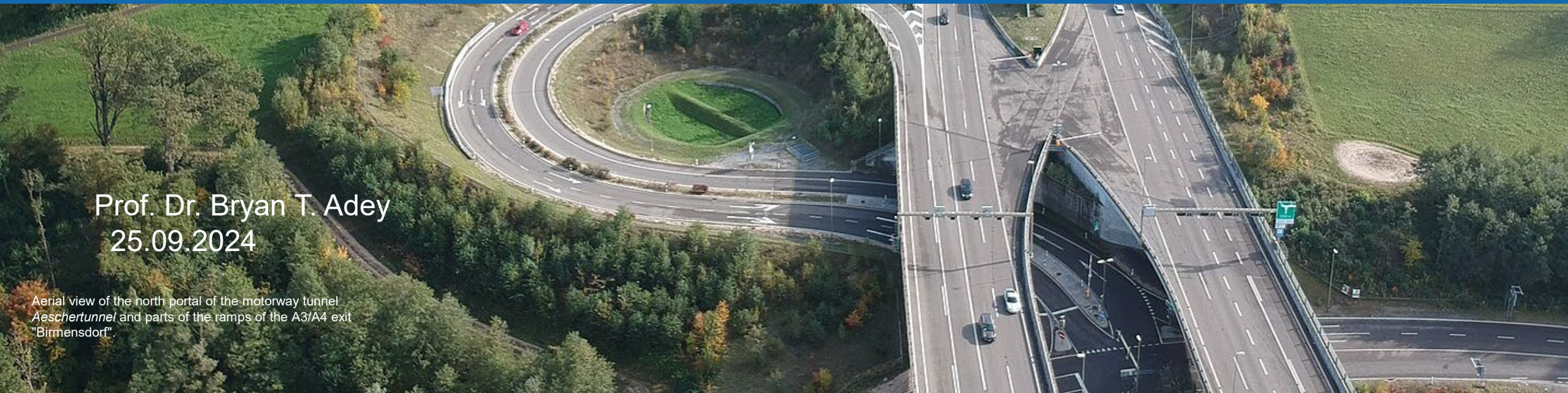# Transport system resilience to disruptive events and long-term trends

Identifying the need to change and appraising modifications

Prof. Dr. Bryan T. Adey
25.09.2024

Aerial view of the north portal of the motorway tunnel
Aeschertunnel and parts of the ramps of the A3/A4 exit
"Birmensdorf".

What is a transport asset?

Aerial view of the north portal of the motorway tunnel *Aeschertunnel* and parts of the ramps of the A3/A4 exit "Birmensdorf".
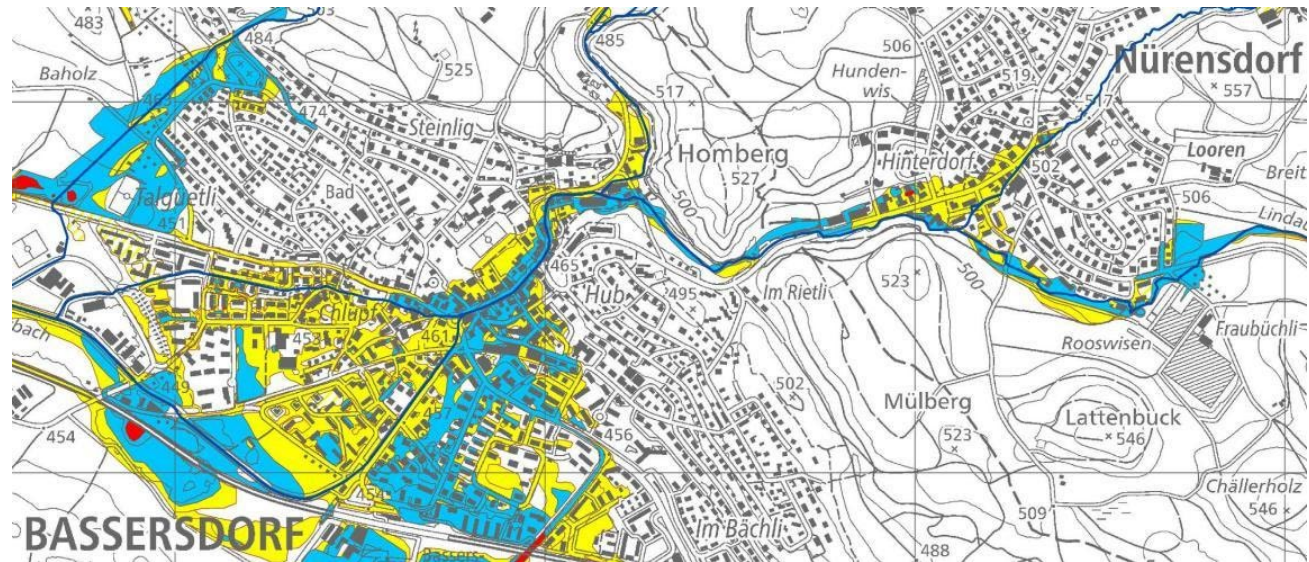
Transport asset resilience cannot be estimated without considering the system

- If you look at the asset without the organisation, how do you know how long it will take to fix the asset if it is damaged?

- If you look at the asset without the environment, how do you know the severity of flood that might happen? How do you know if money will be available to fix the asset?

What is a transport system?

Infrastructure
- The physical assets that are required to provide service

Environment (1/2)
- The physical environment in which the infrastructure is embedded that might affect the provision of service

Environment (2/2)
- The organisational environment in which the infrastructure management organisation is embedded that might affect the provision of service

Organisation
- The organisation(s) responsible for ensuring that the infrastructure provides service

What is expected from a transport system?

The service to be provided by a transport system is the safe and sustainable mobility of persons and goods.	This service can be operationalized, for example, as the ability to transport from A to B goods and persons - within a specific amount of time - with emissions below a specified threshold, and - goods without being damaged and persons without being hurt or losing their lives.

https://vignetteswitzerland.com/it/autostrade-svizzere/

Why modify transport systems?

Potentially disruptive events	Long term trends

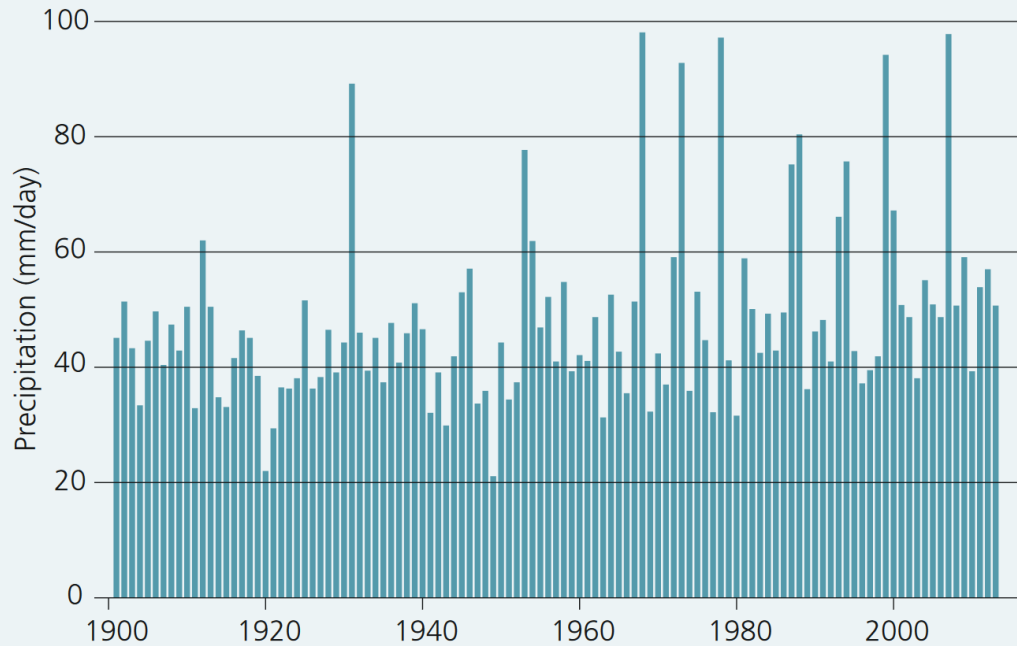https://unece.org/transport/publications/stress-test-framework-evaluating-resilience-transport-systems

https://www.spiegel.de/wirtschaft/unternehmen/dubiose-diesel-lieferanten-draengen-auf-den-deutschen-markt-verdacht-auf-steuerbetrug-a-7cc97ff5-822d-4868-991d-2363add779eb

Why modify transport systems?

