ISSUES CONNECTED WITH INDIRECT COST QUANTIFICATION: A FOCUS ON THE TRANSPORTATION SYSTEM

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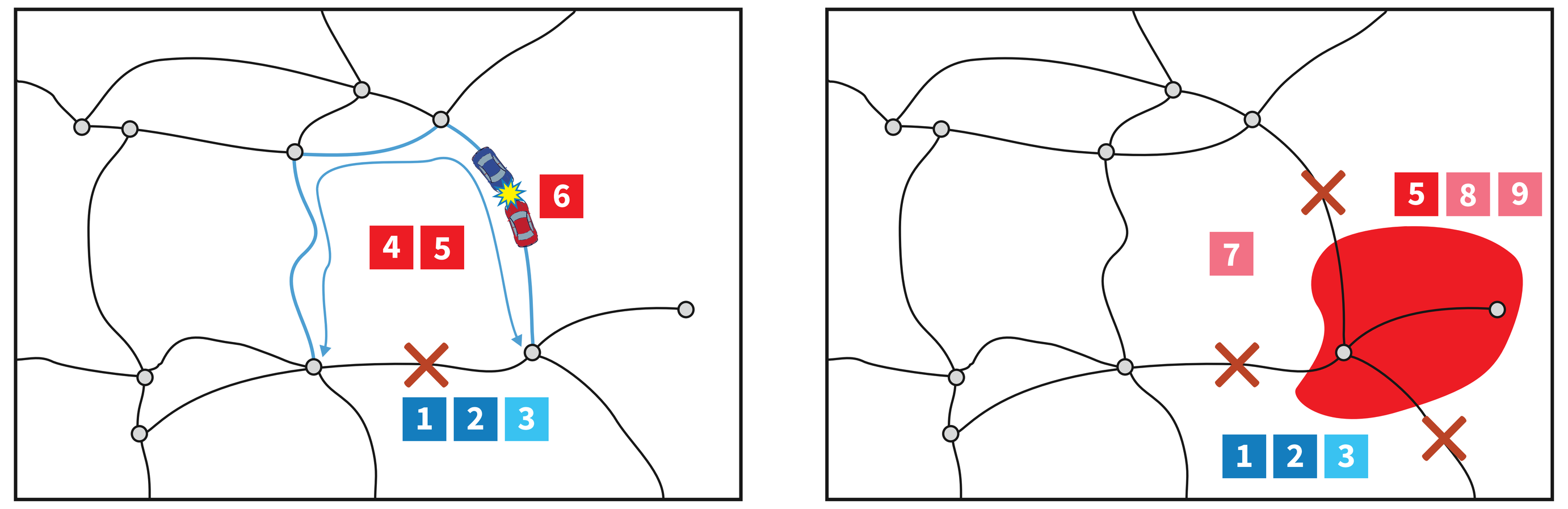
Introduction

The economy relies heavily on transportation system performance. Natural hazards have the potential to disturb transportation systems. Earthquakes, flooding or landsliding are examples of high-energetic processes which can cause direct losses (i.e. physical damage to the infrastructure). Whereas evidence of repair work and general direct costs usually exists or can be estimated, indirect costs are much more difficult to identify particularly when they are not covered by insurance agencies.

Indirect losses

Delimitations of alternative routes (detours) are the most frequent responses to blocked road links. Indirect costs can then be related to increased fuel consumption and additional operating costs. Detours usually result in prolonged travel times. Indirect costs quantification has to therefore cover the value of the time. The costs from the delay are, however, a nonlinear function of travel time. The existence of an alternative transportation pattern may also result in an increased number of traffic crashes. This topic has not been studied in depth but an increase in traffic crashes has been reported when people suddenly changed their traffic modes. The lost user benefit from those trips cancelled or suppressed is also difficult to quantify. No widely accepted methodology is available, however.

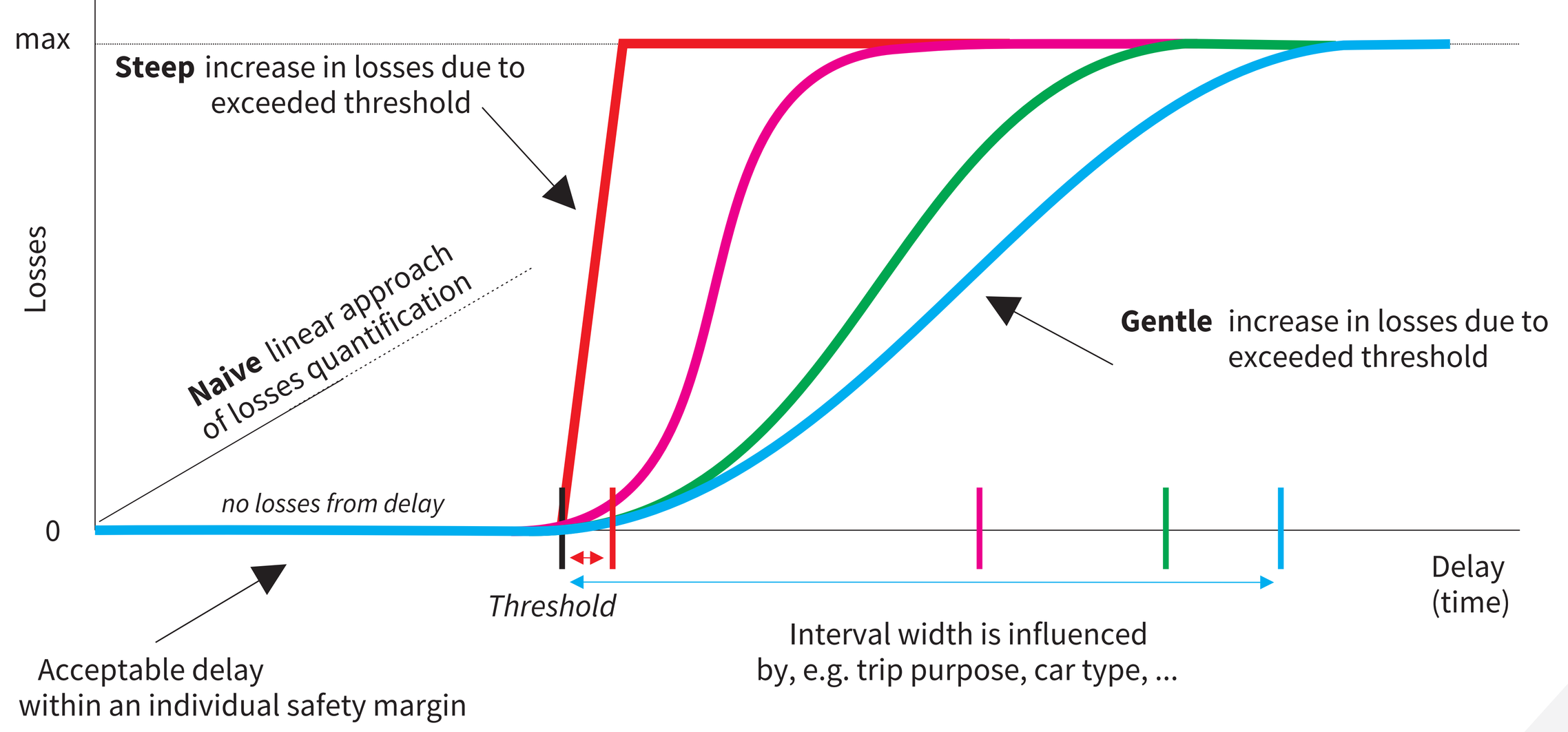
Impacts of natural hazards to road network



