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NbS as adaptation options for resilient road infrastructure

Delft, September 17, 2024

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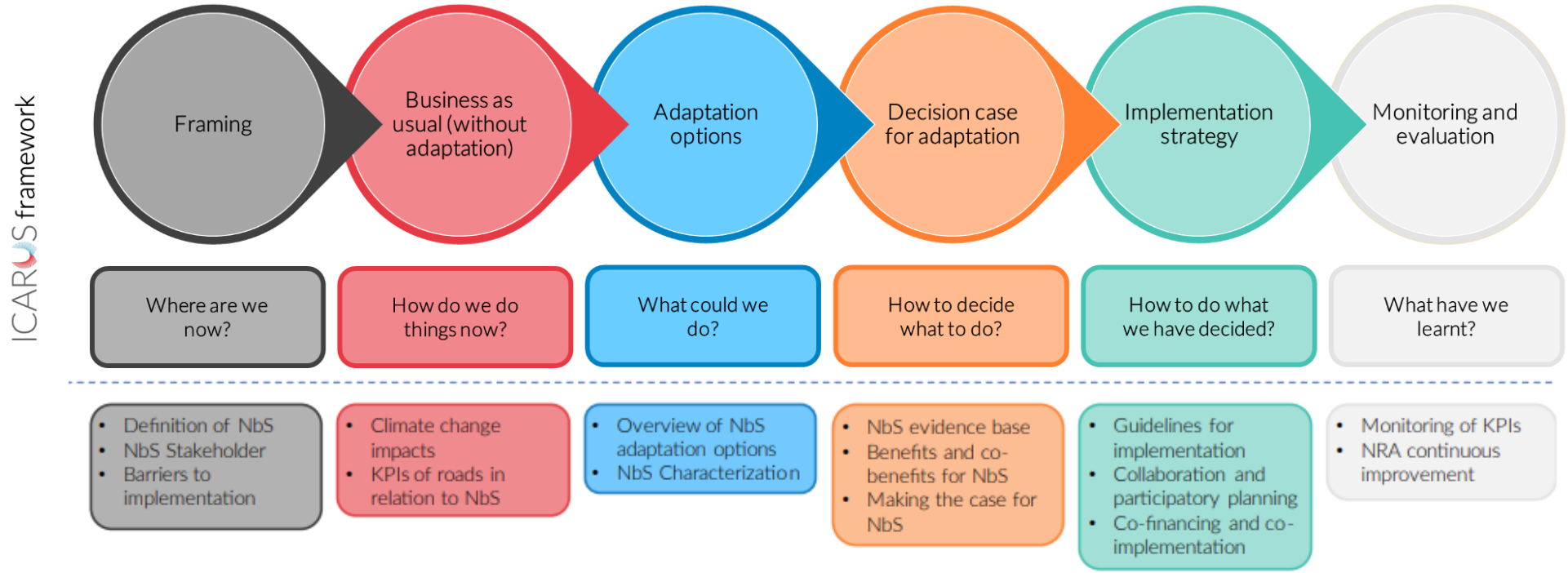
NBS in the context of ICARUS