Potentially disruptive events

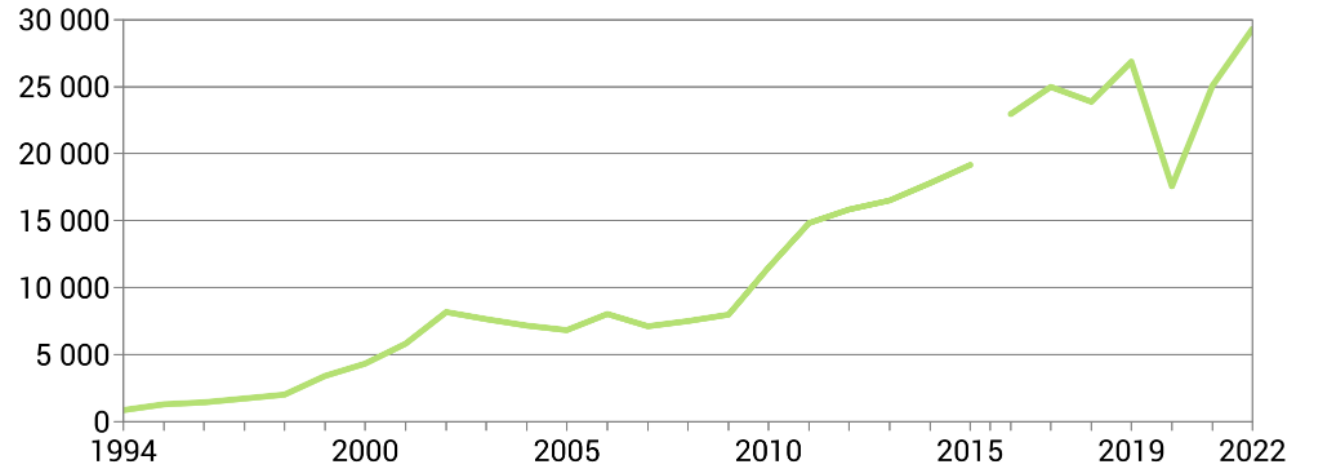Heaviest single-day precipitation event of the year in Zurich

https://www.nccs.admin.ch/nccs/en/home/climate-change-and-impacts/swiss-climate-change-scenarios/order-the-ch2018-brochure.html

Long term trends

Staubelastung auf dem Nationalstrassennetz
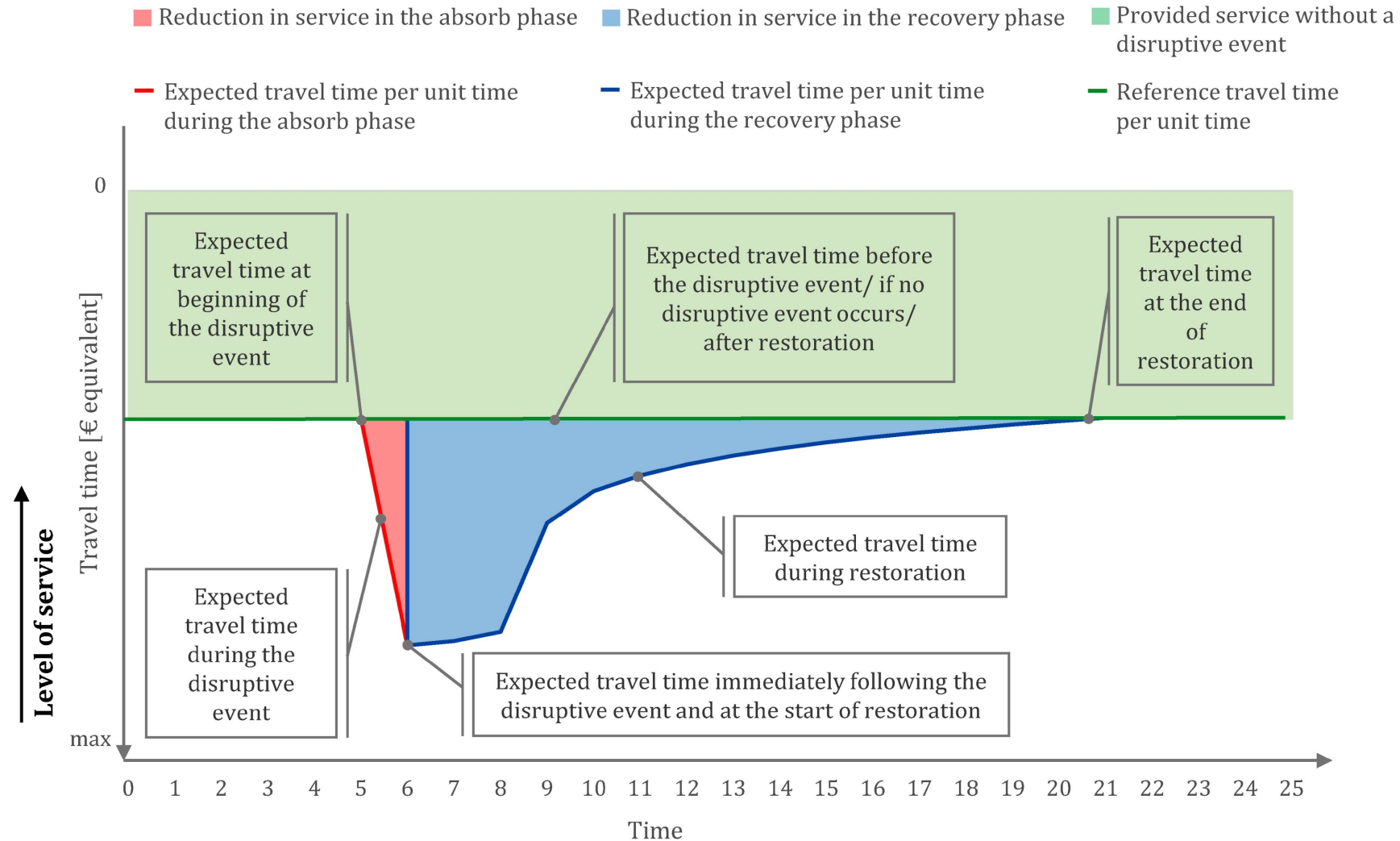Durch Verkehrsüberlastung verursachte Staus

ohne Staus auf den Strecken des neuen Netzbeschlusses (NEB); Anpassung der Berechnungsmethode 2016

Quelle: Bundesamt für Strassen   © BFS 2023

https://www.bfs.admin.ch/bfs/de/home/statistiken/querschnittsthemen/monitoring-legislaturplanung/alle-indikatoren/leitline-1-wohlstand/staubelastung-nationalstrassennetz.html

