Resilient transportation

4TU DeSIRE Conference on Resilience Engineering

Maaike Snelder, Eric van Berkum

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Presentations

- 13:30-13:55h Resilience of Road transport networks – Maaike Snelder (TU Delft)
- 13:55-14:20h Resilience of of traffic and logistics - Oskar eikenbroek (University of Twente
- 14:20-14:45h Resilience of the World Airline Network by Trivik Verma (TU Delft)
- 14:45-15:00h Plenary discussion

Resilient Road Transport

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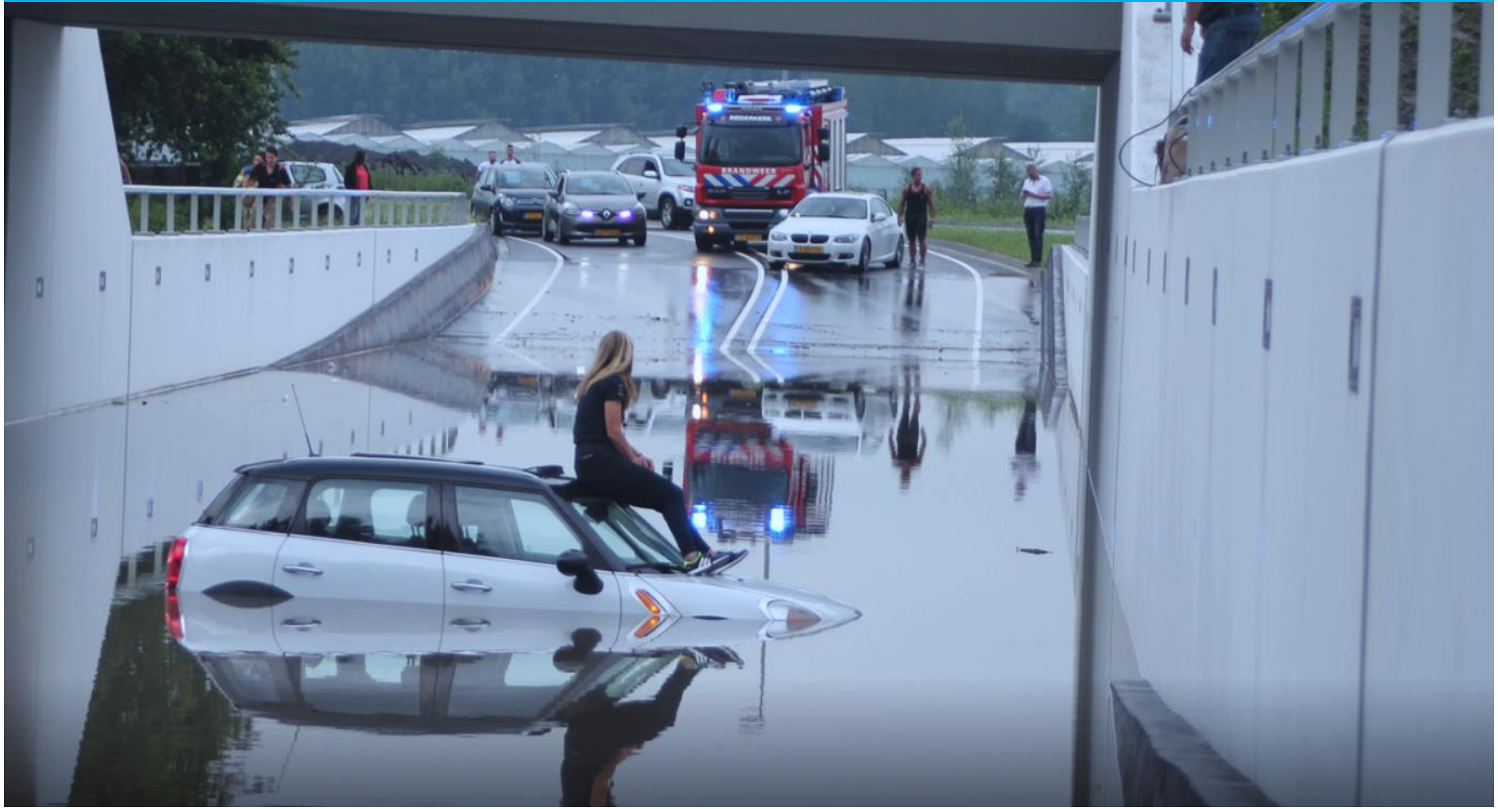
Introduction



Overview analyses and interventions

- Data analyses
- Model analyses
- Interventions

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Daily congestion morning peak

