Deltares

enabling delta life

Deltares

enabling delta life

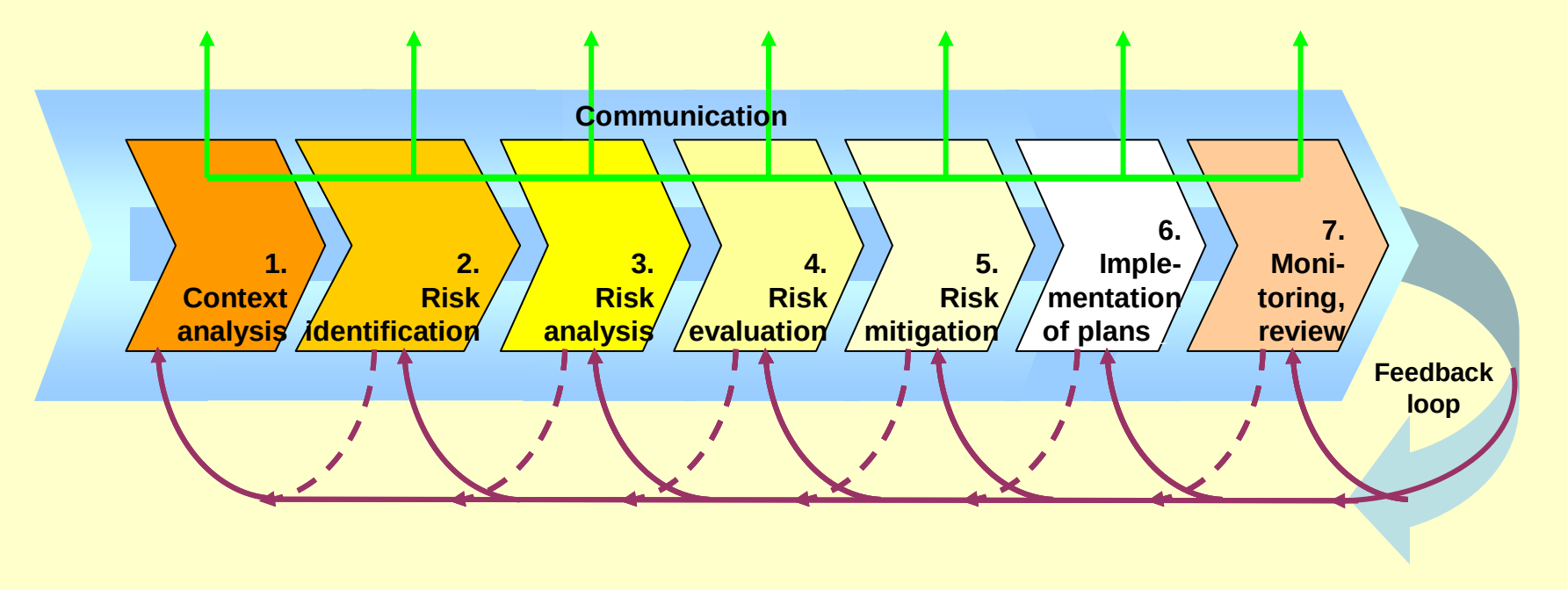
Deltares

Frameworks and methods for Climate Change Risks, Impacts and Adaptation

for Transport Infrastructure

Thomas Bles

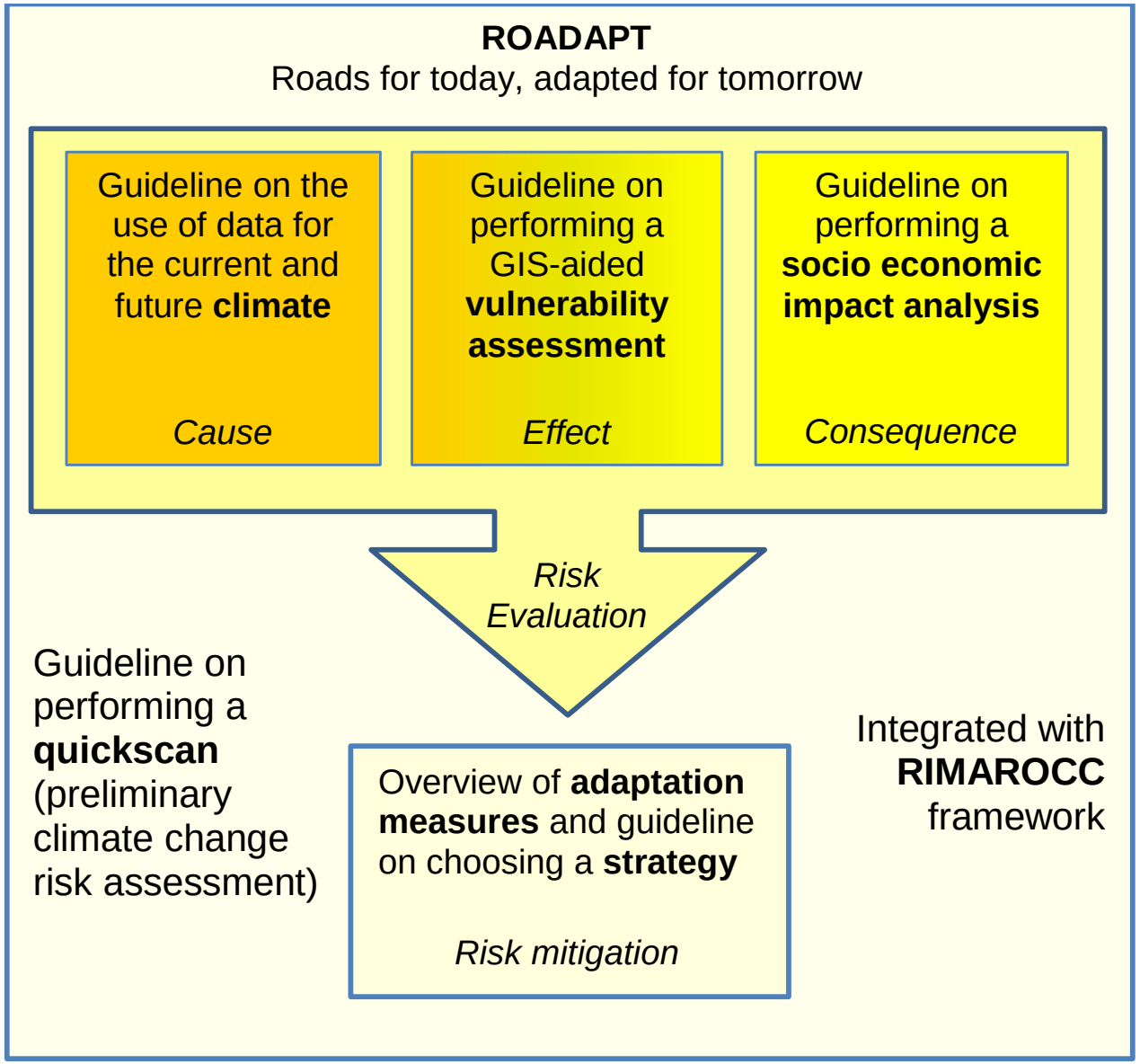
Climate change adaptation frameworks



- RIMAROCC – RIsk MAnagement for ROads in a Changing Climate
- An ERA-NET ROAD framework (2010)

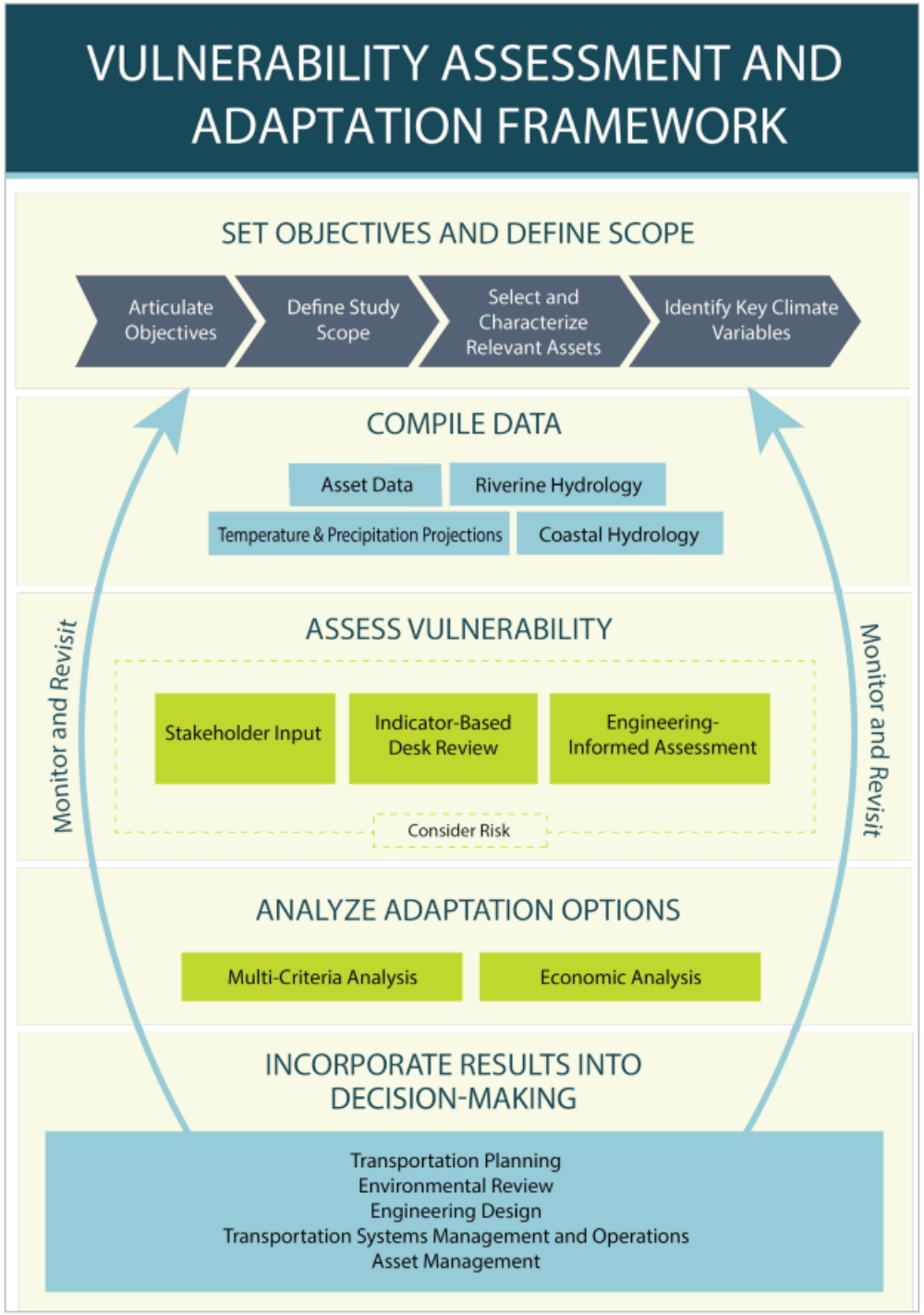
Climate change adaptation frameworks

- ROADAPT
- Roads for today, adapted for tomorrow
- CEDR (2015)



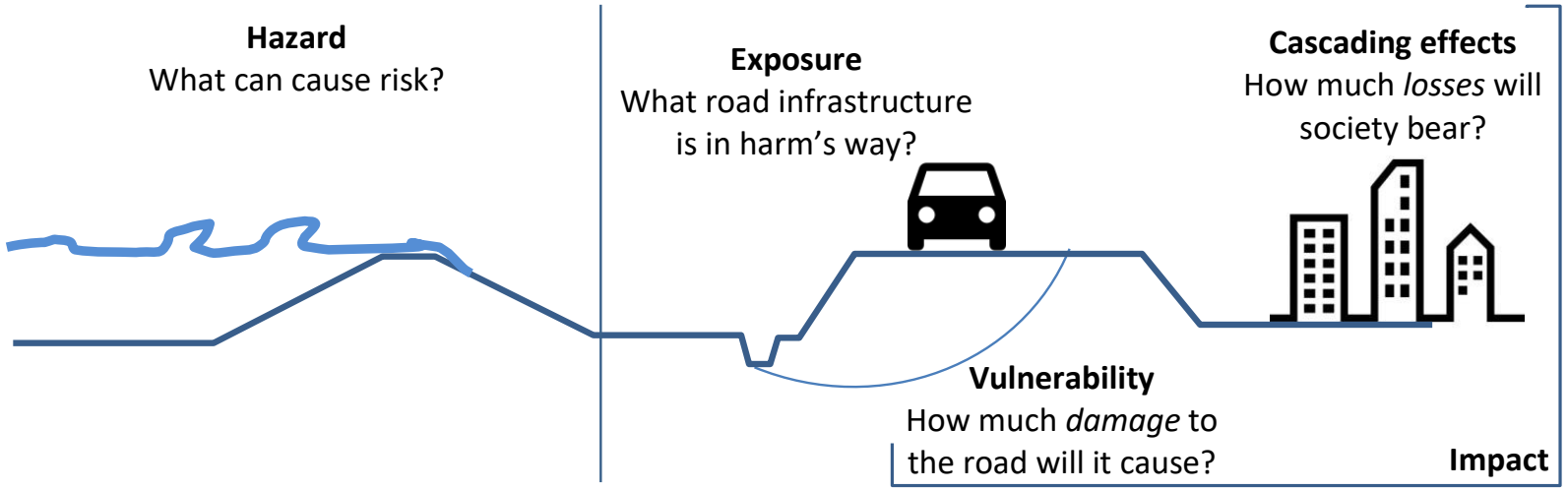
Climate change adaptation frameworks

- Federal Highway Administration
- Vulnerability Assessment and Adaptation Framework
- FHWA (2020)



Natural Hazard Resilience Assessments
From Theory to Practice

Risk Components
(UNISDR 2016)



Hazard assessment → Exposure assessment → Vulnerability assessment → Impact assessment → Resilience evaluation → Action perspective

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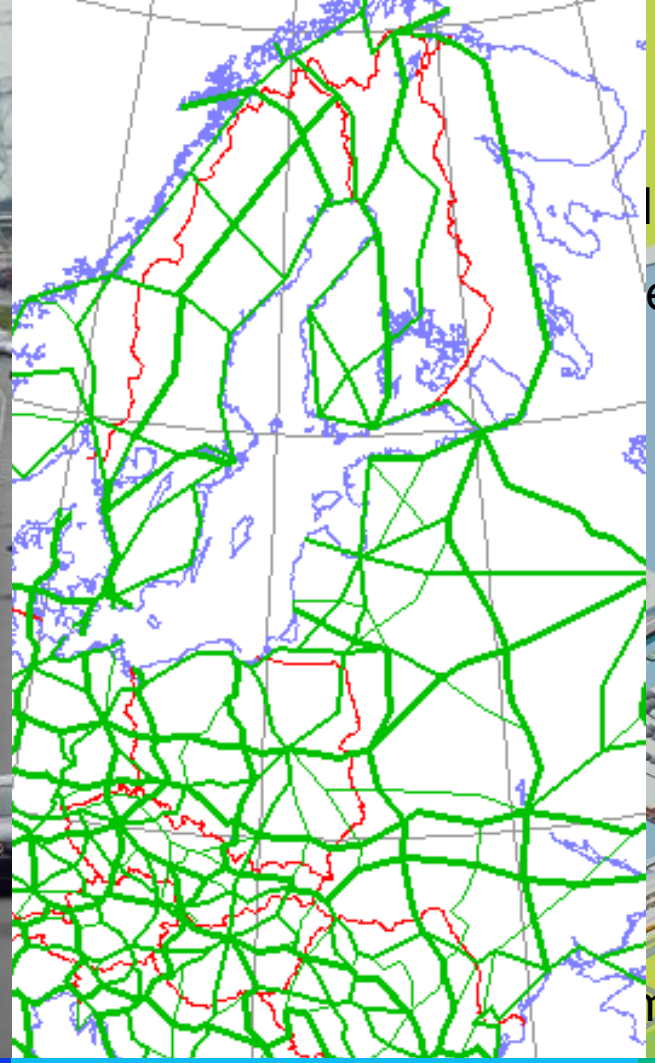

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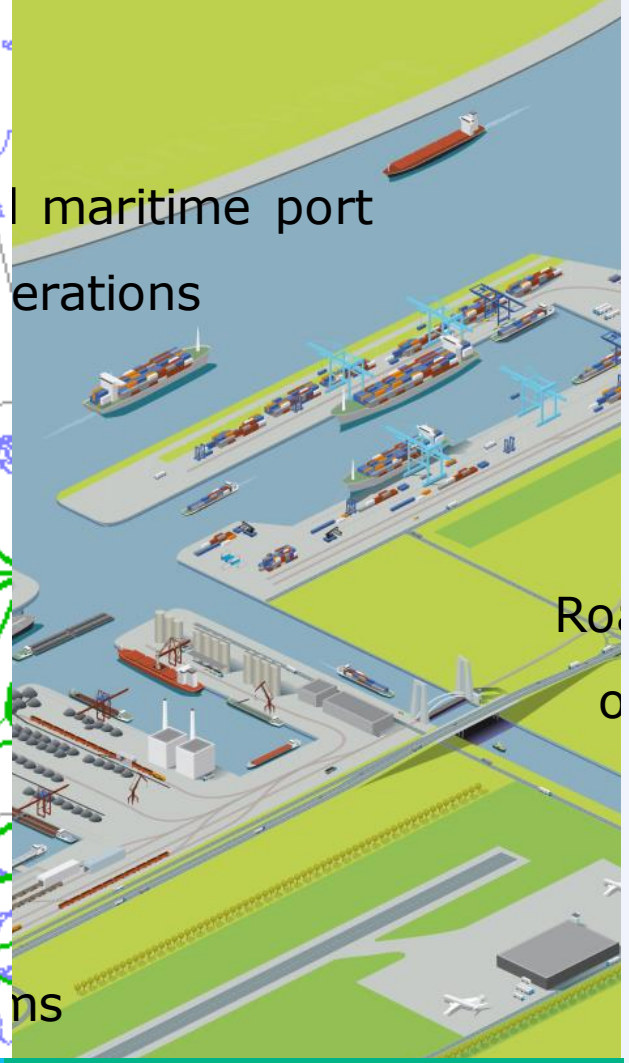