What is transport system resilience?
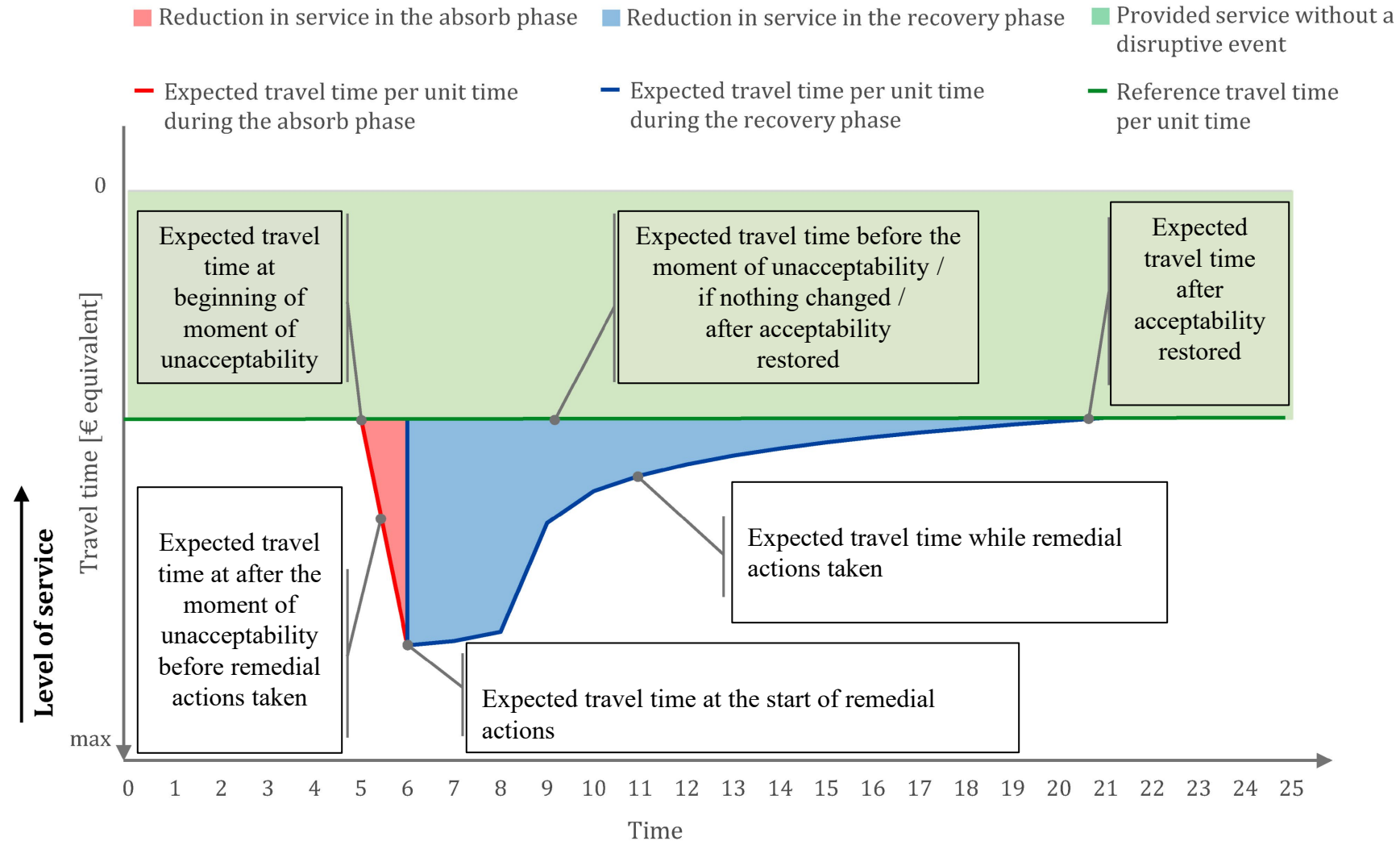## To a potentially disruptive event

What is transport system resilience?
To a long-term trend

Legend:
- Reduction in service in the absorb phase
- Reduction in service in the recovery phase
- Provided service without a disruptive event
- Expected travel time per unit time during the absorb phase
- Expected travel time per unit time during the recovery phase
- Reference travel time per unit time

Expected travel time at beginning of moment of unacceptability

Expected travel time before the moment of unacceptability / if nothing changed / after acceptability restored

Expected travel time after acceptability restored

Expected travel time while remedial actions taken

Expected travel time at after the moment of unacceptability before remedial actions taken

Expected travel time at the start of remedial actions

Travel time [€ equivalent]

Level of service

Time

What are the best areas for improvement?
Run stress tests

A stress test is a set of one or more hypothetical scenarios designed to help determine if a transport system can continue to provide an acceptable level of service when
- subjected to one or more <u>potentially disruptive events</u> / one or more potentially disruptive long-term trends
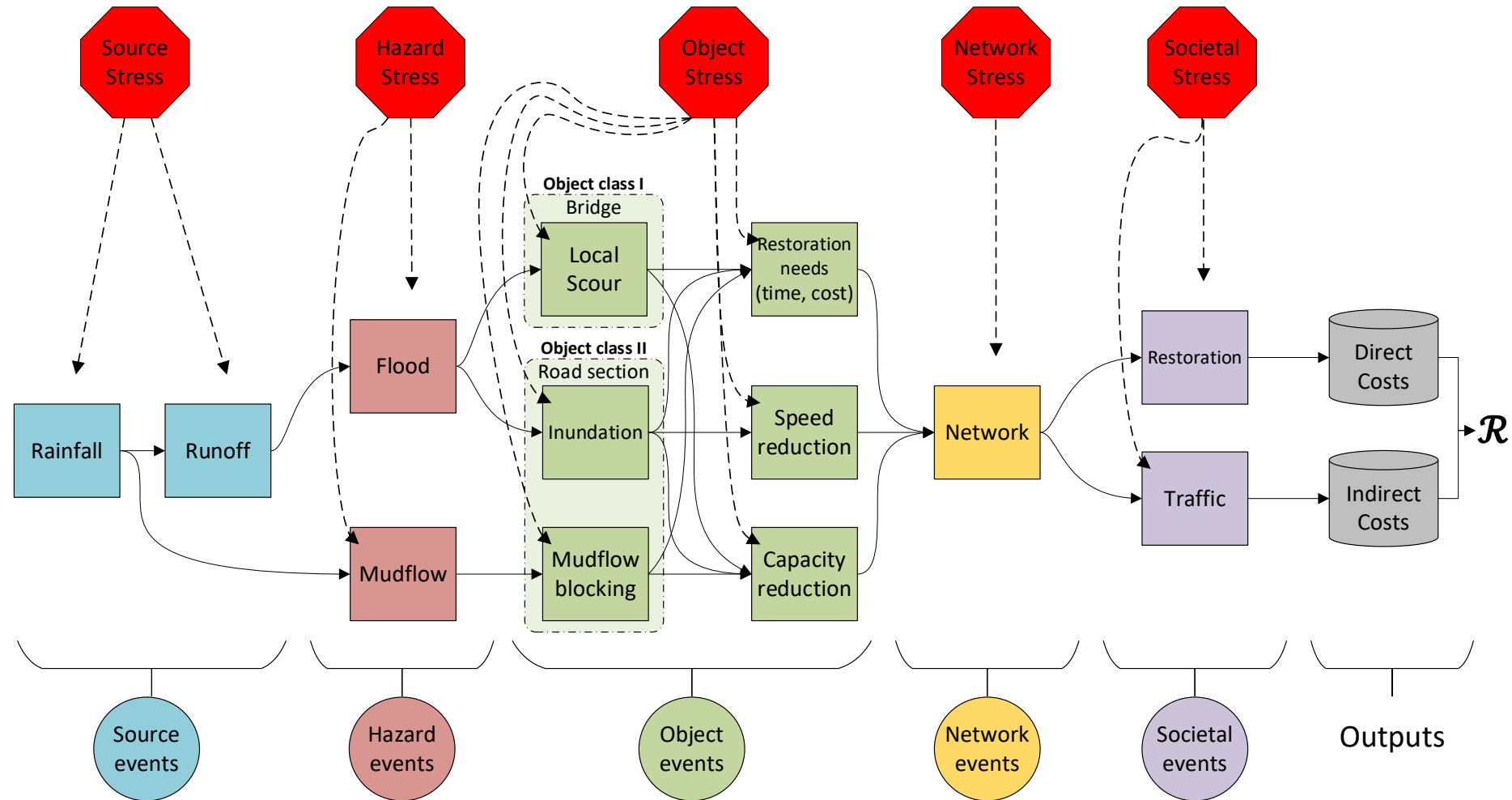
Example potentially disruptive event:
1/500 year
- Damage?
- Time to restoration?
- Cost of restoration?
- Additional travel time?
- Economic impact?
- Fatalities?

