieve with measure (e.g. use bow-ties)
- Select measures that…
  - Perform best (MCA, CBA, other)
  - Fit within local practice e.g. type of measure, amount of maintenance, etc
  - Fall within authority of your organisation e.g. regional flood defences often do not fall within scope of road authority
- Plan measures in time (not all measures have to be taken NOW)
  - Try to implement measures naturally with regular work flow e.g.
  - Sometimes makes sense to combine two or more measures

Formulate an adaptation strategy – combining and long term planning



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Questions?

- If we have time: look at hazard overview table?