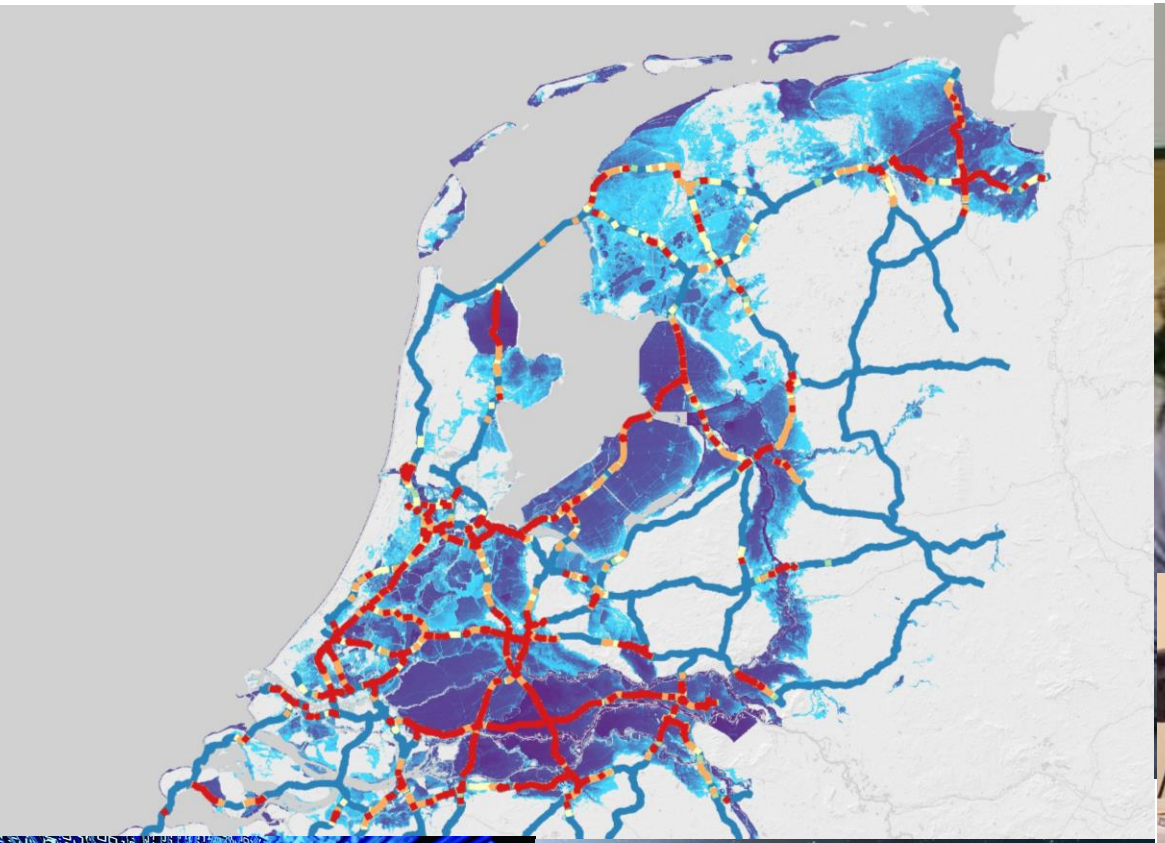
Individual assets

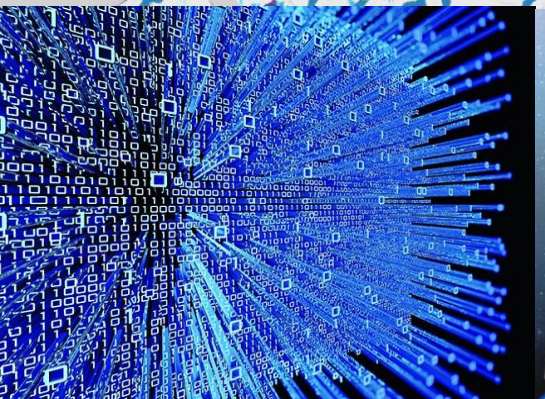
Connections

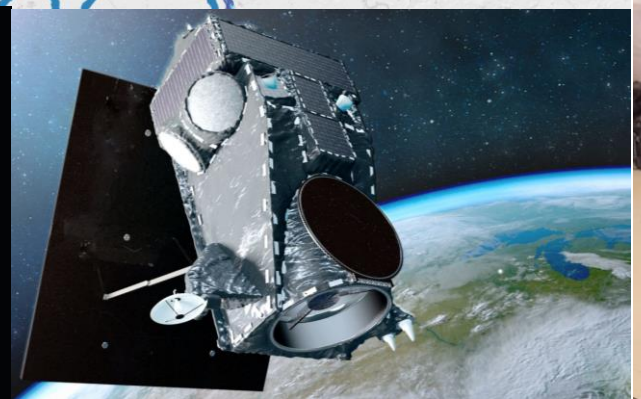
Network level

System of systems

Quantitative and qualitative, desk and collaborative





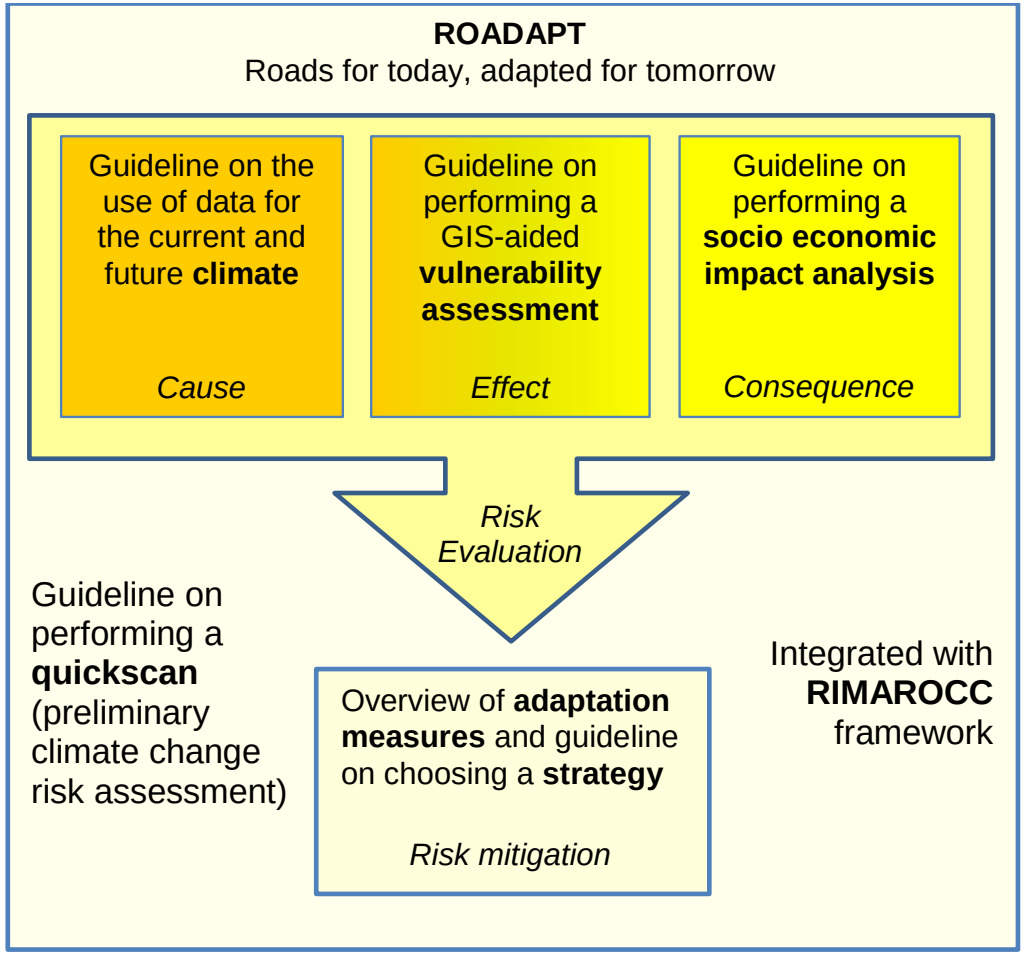


ROADAPT QuickScan approach

- QuickScan – what are the most important risks?

Only for the biggest risk

- Vulnerability assessment of the road
- Identification of measures
- Socio economic analyses
  - do benefits outweigh the costs?
- Climate change adaptation strategy

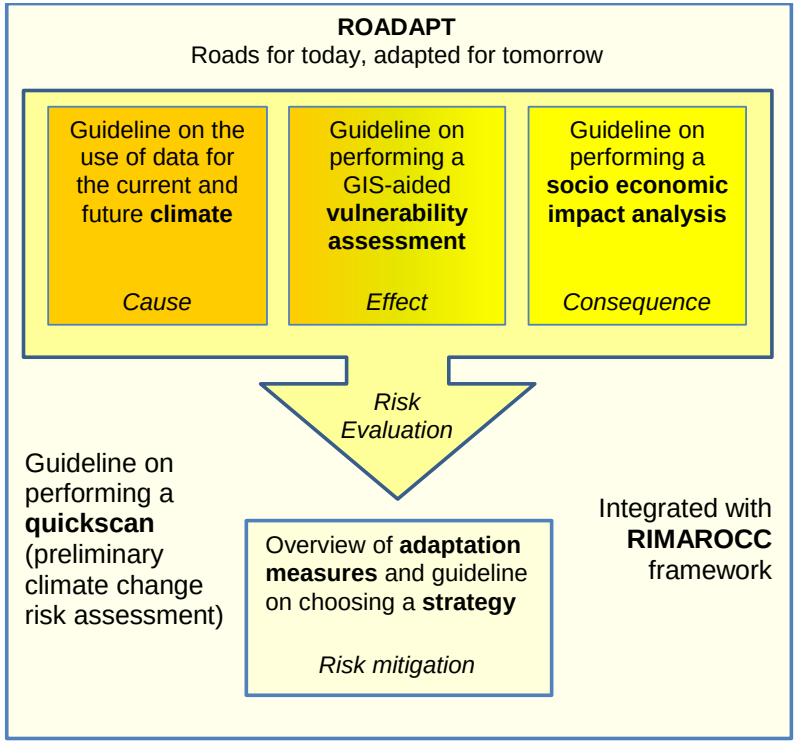


Approach

- QuickScan – what are the most important risks?

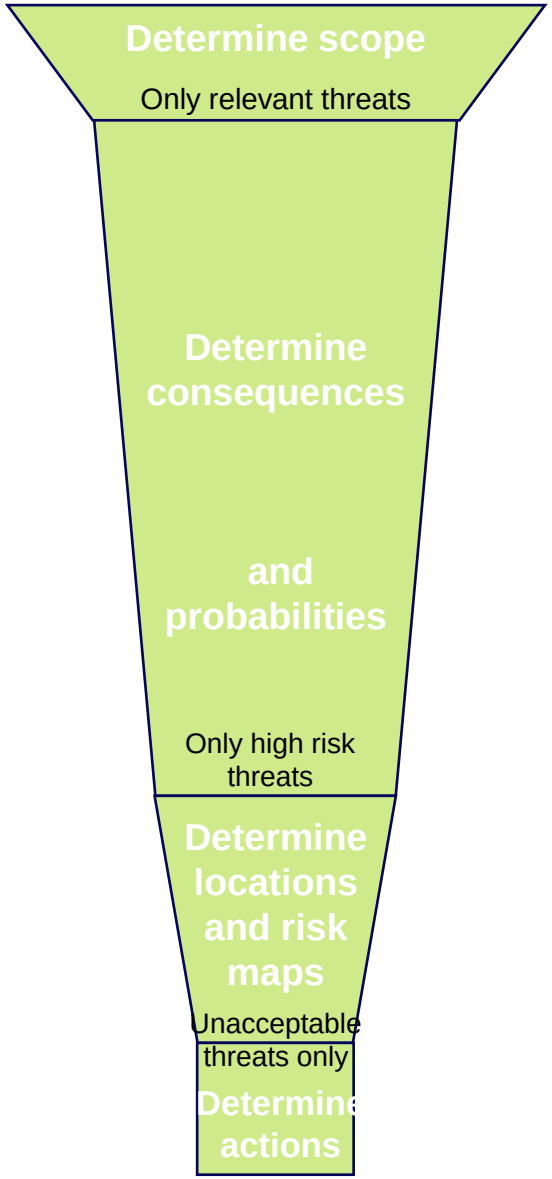
•Only for the biggest risk

- Vulnerability assessment of the road
- Identification of measures
- Socio economic analyses
  - do benefits outweigh the costs?
- Climate change adaptation strategy

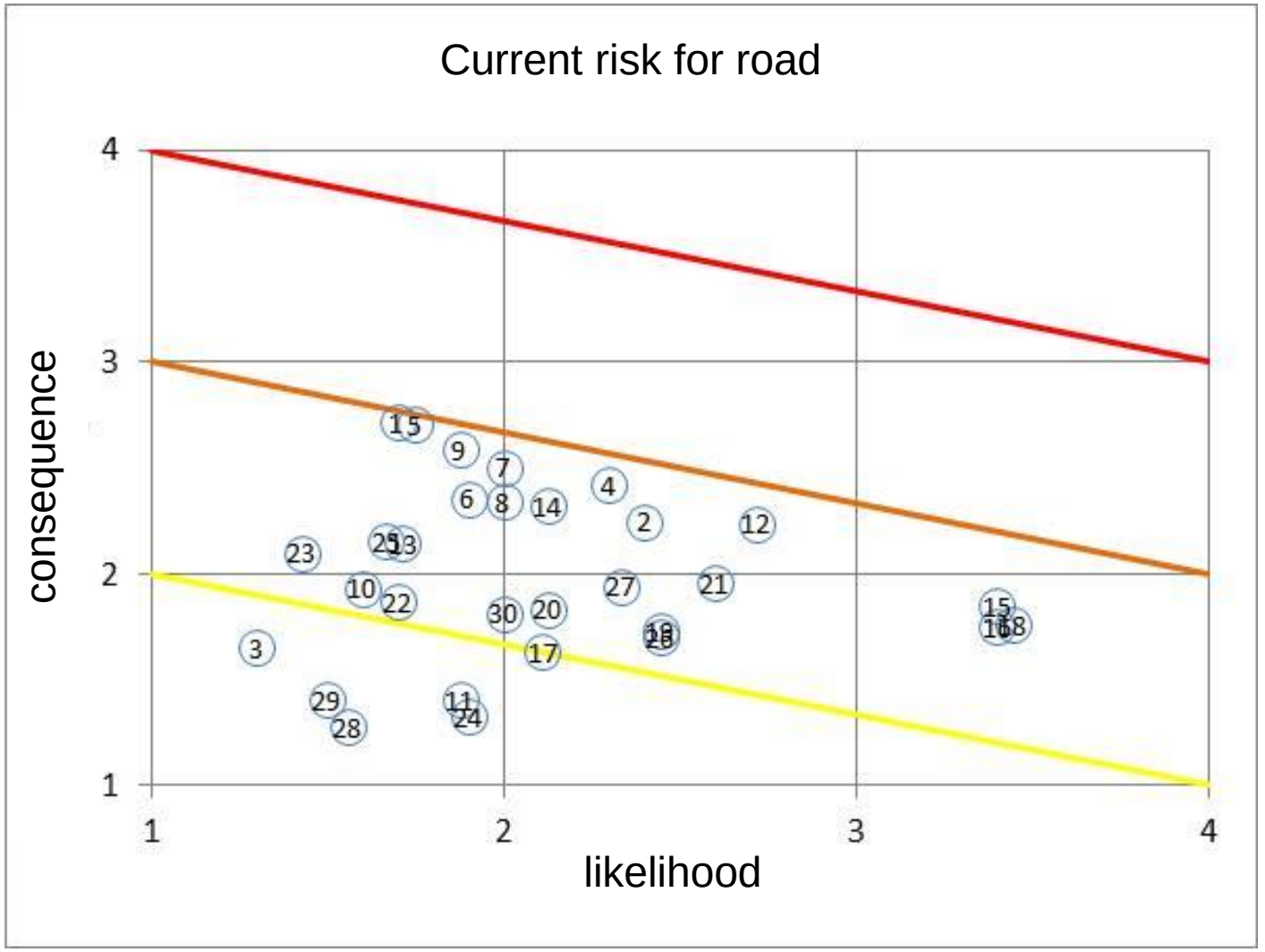


QuickScan steps

- **Step 1 - Desktop 1 - prepare Quick scan**
  - Step 1.1 - Scope definition/ Establish context
  - Step 1.2 - Identify risk sources and possible relevant threats
  - Step 1.3 - Determine importance of road sections in road network
  - Step 1.4 - Prepare workshop 1
- **Step 2 - Workshop 1 - consequences**
  - Step 2.1 Agree with participants on Quick scan approach
  - Step 2.2 Establish consequence criteria
  - Step 2.3 Estimate the consequences of the threats
  - Step 2.4 Evaluate the scoring of consequences
- **Step 3 - Desktop 2 - prepare workshop 2**
- **Step 4 - Workshop 2 - probabilities, risk and locations**
  - Step 4.1 Agree on study method and share status of research
  - Step 4.2 Score the probabilities of the threats
  - Step 4.3 Evaluate the scoring of probabilities
  - Step 4.4 Evaluate and prioritize the risks
  - Step 4.5 Identify location of threats
- **Step 5 - Desktop 3- provide a risk overview**
- **Step 6 - Workshop 3 – action plan**
  - Step 6.1 Wrap up of previous results
  - Step 6.2 Determine unacceptable risk; which threats require action?
  - Step 6.3 Determine action plan
  - Step 6.4 Prioritize actions



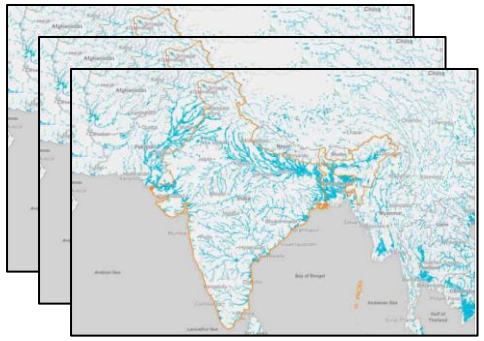
Quick Scan results



Quantitative resilience assessments

- Vulnerability functions
- Resilience functions
- Combining hazard maps with different return periods
- Prioritizing matrix

Overview of steps (RA2CE)



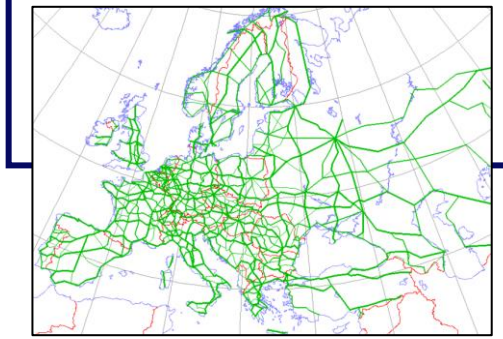
Hazard maps (pref. with return period)

