Landslide Susceptibility Modelling

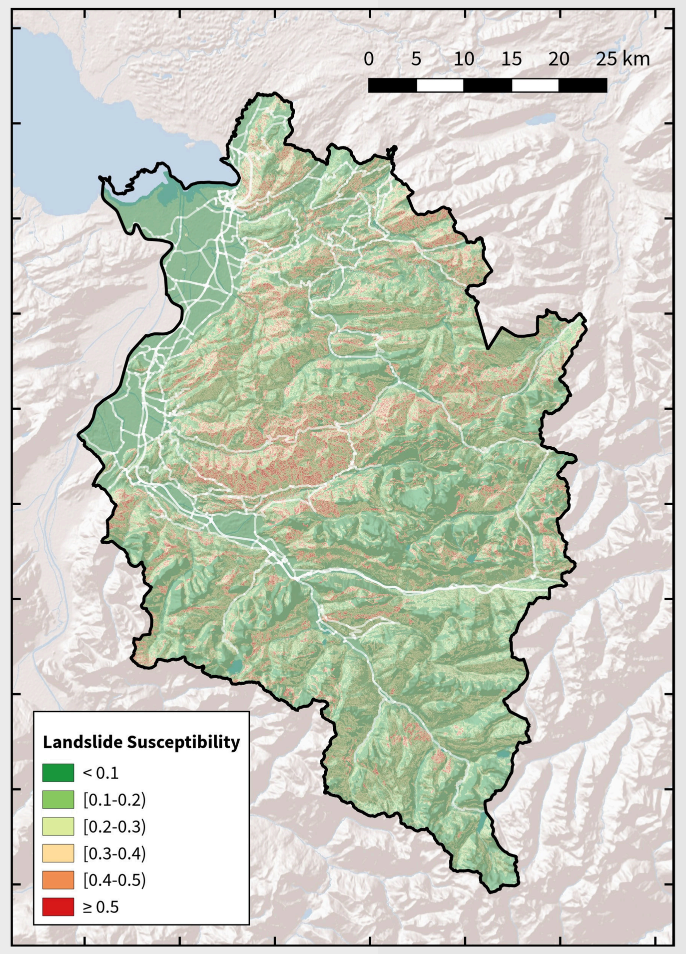
The Weight of Evidence method was used to model landslide susceptibility in the target area. This Bayesian method is based on the spatial distribution of
(1) areas affected by landslides, and
(2) landslide susceptibility factors (predictors).

Input data for obtaining the susceptibility map include:

- Historic events from landslide inventories
- Hazard index map
- Geological map
- Digital Terrain Model
- Slope
- Aspect
- Positive topographic openness
- Topographic position index
- Terrain ruggedness index
- Topographic wetness index

Schlögl, M., Avian, M., Richter, G., Thaler, T., Heiss, G., Fuchs, S., and Lenz, G.: On the nexus between landslide susceptibility and transport infrastructure – agent-based vulnerability assessment of rural road networks in the Eastern European Alps. Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2018-93, in review, 2018.

Susceptibility map derived via weight of evidence method



Transport Modelling

An agent-based traffic model was employed in the target area in order to assess the effects of road network interruptions on the local population. The mobility simulation is conducted on a routeable road graph, which includes data on infrastructure features (e.g. road capacity, speed limits). Traffic demand and agent characteristics are based on traffic behaviour (derived from mobility surveys) and socio-demographic data (e.g. commuting flows, employment statistics, population numbers).

This activity-based implementation of the transport model does not only allow for large-scale agent-based transport simulations in the test area, but also retains detailed socio-demographic information on single agents represented in the model runs. The model setup constitutes the representation of traffic flow on a generic, average weekday under normal (i.e. undisturbed) network conditions.