	DIRECT	INDIRECT
TANGIBLE	1 damage to infrastructure 2 mitigation	4 extra fuel 5 losses and delays to related companies 6 costs of traffic crashes on detours
INTANGIBLE	3 loss of life, injuries	7 lost benefit from cancelled trips 8 trauma from isolation 9 emotional loss to tourists

inspired by Merz et al., 2010

What is the value of the time?


max
Losses
0
Steep increase in losses due to exceeded threshold
Naive linear approach of losses quantification
Gentle increase in losses due to exceeded threshold
no losses from delay
Threshold
Delay (time)
Acceptable delay within an individual safety margin
Interval width is influenced by, e.g. trip purpose, car type, ...

Related publications:

Bíl, M., Vodák, R., Kubeček, J., Bílová, M., Sedoník, J. (2015): **Evaluating road network damage caused by natural disasters in the Czech Republic between 1997 and 2010**, Transportation Research Part A: Policy and Practice 80, 90–103.

Vodák, R., Bíl, M., Sedoník, S. (2015): **Network robustness and random processes**, Physica A: Statistical Mechanics and its Applications 428, 368–382.

Bíl, M., Kubeček, J., Andrášik, R. (2014): **An epidemiological approach to determining the risk of road damage due to landslides**, Nat Haz. 73 (4), 1323–1335.

Bíl, M., Vodák, R. (2014): **The stochastic approach in road network vulnerability analysis**, Safety and Reliability: Methodology and Applications – Nowakowski et al. (Eds), 929–932.

Merz, B., Kreibich, H., Schwarze, R., Thieken, A. (2010): **Review article "Assessment of economic flood damage"**. Nat Haz. Earth Syst Sci, 10, 8, 697–1724.

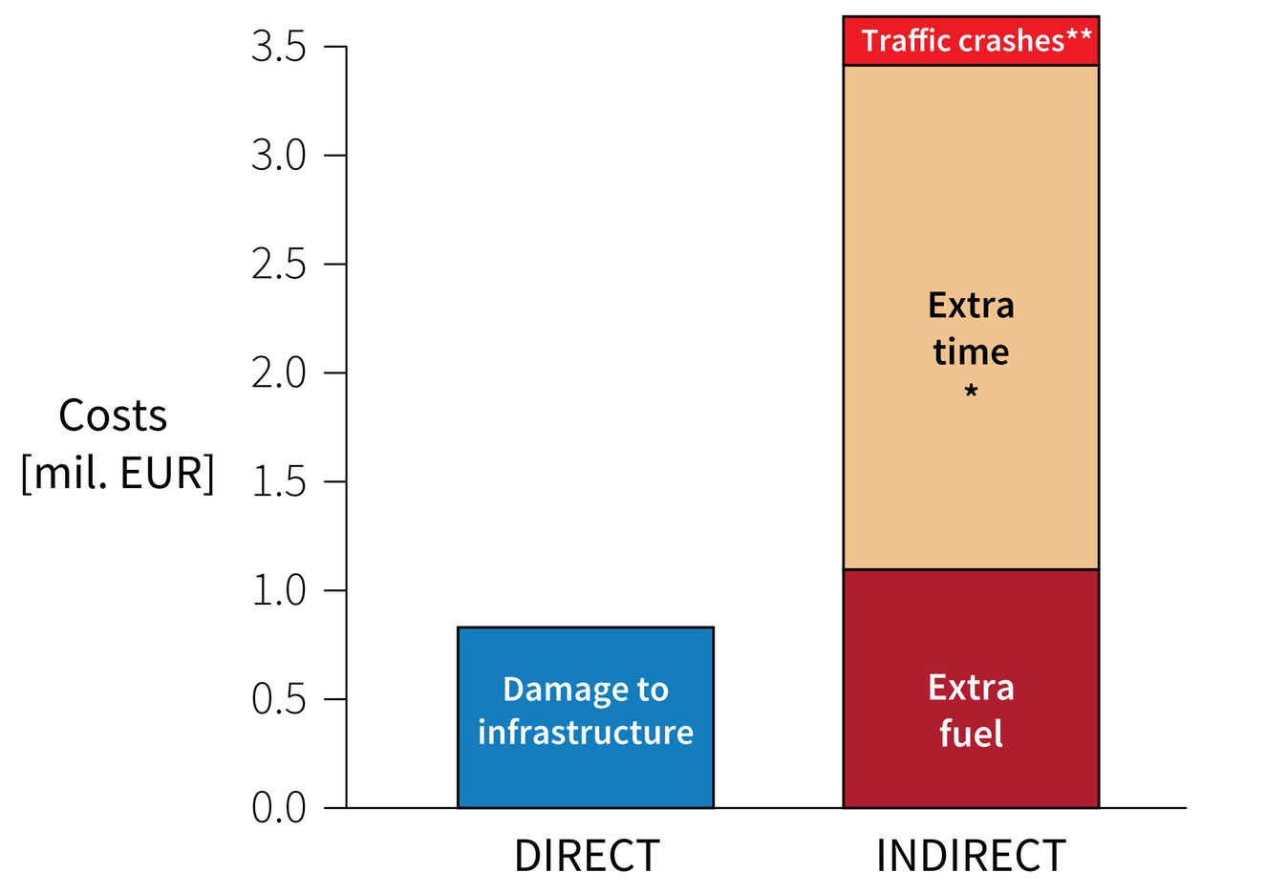
MacLeod, A., Hofmeister, R. J., Wang A., Burns, S. (2005): **Landslide indirect losses: Methods and case studies from Oregon**

Case study

A landslide which took place near the II/432 road was the most damaging result of floods in May 2010. The road had to be completely closed due to ongoing movement of subsoil until it was repaired. It lasted approximately five months.