Source: Google

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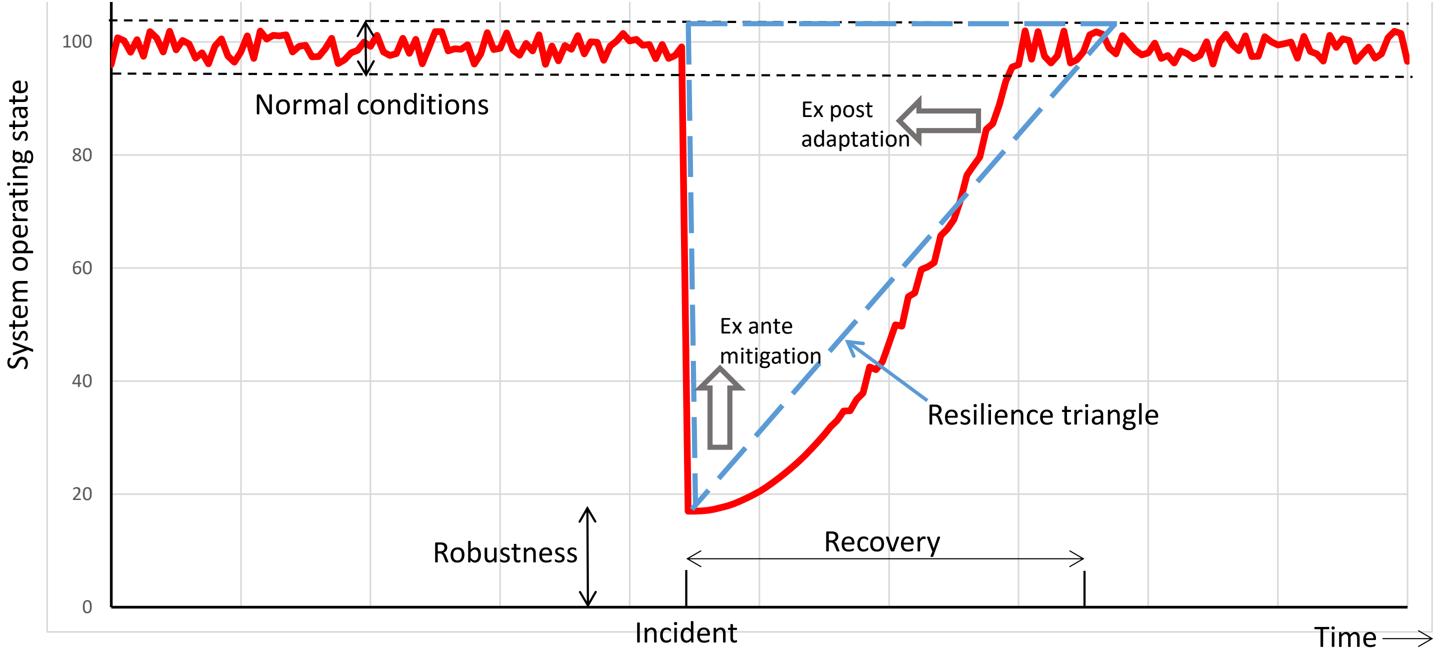
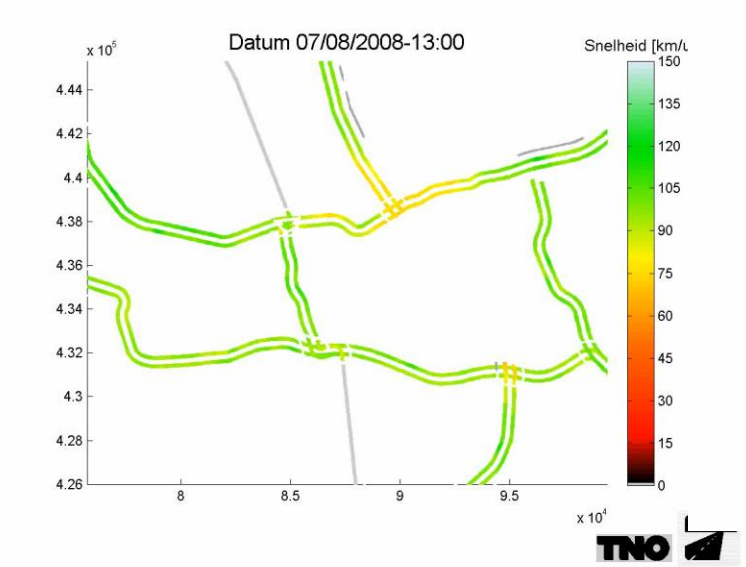
Resilience triangle