Vulnerability curves
Replacement costs

1. Transportation network

Provided by user (shapefile)

Open Street Map (anywhere in the world)



2. Network Exposure

3. Direct damages ($$$)

6. Annual expected Damages and Losses

8. Adaptation measures/ Cost Benefit Ratios Measures

4. Network criticality (Redundancy)

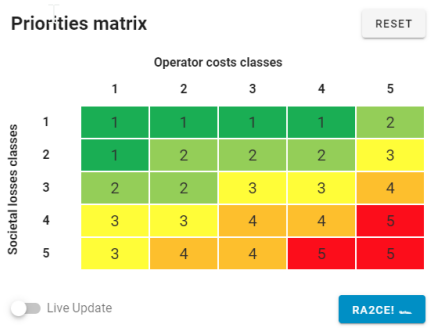
5. Societal costs ($$$)

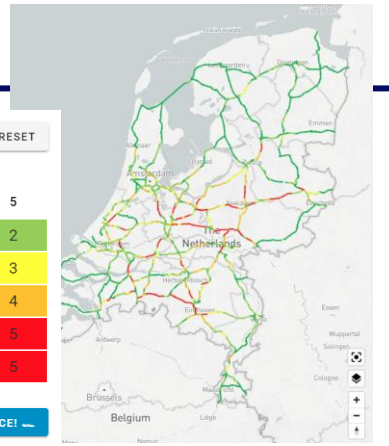
7. Prioritization

Multi-link disruption

Single-link disruption

Traffic Data
Value of Time
Duration of failure
Social Inclusiveness





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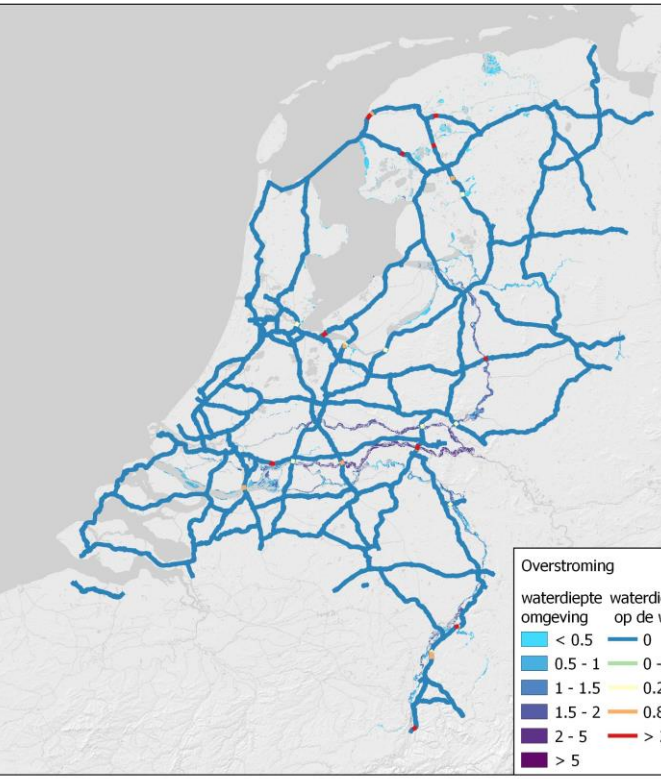
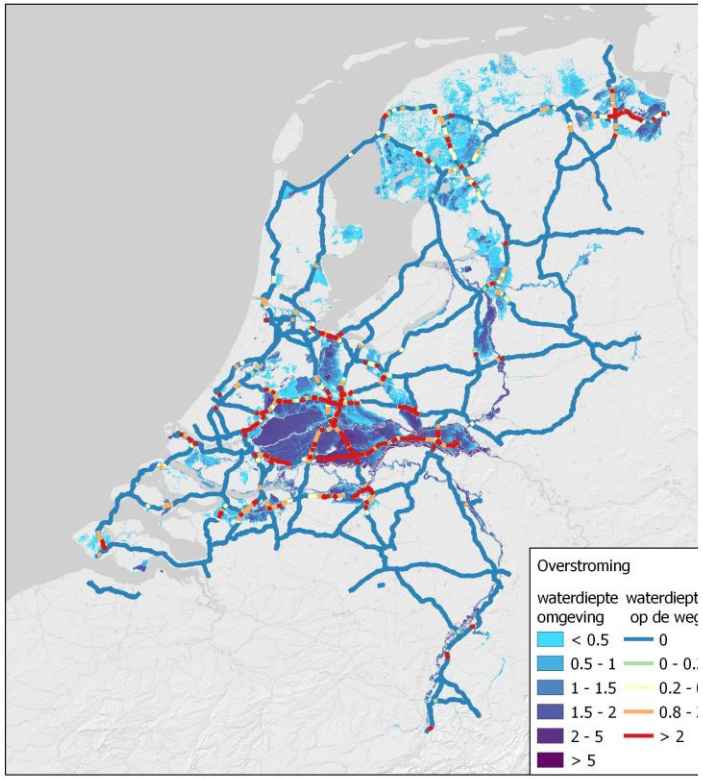
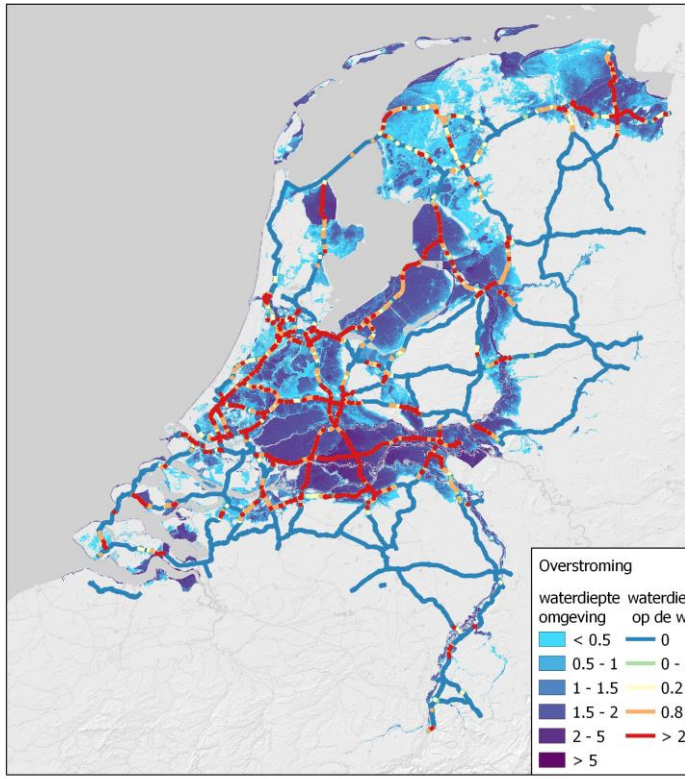
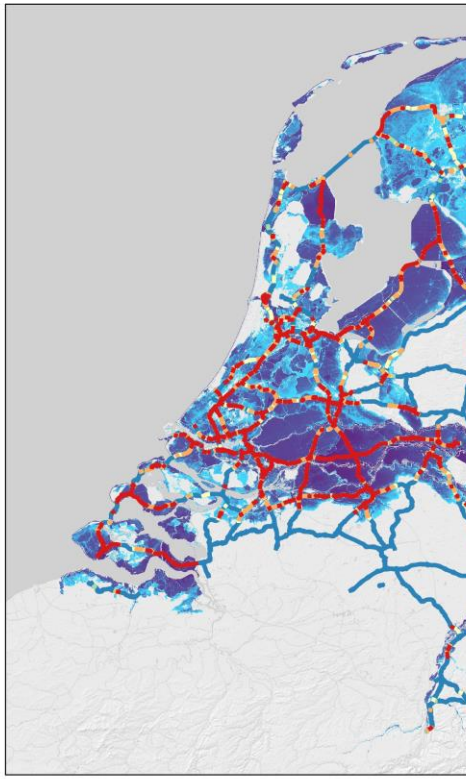
Hazard maps

- Normally input from:
  - Meteorological institute (direct impacts like temperature)
  - Relevant authority (e.g. for making hydrological assessment to generate flood maps)
- Ideally hazard maps for different return periods (example Netherlands: 30 – 300 – 3000 - > 10000)









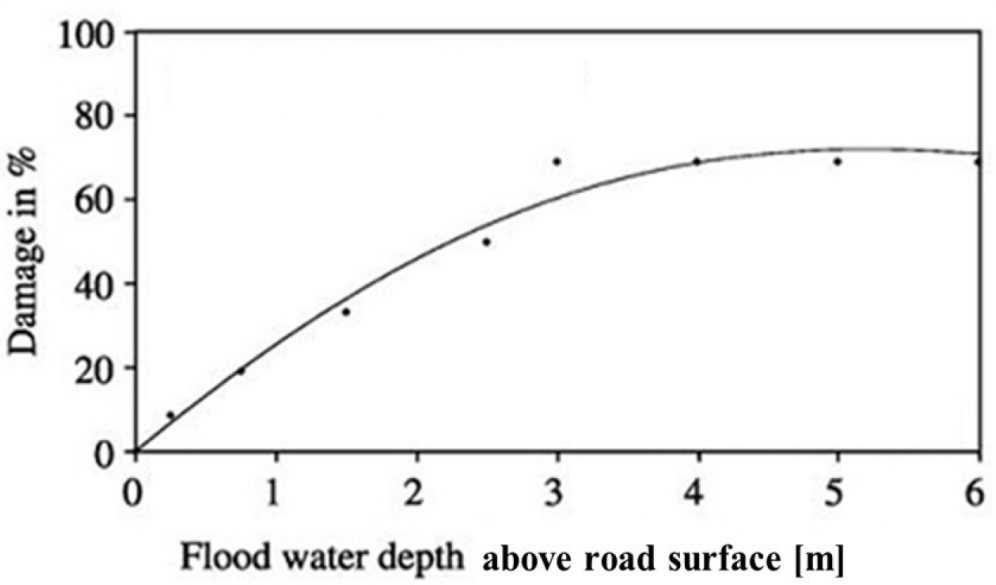
Hazard maps

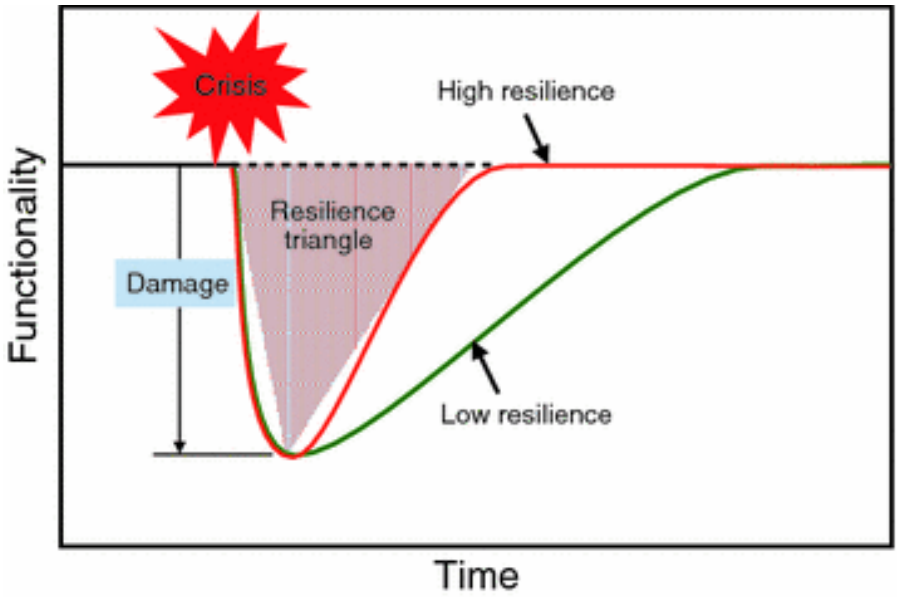
- Normally input from:
  - Meteorological institute (direct impacts like temperature)
  - Relevant authority (e.g. for making hydrological assessment to generate flood maps)
- Ideally hazard maps for different return periods
- Determine exposure, vulnerability and losses for all return periods
- Calculate the yearly to be expected damages and losses

- Sometime no hazard maps are present
  - Often the case for landslides: susceptibility maps

Quantitative Vulnerability and Resilience assessments

Vulnerability = percentage of construction costs for a hazard intensity





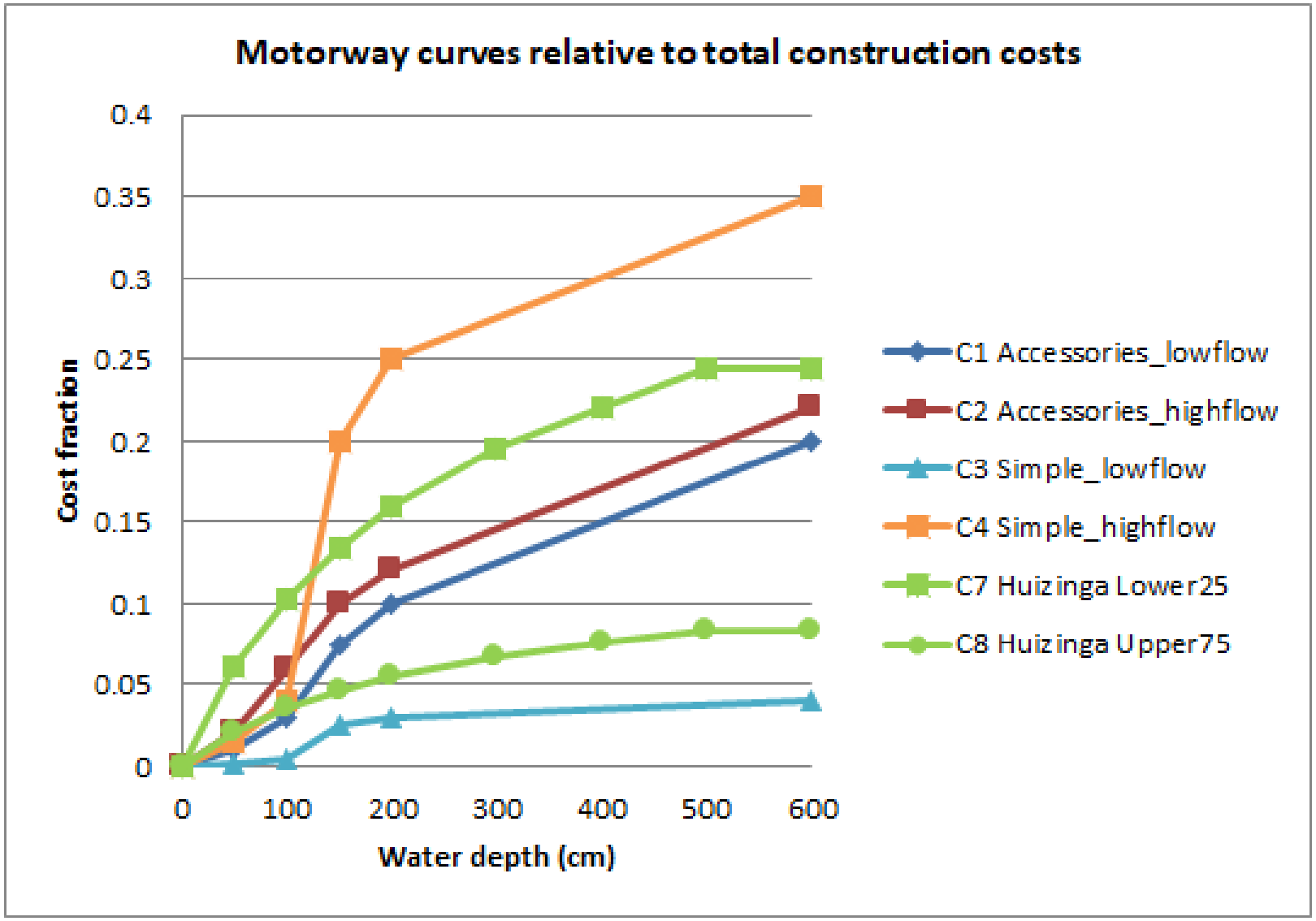
Vulnerability functions

Table 1. Road construction costs and maximum damage per road type, differentiated between low flow (low-flow velocities) and high flow (high-flow velocities). The values present the average for the former EU-28, in millions of euros (year 2015) per kilometre.

Road type	Lanes (–)	Construction cost range (millions of euros per kilometre)	Max damage (low flow) (–)	Max damage (high flow) (–)	Max damage (low flow) (millions of euros per kilometre)	Max damage (high flow) (millions of euros per kilometre)	Huizinga max damage[a, d] (millions of euros per kilometre)	Applicable damage curves[d]
			Relative to construction costs		Absolute values			
Motorway	2 × 2	3.5–35	20 % (ac)[b] 4 % (si)[b]	22 % (ac)[b] 35 % (si)[b]	3.9–7.0 (ac)[c] 0.1–0.8 (si)[c]	4.2–7.7 (ac)[c] 1.2–6.7 (si)[c]	0.90	C1, C2 C3, C4
Trunk	2 × 2	2.5–7.5	20 % (ac)[b] 4 % (si)[b]	22 % (ac)[b] 35 % (si)[b]	1.0-1.5 (ac)[c] 0.10–0.20 (si)[c]	1.1-1.7 (ac)[c] 0.88–1.75 (si)[c]	0.60	C1, C2 C3, C4
Primary	2 × 1	1.0–3.0	5 %	35 %	0.050–0.150	0.350–1.050	0.25	C5, C6
Secondary	2 × 1	0.50–1.5	5 %	35 %	0.025–0.075	0.175–0.525	0.225	C5, C6
Tertiary	2 × 1	0.20–0.60	5 %	35 %	0.010–0.030	0.070–0.210	0.175	C5, C6
Other	1	0.10–0.30	5 %	35 %	0.005–0.015	0.035–0.105	0.075	C5, C6

[a] Huizinga max damage costs (euros per kilometre) are obtained by multiplying the costs per square metre with typical road widths per road type (Table S4).
[b] "ac" refers to a sophisticated road with accessories such as street lighting and electronic signalling; "si" refers to a simple road without accessories.
[c] For accessories roads: 50 %–100 % of the construction cost range; for simple roads: 0 %–50 % of the construction cost range.
[d] Huizinga max damage is to be combined with the Huizinga damage function, not C1–C6.