The length of the detour was 38 km for passenger cars and 56 km for heavy vehicles, while the closed road link was 2 km long only. Detour costs per one day of closure can be calculated as follows:

» **Detour time (DT)** – average time needed for passing the links on the detour
» **Operating costs (OC)** – value of time of each person in a car multiplied by average car occupancy
» **Extra fuel (EF)** – length of detour times the average consumption of fuel per 100 km
» **Number of travelers (NT)** – average daily traffic
» **Traffic crashes** – costs of traffic crashes on the detour due to increased traffic intensity



Detour cost formula (according to MacLeod et al., 2005):

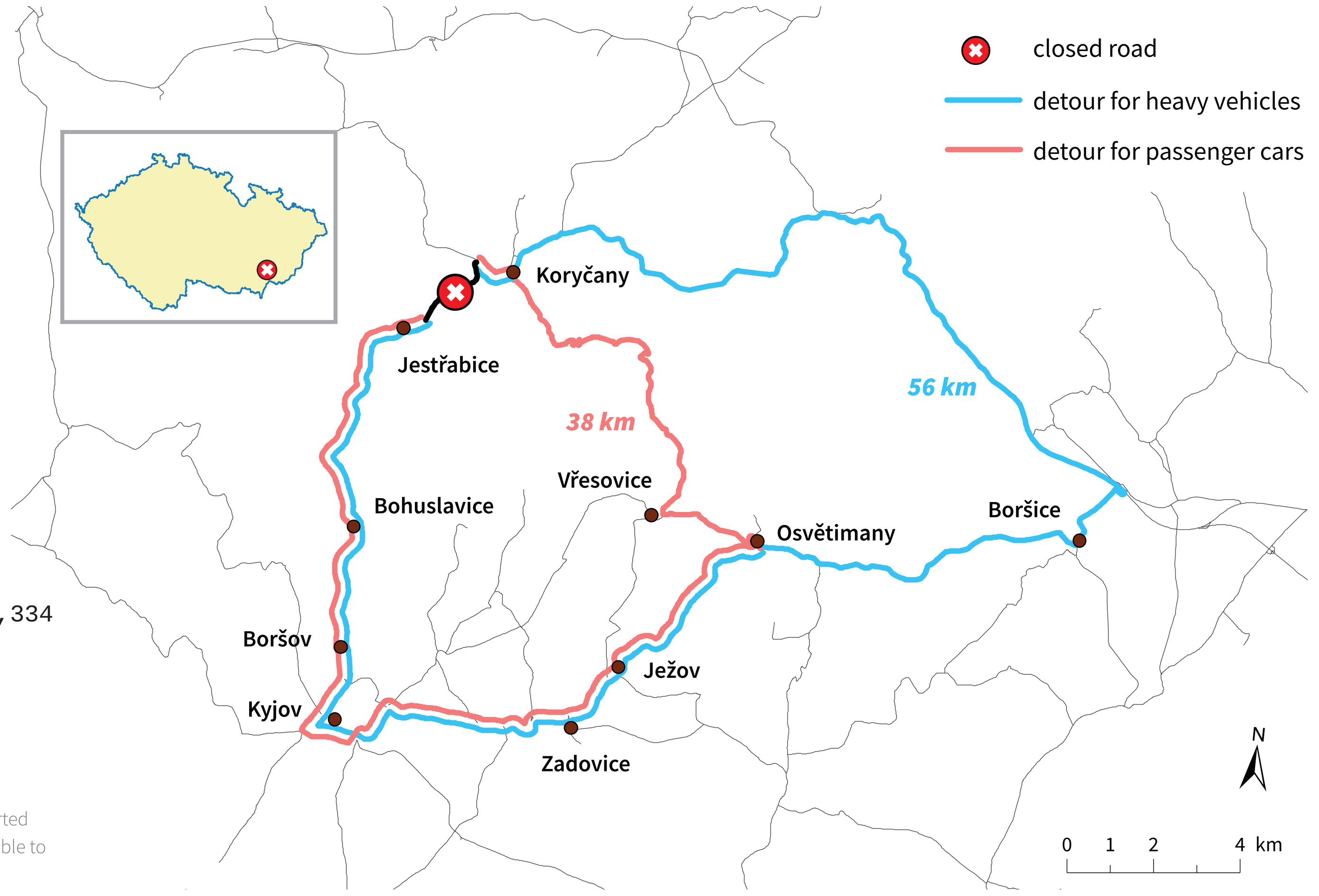
= [DT × OC + EF × price of fuel] × NT

Detour cost of case study:

```
=   [0.85 × (10.76×1.9) + (6×38/100) × 1.26] × 3,334
=   67,499 EUR per day for passenger cars
...
=   9,140 EUR per day for heavy vehicles
...
TOTAL costs: EUR 3 414,229 per five months
```

*Unscheduled blockages may have significant impacts as drivers who have already started their trips are unaware of these events. Scheduled or long-term blockages – users are able to prepare for a longer trip, they also can change traffic mode or postpone the trip.

**Number of traffic crashes increased by 10.23: Costs of crashes = 10.23 × 21,883.41 = EUR 223,845



Historical data from 1997 to 2010
Road management and maintenance services, Road administrators, printed sources, Internet
&
Online traffic information data since 2010 (JSDI)