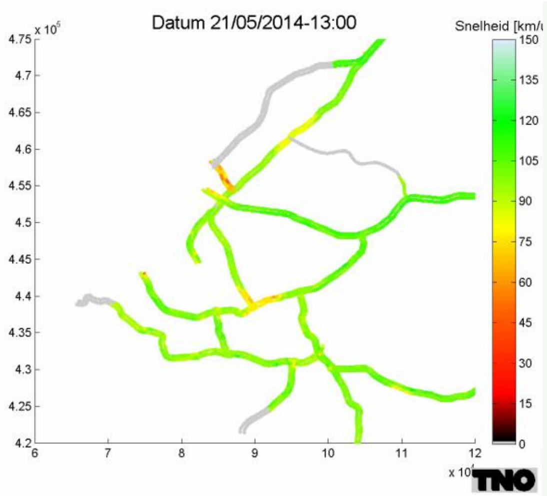


Source: Prof Michael A P Taylor University of South Australia

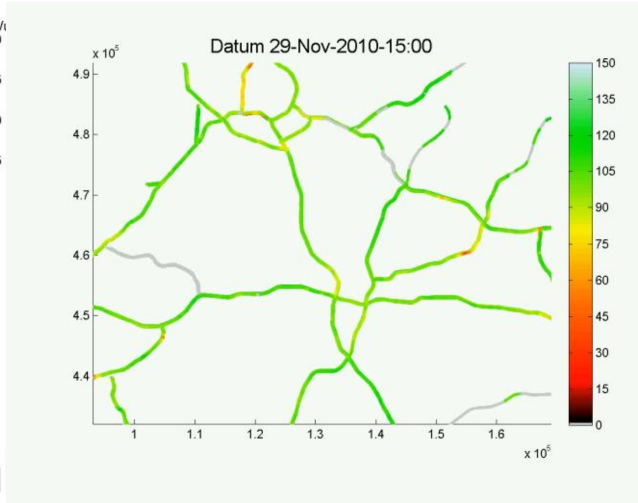
Heavy rain and thunder



Fatal accident

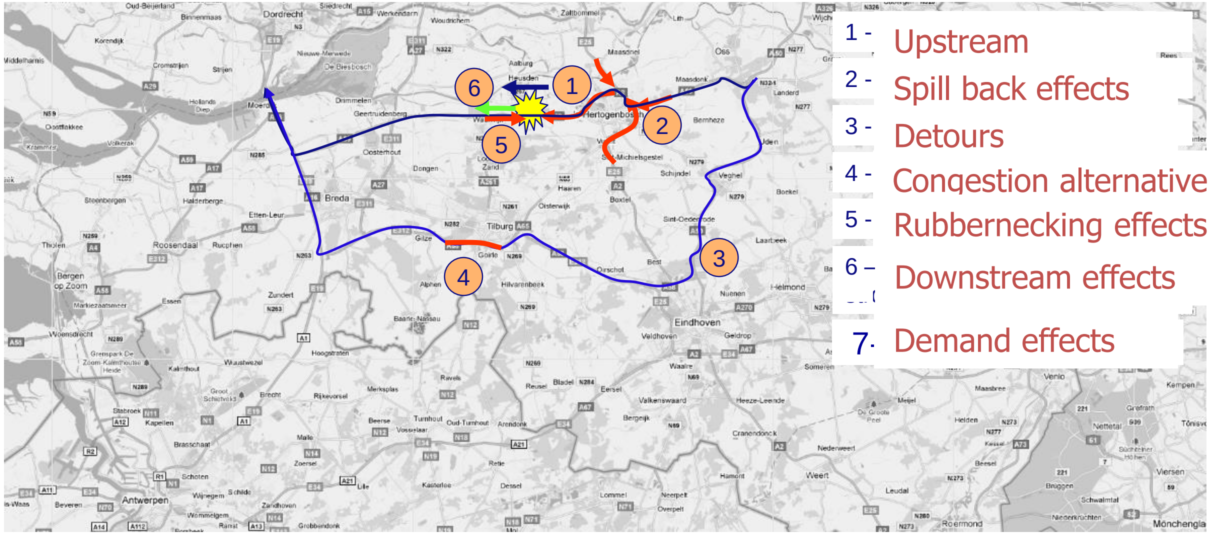


Snow



1. Incidents
2. Weather
3. Work zones
4. Fluctuation in demand
5. Special events
6. Traffic control devices
7. Inadequate base capacity
8. Disasters e.g. tsunami, earthquake, flood

Possible effects of an incident



Focus on 1, 2 and 5

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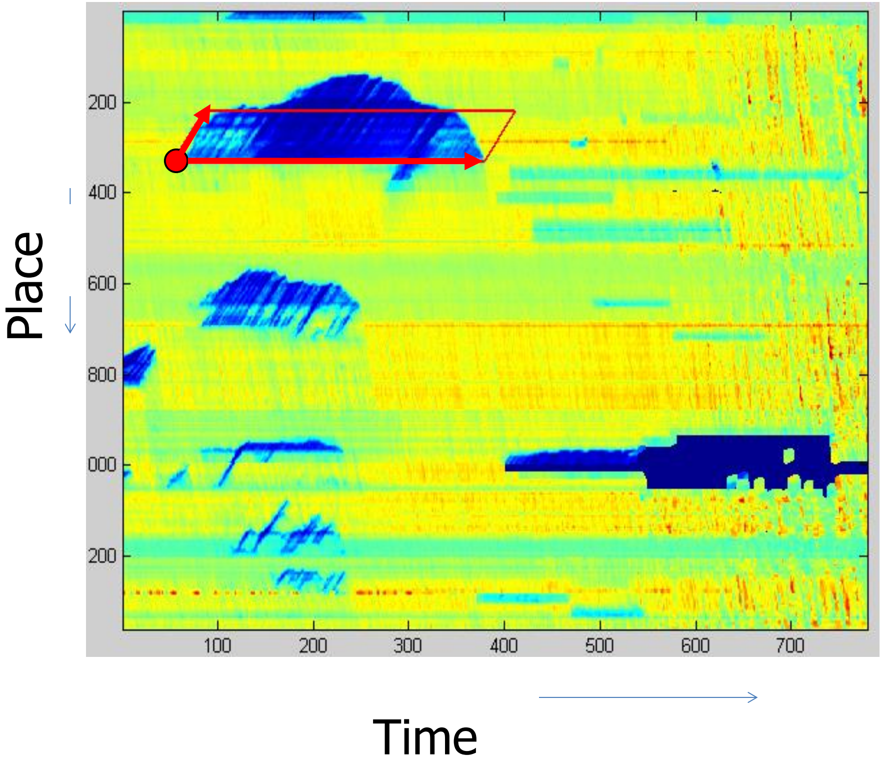
Detection queues (rule based)



- Indication start time, location, duration
- Spill back speed
- Stop speed > 70 km/h