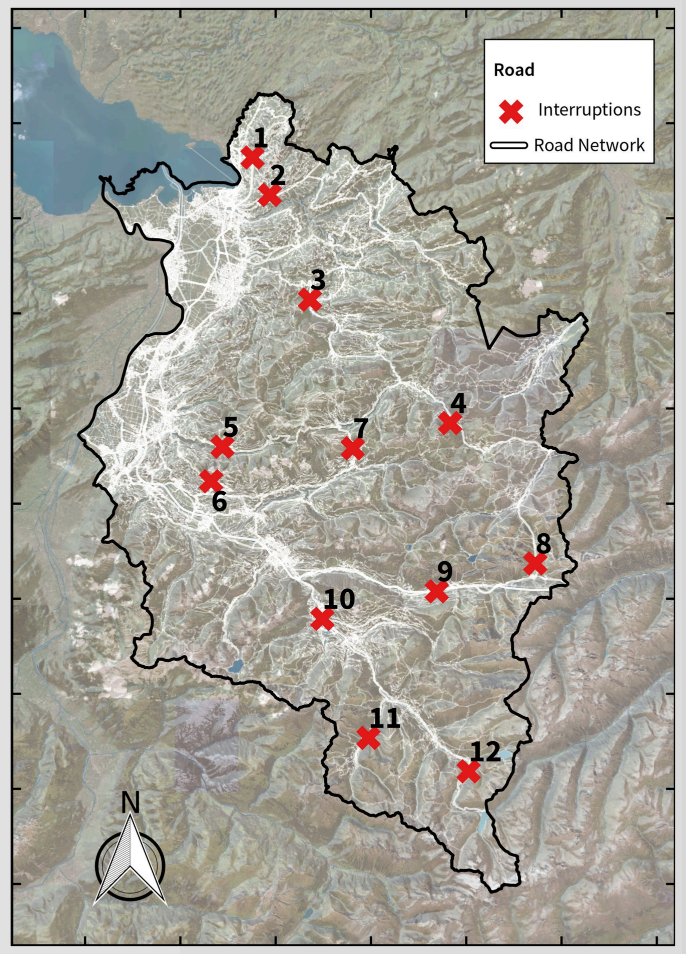
Motivation

Landslides are destructive events jeopardizing the integrity of land transport systems by causing structural damage and network interruptions.

The aim of this study is to present how road infrastructure is vulnerable towards landslide events, with emphasis on the consequences for the affected road users.

Location of the case study area

Overview of incident sites selected for traffic impact assessment



Traffic Impact Assessment

By concatenating the results of the landslide susceptibility map with a digital road graph and historic data of landslide inventories, critical sections of the road network were identified.

In total, 12 incident sites located in different regions of the case study area have been selected for further analysis.

Incident 12 had to be removed due to its close proximity to a cross-border toll road with winter closure, which leads to biased simulation results.

Following the establishment of an equilibrium in an undisturbed traffic network state (baseline scenario), the model is re-run on the modified routing graphs for each of the landslide-scenarios considered. For each of these incident scenarios, the affected network links are removed from the graph in order to indicate a network interruption caused by a landslide, and the altered behavior of the agents (new equilibrium states) is recorded.

This allows to derive evasion costs.