112 – Police, Fire Brigade, Ambulance, Road administrators

DATA IMPORT

» sorting
» filtering
» SQL querying
» updating

Spatial database POSTGIS
Interruptions of roads

Road interruptions from 1997 – 2014
STATIC DATA

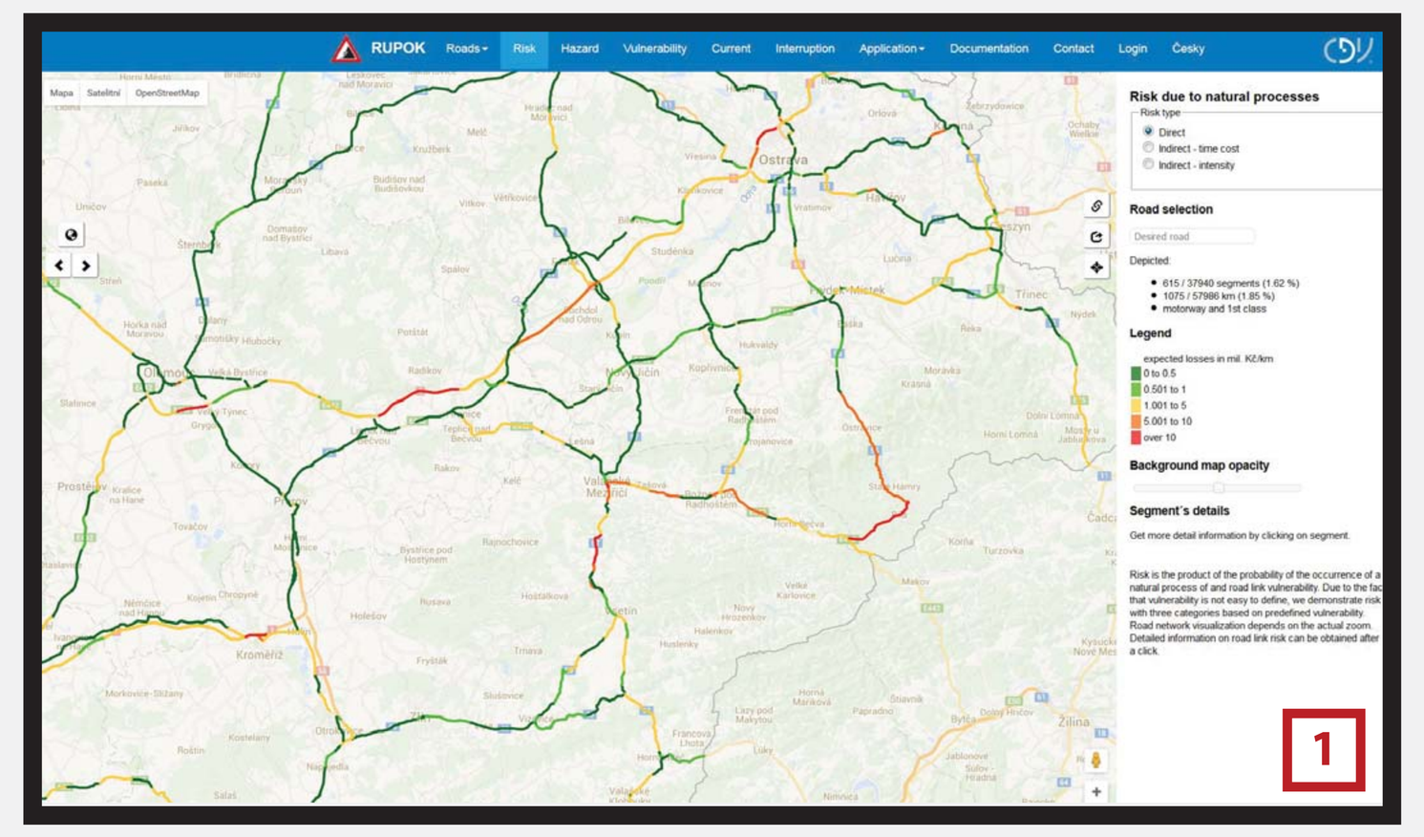
Current interruptions
DYNAMIC DATA

RUPOK WEB MAP

Visualisation
» Google API
» Open Street Map

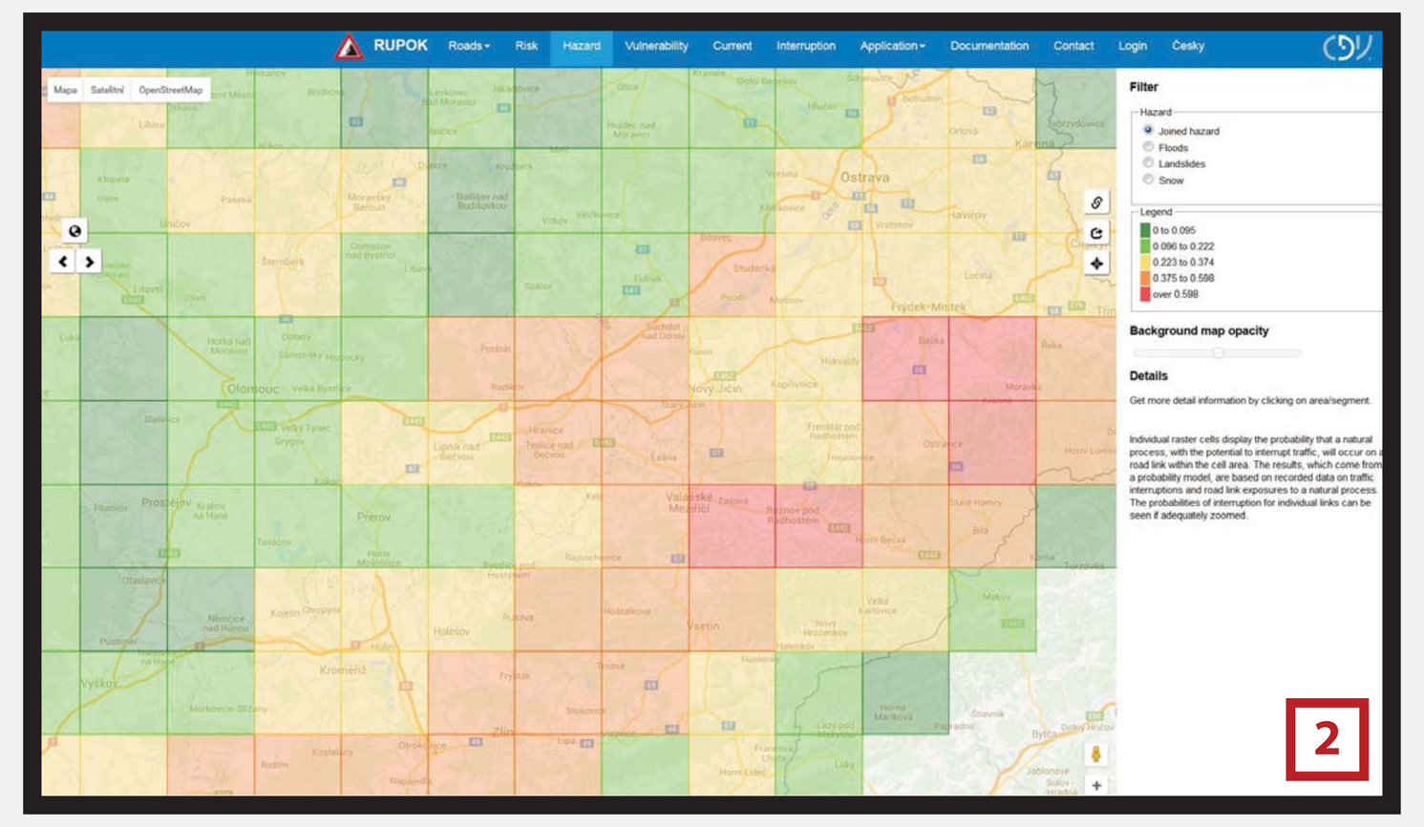
Risk

» computed as a product of possible impacts and the probability of occurrence of such natural process which is capable of interrupting a road section