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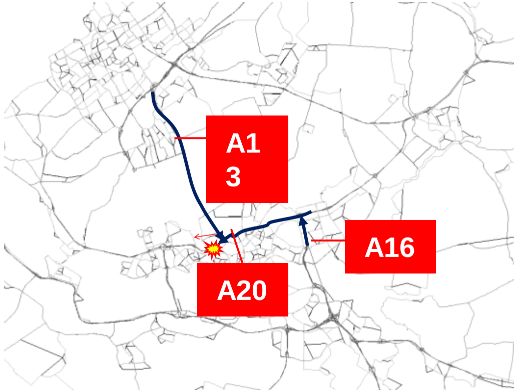
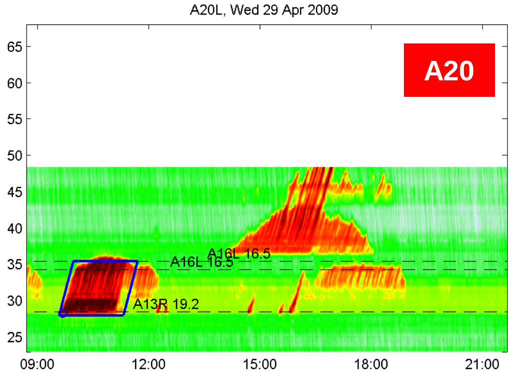
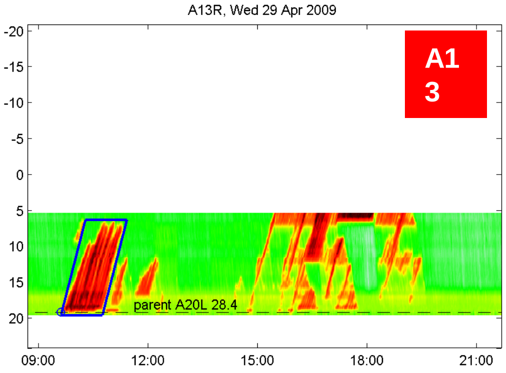
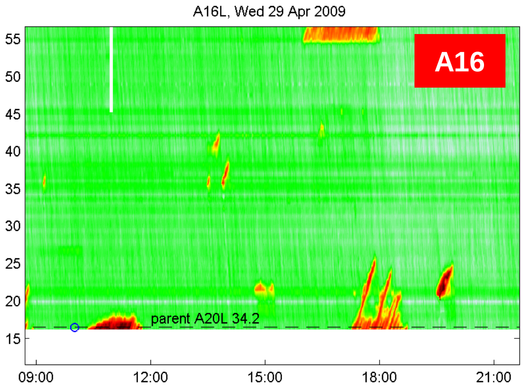
Spillback effects









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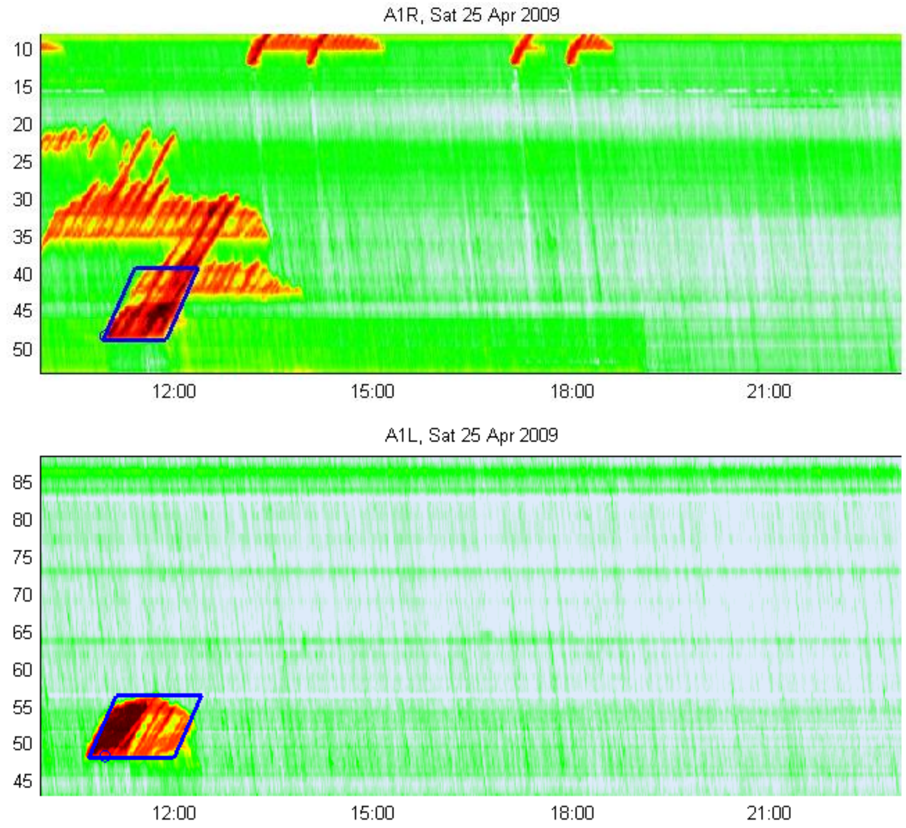
Rubbernecking effects



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Reference choice - example

	Weight	VLH
13-jan-09	1	1200
20-jan-09	2	600
27-jan-09	3	430
3-feb-09	4	500
10-feb-09	day incident	800
17-feb-09	4	550
24-feb-09	3	800
3-mrt-09	2	480
10-mrt-09	1	580

	VLH
27-jan-09	430
27-jan-09	430
27-jan-09	430
3-mrt-09	480
3-mrt-09	480
3-feb-09	500
3-feb-09	500
3-feb-09	500
3-feb-09	500
17-feb-09	550
17-feb-09	550
17-feb-09	550
17-feb-09	550
10-mrt-09	580
20-jan-09	600
20-jan-09	600
24-feb-09	800
24-feb-09	800
24-feb-09	800
13-jan-09	1200
Mediaan	550