Vulnerability functions



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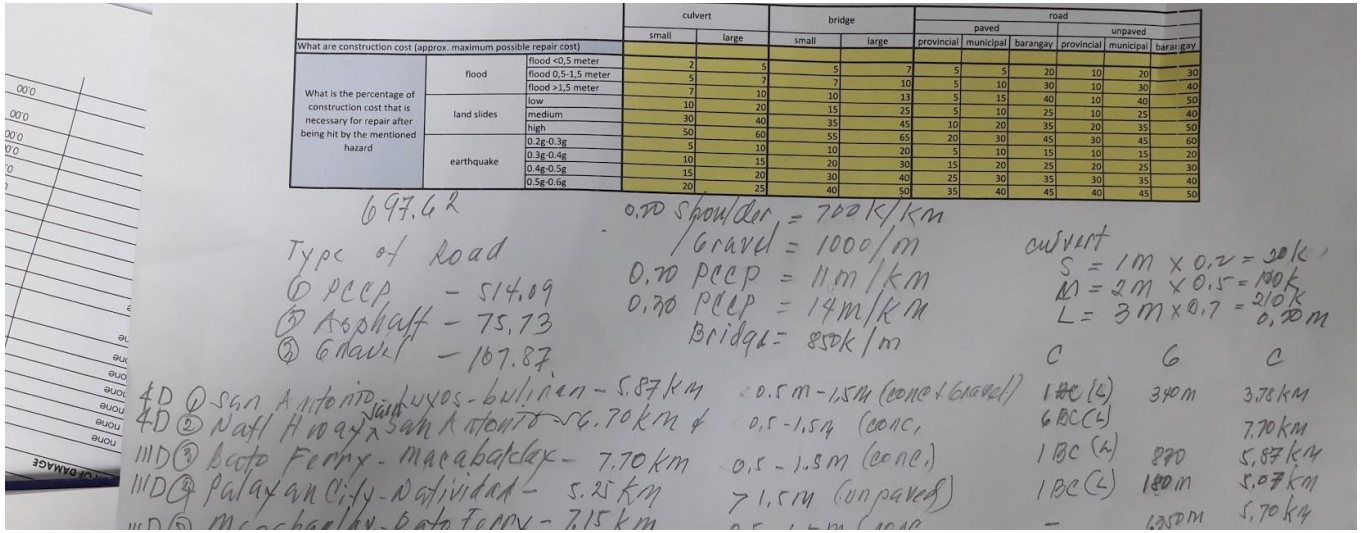
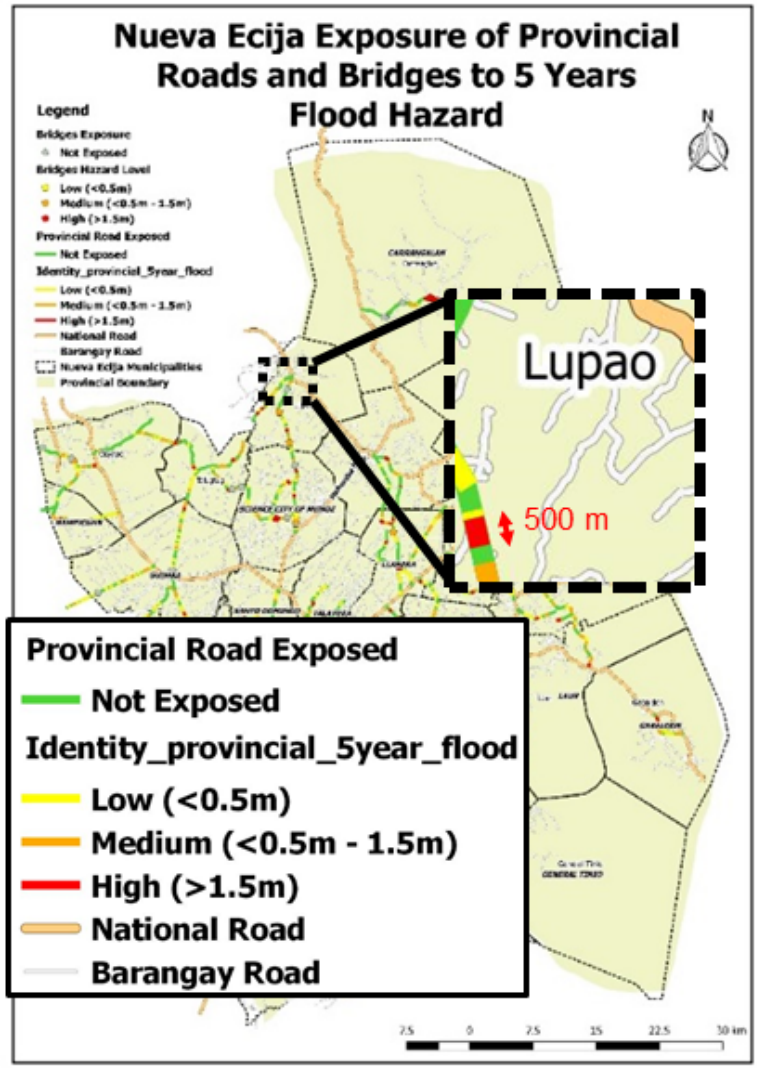
Vulnerability functions



Repair costs as a percentage of construction costs, per hazard, per asset type		Culverts		Bridges		Provincial road	
		Small	Large	Small	Large	Paved	Unpaved
		(PHP/unit)	(PHP/unit)	(PHP/m)	(PHP/m)	(PHP/m)	(PHP/m)
Flood hazard	<0.5	49%	7%	2%	2%	122%	283%
	0.5m-1.5m	44%	10%	2%	5%	122%	280%
	>1.5m	66%	13%	5%	12%	122%	278%
Earthquake hazard	0.2g-0.3g	10%	15%	8%	16%	15%	4%
	0.3g-0.4g	15%	20%	16%	24%	25%	6%
	0.4g-0.5g	20%	25%	24%	32%	35%	8%
	0.5g-0.6g	25%	30%	32%	40%	45%	10%

Damage calculation



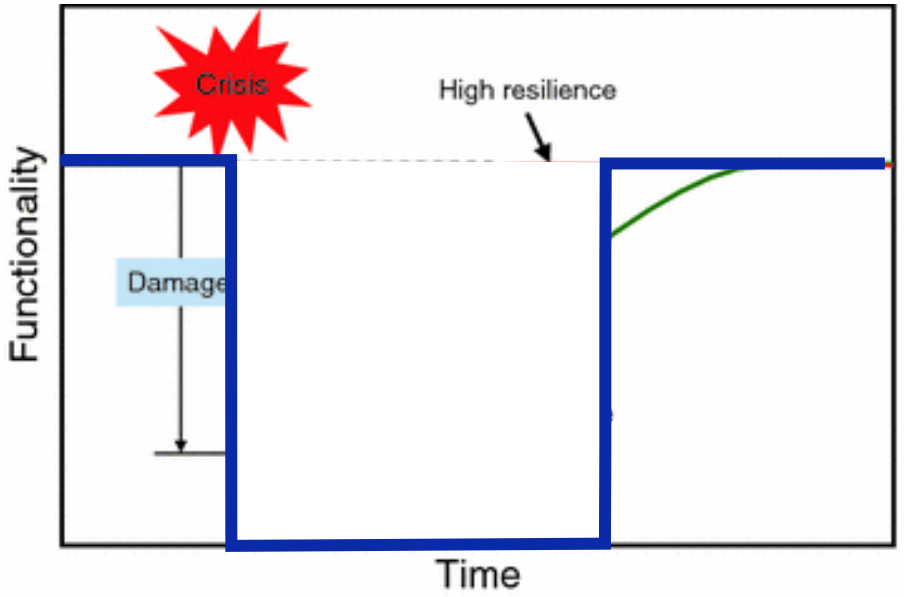
From Vulnerability Table:

- Cost of Provincial Paved Road: **14,000 pesos/m**
- Vulnerability for flood depth > 1.5m = **122%**

Damage (for stretch)

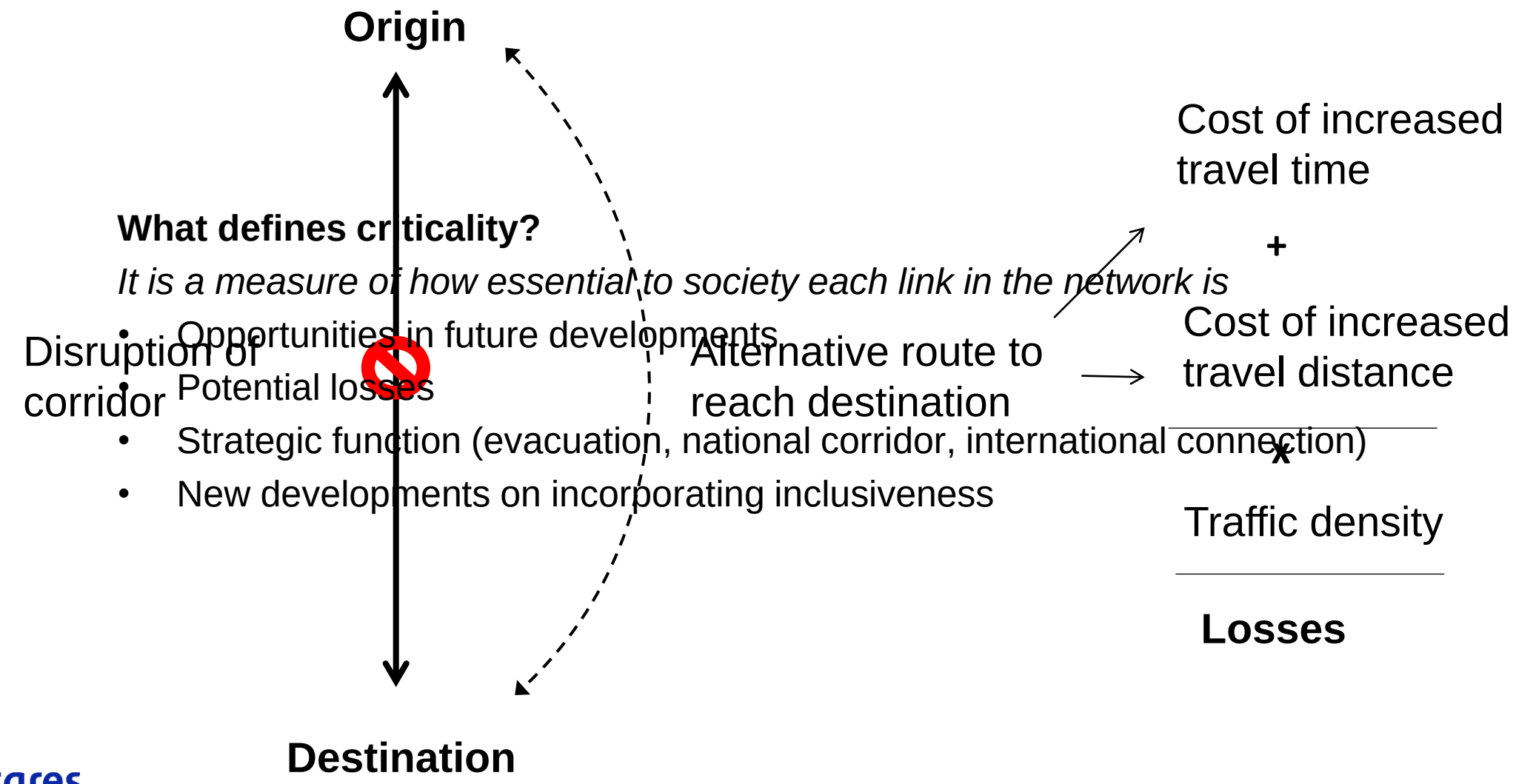
14,000 pesos/m * 122% * 500m = **8,540,000**

Resilience functions



Estimated duration			Culverts		Bridges		Provincial road	
			Small	Large	Small	Large	Paved	Unpaved
Flood hazard	<0.5	< 2 hours	X		X			X
		2 hours – day		X		X		
		day – week						
		> week					X	
	0.5m-1.5m	< 2 hours						
		2 hours – day	X					
		day – week						X
		> week		X	X	X	X	
	>1.5m	< 2 hours						
		2 hours – day	X					
		day – week			X			
		> week		X		X	X	X

Use of resilience functions → criticality assessment



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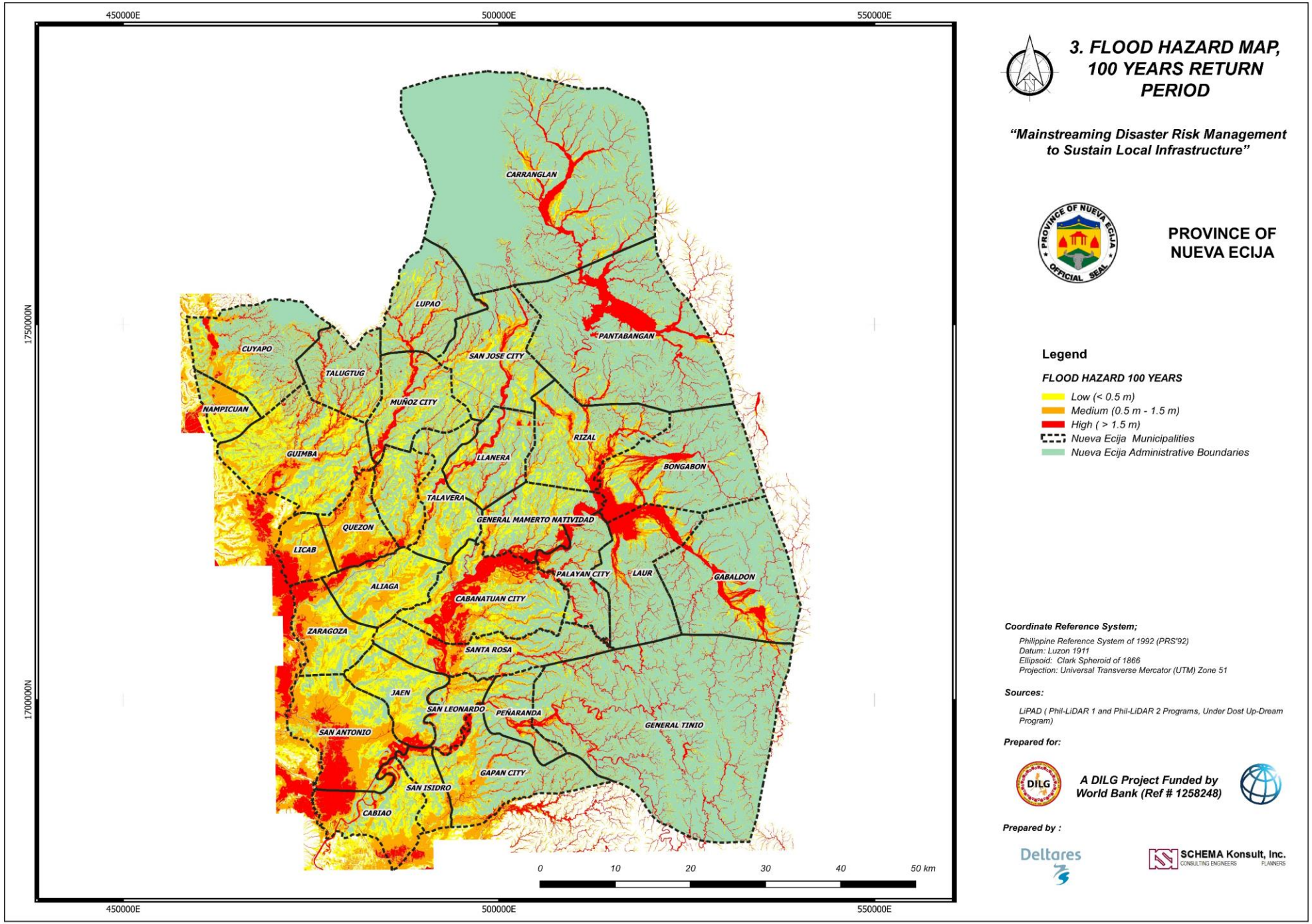
Example results of use of all steps to assess resilience