https://www.swissinfo.ch/eng/politics/harnessing-nature_politicians-give-chf1-billion-to-prevent-future-rh%C3%B4ne-flooding/45414070

What are the best areas for improvement?
Run stress tests

A stress test is a set of one or more hypothetical scenarios designed to help determine if a transport system can continue to provide an acceptable level of service when
- subjected to one or more potentially disruptive events / one or more <u>potentially disruptive long-term trends</u>

Example long term event:
doubling of traffic
- Increase in traffic jams?
- Costs to modify infrastructure?
- Additional travel time?
- Economic impact?
- Fatalities?

https://www.spiegel.de/wirtschaft/unternehmen/dubiose-diesel-lieferanten-draengen-auf-den-deutschen-markt-verdacht-auf-steuerbetrug-a-7cc97ff5-822d-4868-991d-2363add779eb

How are transport system stressed?
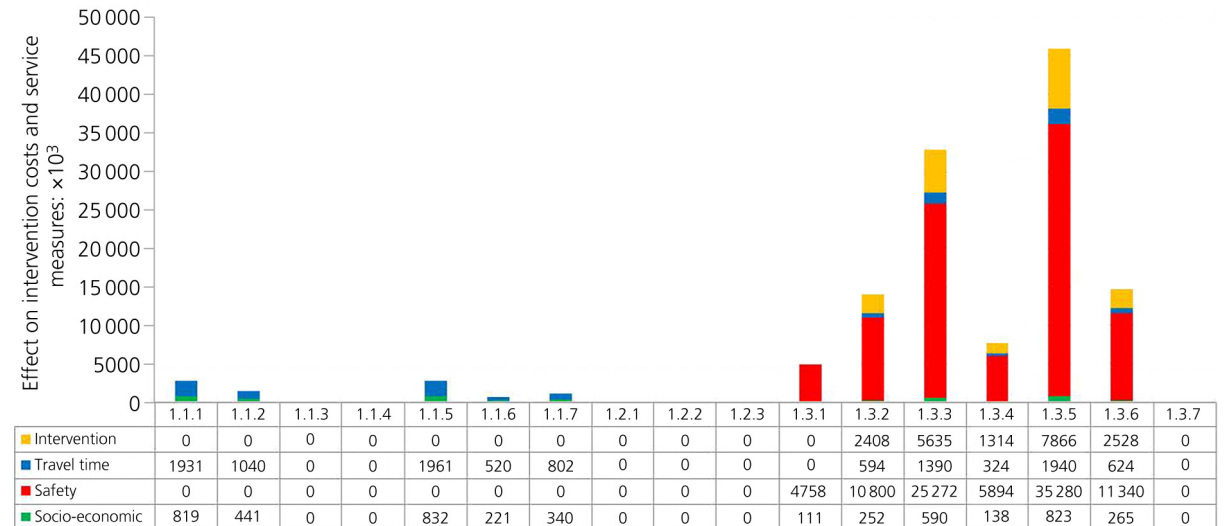## with respect to potentially disruptive events?

What knowledge is gained?
## Insight into if, how, and when our transport system should be modified

Total costs per return period

Cumulatively

Millions

Costs [CHF]

- base
- RCP 2.6
- RCP 4.5
- RCP 8.5

Recurrence Period
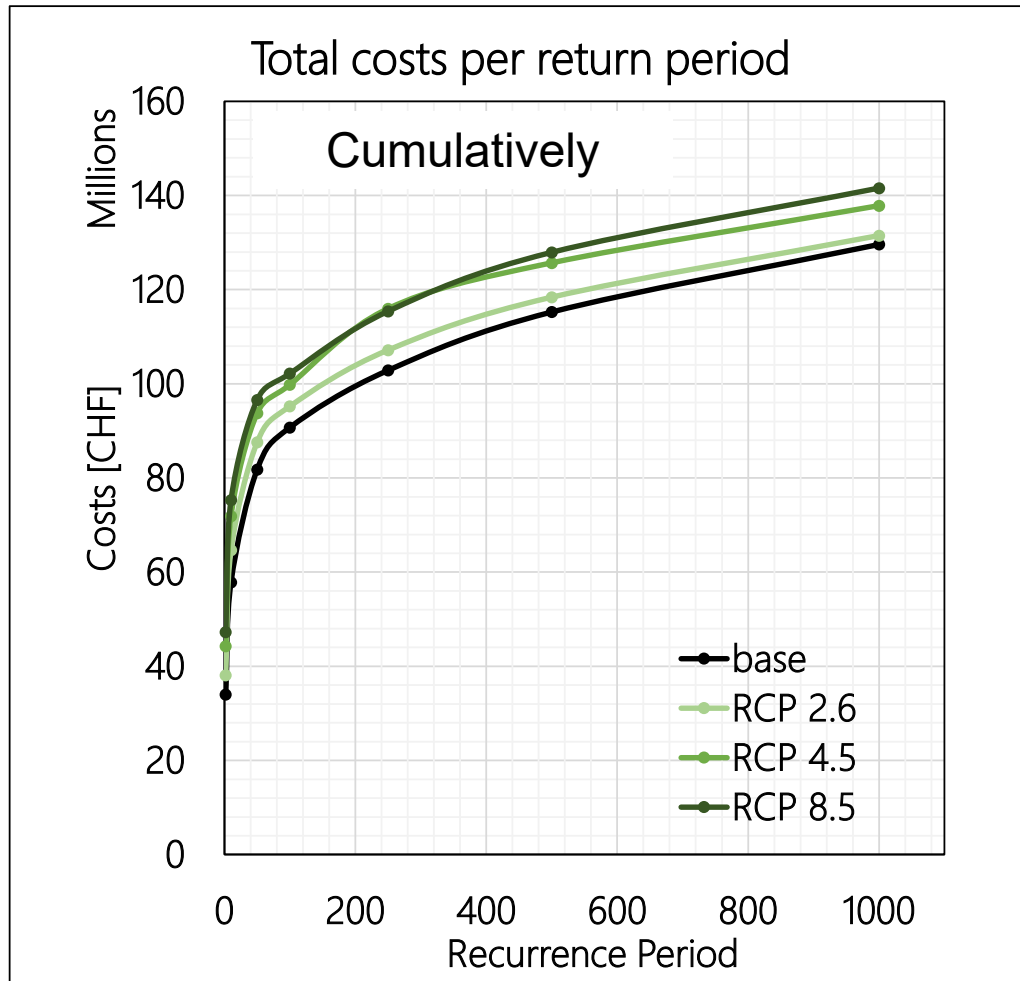
Bar charts pro indicator

Effect on intervention costs and service measures: $\times 10^3$

	1.1.1	1.1.2	1.1.3	1.1.4	1.1.5	1.1.6	1.1.7	1.2.1	1.2.2	1.2.3	1.3.1	1.3.2	1.3.3	1.3.4	1.3.5	1.3.6	1.3.7
Intervention	0	0	0	0	0	0	0	0	0	0	0	2408	5635	1314	7866	2528	0
Travel time	1931	1040	0	0	1961	520	802	0	0	0	0	594	1390	324	1940	624	0
Safety	0	0	0	0	0	0	0	0	0	0	4758	10 800	25 272	5894	35 280	11 340	0
Socio-economic	819	441	0	0	832	221	340	0	0	0	111	252	590	138	823	265	0