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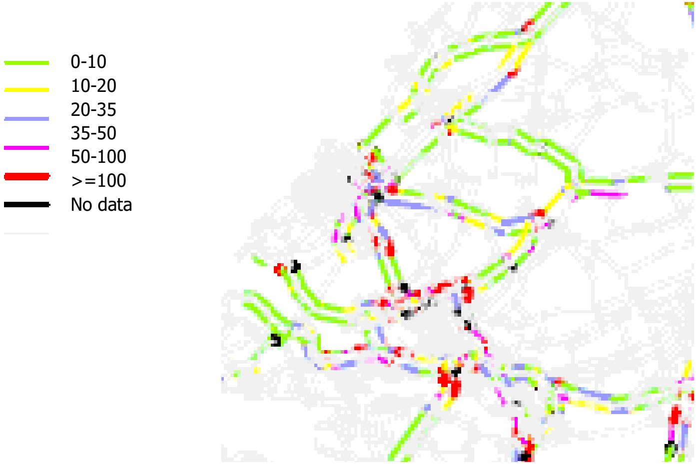
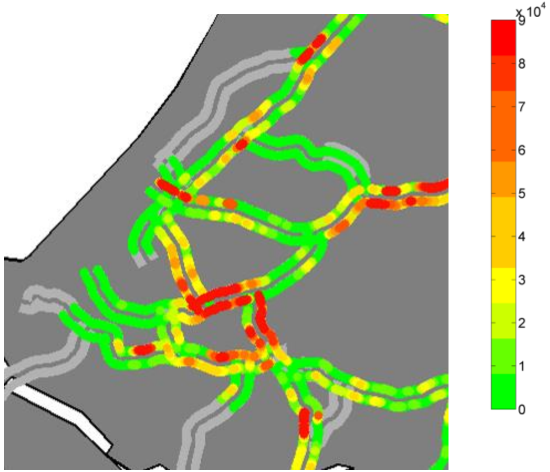
Vulnerable road sections 2007-2009

Number of incidents



Extra travel time



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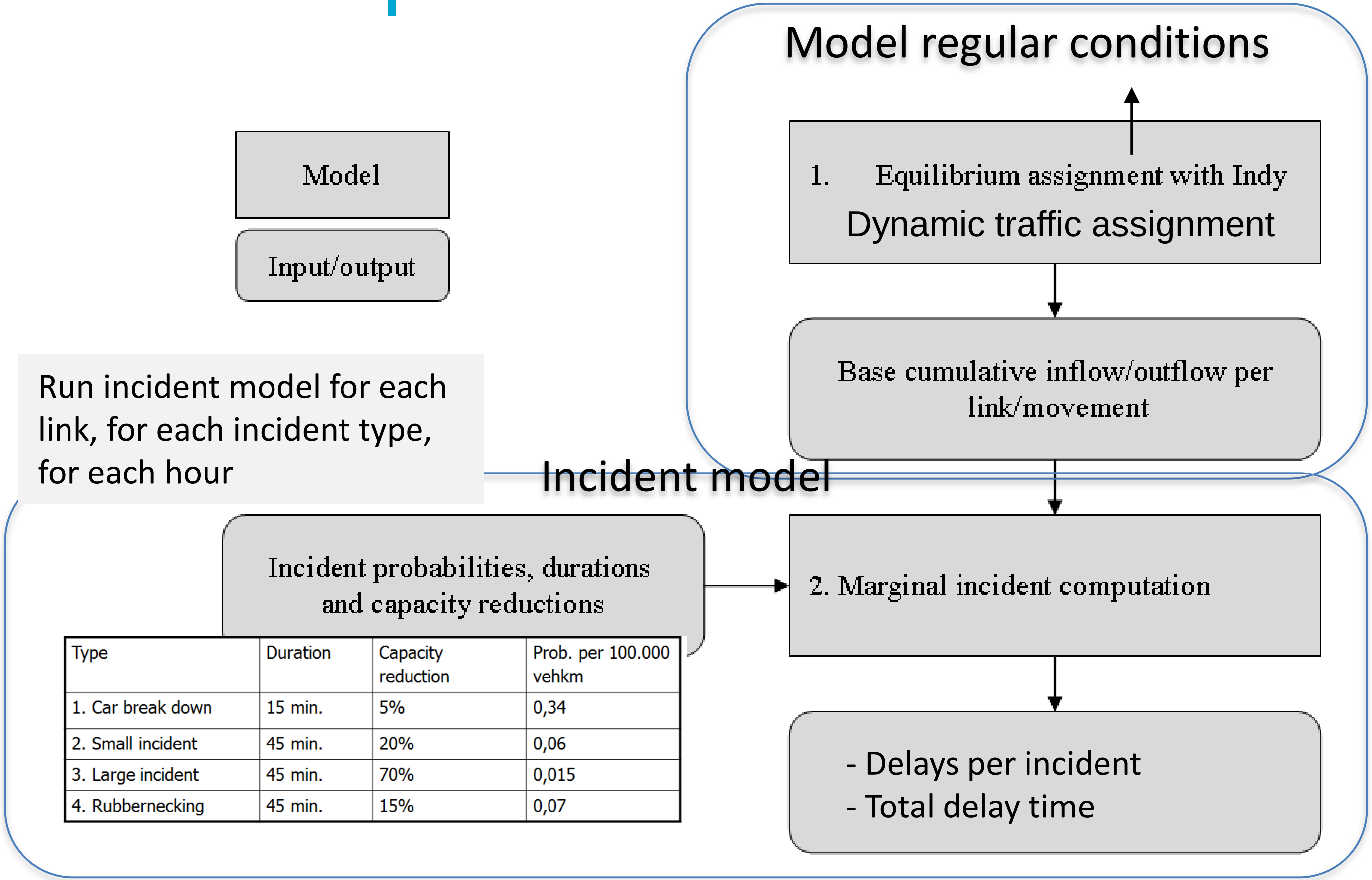
Conceptual model