450000E
500000E
550000E
1750000N
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CARRANGLAN
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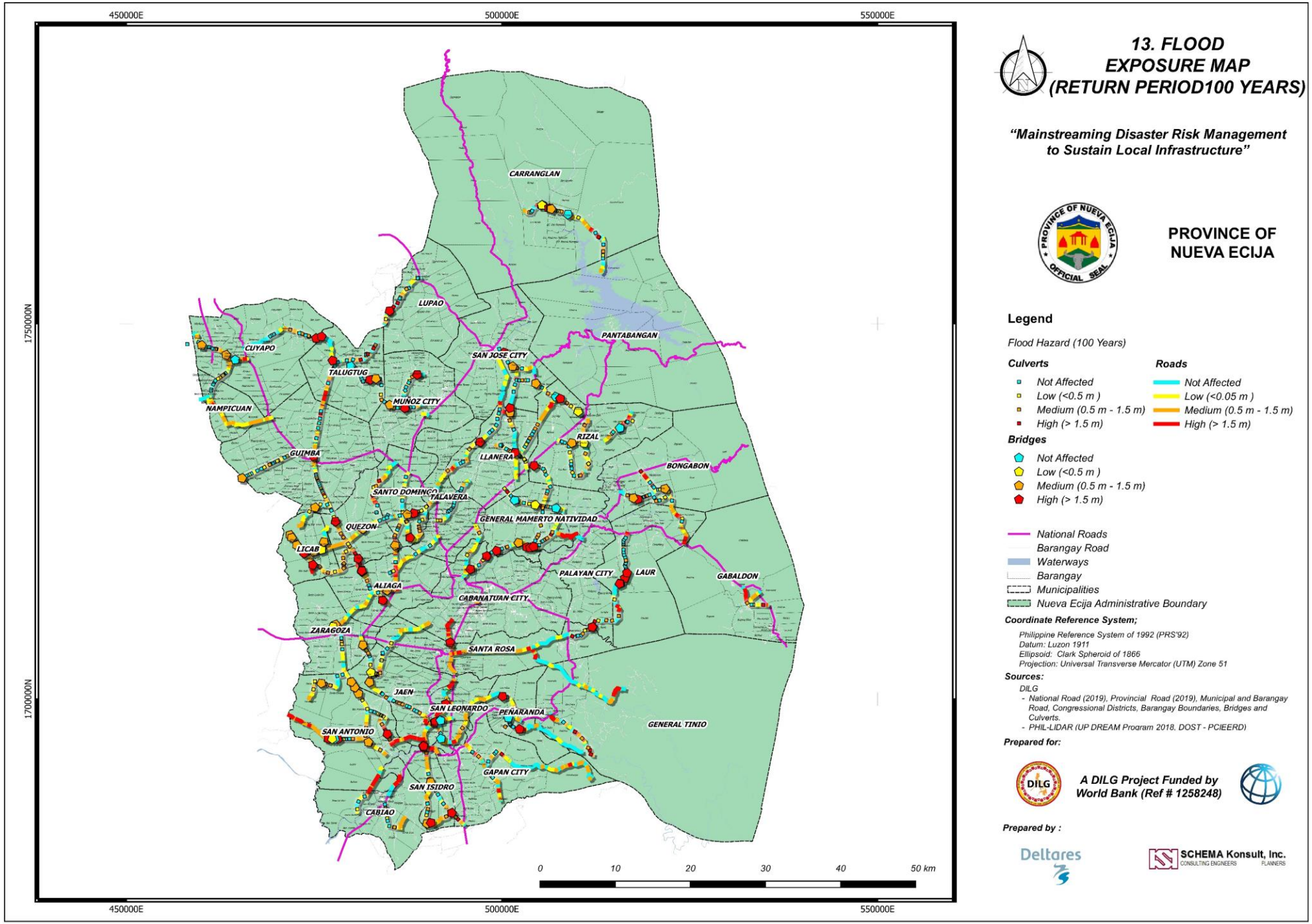
SAN JOSE CITY
CUYAPO
TALUGTUG
MUÑOZ CITY
NAMPICUAN
RIZAL
GUIMBA
LLANERA
BONGABON
TALAVERA
GENERAL MAMERTO NATIVIDAD
QUEZON
LICAB
PALAYAN CITY
LAUR
GABALDON
ALIAGA
CABANATUAN CITY
ZARAGOZA
SANTA ROSA
JAEN
SAN LEONARDO
PEÑARANDA
GENERAL TINIO
SAN ANTONIO
GAPAN CITY
SAN ISIDRO
CABIAO
0
10
20
30
40
50 km
3. FLOOD HAZARD MAP, 100 YEARS RETURN PERIOD
"Mainstreaming Disaster Risk Management to Sustain Local Infrastructure"
PROVINCE OF NUEVA ECIJA
Legend
FLOOD HAZARD 100 YEARS
Low (< 0.5 m)
Medium (0.5 m - 1.5 m)
High (> 1.5 m)
Nueva Ecija Municipalities
Nueva Ecija Administrative Boundaries
Coordinate Reference System;
Philippine Reference System of 1992 (PRS'92)
Datum: Luzon 1911
Ellipsoid: Clark Spheroid of 1866
Projection: Universal Transverse Mercator (UTM) Zone 51
Sources:
LiPAD (Phil-LiDAR 1 and Phil-LiDAR 2 Programs, Under Dost Up-Dream Program)
Prepared for:
DILG
A DILG Project Funded by World Bank (Ref # 1258248)
Prepared by :
Deltares
SCHEMA Konsult, Inc.
CONSULTING ENGINEERS
PLANNERS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SANTA ROSA
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SAN LEONARDO
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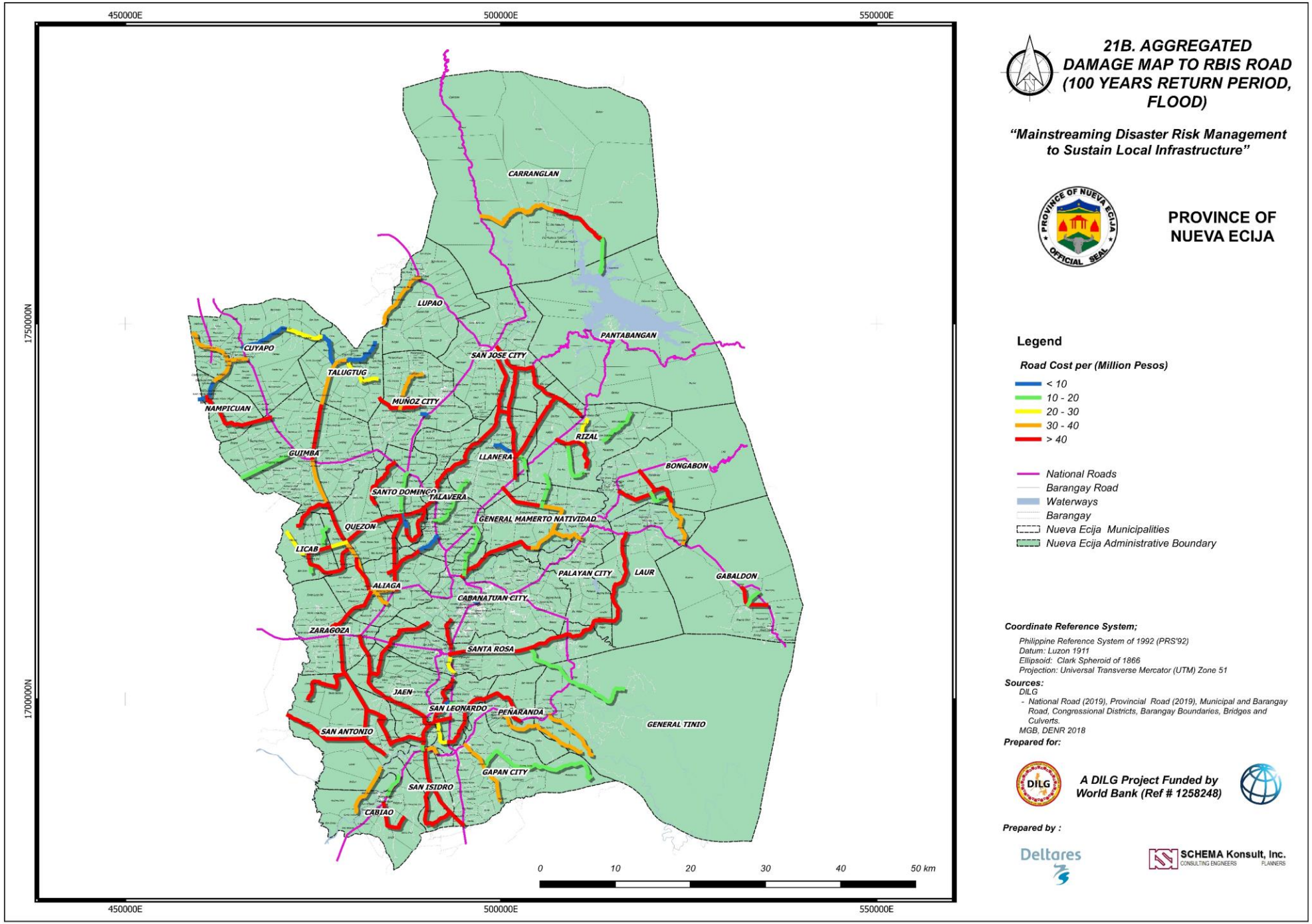
GENERAL TINIO
SAN ANTONIO
GAPAN CITY
SAN ISIDRO
CABIAO
0
10
20
30
40
50 km
13. FLOOD EXPOSURE MAP (RETURN PERIOD100 YEARS)
"Mainstreaming Disaster Risk Management to Sustain Local Infrastructure"
PROVINCE OF NUEVA ECIJA
Legend
Flood Hazard (100 Years)
Culverts
Not Affected
Low (<0.5 m)
Medium (0.5 m - 1.5 m)
High (> 1.5 m)
Roads
Not Affected
Low (<0.05 m)
Medium (0.5 m - 1.5 m)
High (> 1.5 m)
Bridges
Not Affected
Low (<0.5 m)
Medium (0.5 m - 1.5 m)
High (> 1.5 m)
National Roads
Barangay Road
Waterways
Barangay
Municipalities
Nueva Ecija Administrative Boundary
Coordinate Reference System;
Philippine Reference System of 1992 (PRS'92)
Datum: Luzon 1911
Ellipsoid: Clark Spheroid of 1866
Projection: Universal Transverse Mercator (UTM) Zone 51
Sources:
DILG
- National Road (2019), Provincial Road (2019), Municipal and Barangay Road, Congressional Districts, Barangay Boundaries, Bridges and Culverts.
- PHIL-LIDAR (UP DREAM Program 2018, DOST - PCIEERD)
Prepared for:
DILG
A DILG Project Funded by World Bank (Ref # 1258248)
Prepared by :
Deltares
SCHEMA Konsult, Inc.
CONSULTING ENGINEERS
PLANNERS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CARRANGLAN
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CUYAPO
SAN JOSE CITY
TALUGTUG
MUÑOZ CITY
NAMPICUAN
RIZAL
GUIMBA
LLANERA
BONGABON
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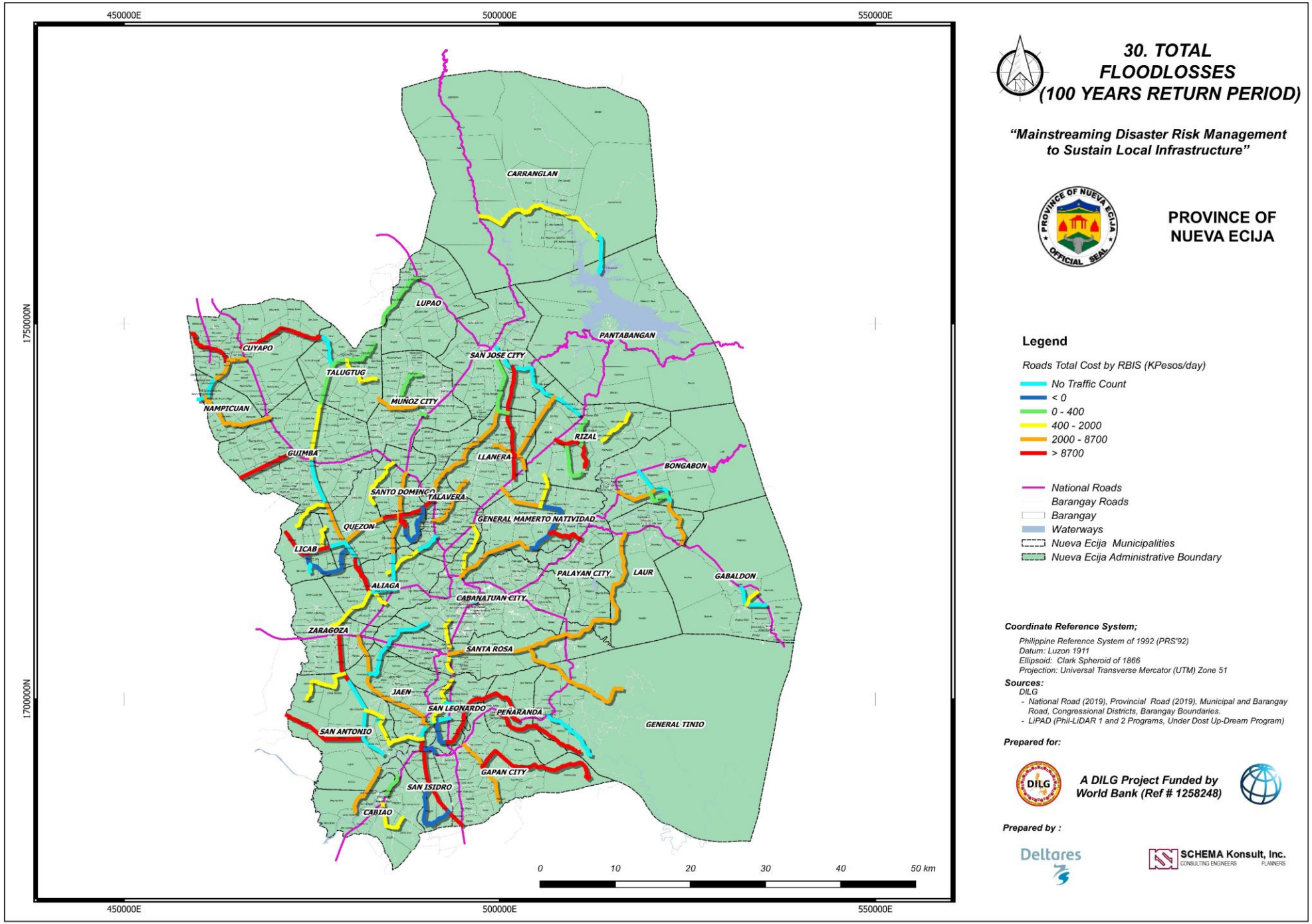
ZARAGOZA
SANTA ROSA
JAEN
SAN LEONARDO
PEÑARANDA
SAN ANTONIO
GENERAL TINIO
GAPAN CITY
SAN ISIDRO
CABIAO
0
10
20
30
40
50 km
21B. AGGREGATED DAMAGE MAP TO RBIS ROAD (100 YEARS RETURN PERIOD, FLOOD)
"Mainstreaming Disaster Risk Management to Sustain Local Infrastructure"
PROVINCE OF NUEVA ECIJA
Legend
Road Cost per (Million Pesos)
< 10
10 - 20
20 - 30
30 - 40
> 40
National Roads
Barangay Road
Waterways
Barangay
Nueva Ecija Municipalities
Nueva Ecija Administrative Boundary
Coordinate Reference System;
Philippine Reference System of 1992 (PRS'92)
Datum: Luzon 1911
Ellipsoid: Clark Spheroid of 1866
Projection: Universal Transverse Mercator (UTM) Zone 51
Sources:
DILG
- National Road (2019), Provincial Road (2019), Municipal and Barangay Road, Congressional Districts, Barangay Boundaries, Bridges and Culverts.
MGB, DENR 2018
Prepared for:
A DILG Project Funded by World Bank (Ref # 1258248)
Prepared by :
Deltares
SCHEMA Konsult, Inc.
CONSULTING ENGINEERS
PLANNERS


450000E
500000E
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CARRANGLAN
LUPAO
CUYAPO
SAN JOSE CITY
PANTABANGAN
TALUGTUG
MUÑOZ CITY
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QUEZON
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ZARAGOZA
SANTA ROSA
JAEN
SAN LEONARDO
PEÑARANDA
GENERAL TINIO
SAN ANTONIO
GAPAN CITY
SAN ISIDRO
CABIAO
0
10
20
30
40
50 km
30. TOTAL FLOODLOSSES (100 YEARS RETURN PERIOD)
"Mainstreaming Disaster Risk Management to Sustain Local Infrastructure"
PROVINCE OF NUEVA ECIJA
Legend
Roads Total Cost by RBIS (KPesos/day)
No Traffic Count
< 0
0 - 400
400 - 2000
2000 - 8700
> 8700
National Roads
Barangay Roads
Barangay
Waterways
Nueva Ecija Municipalities
Nueva Ecija Administrative Boundary
Coordinate Reference System;
Philippine Reference System of 1992 (PRS'92)
Datum: Luzon 1911
Ellipsoid: Clark Spheroid of 1866
Projection: Universal Transverse Mercator (UTM) Zone 51
Sources:
DILG
- National Road (2019), Provincial Road (2019), Municipal and Barangay Road, Congressional Districts, Barangay Boundaries.
- LiPAD (Phil-LiDAR 1 and 2 Programs, Under Dost Up-Dream Program)
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Prioritization of risk

	EAD	EAL	Total (EAD+EAL)
	(Million Pesos)		
Floods	534	110.6	644.6
Earthquakes	5.8	1.0	6.8

Category	Expected Annual Costs - EAD and EAL	
	Floods (MPesos)	Earthquakes (KPesos)
C1	< 1.70	< 23
C2	1.70 to 4.50	23 to 40
C3	4.50 to 6.50	40 to 60
C4	6.50 to 8.40	60 to 85
C5	> 8.40	> 85

Losses Category	Damage Category C1	C2	C3	C4	C5
C1	1	1	2	2	3
C2	2	2	3	3	4
C3	3	3	3	4	4
C4	3	4	4	5	5
C5	4	4	5	5	5