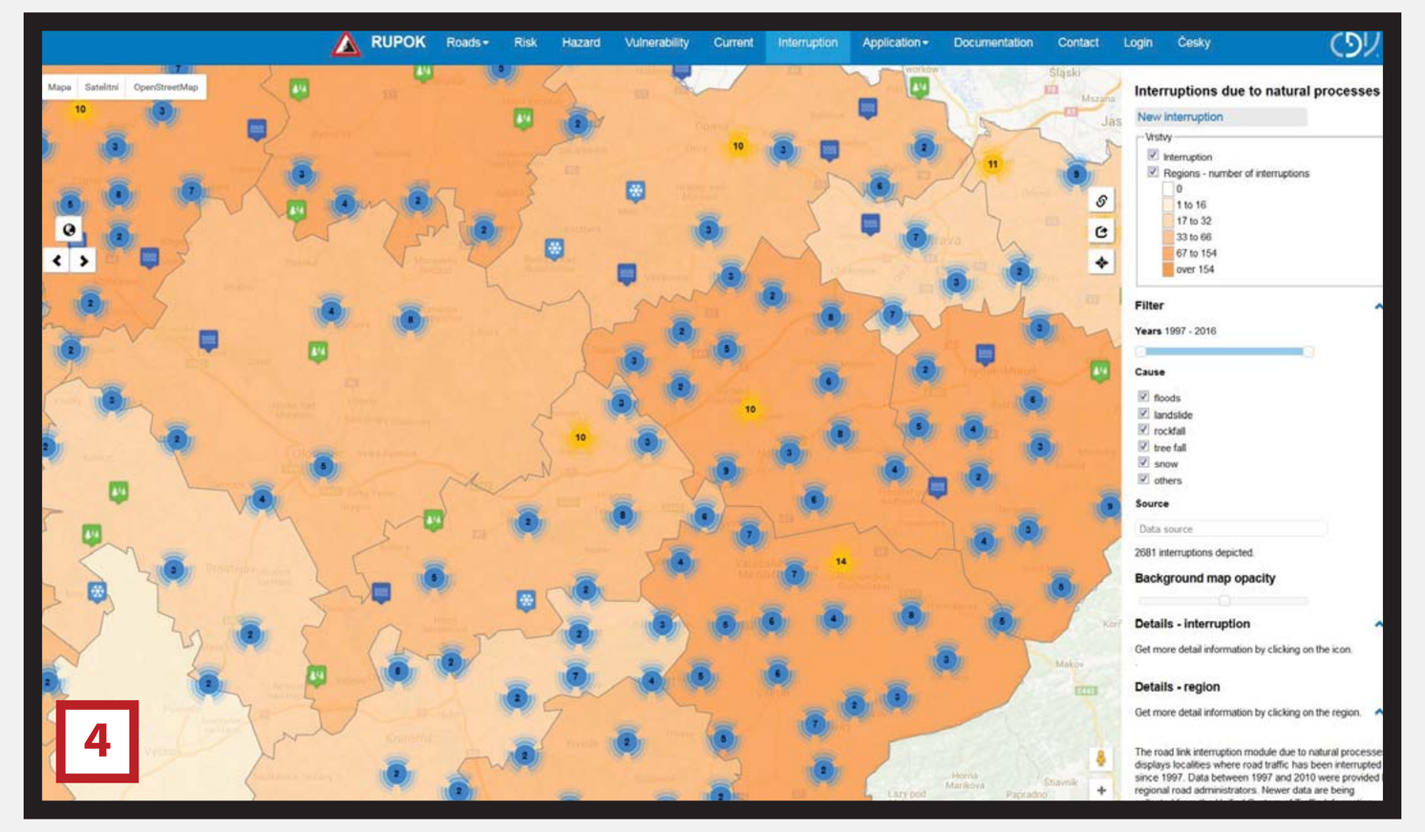
Hazard

» of sufficient energy to interrupt a section)
» on two zoom levels:
» a grid
» individual road sections
» natural processes (flooding, landsliding and snow)



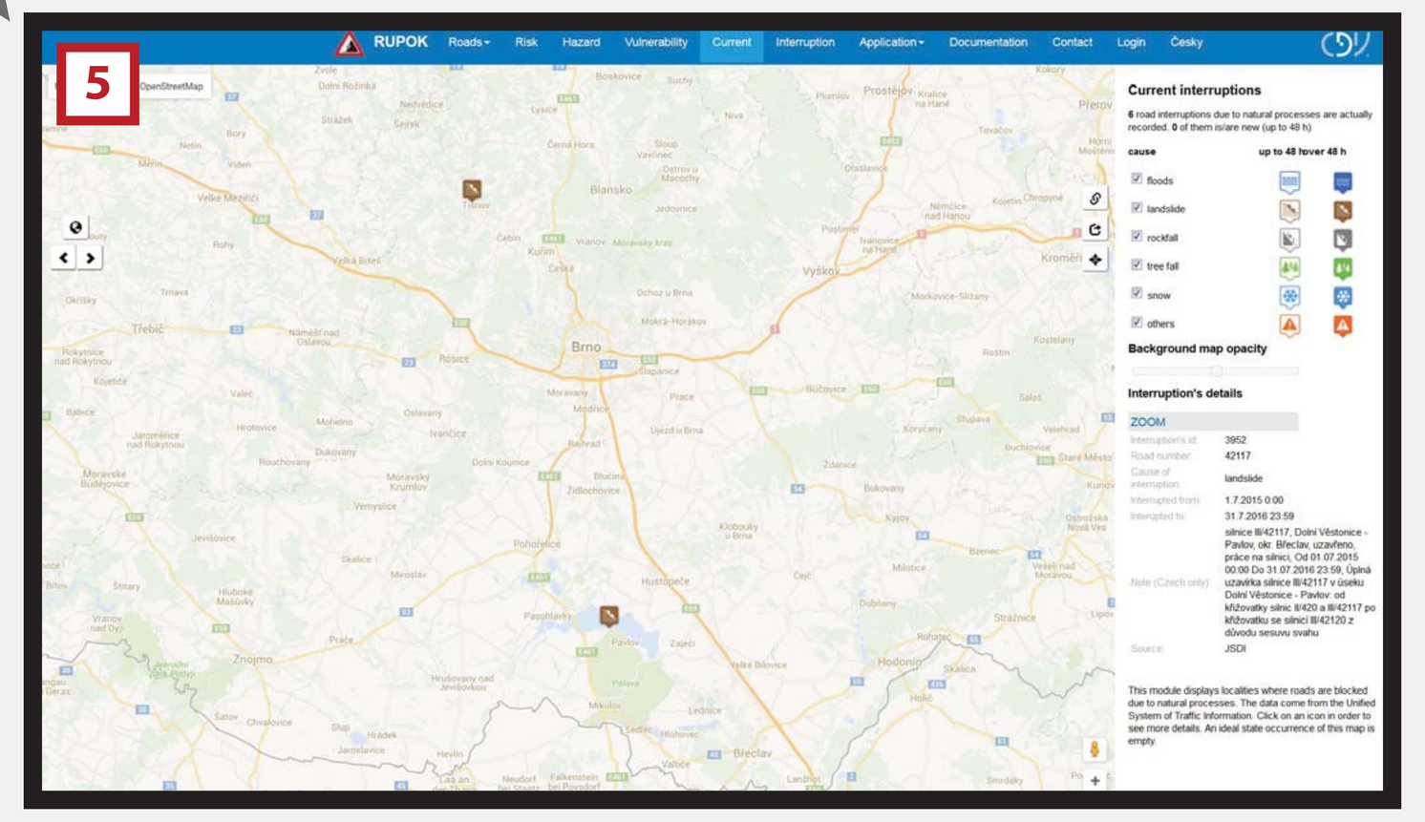
Interruption

» spatial database
» from 1997 to present
» natural processes (floods, landslide, rockfall, tree fall, snow)