Martani, C., Adey, B.T., Robles, I., di Gennarod F., Pardi, L., Beltran-Hernando, I., Concepcion Toribio Diaz, I., Jimenez Redondo, N., Antonio Moli Díaz, A., (2021), Estimating the resilience of, and targets for, a transport system using expert opinion, Special Issue: Resilient infrastructure for improved disaster management, Infrastructure Asset Management, 8(4), 191-208, DOI: 10.1680/jinam.20.00029
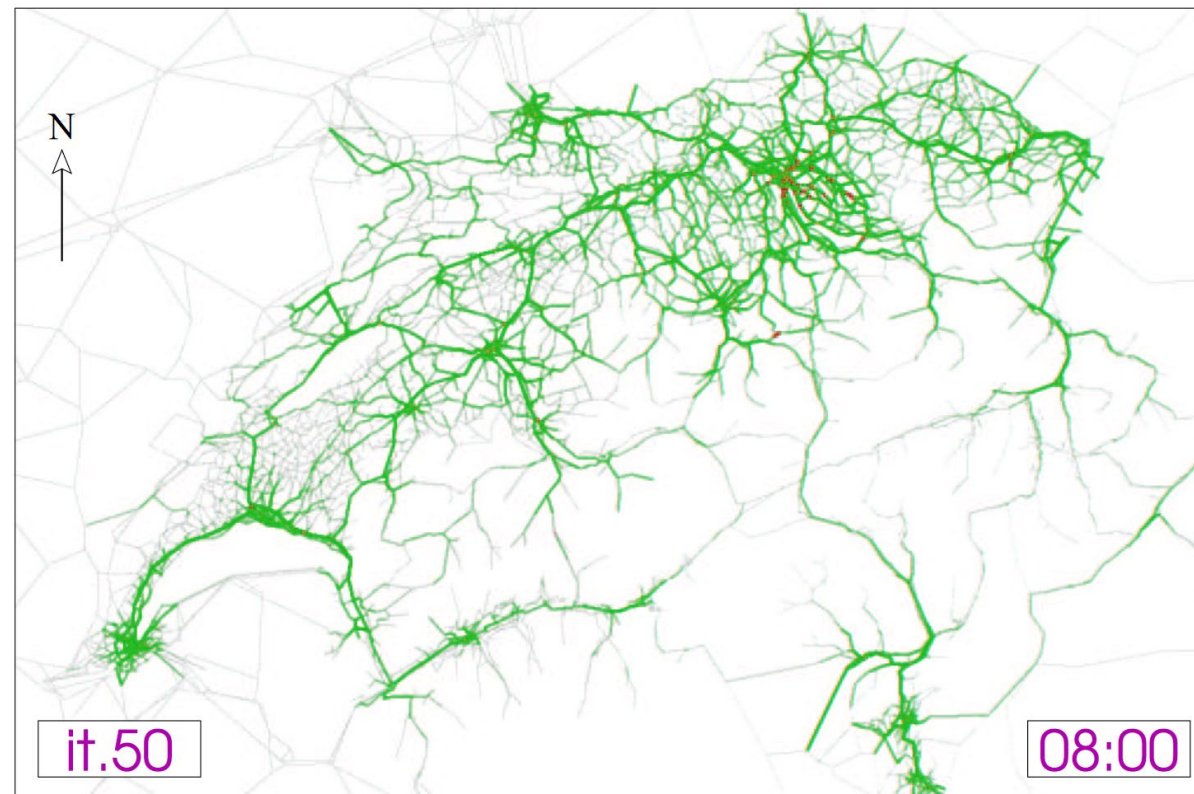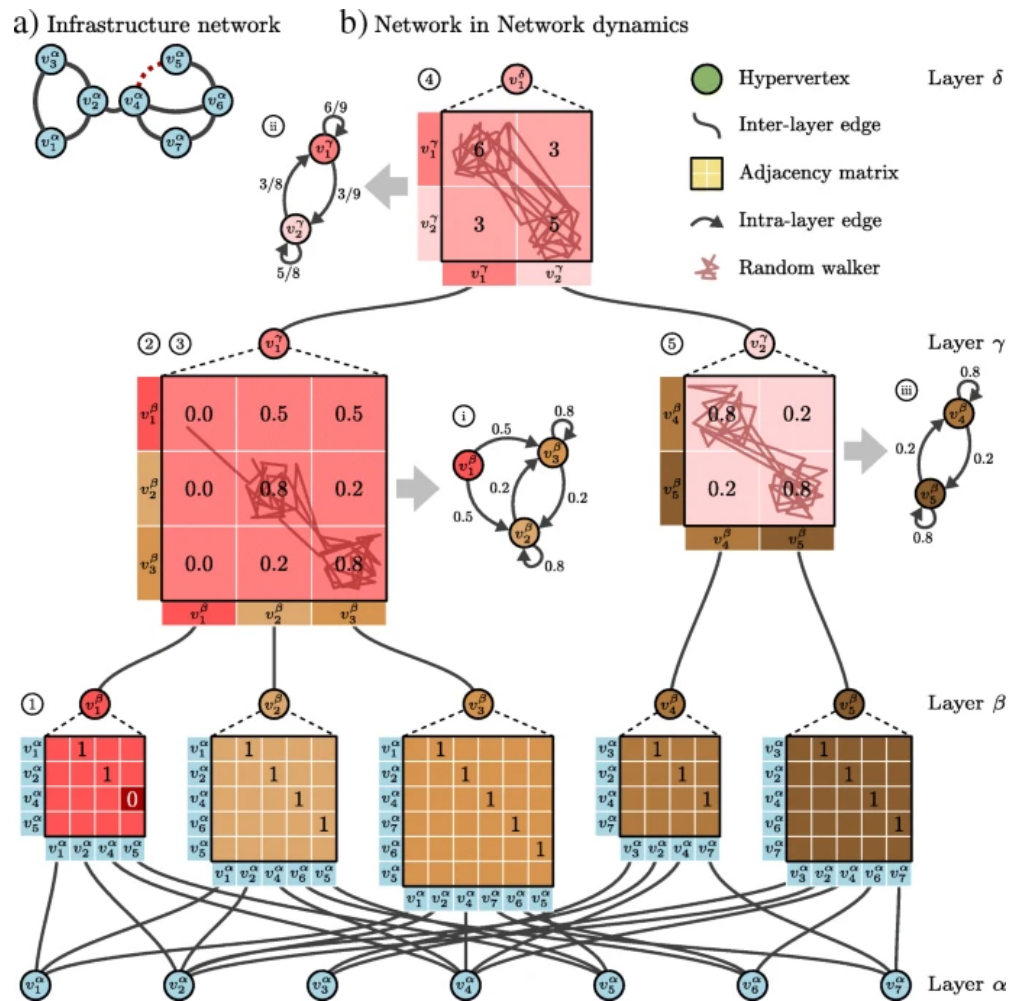
What knowledge is gained?
Insight into if, how, and when our transport system should be modified
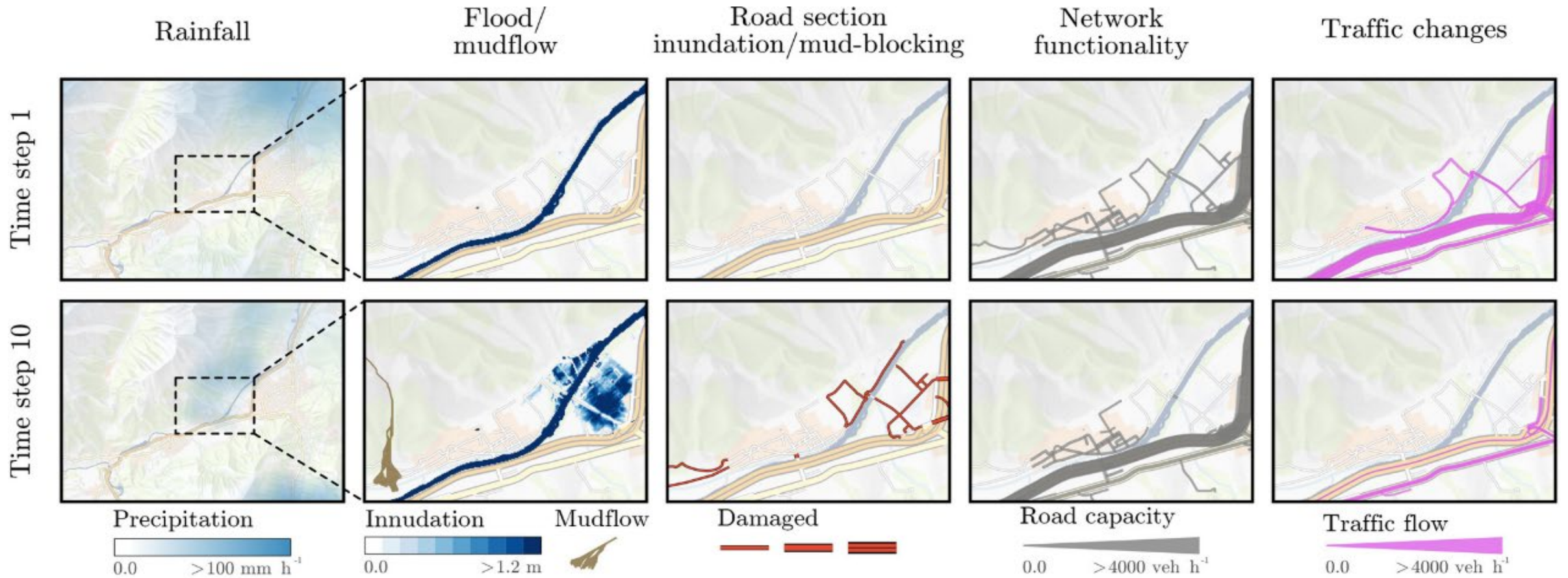
Hackl, J., Lam, J.C., Heitzler, M., Adey, B.T., Hurni, L., (2018), Estimating network related risks: a methodology and an application for roads, Natural Hazards and Earth System Sciences, 18, 2273–2293 DOI: 10.5194/nhess-18-2273-2018