Key learning points

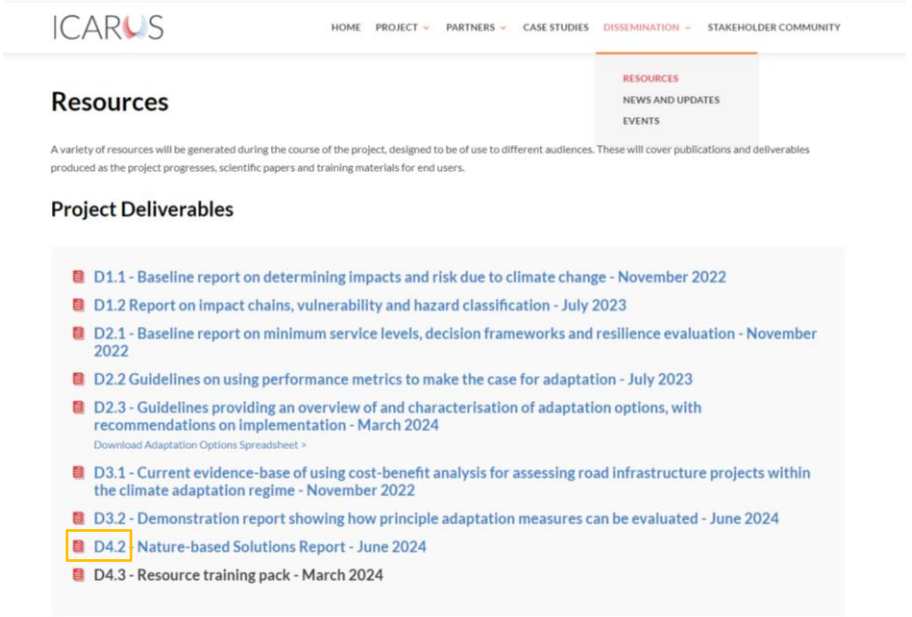
D4.2

Chapter 1 • Introducing NBS in the context of ICARUS

Chapter 2 • NBS in the context of climate change

Chapter 3 • NBS Adaptation Options to enhance resilience

Chapter 4 • Evaluation of NBS adaptation options



What are Nature-based Solutions?

The European Commission defines NBS as *'solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience'.*

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The Swedish road and railway administration Trafikverket (2024) has developed a list of indicative NBS criteria:

- the solution addresses the challenge
- local prerequisites are considered
- co-operation with other actors is included from planning to implementation
- biodiversity is regarded
- negative effects on reducing the emissions or people's health are avoided
- solution is multifunctional
- solution is resource effective and economically sustainable
- solution is implemented through an iterative learning process with an adaptive approach to management

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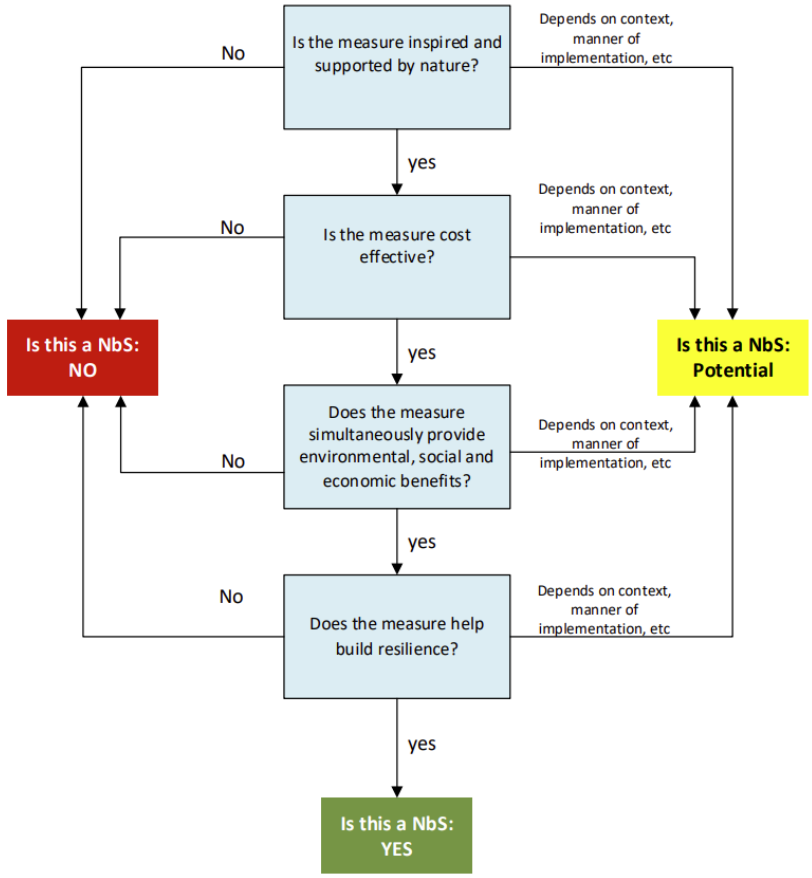
Why NBS for adaptation of road infrastructure?