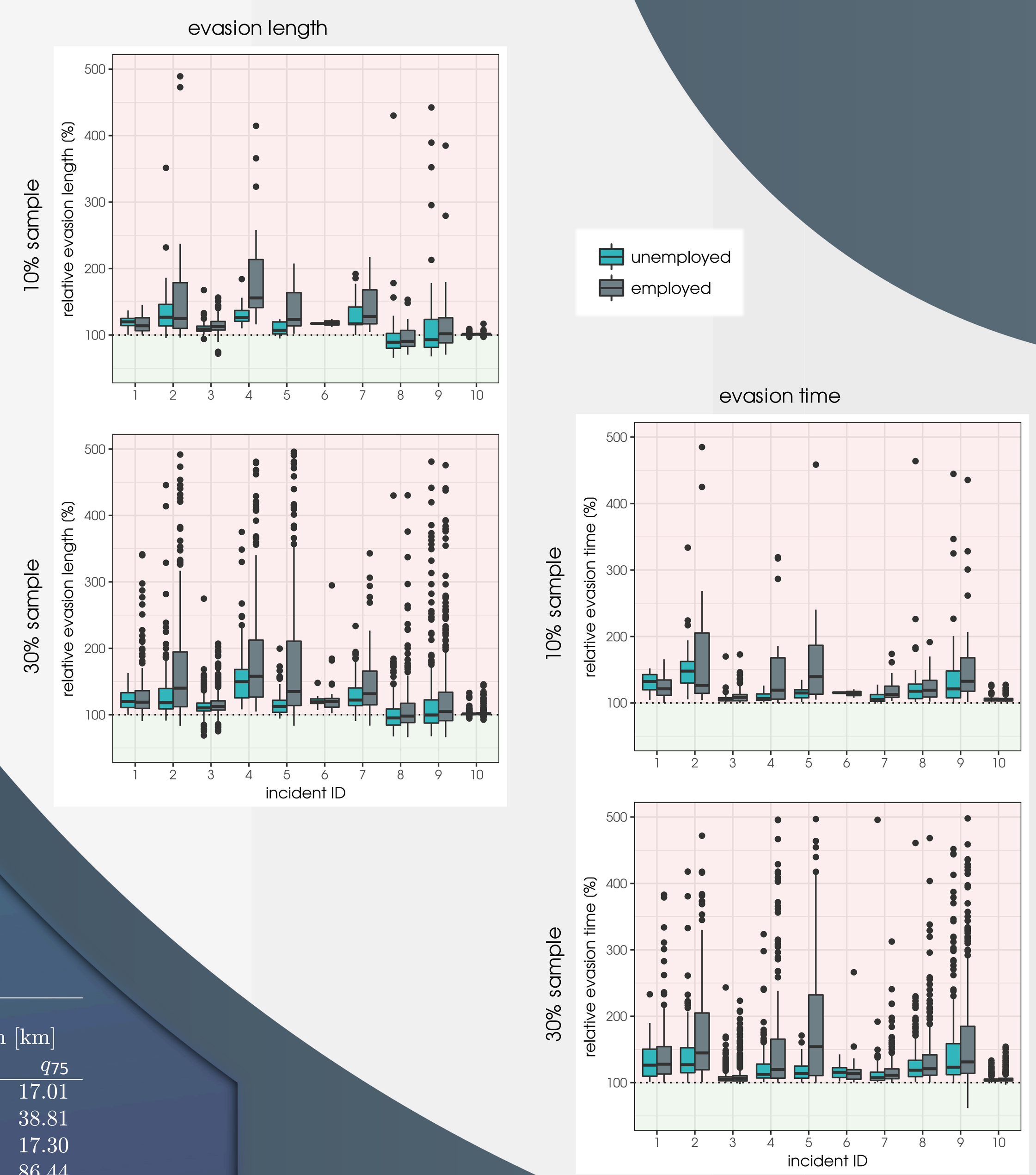
Agent-based Vulnerability Assessment of Road Networks in a Rural Alpine Area

On the Nexus between Critical Transport Infrastructure and Society

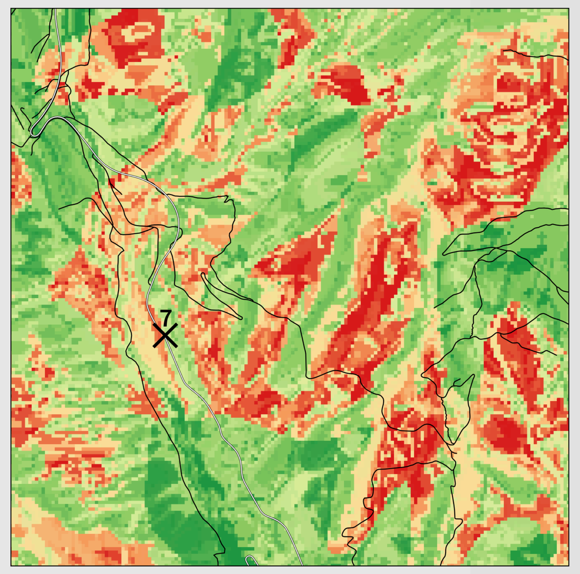
Matthias Schlögl[1,2], Michael Avian[3], Thomas Thaler[4], Gerald Richter[5], Gerhard Heiss[6], Sven Fuchs[4], Melitta Dragaschnig[5] and Gernot Lenz[5]

(1) **Austrian Institute of Technology**
Transportation Infrastructure Technologies
(2) **University of Natural Resources and Life Sciences**
Institute of Applied Statistics and Computing
(3) **Central Institution for Meteorology and Geodynamics**
Staff Unit Earth Observation
(4) **University of Natural Resources and Life Sciences**
Institute of Mountain Risk Engineering
(5) **Austrian Institute of Technology**
Dynamic Transportation Systems
(6) **Austrian Institute of Technology**
Environmental Resources & Technologies

relative changes of evasion time and evasion length with respect to the baseline scenario



Close-up view of incident #7: susceptibility map



Close-up view of incident #7: satellite image

Landslide Incident Scenarios

Summary statistics of differences between each interruption scenario and the undisturbed baseline scenario, for both 10% and 30% population samples. They are expressed in terms of quartiles of (additional) evasion lengths and times.