How are transport systems stressed?
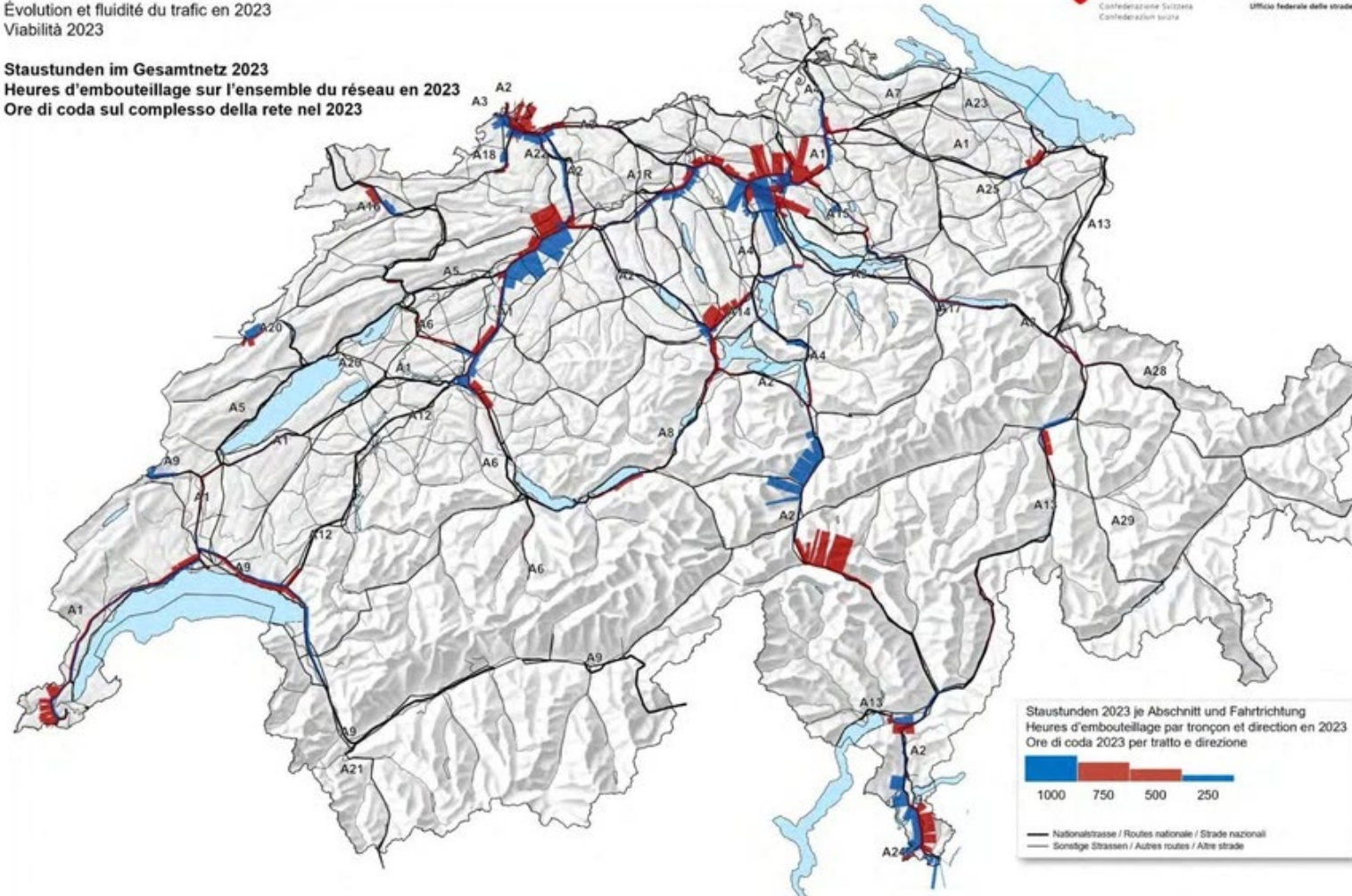## with respect to a long-term trend?

Hackl, J., Adey, B.T., (2019), Estimation of traffic flow changes using networks in networks approaches, Applied Network Science, 4:28, DOI: 10.1007/s41109-019-0139-y, 26 pages.

What knowledge can be gained from such a stress test?
Insight into if, how and when our transport system should be modified

How is it best to modify the transport system?
Adaptive plans addressing long-term trends

- Generate random access points
- Filter points based on land use and land cover
- Connect generated access point to closest existing highway access (Euclidean distance)
- From beeline connection to possible highway routing considering landcover and land use