Type	Duration	Capacity reduction	Prob. per 100.000 vehkm
1. Car break down	15 min.	5%	0,34
2. Small incident	45 min.	20%	0,06
3. Large incident	45 min.	70%	0,015
4. Rubbernecking	45 min.	15%	0,07

Input incident types

	ID	Incident type	With hard shoulder			without hard shoulder			Weaving section			Weaving section withou hard shoulder		
			risk	duration	capacity reduction factor	risk	duration	capacity reduction factor	risk	duration	capacity reduction factor	risk	duration	capacity reduction factor
Road with 1 lane	1	car break down on the road	0.18	0.28	0.75	0.31	0.33	0.75	0.18	0.28	0.75	0.31	0.33	0.75
	2	truck break down	0.53	0.53	0.80	0.70	0.58	0.80	0.53	0.53	0.80	0.70	0.58	0.80
	3	truck accident	0.18	1.80	0.80	0.23	1.84	0.80	0.21	1.80	0.80	0.26	1.84	0.80
	4	car accident with one lane closed	0.13	0.44	0.60	0.19	0.49	0.60	0.14	0.44	0.60	0.21	0.49	0.60
	5	road closure	0.03	0.89	0.90	0.05	0.93	0.90	0.04	0.89	0.90	0.06	0.93	0.90
Road with 2 lanes	6	car break down on the road	0.18	0.28	0.53	0.31	0.33	0.53	0.18	0.28	0.53	0.31	0.33	0.53
	7	truck break down	0.53	0.53	0.53	0.70	0.58	0.53	0.53	0.53	0.53	0.70	0.58	0.53
	8	truck accident	0.18	1.80	0.76	0.23	1.84	0.76	0.21	1.80	0.76	0.26	1.84	0.76
	9	car accident with one lane closed	0.13	0.44	0.60	0.19	0.49	0.60	0.14	0.44	0.60	0.21	0.49	0.60
	10	car accident with two lanes closed	0.03	0.89	0.90	0.05	0.93	0.90	0.04	0.89	0.90	0.06	0.93	0.90
Road with 3 lanes	11	car break down on the road	0.24	0.28	0.36	0.37	0.33	0.36	0.24	0.28	0.36	0.37	0.33	0.36
	12	truck break down	0.70	0.53	0.38	0.87	0.58	0.38	0.70	0.53	0.38	0.87	0.58	0.38
	13	truck accident	0.24	1.80	0.59	0.29	1.84	0.59	0.27	1.80	0.59	0.33	1.84	0.59
	14	car accident with one lane closed	0.10	0.41	0.40	0.16	0.46	0.40	0.11	0.41	0.40	0.17	0.46	0.40
	15	car accident with two lanes closed	0.03	0.65	0.70	0.05	0.69	0.70	0.04	0.65	0.70	0.06	0.69	0.70
	16	car accident with three or more lanes closed	0.00	1.93	0.90	0.01	1.98	0.90	0.01	1.93	0.90	0.01	1.98	0.90
Road with 4 lanes	17	car break down on the road	0.27	0.28	0.28	0.40	0.33	0.28	0.27	0.28	0.28	0.40	0.33	0.28
	18	truck break down	0.79	0.53	0.31	0.96	0.58	0.31	0.79	0.53	0.31	0.96	0.58	0.31
	19	truck accident	0.27	1.80	0.46	0.32	1.84	0.46	0.31	1.80	0.46	0.36	1.84	0.46
	20	car accident with one lane closed	0.18	0.38	0.30	0.24	0.42	0.30	0.19	0.38	0.30	0.26	0.42	0.30
	21	car accident with two lanes closed	0.05	0.57	0.55	0.08	0.61	0.55	0.06	0.57	0.55	0.09	0.61	0.55
	22	car accident with three or more lanes closed	0.01	1.22	0.80	0.01	1.26	0.80	0.01	1.22	0.80	0.02	1.26	0.80
Road with 5 lanes	23	car break down on the road	0.29	0.28	0.28	0.42	0.33	0.28	0.29	0.28	0.28	0.42	0.33	0.28
	24	truck break down	0.84	0.53	0.31	1.02	0.58	0.31	0.84	0.53	0.31	1.02	0.58	0.31
	25	truck accident	0.29	1.80	0.46	0.34	1.84	0.46	0.33	1.80	0.46	0.38	1.84	0.46
	26	car accident with one lane closed	0.19	0.38	0.30	0.25	0.42	0.30	0.21	0.38	0.30	0.27	0.42	0.30
	27	car accident with two lanes closed	0.05	0.57	0.55	0.08	0.61	0.55	0.07	0.57	0.55	0.10	0.61	0.55
	28	car accident with three or more lanes closed	0.01	1.22	0.80	0.02	1.26	0.80	0.01	1.22	0.80	0.02	1.26	0.80
Road with 6 lanes	29	car break down on the road	0.30	0.28	0.28	0.43	0.33	0.28	0.30	0.28	0.28	0.43	0.33	0.28
	30	truck break down	0.88	0.53	0.31	1.05	0.58	0.31	0.88	0.53	0.31	1.05	0.58	0.31
	31	truck accident	0.30	1.80	0.46	0.35	1.84	0.46	0.34	1.80	0.46	0.40	1.84	0.46
	32	car accident with one lane closed	0.20	0.38	0.30	0.26	0.42	0.30	0.22	0.38	0.30	0.28	0.42	0.30
	33	car accident with two lanes closed	0.06	0.57	0.55	0.09	0.61	0.55	0.07	0.57	0.55	0.10	0.61	0.55
	34	car accident with three or more lanes closed	0.01	1.22	0.80	0.02	1.26	0.80	0.01	1.22	0.80	0.02	1.26	0.80