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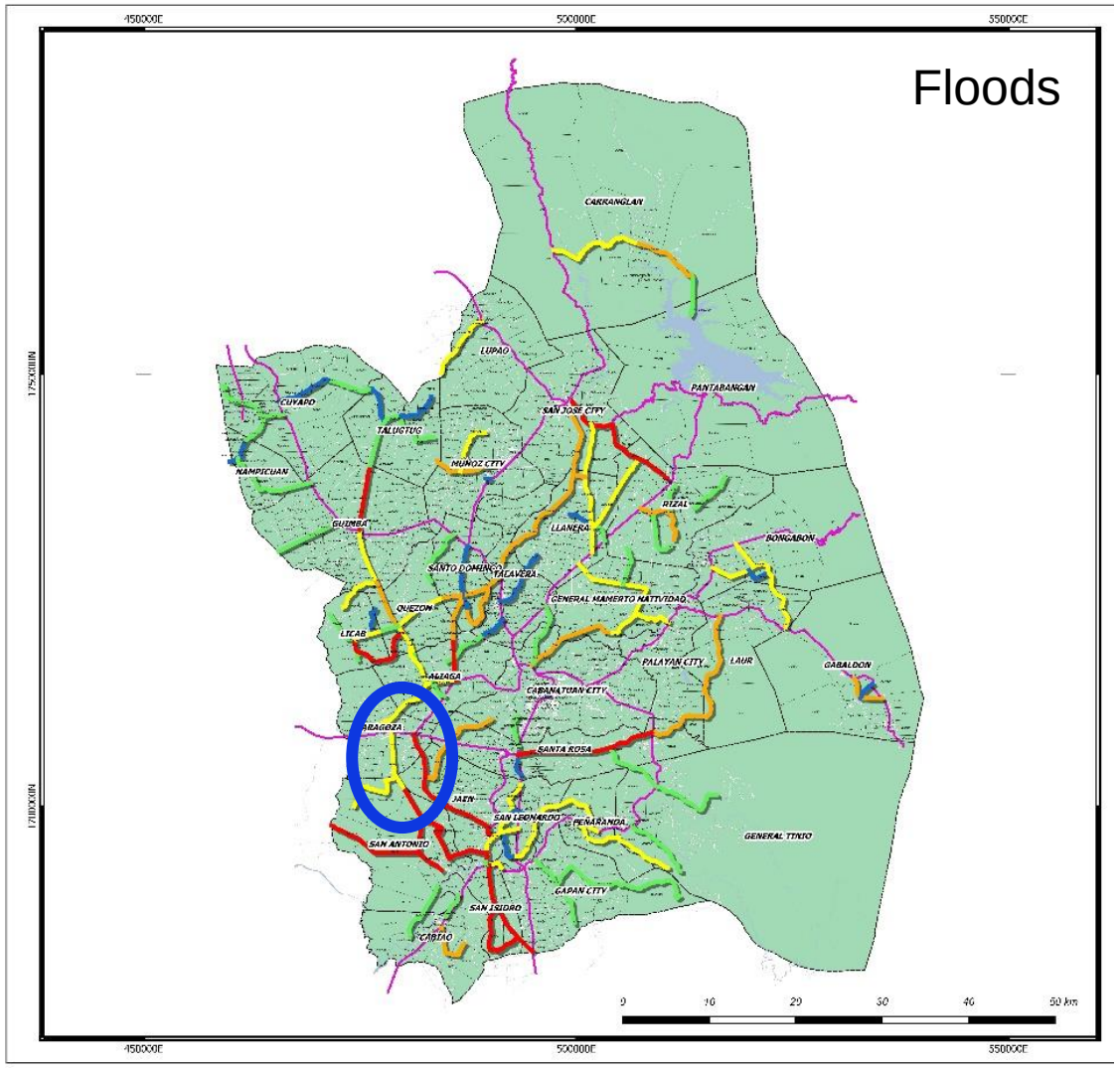
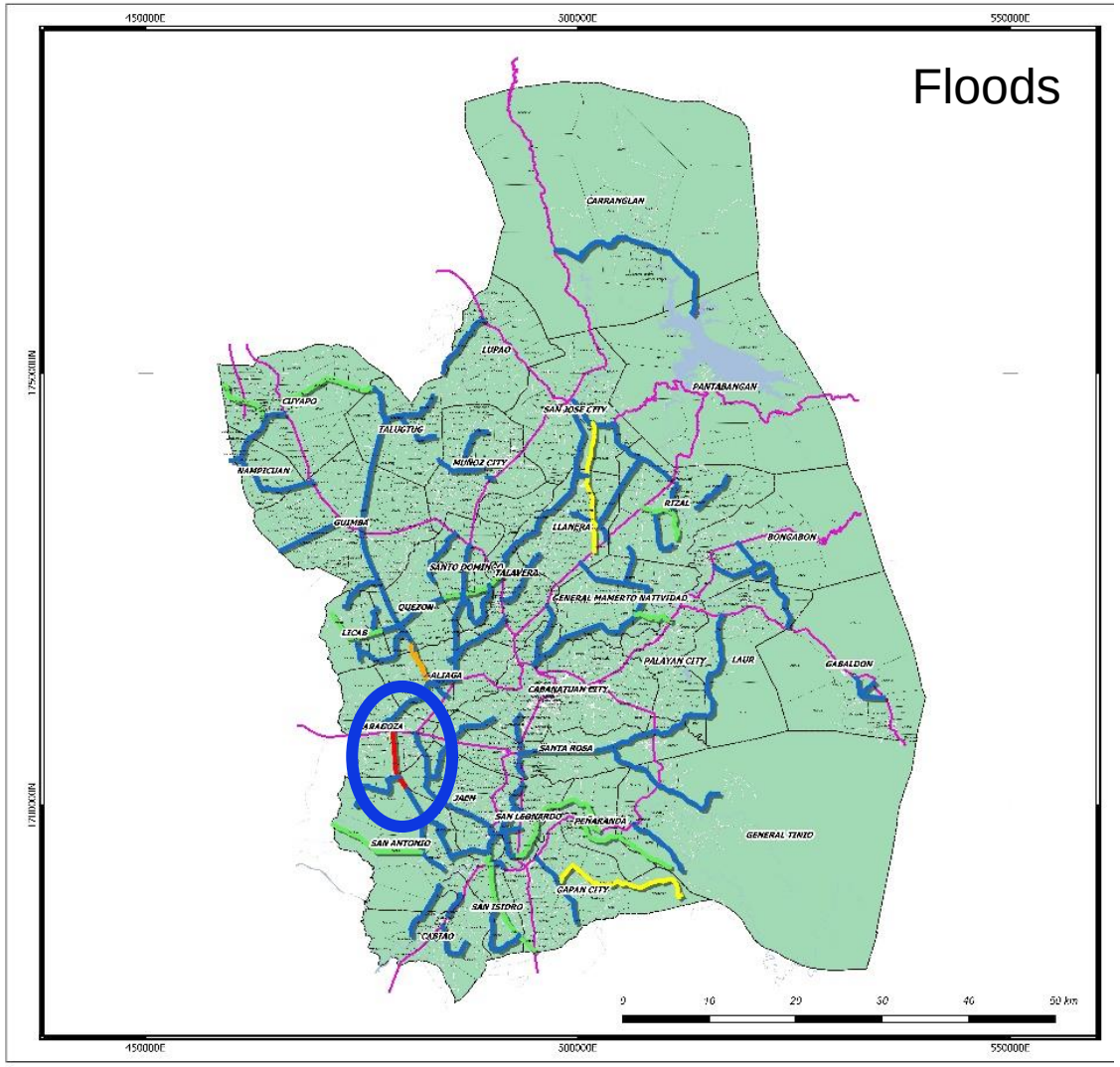
EAD



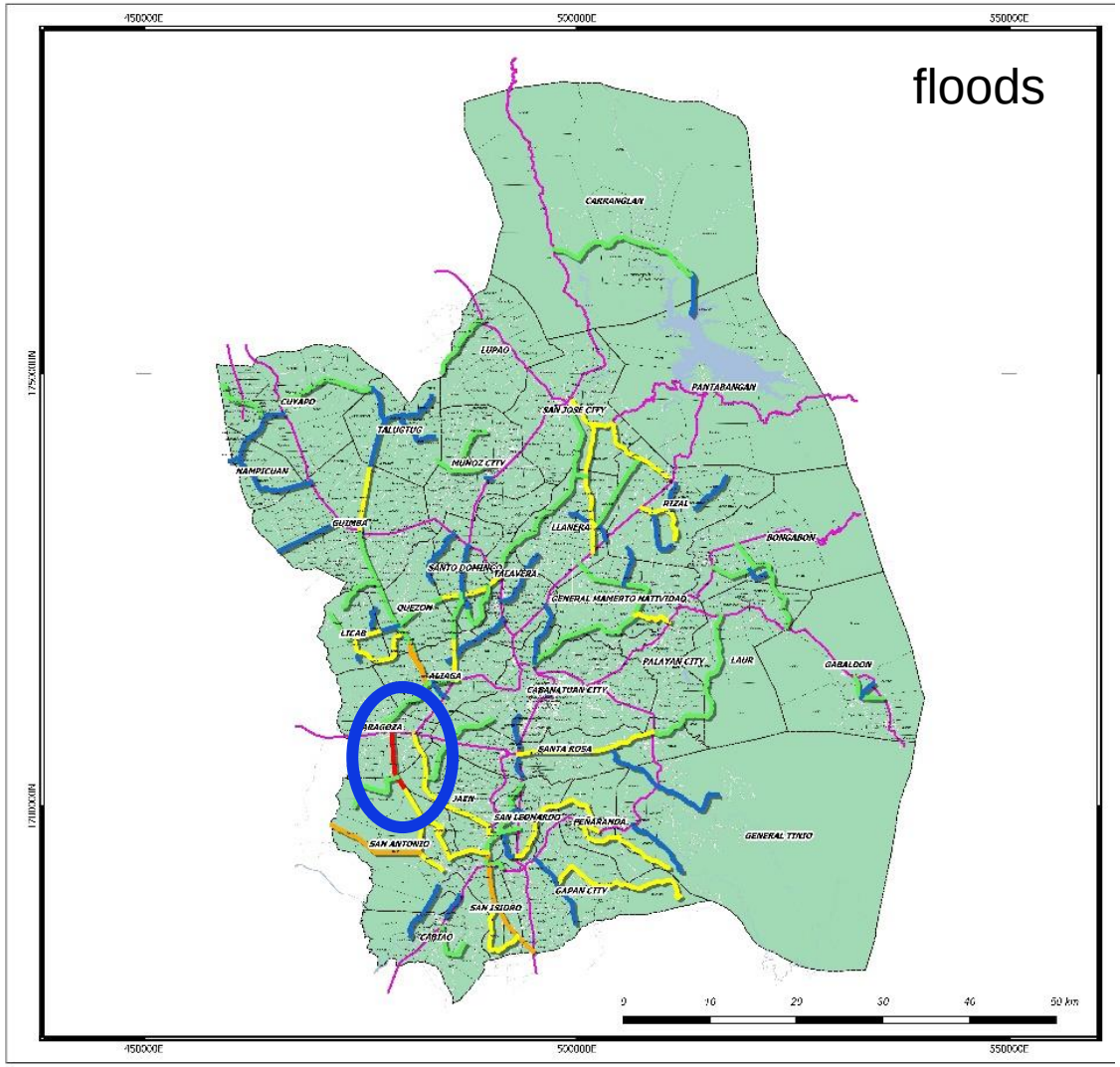
		Damage Category				
		C1	C2	C3	C4	C5
Losses Category	C1	1	1	2	2	3
	C2	2	2	3	3	4
	C3	3	3	3	4	4
	C4	3	4	4	5	5
	C5	4	4	5	5	5

EAD + EAL

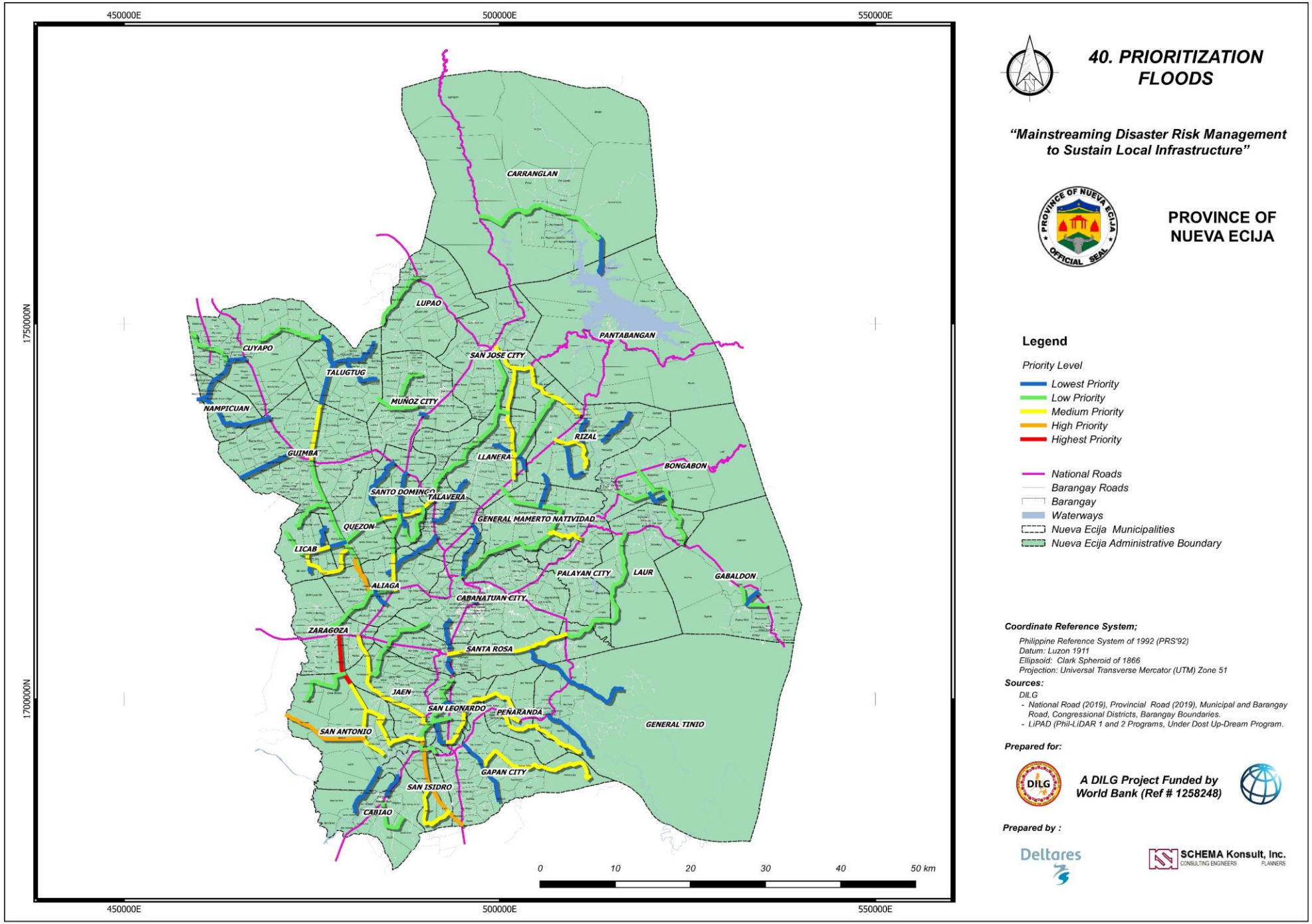


		Damage Category				
		C1	C2	C3	C4	C5
Losses Category	C1	1	1	2	2	3
	C2	2	2	3	3	4
	C3	3	3	3	4	4
	C4	3	4	4	5	5
	C5	4	4	5	5	5

EAD + EAL → prioritization



		Damage Category				
		C1	C2	C3	C4	C5
Losses Category	C1	1	1	2	2	3
	C2	2	2	3	3	4
	C3	3	3	3	4	4
	C4	3	4	4	5	5
	C5	4	4	5	5	5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40
50 km
40. PRIORITIZATION
FLOODS
"Mainstreaming Disaster Risk Management to Sustain Local Infrastructure"
PROVINCE OF NUEVA ECIJA
Legend
Priority Level
Lowest Priority
Low Priority
Medium Priority
High Priority
Highest Priority
National Roads
Barangay Roads
Barangay
Waterways
Nueva Ecija Municipalities
Nueva Ecija Administrative Boundary
Coordinate Reference System;
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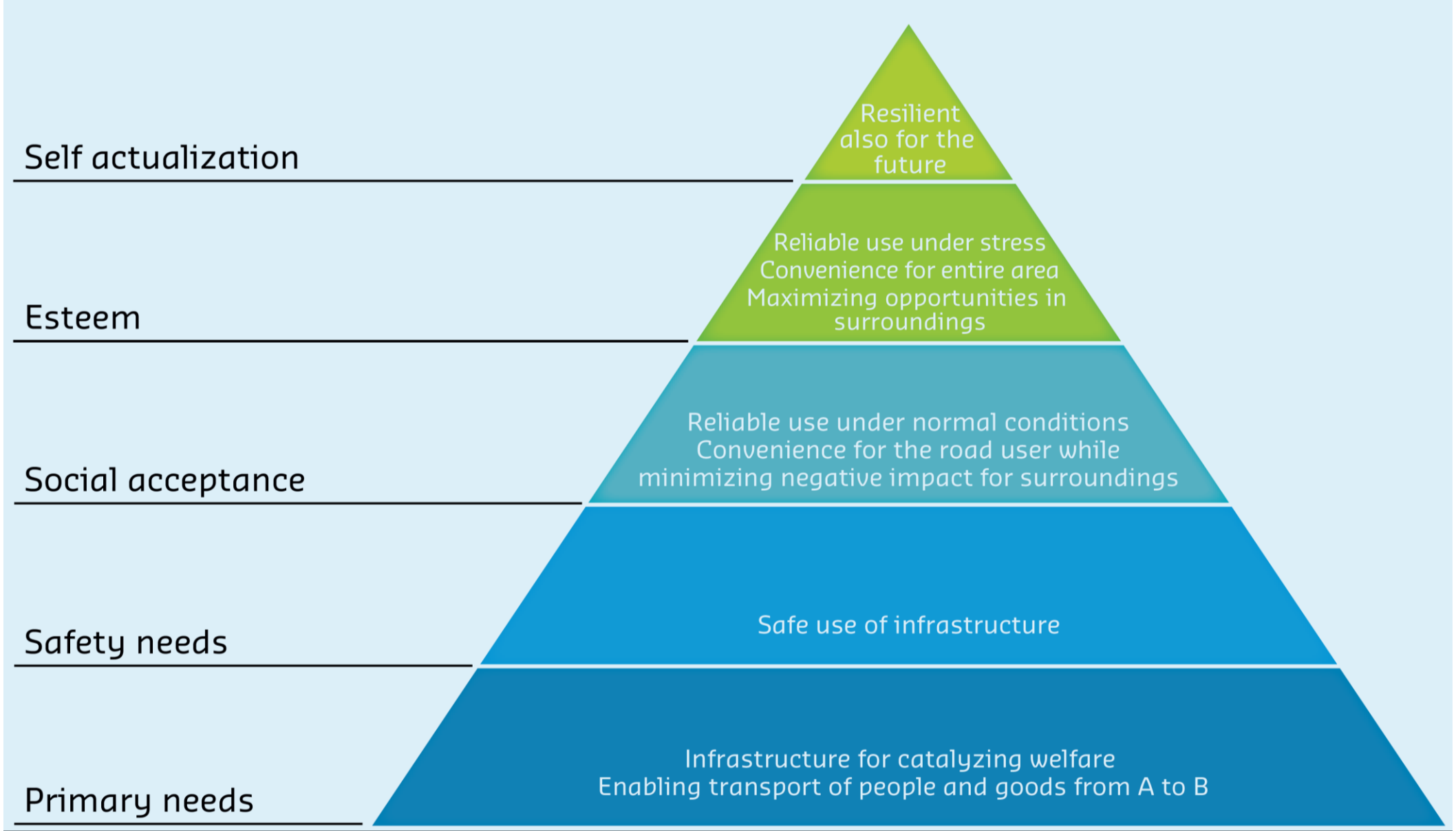
Pyramid


Self actualization
Resilient also for the future
Esteem
Reliable use under stress
Convenience for entire area
Maximizing opportunities in surroundings
Social acceptance
Reliable use under normal conditions
Convenience for the road user while minimizing negative impact for surroundings
Safety needs
Safe use of infrastructure
Primary needs
Infrastructure for catalyzing welfare
Enabling transport of people and goods from A to B