Detour length is the shortest alternate route length between the ends of the road links that were severed by the landslide. While the full population was used for establishing the baseline scenario, 10% and 30% samples were used for obtaining the incident sencarios. Due to the lack of alternative routes, no incident simulation was prerformed for incident 11.

Incident	detour length [km]	incident scenarios: 10 % sample						incident scenarios: 30 % sample					
		evasion time [h:m:s]			evasion length [km]			evasion time [h:m:s]			evasion length [km]		
		q_{25}	q_{50}	q_{75}	q_{25}	q_{50}	q_{75}	q_{25}	q_{50}	q_{75}	q_{25}	q_{50}	q_{75}
1	16.4	00:05:41	00:12:10	00:22:34	5.04	8.18	13.01	00:08:07	00:12:02	00:23:34	6.27	8.94	17.01
2	50.2	00:14:47	00:31:48	00:52:06	14.71	21.80	46.10	00:15:53	00:25:14	00:44:55	12.00	20.92	38.81
3	11.9	00:04:05	00:07:02	00:10:21	7.28	9.79	17.06	00:03:20	00:06:15	00:08:53	7.19	9.57	17.30
4	106.9	00:06:32	00:16:11	00:44:30	37.85	61.17	72.97	00:09:23	00:19:43	00:52:20	39.47	66.26	86.44
5	65.7	00:12:51	00:16:10	00:49:54	7.63	19.88	34.52	00:10:58	00:24:44	00:51:10	11.09	22.90	45.14
6	27.2	00:07:56	00:10:36	00:11:25	11.90	15.17	15.89	00:04:20	00:05:43	00:11:20	7.11	8.28	15.21
7	65.7	00:06:24	00:13:22	00:21:22	18.32	27.39	46.30	00:06:52	00:11:52	00:21:32	18.61	32.58	48.13
8	107.9	00:10:42	00:21:18	00:34:51	-30.52	-15.82	8.61	00:13:09	00:27:58	00:42:52	-22.90	-5.38	16.51
9	107.7	00:15:05	00:31:50	01:14:09	-21.62	-0.71	31.43	00:17:15	00:35:56	01:15:42	-17.98	3.64	37.22
10	6.1	00:02:38	00:04:01	00:05:31	0.79	1.42	1.79	00:02:30	00:03:10	00:04:16	0.84	1.68	1.77

Baseline Scenario

Summary of car trip characteristics for agents in the traffic model of the undisturbed baseline scenario, to be affected by incident scenarios.

Affected agents refer to those crossing the incident site at least once within their regular daily plans. Employment rate is the share of working people within this group. Affected car trips designate the number of incident site traversals by agents in that transport mode. Share of mode car gives the proportion of site traversals by car relative to all traversals (in any mode). Medians of daily travel time and distance are displayed for employed and not employed people, respectively, which again refer to all affected agents and their trips crossing the respective site.

Incident	affected agents []	employment rate [%]	affected car trips []	share of mode car ≙ [%]	median daily travel time [h:m:s]		median daily travel distance [km]	
					employed	not employed	employed	not employed
1	565	83.54	1363	93.81	00:46:58	00:51:13	46.4	54.9
2	1486	64.20	3968	91.66	01:01:02	01:12:18	62.5	76.4
3	4794	64.15	13856	93.15	01:31:14	01:43:30	91.5	106.3
4	586	58.42	4285	93.33	02:07:49	02:22:19	118.2	143.5
5	858	67.53	3032	95.74	01:18:40	01:47:11	79.3	110.9
6	128	73.19	355	89.65	00:53:31	01:06:54	58.3	68.9
7	572	63.68	3200	93.73	01:52:53	01:59:40	103.2	118.8
8	1404	49.68	6305	92.93	02:13:48	02:18:50	159.4	166.8
9	576	52.06	7815	92.07	02:01:21	02:12:20	149.1	160.6
10	4709	52.16	16372	91.87	01:24:32	01:32:02	104.4	122.1
11	5	74.00	118	87.41	01:14:50	02:08:56	75.2	156.5