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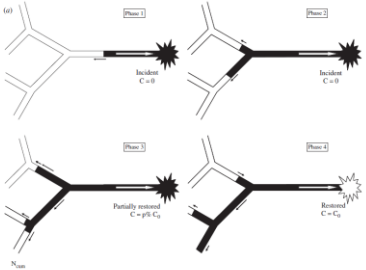
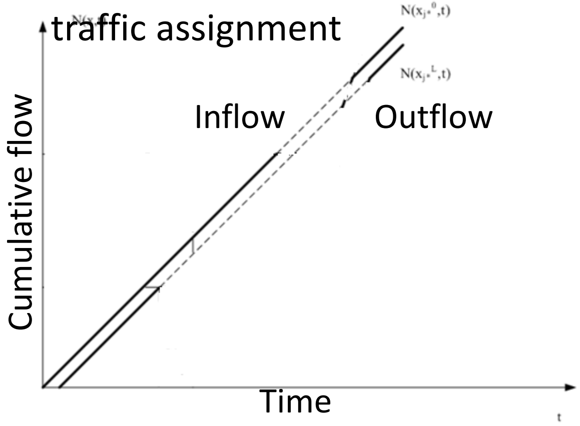
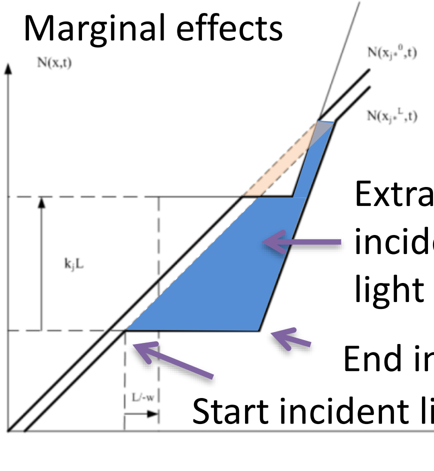
Marginal incident model



Reference run dynamic traffic assignment



Marginal effects



Extra travel time due to incident = blue surface – light orange surface

End incident

Start incident link closure

Advantage:

- Low computation
- Accurate approximation

Disadvantage:

- Difficult to take alteranatieve route choice into account.

Alternative route choice:

- Approximation algorithm added for alternative route choice
- Spare capacity on alternative routes considerd
- Traffic on 'incident route' reduced by a percentage of cars that chooses the alternatives routes which still have spare capacity

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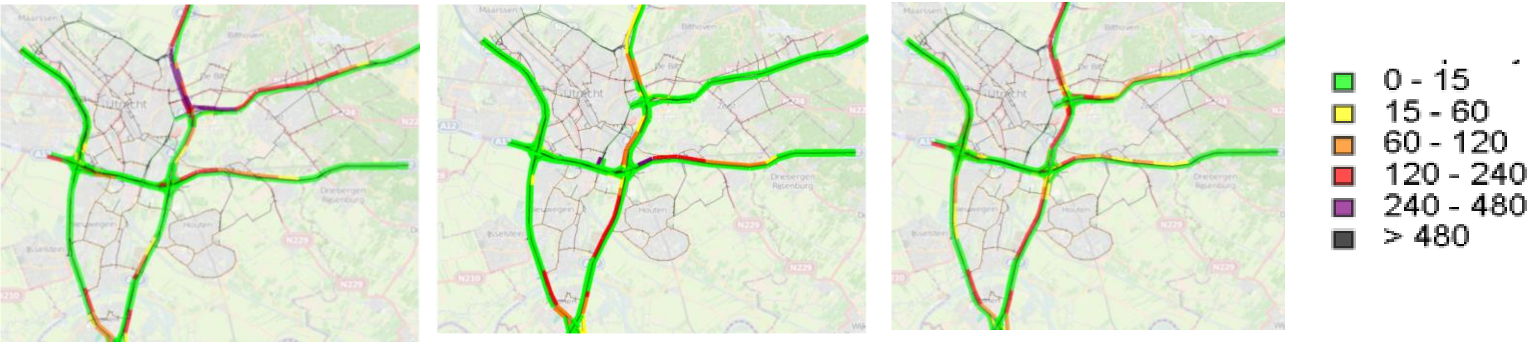
Analysis – regular conditions congestion duration



Reference (2030)
Lanes: S6 - N4

Alt 1+2
S5+2 – N3+4

Alt 3
S6 – N6

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Results

Variant	Vehicle kilometers in the project area x 1,000,000 (km)	Total travel time delay in the project area x 10,000 (hours)
Reference 2012	3.61	0.59
Reference 2030	4.29	1.65
Alternative 1 +2	4.33 (+1%)	0.77 (-53%)
Alternative 3	4.34 (+1%)	1.49 (-10%)

	Expected number of incidents per workday		Average total delay per incident (vehicle hours)		Total delay caused by all incidents per workday (vehicle hours)	
	Project area	Kp. Lun. – kp. Rijnsw.	Project area	Kp. Lun. – kp. Rijnsw.	Project area	Kp. Lun. – kp. Rijnsw.
Ref. 2012	1.62	0.34	227	82	368	28
Ref. 2030	1.99	0.42	462	512	919	215
* **Alt. 1**	1.91 (-4%)	0.31 (-27%)	226 (-51%)	148 (-71%)	433 (-53%)	46 (-78%)
** **Alt. 2**	2.05 (+3%;+7%)	0.41 (+2%;+32%)	226 (-51%; 0%)	174 (-66%; +18%)	465 (-49%;+7%)	75 (-65%;+63%)
*** **Alt 3**	2.12 (+7%;+3%)	0.51 (+20%; +24%)	282 (-39%; +25%)	154 (-70%;-11%)	600 (-35%; +29%)	78 (-64%;+4%)