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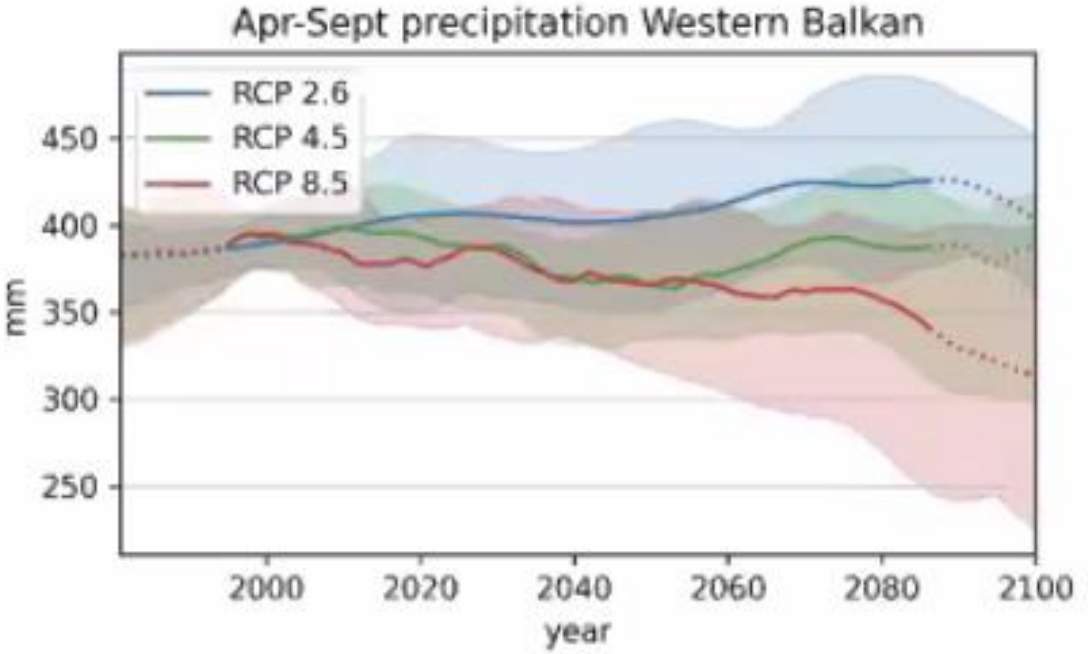
Dealing with uncertainties

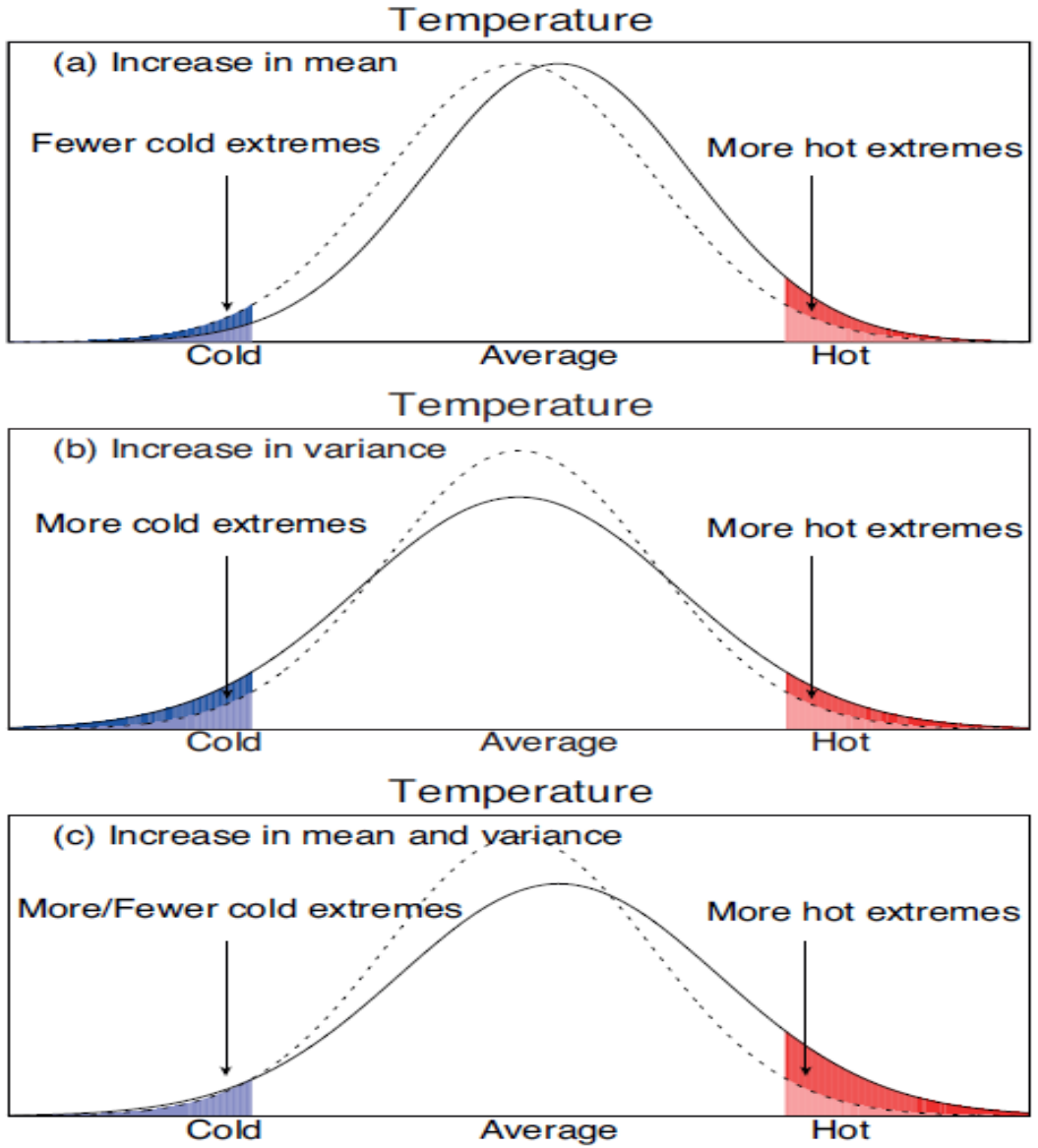
importance of integrating climate risk assessment into infrastructure design process

Thomas Bles

Status quo and looking towards an uncertain future



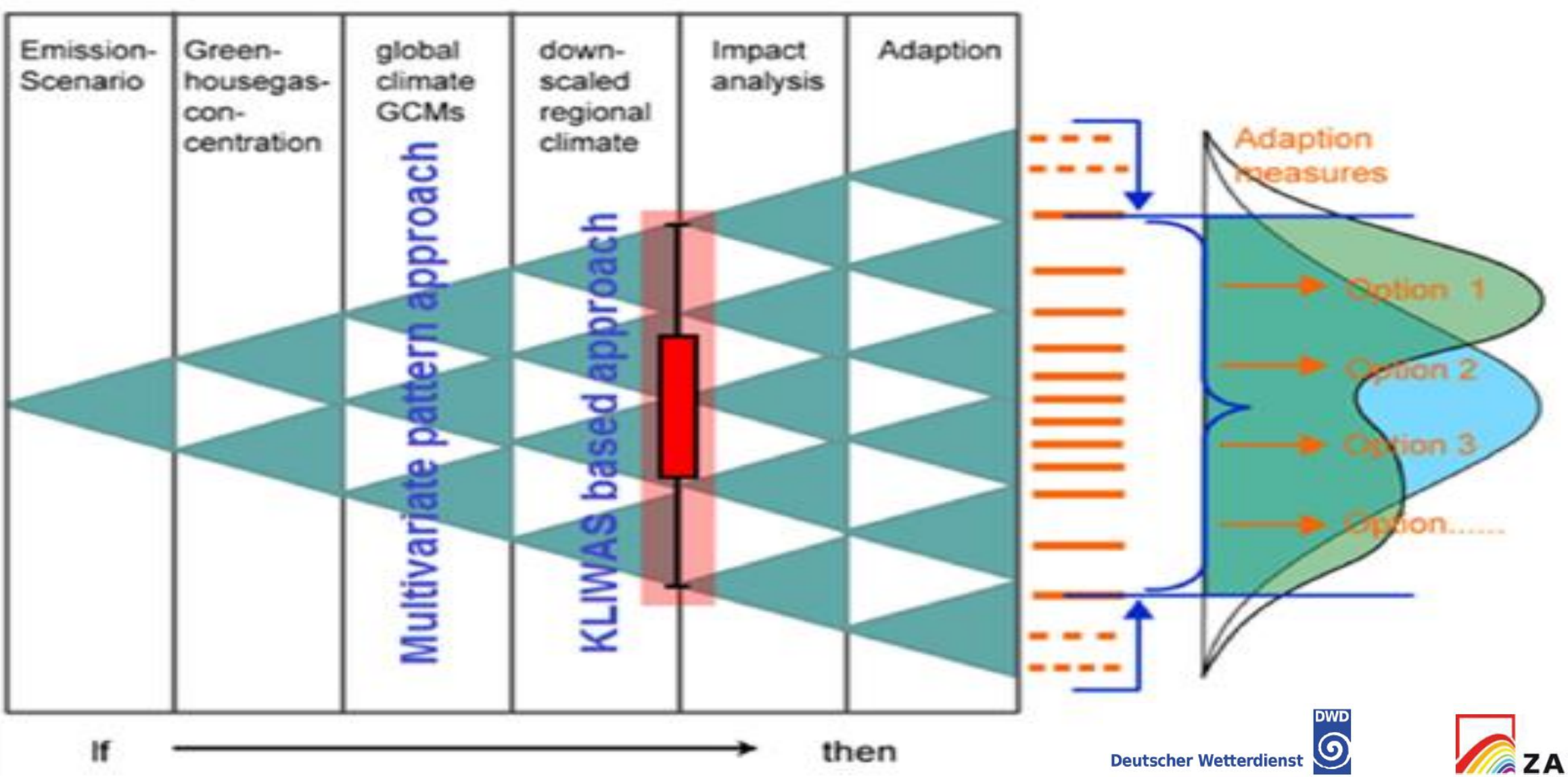
What is climate change?



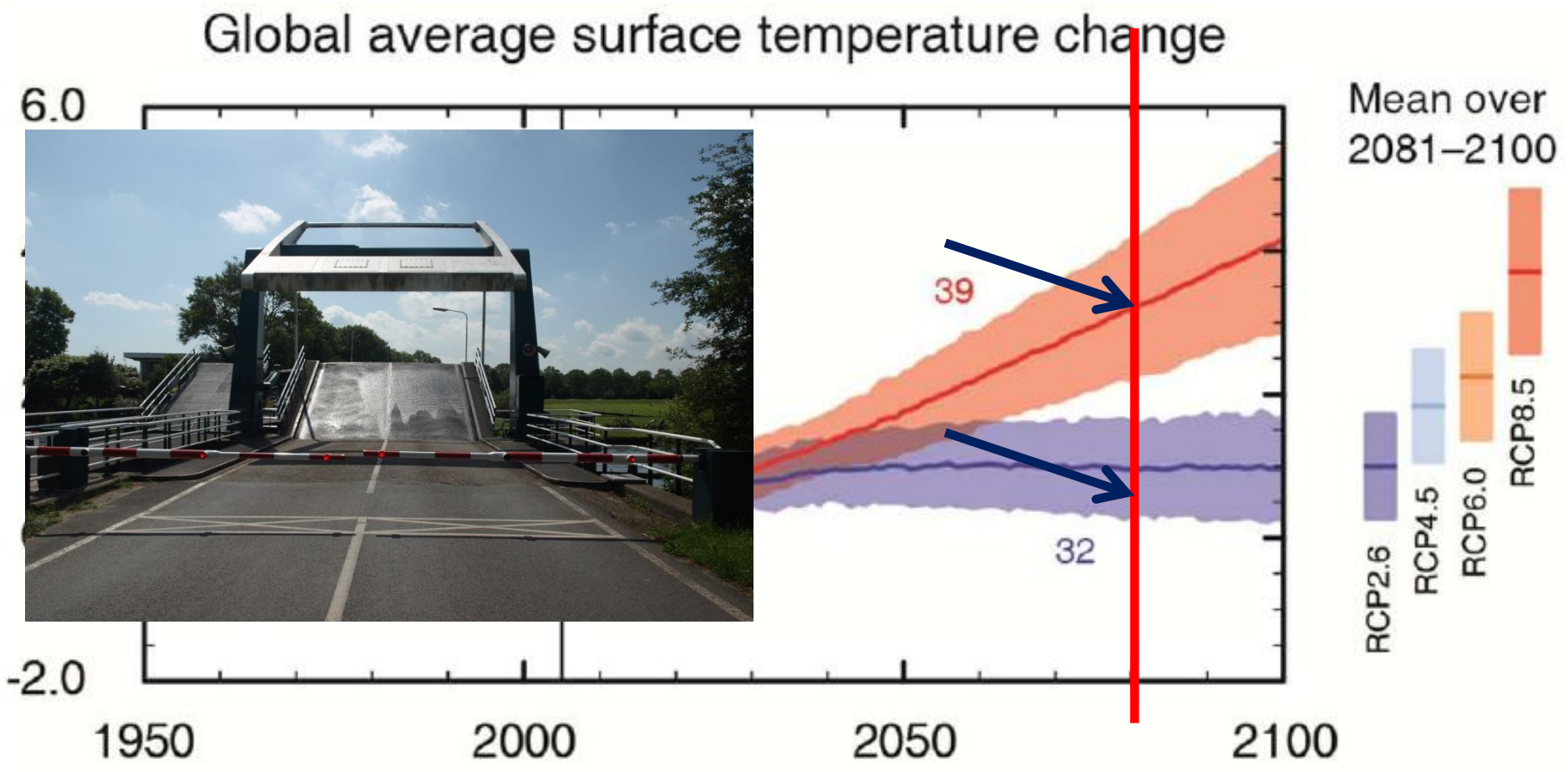
Change in the statistics

- Averages
- Extremes
- Or both

Uncertainty in climate change adaptation



Use of climate models



Different types of uncertainties!

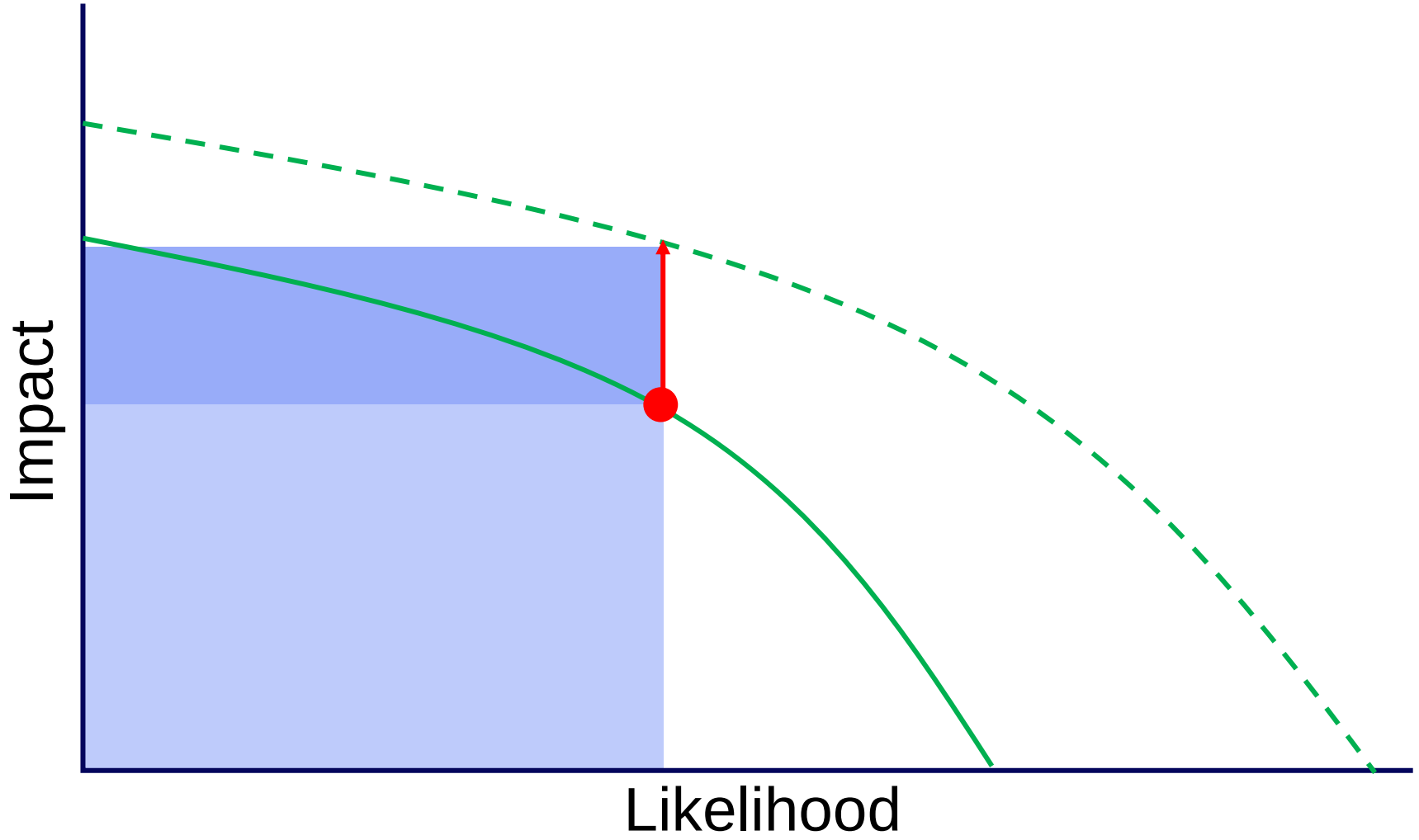
Do not trust in the results of only one climate projection