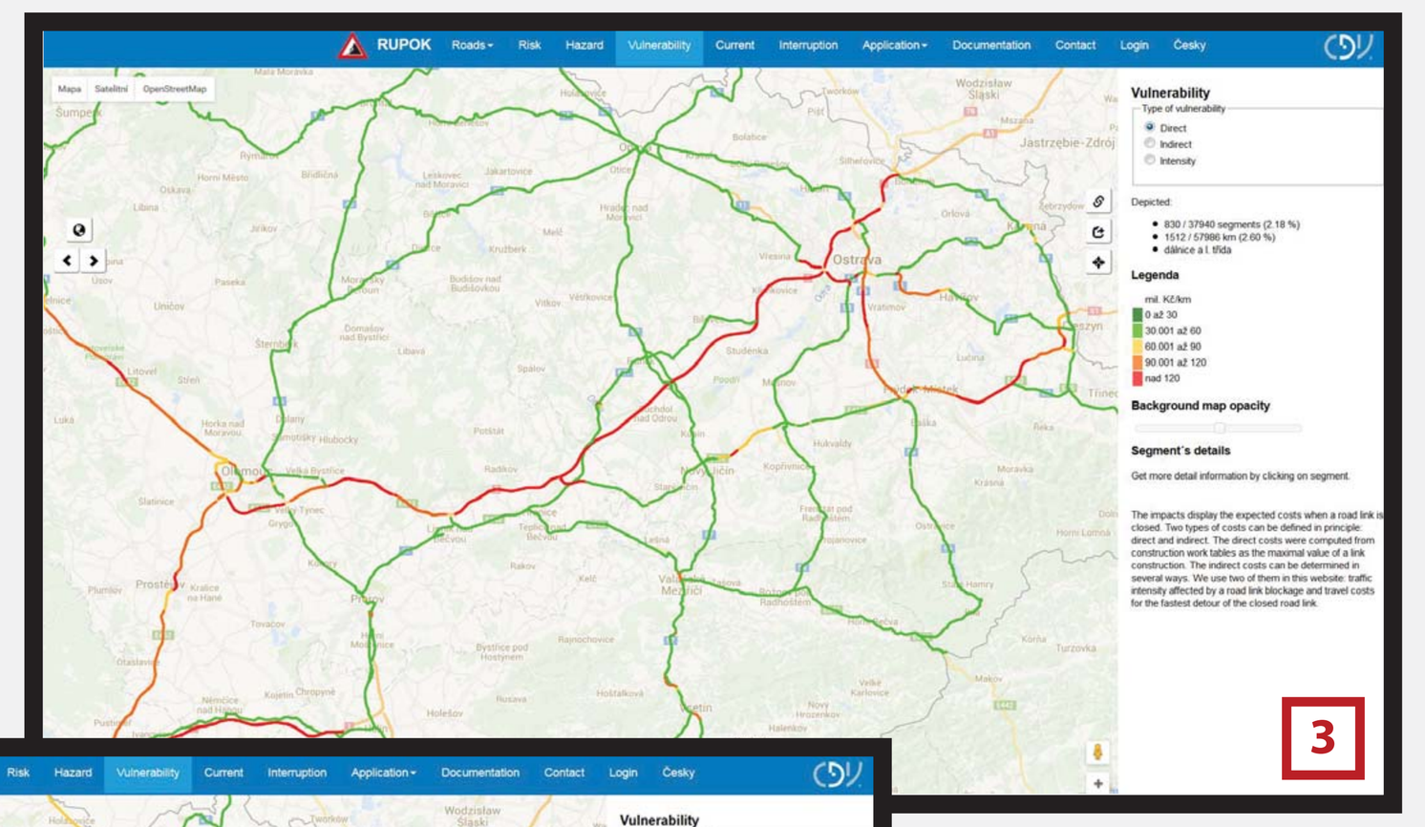
Current

» began up to 48 hours
» continuing

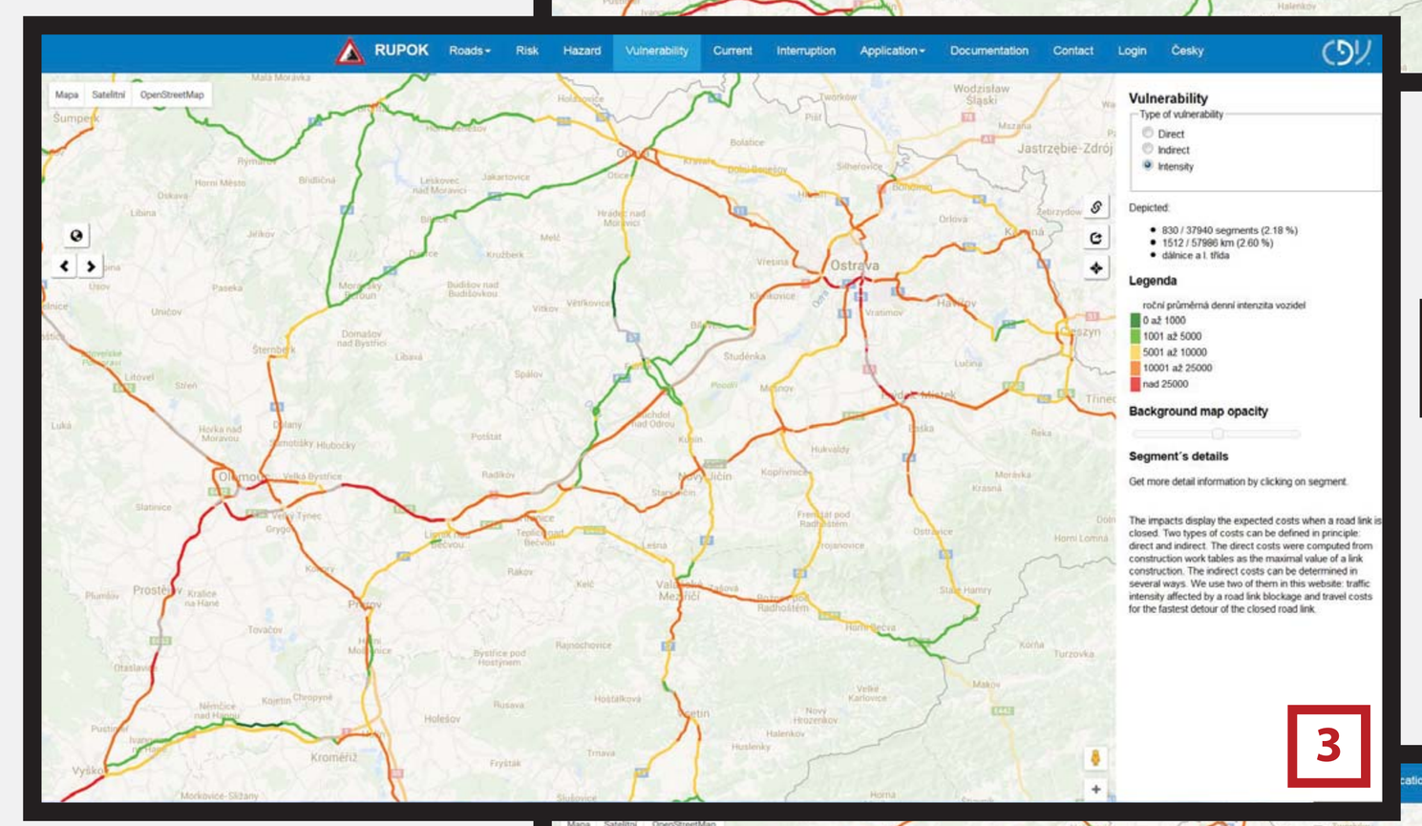


Vulnerability

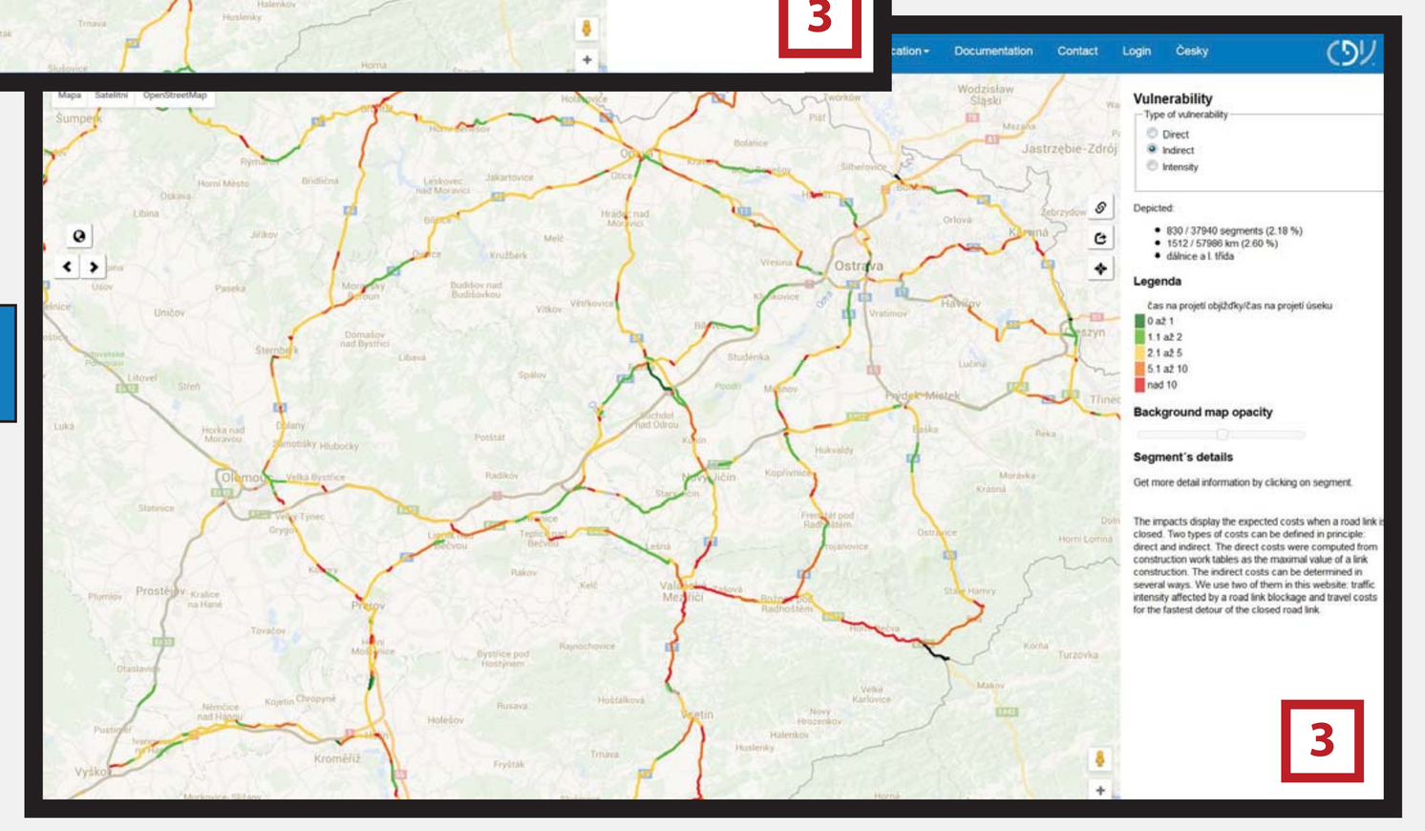
Direct – Cost of remedial works
» as monetary values per road section unit
» calculated from official tables containing prices for construction works