Generate access points

0   1   multiples
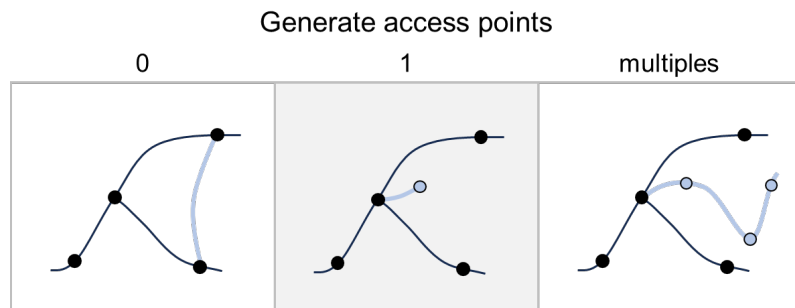
- ● Existing highway infrastructure
- ○ Generated bifurcations
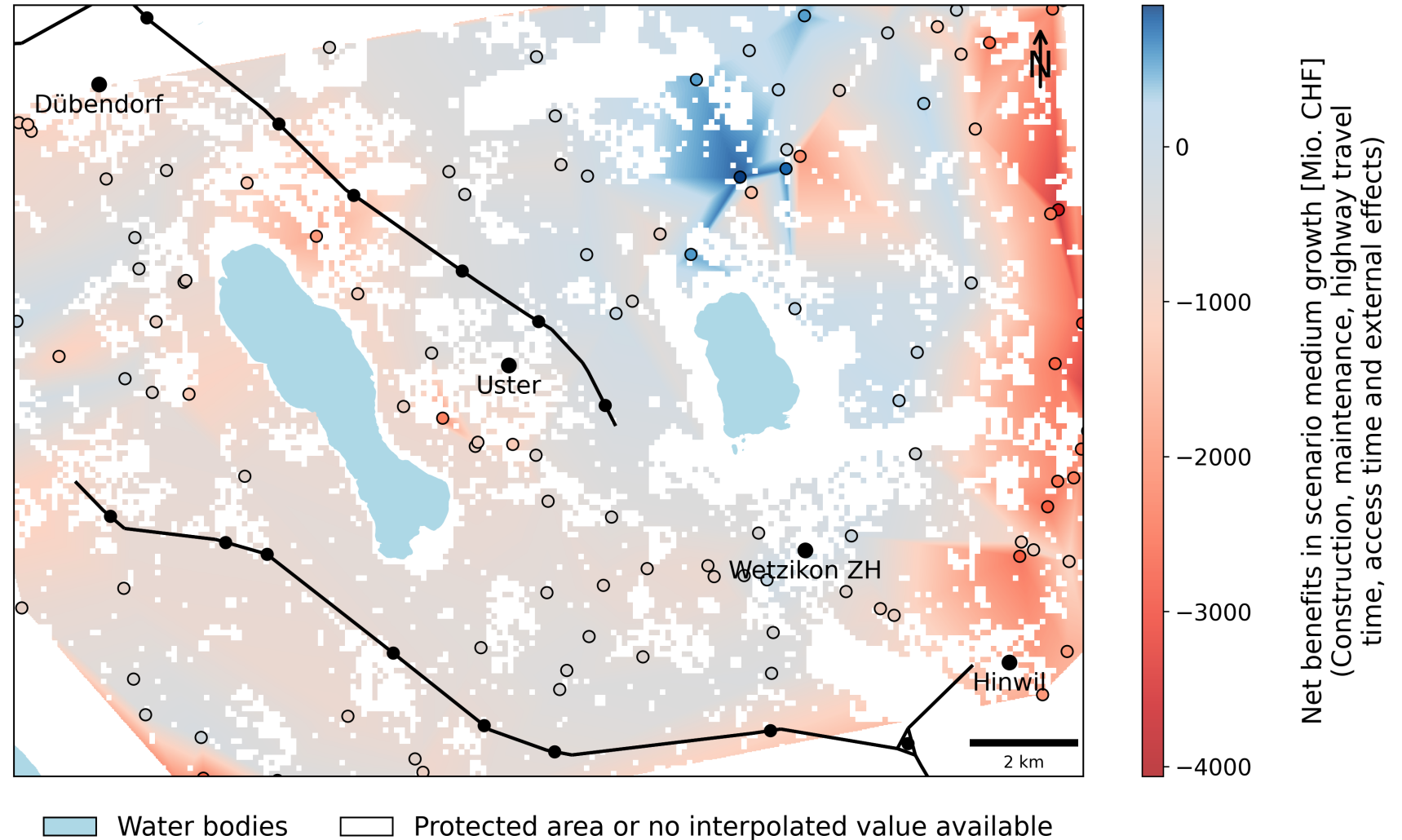- ● Generated access points
- ～ Generated links
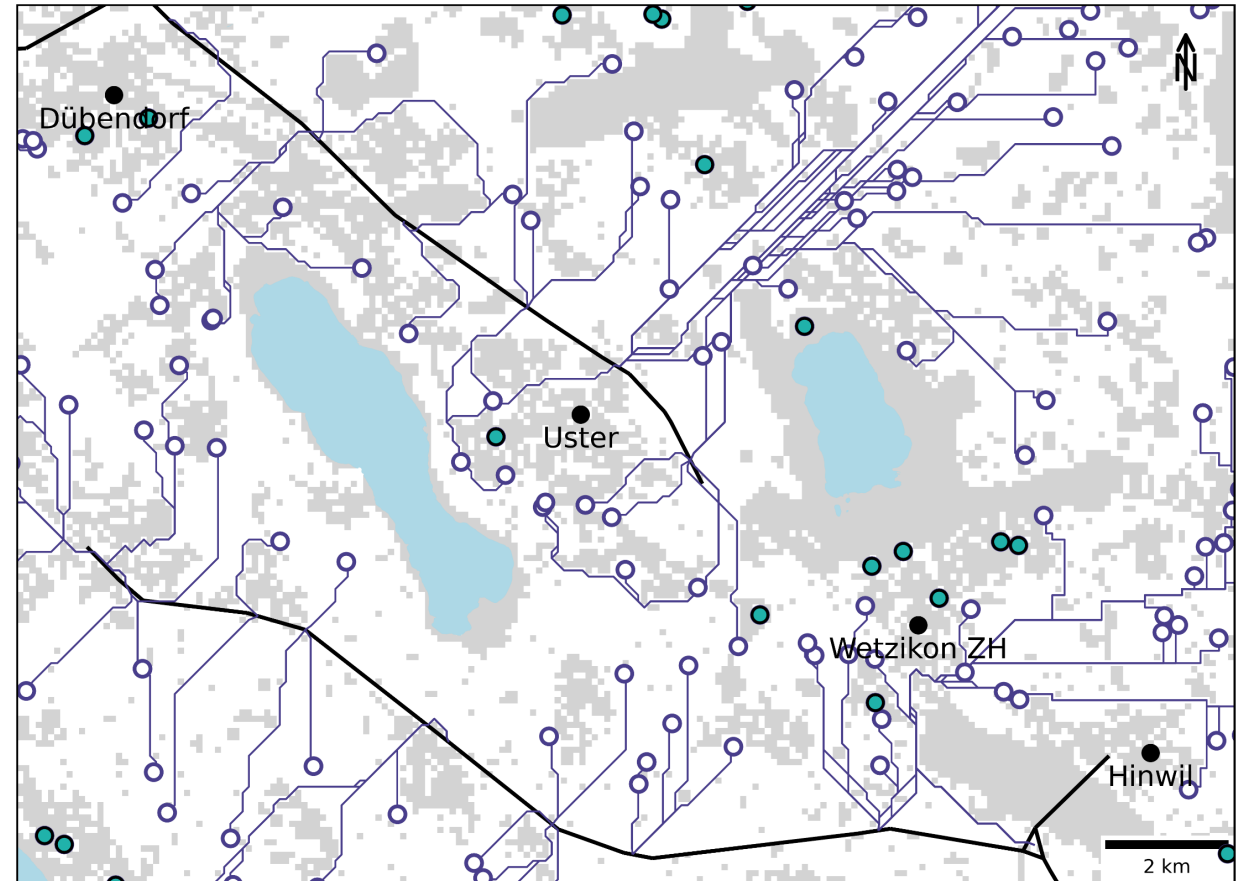
Legend
— Current highway network
○ Generated points
● Deleted points
— Generated links
▨ Water bodies
▨ Infeasible area

How is it best to modify the transport system?
## Adaptive plans addressing long-term trends

Marggi, F., Elvarsson, A., Adey, B.T., (2024) Implementing early-stage highway planning support in Dübendorf-Hinwil considering uncertain land-use and mobility demand, Swiss Transport Research Conference, May 15-17, Ascona, Switzerland.