How to include climate change in resilience assessment

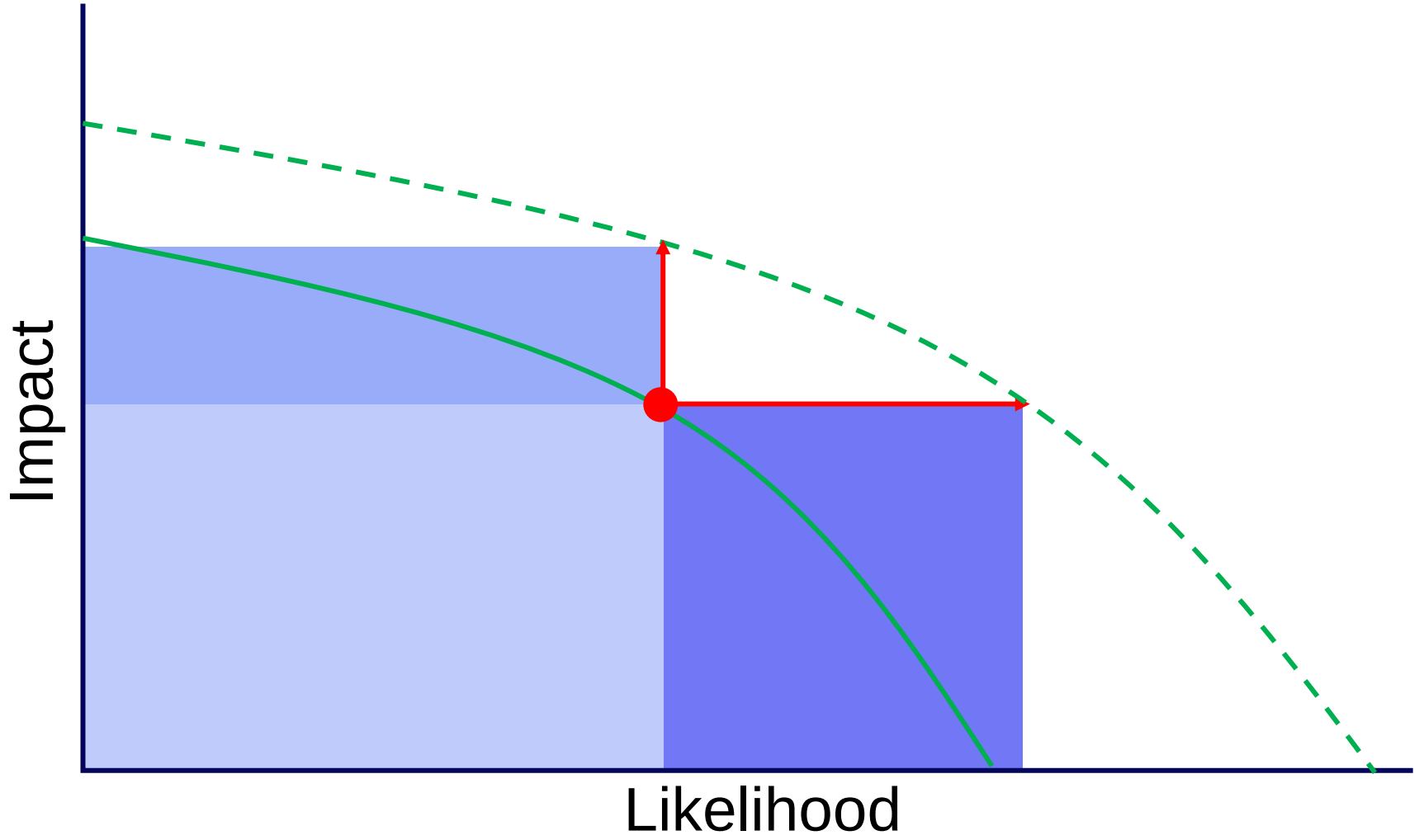
- Change hazard maps
  - Provides the best results
  - Time consuming
  - Data often unavailable

- Change likelihood / return period
  - And keep impact the same
  - Keep the available hazard maps and change the return period

Considering climate change



Considering climate change



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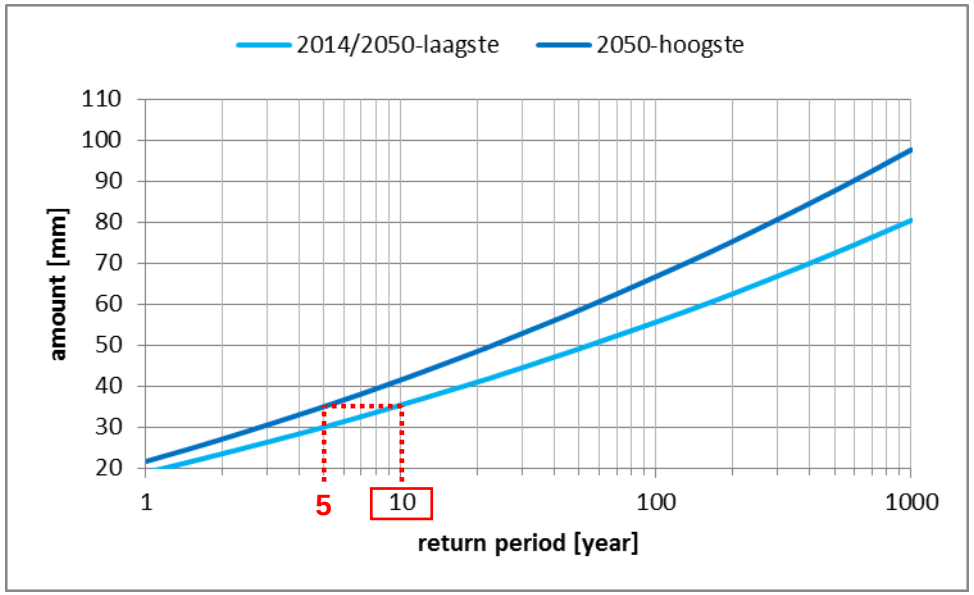
KNMI Statistics – 2 hour shower

Select proper precipitation regime

hoeveelheden		2014	2050												
			GL			GH			WL			WH			
	2014/2050-lower	low	centr	upp	low	centr	upp	low	centr	upp	low	centr	upp	2050-lower	2050-upper
0,5	15	15	15	15	14	15	15	15	16	16	14	15	16	14	16
1	19	19	20	20	19	19	20	19	20	22	18	20	21	18	22
2	24	24	24	25	23	24	25	24	26	27	23	25	27	23	27
5	30	30	31	32	30	31	32	30	33	35	30	32	35	30	35
10	36	35	37	38	35	36	38	35	39	42	35	38	42	35	42
20	41	41	43	44	40	42	45	41	45	48	41	45	49	40	49
25	43	43	45	46	42	44	47	43	47	51	43	47	51	42	51
50	49	49	51	53	48	51	53	49	54	58	49	54	59	48	59
100	56	56	58	60	54	57	61	56	61	66	55	61	67	54	67
200	63	62	65	68	61	65	68	62	69	74	62	69	75	61	75
500	73	72	76	79	71	75	79	72	79	86	72	80	88	71	88
1000	81	80	84	87	78	83	88	80	88	96	80	89	98	78	98



probability of extreme weather:

- Current 1:10 years
- Future 1:5 years

‘probability’ increases by factor: 2

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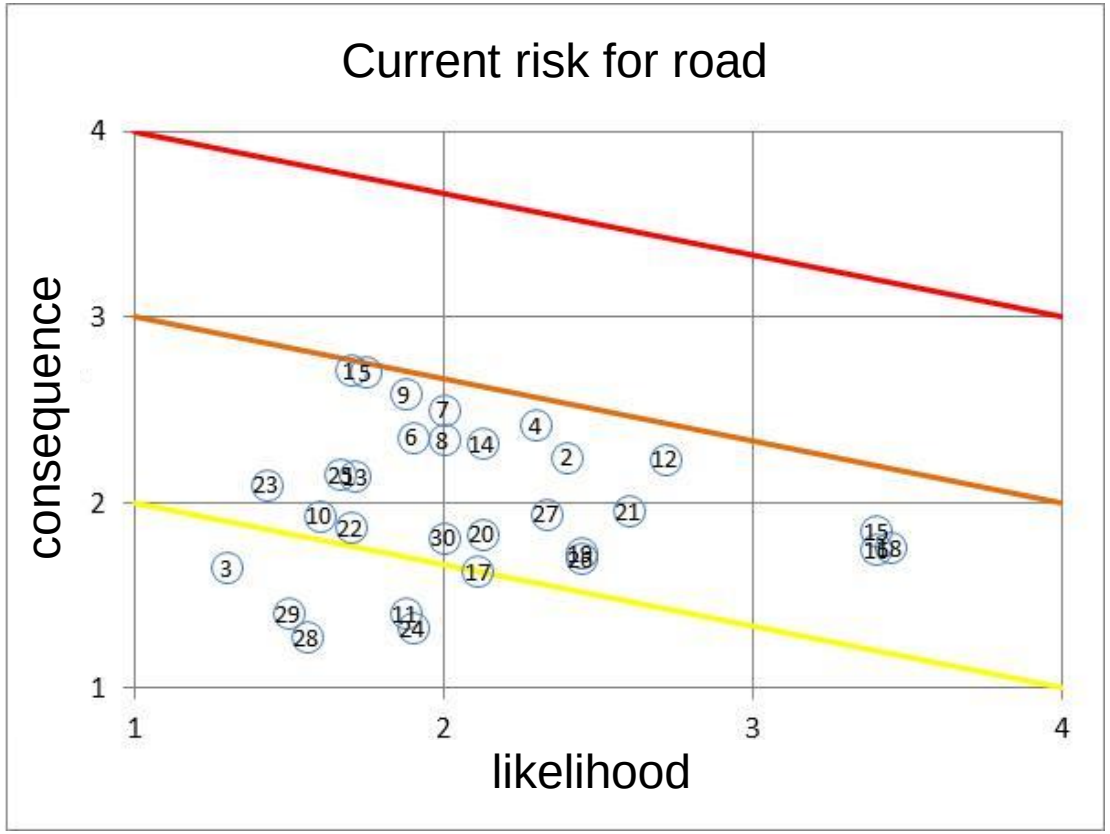
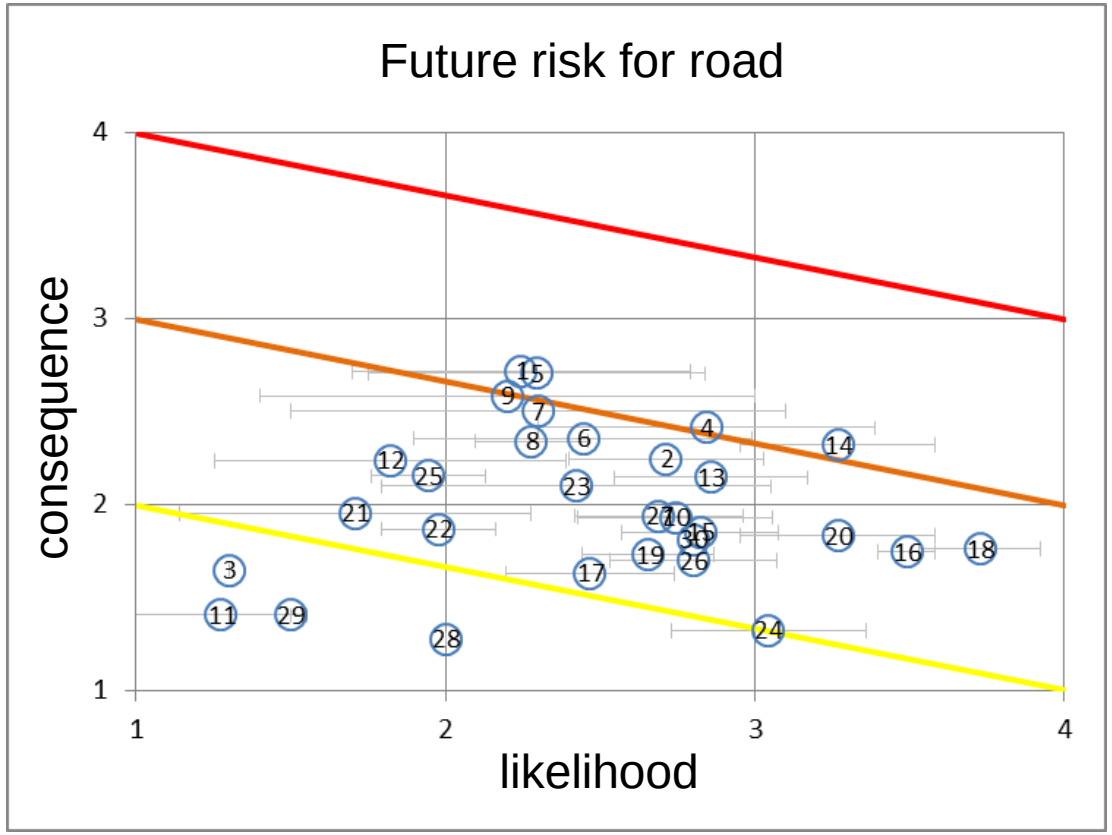
Climate change → risk changes

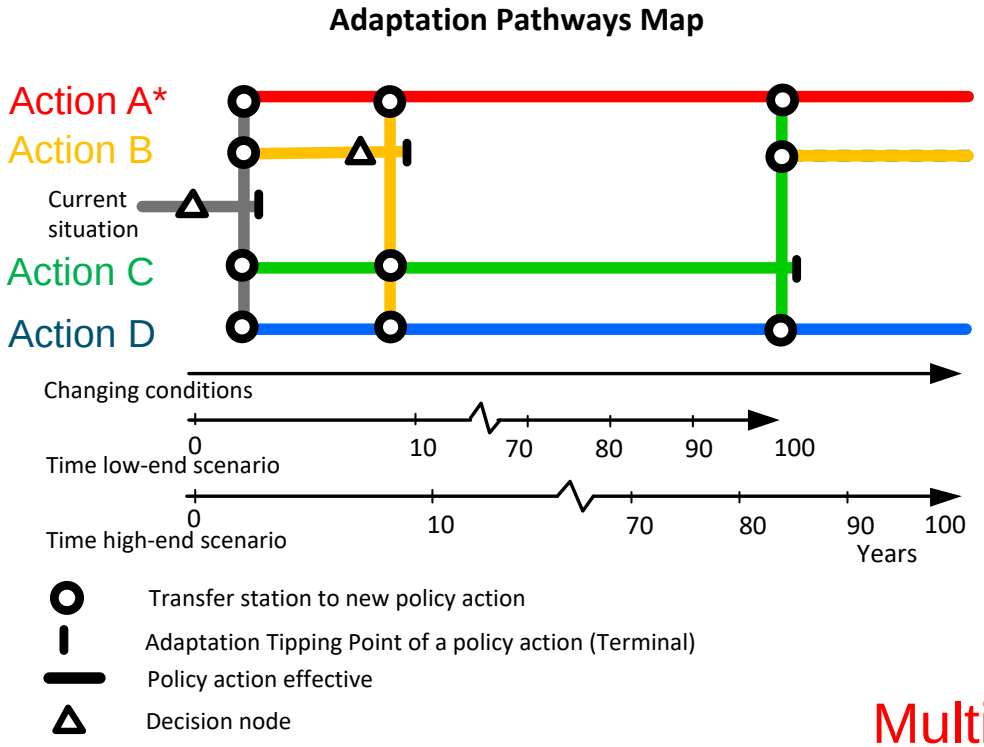


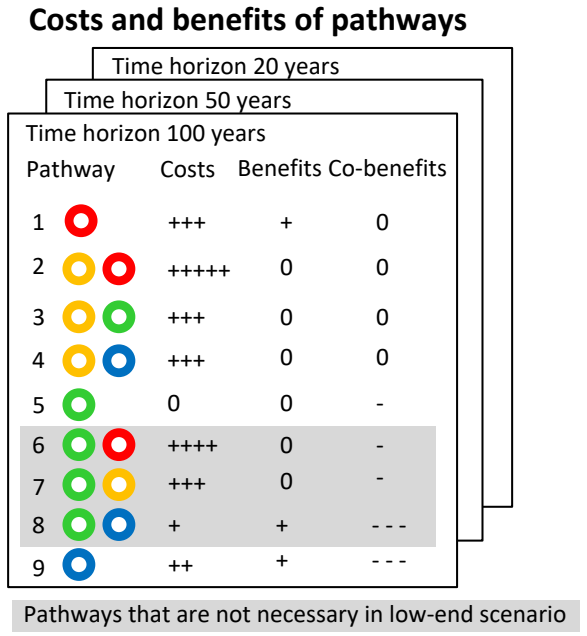


Decision making under (deep) uncertainty

Adaptation pathways illustrate **different possible sequences of investment decisions**.

MCA scorecard can be used to evaluate the pathways and potential decisions.



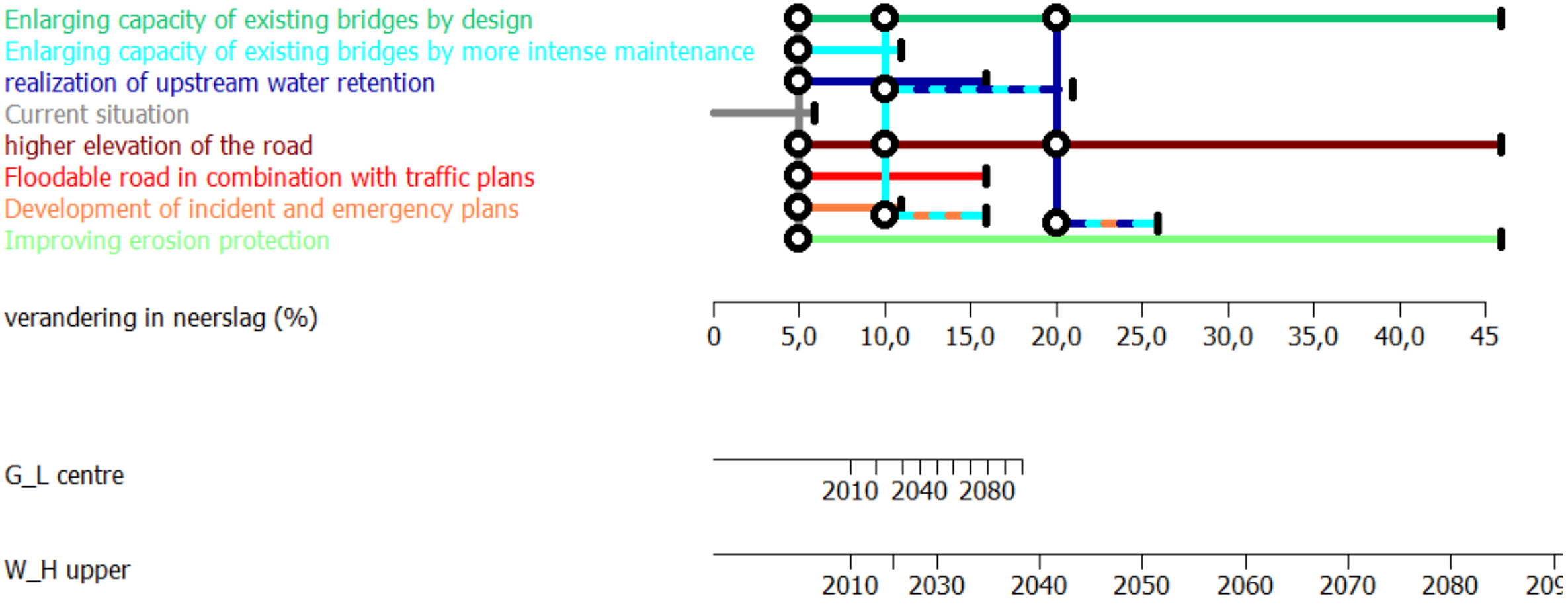


Multiple time-axes display uncertainty in moment of ATP

* single action or portfolio of actions

Haasnoot et al. (2012). Clim. Change.; Haasnoot et al. (2013) Glob. Env. Change. 10.1016/j.gloenvcha.2012.12.006

Example river crossings



Map generated with Pathways Generator, @2015, Deltares, Carthago Consultancy

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Thomas.Bles@deltares.nl