* 7 lanes both directions parallel road structure + hard shoulder

** 7 lanes both directions parallel road structure + no hard shoulder

*** 6 lanes both directions + no hard shoulder

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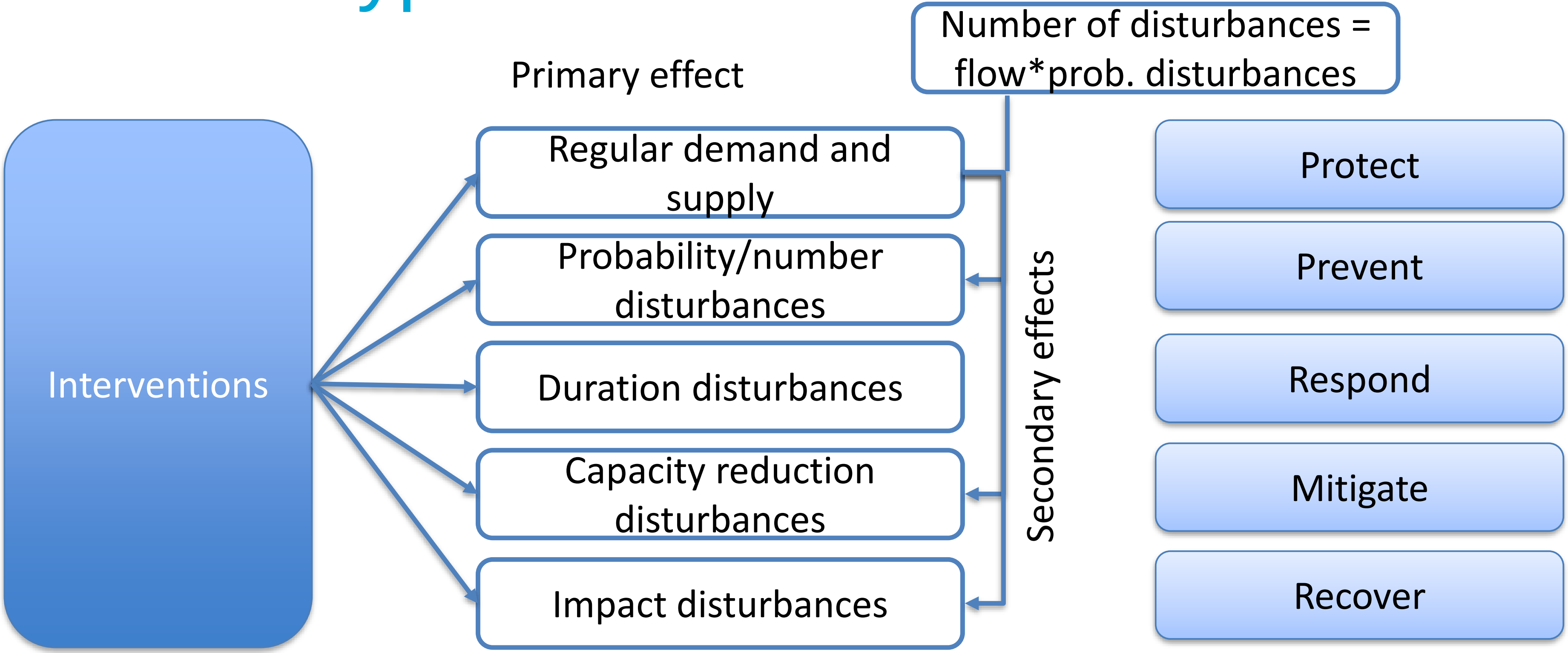
Types of interventions



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Interventions assignment (see how to measures Brithspace)

	Reg demand and supply	Dist. Proba-bility	Dist. duration	Dist. Cap reduction	Dist Impact
New road	x	x		x	X
New lane	x	x		x	x
Peak hour lane/hard shoulder	x	x	x	x	x
Dynamic route information panel	x				x
C-ITS (intelligent vehicle safety systems)		x			
Road works at night					x
New asphalt		x		x	
Incident management			x		
Peak hour avoidance	x				x
Modal shift trucks and cars	x				x

Conclusion

- The impact of disturbances can be assessed using data an models
- Little is known about behavioural changes → assumptions about route choice effects
- Robustness/Resilience benefits should be considered in cost-benefit analysis
- Many interventions possible

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Based on:

- Snelder, M., B. Wesseling, B. van Arem, B and M. Hertogh (2017) Evaluating the robustness of road networks in case of incidents for different topological and geometrical roadway designs. Transport Policy, Vo 57, pp. 20-30.
- Snelder, M., T. Bakri, B. Van Arem (2013) Delays caused by incidents; a data driven approach, in *Transportation Research Record: Journal of the Transportation Research Board*, 2333, pp. 1-8.
- Snelder, M., L.H. Immers, H.J. van Zuylen (2012) The best of two worlds - a robust road network design method based on an optimization model and expert judgement, in: *Proceedings of the 5th International Symposium on Transportation Network Reliability*, Hong Kong.
- Snelder, M, H.J. van Zuylen, L.H. Immers (2012) A framework for robustness analysis of road networks for short term variations in supply, in: Transportation research part A, Volume 46, Issue 5, pp. 828–842.

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Questions?

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