Net benefits in scenario medium growth [Mio. CHF] (Construction, maintenance, highway travel time, access time and external effects)

Water bodies   Protected area or no interpolated value available

B.T.Adey

How is it best to modify the transport system?
Adaptive plans addressing long-term trends

Example: The Swiss A53 highway extension
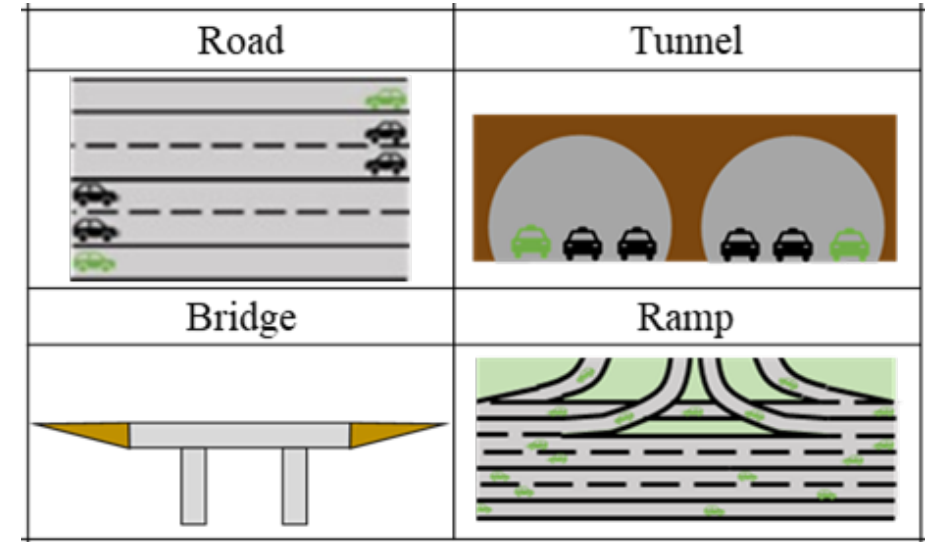
Martani, C., Eberle, S., Adey, B.T., (2022), Evaluating highway designs considering uncertain mobility patterns and flexibility using real options, Infrastructure Asset Management, 9(3), pp. 135–155, DOI: 10.1680/jinam.21.00018

- Convert the highway into 3 separate-traffic lanes per direction

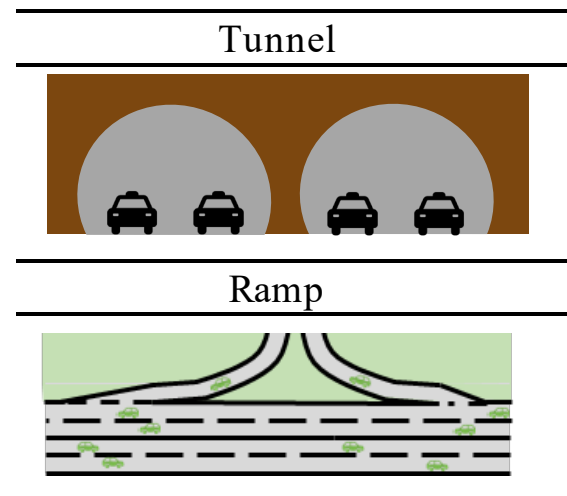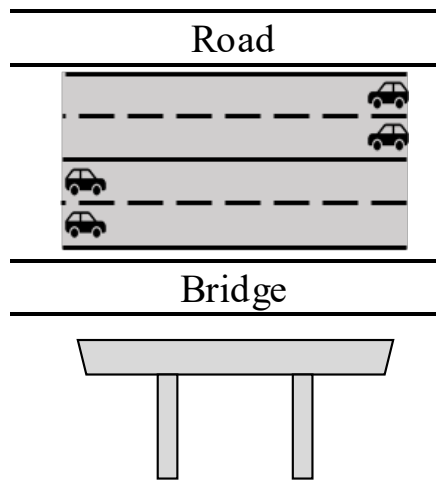- triggered when the number of human driven vehicles is higher than 10'000 per hour

Can infrastructure be designed to make changes easy?
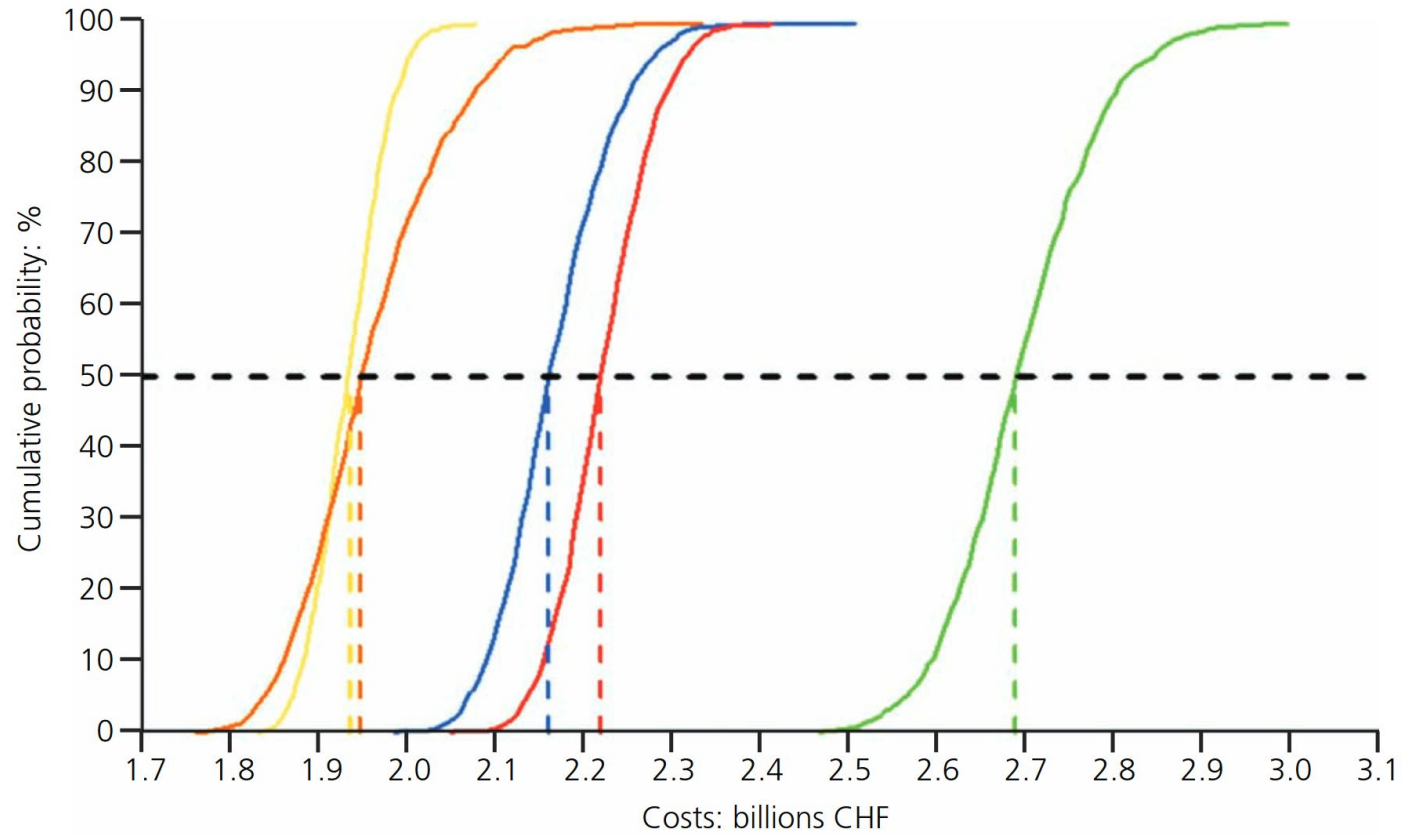## Flexible infrastructure addressing long-term trends

Example: The Swiss A53 highway extension

Flexible Infrastructure

- two lanes in each direction, for the use of both human-driven vehicles and autonomous vehicles (mixed traffic)

- the bridges are designed with the load bearing capacity to enable an extension of a third lane per direction, and the tunnels are excavated from the beginning with the width required to accommodate a third lane per direction

- the on and off ramps are designed as bridges to allow a third lane to pass underneath

ETH zürich   B.T.Adey

Is it worth it?

Conclusions

Potentially disruptive events and long-term trends may require modifications to transport systems

Where and how is hard to determine

Stress tests help

They can lead to the development of adaptive plans

Flexible infrastructure can help the implementation of adaptive plans

It has to be worth it though

Aerial view of the north portal of the motorway tunnel *Aeschertunnel* and parts of the ramps of the A3/A4 exit "Birmensdorf".