- Natural resilience
- Cost effectiveness
- Multiple benefits
- Adaptability
- Reduced environmental impact
- Enhanced social equity
- Community engagement
- Long term viability
- Enhanced reputation

How do we define NBS in ICARUS

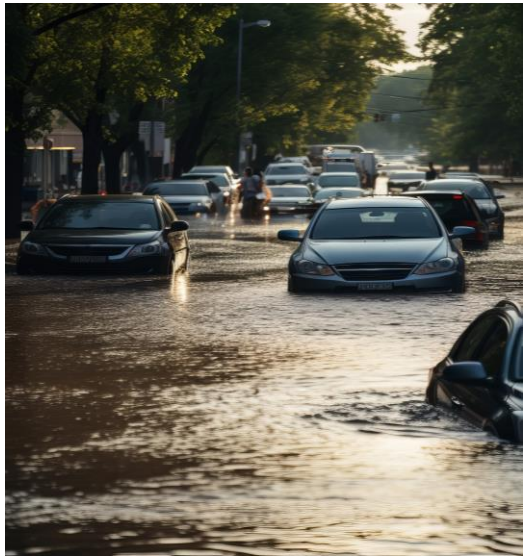
Must fulfil **all** the NBS sub-criteria:

- Is the measure inspired and supported by nature?
- Is the measure cost effective?
- Does the measure simultaneously provide environmental, social and economic benefits?
- Does the measure help build resilience?



Climate change and NBS

Heavy precipitation and pluvial flood (Wet and dry)



Source: Adobe Stock

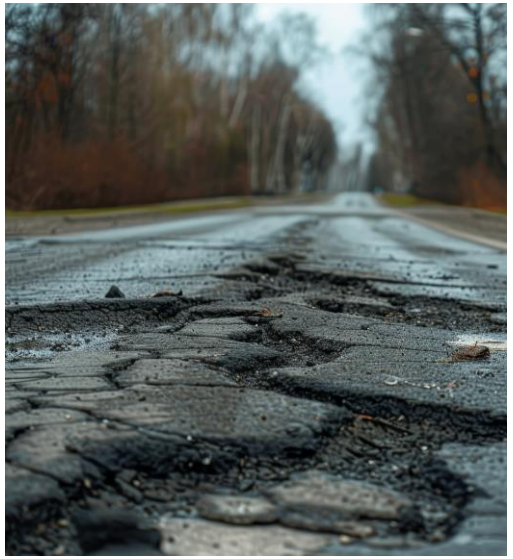
- Sustainable drainage systems (SuDS)
- Permeable pavments
- Green walls and infiltration trenches

Landslides (Wet and dry)

Source: Adobe Stock

- Retaining and restoring forests on slopes
- Vegetation as a soil stabilizer
- Slope terracing

Mean air temperature (Heat and cold)