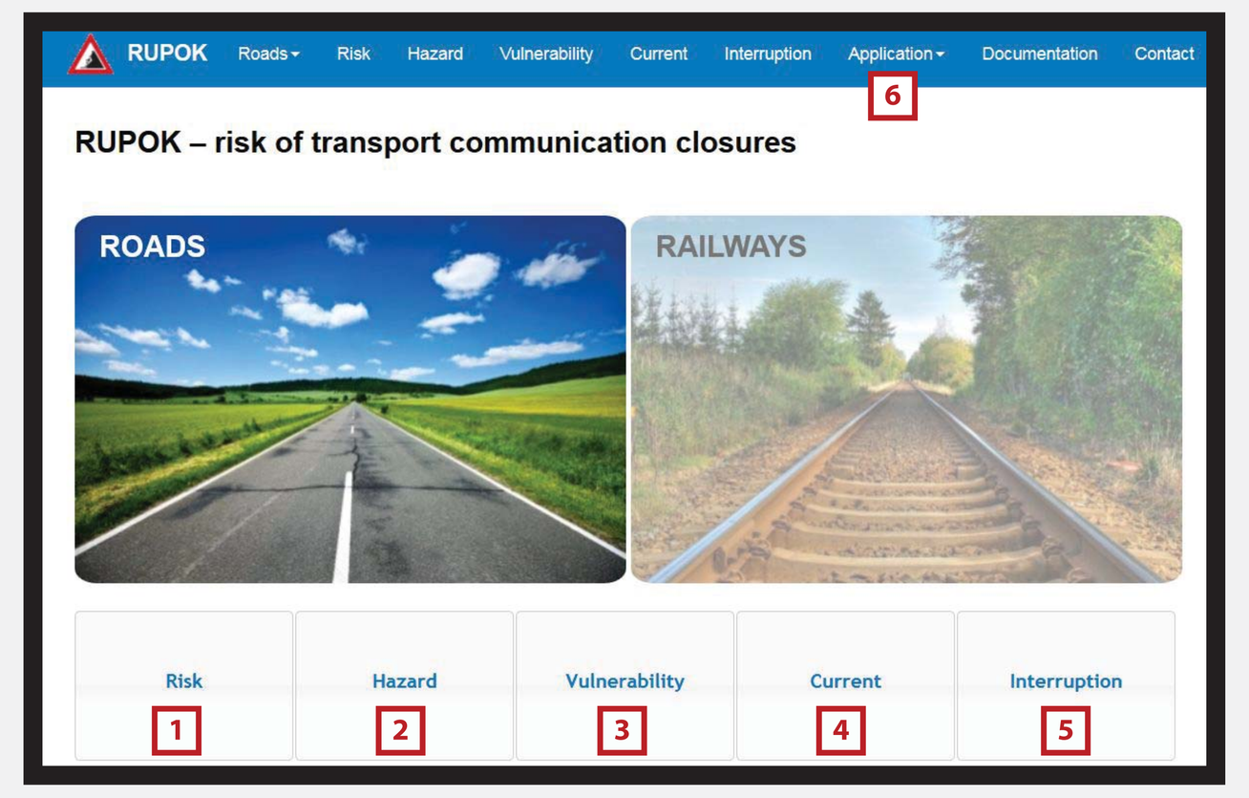


INDIRECT – Traffic intensities



INDIRECT – Travel costs
» costs as time needed for the fastest detour of a blocked link

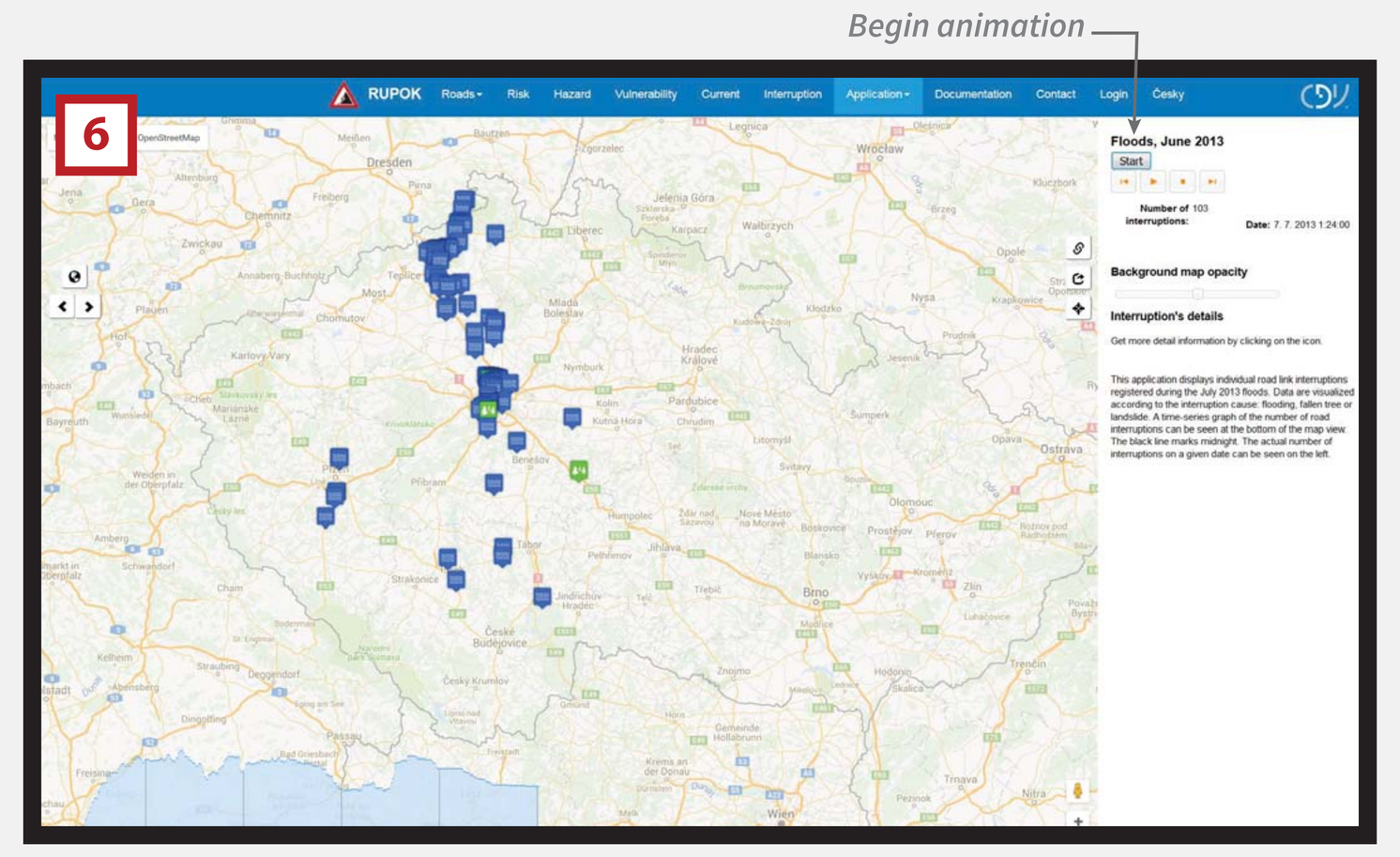




RUPOK.CZ
The RUPOK webpage contains unique information on the probabilities of transportation section interruptions due to natural processes as well as the impacts of possible interruptions. We divide the losses into direct and indirect where the direct ones are related to damage to infrastructure, the indirect ones mean additional expenses to detours and impacted traffic flow. RUPOK also visualizes natural risk related to railways.

Animation of closed roads

» An example of June 2013 flood
» Road closures change over time



Alternative routes module

» The green lines show an optimal alternative route between origin and destination node (red nodes).
» Each pair of nodes can be selected. Positions of the interrupted road sections can be specified by a user (black lines).