Source: Adobe Stock

- Green roofs
- Rain gardens
- Vegetated permeable pavements

Identifying NBS Adaptation Options

Climate Impact Driver			Impact on Infrastructure	Adaptation Option	Adaptation Option Characteristics								Evaluation Criteria						
													Benefits and Co-Benefits						
Climate Impact Driver	Sub-driver	Type of event (Extreme event or slow-onset process or trend)			Applicable Asset Type	Asset Scale (Object / Connection / Network)	Road Project Life Cycle Stage	Impact Chain Stage 1. Hazard 2. Exposure 3. Vulnerability 4. Impact	Disaster Risk Management Cycle Stage Prevention Preparedness Response Recovery	Short/ Long Term Solution	Is the climate impact driver addressed?	Is this a Nature-Based Solution?	Availability -1: decreased network availability 0: No change +1: Increased network availability	Durability -1: decreased asset durability 0: No change +1: Increased asset durability	Impact on Safety -1: Increase in no. of collisions 0: No change +1: Decrease in no. of collisions	Impact on Health -1 : Negative 0: No change +1: Positive	EcoSystem Services -1: Decrease in level of greening of area 0: No change +1: Increase in level of greening of area	Water Quality -1: Deterioration in water quality 0: No change +1: Improvement in water quality	Climate: Embodied Carbon -1: Increase in carbon emissions 0: No change +1: Decrease in carbon emissions
Snow and Ice	Landslide	Extreme event	03-2 Slides of the road embankment following extreme rainfall events and after drought	Cover slope with vegetation	Geotechnics, including landslips and	Object	Construction	3. Vulnerability	Prevention	Short term (operational and tactical)	Yes	yes	1	1	1	0	1	0	1
	Wildfire Conditions	Extreme event	Lower visibility for users. Increased risk of respiratory illnesses for employees working near fires due to release of toxic gases.	Canal Construction to prevent wildfire spread	All road infrastructure	Network	Initial Proposal Stage	1. Hazard	Prevention	Long term (tactical and strategic)	Yes	Yes	1	1	1	0	1	0	0
	Tropical Cyclone	Extreme event	Road signs damaged or fallen, fallen trees and other obstacles blocking road, power lines damaged, bridge cables damaged.	Protection of wind exposed road sections and assets with planted forests and other vegetation.	All road infrastructure	Connection - Network	Construction	2. Exposure	Preparedness	Long term (tactical and strategic)	No	Yes	1	0	1	1	1	0	1
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Coastal and oceanic	Coastal flood	Extreme event	01-3 Inundation of roads in coastal areas, combining the effects of sea level rise and storm surges due to sea level rise, extreme wind speed,	Mangroves restoration to reduce wave run-up and shore erosion	All road infrastructure	Network	Construction	3. Vulnerability	Prevention	Short term (operational and tactical)	Yes	yes	1	1	1	0	1	1	1
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Others: radiation, subsidence	Radiation at surface	Slow-onset processes and trends	Asphalt pavement surfaces tend to absorb a large amount of heat through solar radiation and increase the air temperature resulting in the Urban	Vegetation for shading of concrete and asphalt pavements against sun.	Pavements: bituminous, concrete, semi-	Network	Construction	3. Vulnerability	Prevention	Short term (operational and tactical)	Yes	Yes	1	1	1	0	1	0	1

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Evaluation of NbS Options

1. Take a look at the grey solutions you selected for your asset/CID. Using the adaptation database, find alternative NBS that can solve the same challenges. (5-10 min)

2. (Pair and share) Why did you choose the grey solutions? What would enable you to choose a NBS instead? (5 min)

Coming back to the case study

- **Problem:** The capacity of the existing culvert is exceeded, the road is flooded frequently

- **Solutions identified:**

  Retention (NbS)

  Conveyance (Increase the size of the culvert)

Optimization level 1			
		Increase size of culvert	Nature-based solution
Benefits	Availability	*Improved compared to reference scenario*	*Improved compared to reference scenario*
Benefits	Safety	*Improved compared to reference scenario*	*Improved compared to reference scenario*
Benefits	Costs associated with repair and maintenance after flooding	*Reduction compared to reference scenario*	*Reduction compared reference scenario*
Co-benefits	Increase in co-benefits associated with ecosystem services	*No co-benefits associated with increasing the culvert*	*Co-benefits associated with applying nature-based solutions.*

Optimization level 2			
		Increase size of culvert	Nature-based solution
Benefits	Availability	*Significantly improved compared to reference scenario*	*Significantly improved compared to references scenario*
Benefits	Safety	*Significantly improved compared to reference scenario*	*Significantly improved compared to reference scenario*
Benefits	Costs associated with repair and maintenance after flooding	*Reduction compared to reference scenario*	*Reduction compared to reference scenario*
Co-benefits	Increase in co-benefits associated with ecosystem services	*No co-benefits associated with increasing the culvert*	*Co-benefits associated with applying nature-based solutions.*

Case study: Nature-based Solution - wider benefits

The nearby catchment area has the potential to provide additional ecosystem services in the form of increased recreational value for any visitors. Currently, the areas illustrated on the map below are not accessible due to dense vegetation and very wet and swampy soil.

The NbS will be located upstream in the catchment.
By detaining stormwater upstream, the peak flow in the culvert is reduced along with the risk of flooding of the highway.

Storage volume required:

Optimization level 1: 114.000 m3

Optimization level 2: 145.000 m3

Evaluation of NBS: Benefits and Co-benefits

Benefit	Description	Quantification	Valuation	Indicator for magnitude of impact	NbS impact
Availability					
Travel time, leisure	Value of travel time for persons in their leisure time	Minutes of increase/decrease in travel time	Travel loss hours / value of travel time	Number of users of network and level of change	-
Travel time business	Value of travel time for businesses	Minutes of increase/decrease in travel time	Travel loss hours / value of travel time	Number of users of network and level of change	-
Reliability of travel time	The value of reliability of predicted travel time for users	Reliability of predicted travel time measured as e.g., percentage of average travel time of a road network	Value of reliability	Number of users of network and level of change	-
Availability of network	The value of being able to always access public services and critical infrastructure	-	-	-	-
Availability: Connectivity and social inclusion	Connectivity and travel time to basic everyday activities	-	-	-	-
Durability					
Replacement	Costs associated with wages, materials etc.	Hours worked, units of material, fuel machine hours etc	Wages, costs of materials, fuels, machinery, etc.	-	-
Upgrading	Costs associated with wages, materials etc.	Hours worked, units of material, fuel machine hours etc	Wages, costs of materials, fuels, machinery, etc.	-	-
Safety	Value of injuries/fatalities	Increase/decrease in the risk of injuries/fatalities	Value of statistical life	Number of users of the network and level of change	-
Health effects					
Air pollution	Improved air quality from increased coverage of plants	Increase/decrease in the level of particle matter	Value of statistical life, quality adjusted life year	Number of affected individuals and level of change	Very positive
Noise	Lowered noise levels from noise barriers of coverage from plants	Increase/decrease in the level of decibel	Value of statistical life, quality adjusted life year	Number of affected individuals and level of change	Positive
Ecosystem services					
Environmental goods	Value assigned to areas due to their aesthetics, opportunities for walking, socializing etc.	Increase/decrease in level of greening or hectares of green areas	Stated/revealed preference methods	Number of users of the area, and level of change in provision of environmental good	Very positive
Job creation	Job creation from investment in climate adaptation/resilience				
Water quality	Value assigned to good quality of water, e.g., stemming from contaminants from run-off	Increase/decrease in quality status, e.g., ecological status based on threshold values	-	Number of affected individuals and level of change.	Very positive
Climate					
Embodied carbon	Emissions arising from construction materials, transport, and installation	Increase/decrease in the number of embodied carbon emissions	Social cost of carbon	Level of change in the number of embodied carbon emissions	Very positive

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Evaluation of NBS

Benefit/Co-benefit	Negative effect, -1	Neutral / no change, 0	Positive effect, +1
Availability	Decreased network availability	No change	Increased network availability
Durability	Decreased asset durability	No change	Increased asset durability
Impact on Safety	Increase in no. of collisions	No change	Decrease in no. of collisions
Impact on Health	Negative health impacts	No change	Positive health impacts
Ecosystem Services	Decrease in level of greening of area	No change	Increase in level of greening of area
Water Quality	Decrease in water quality	No change	Increase in water quality
Climate: Embodied Carbon	Increase in carbon emissions	No change	Decrease in carbon emissions

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Evaluation of NBS: Valuation of benefits/co-benefits

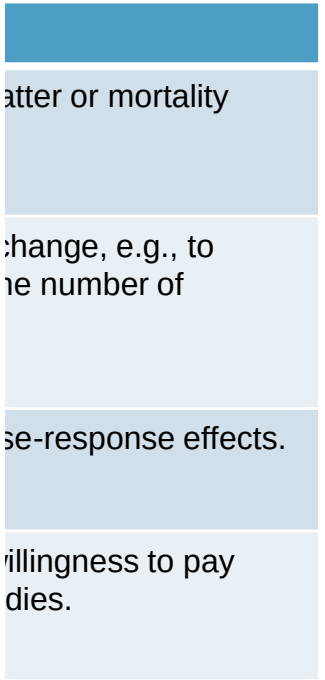
For example:

1. **Define and describe project and scope of impact of adaptation/resilience measure** and hereunder the expected associate costs and benefits. Benefits should be defined as either benefits or co-benefits, depending on the defined KPIs

2. **Assess the magnitude of identified effects.** Table 5.1 provides an overview of relevant parameters to consider, to assess the magnitude of the benefits. Significant effects associated with implementation of adaptation/resilience measures should be considered for quantification and eventually valuation.

3. **Identify means of possible quantification/measurement of benefits:** To enable valuation for at least quantification to include in the decision-making process, it is necessary to consider possible means of measurement of the identified benefits. Also, whether data of sufficient quality can be gathered.

4. **Identify potential means of valuation.** Depending on whether identified benefits are defied as either tangible or intangible goods. Different means of quantification exists.



For more information check D2.2 – Guidelines on using performance metrics to make the case for adaptation, Chapter 5

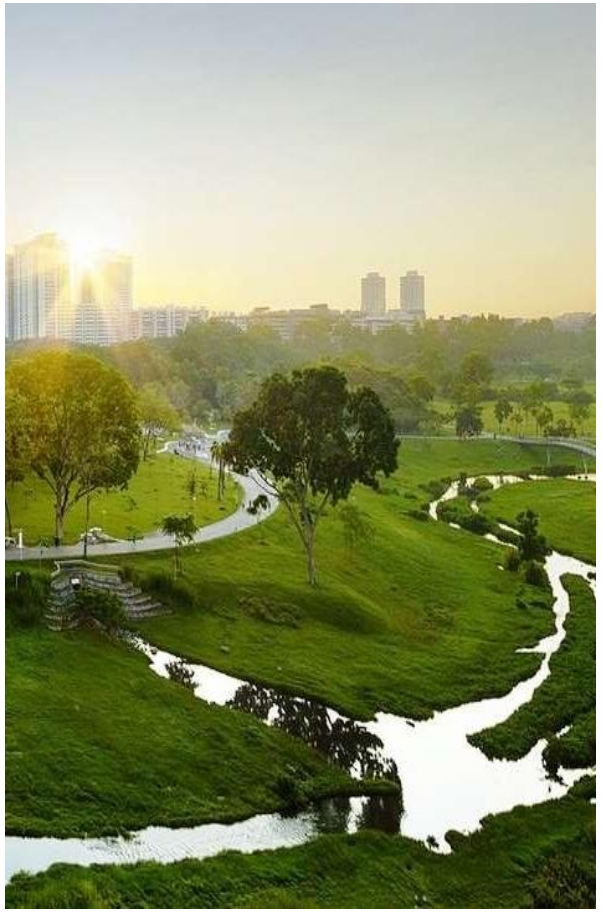
Implementation of NBS

Important considerations:

- Getting buy-in from the organization
- Involvement of stakeholders and local communities
- Including maintenance as an essential part of the planning process
- Monitoring
- Detailed design and procurement specifications required

Considerations and limitations of NbS

- Some measures take **time** to become fully effective, e.g. measures that rely on fully grown/ mature vegetation cover. Vegetation may also need specific kind of **maintenance** which needs to be organized and financed for several year.
- To be effective, some measures may need to be implemented in areas where they are the most effective which may fall outside the jurisdiction of the road authority.
- Climate change adds additional challenges in predicting future environmental conditions. This creates an additional obstacle for designing NBS that are resilient to climate variability and uncertainty.
- Because ecosystems are composed with living organisms and their growth is based on several factors, it can be difficult to predict exact results when implementing NBS.



Evaluation of NBS Adaptation Options

3. Using the Adaptations Options database, identify potential benefits/co-benefits from your selected NBS.
   Use the evaluation criteria to estimate the potential impact related to benefits/co-benefits your selected NBS options.

Benefit/Co-benefit	Negative effect, -1	Neutral / no change, 0	Positive effect, +1
Availability	Decreased network availability	No change	Increased network availability
Durability	Decreased asset durability	No change	Increased asset durability
Impact on Safety	Increase in no. of collisions	No change	Decrease in no. of collisions
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Water Quality	Decrease in water quality	No change	Increase in water quality
Climate: Embodied Carbon	Increase in carbon emissions	No change	Decrease in carbon emissions

4. (Pair and share) Reflect of the link between the co-benefits/benefits of your selected NBS and the priorities/KPIs of your organization. Based on these links, are any of the selected NBS feasible for further evaluation in your organization? Why/why not?

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Evaluation of NBS Adaptation Options

- Questions?
- What are the experiences with NBS in your organization? Success stories? Challenges?
- What would it take to mainstream NBS into regulations, plans, and guidelines in your organization?