KATHOLIEKE UNIVERSITEIT
LEUVEN

Assessment of the variable speed limits around Antwerp

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Overview of presentation

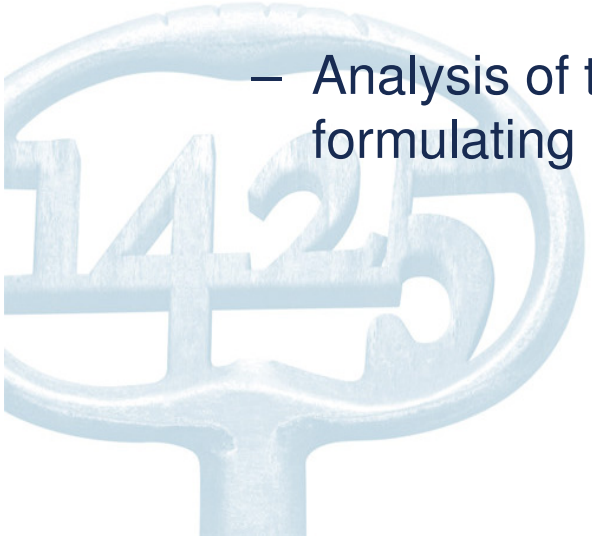
- Introduction and scope
- Assessment from the drivers' perspective
- Case study Antwerp
- Ex-ante evaluation of targeted improvements
- Conclusion

Introduction and scope

- Rijstrooksignalering (RSS): system that shows variabel speed limits (VSL) according to the traffic conditions
  - Developped and managed by Vlaams Verkeerscentrum
  - Algorithm uses speed and occupancy detection from cameras
  - Primary function = warning for queue tails
  - 50-70-90-100-(120) km/h
  - VSL depend mostly on detectors of the section immediately downstream
    - Response to traffic condition (with VSL of 50 and 70 km/u)
  - Equalisation over lanes + gradual speed reduction over gantries
  - From the detected speeds it is apparent that drivers' compliance to the VSL is poor

Introduction and scope

- Study KULeuven had two goals:
  - Literature study for foreign VSL systems and experiments
    - Expanding the functionality of the RSS system
      - More locations
      - Improving throughput
      - Moving towards a global approach instead of only a local reaction
    - Look for possible improvements to the current functionality of the RSS system
  - Analysis of the performance of the current RSS system and formulating possible ways to improve



Introduction and scope

- Analysis of the RSS system:
  - Safety
    - Asses performance of warning function: are drivers properly warned for downstream congestion
  - Credibility
    - Are the VSL trustworthy messages to drivers?
    - May indirectly influence safety (and throughput)
  - Impact on throughput, travel times, environment, noise
    - Not included in the study

Introduction and scope

- Analysis of the RSS system:
  - One week of data was available (20/4/2009 – 26/4/2009)
    - R1 and E313 (Ranst → Antwerpen)
    - Logging of VSL that were shown
    - Speed and occupancy data from cameras
  - Indirect analysis of data
    - Detection rate (DR):
      - Indicates effectiveness of warning function (safety)
    - False alarm rate (FAR)
      - Indicates credibility; indirect safety benefits
    - Stability of VSL messages
      - Indicates credibility; indirect safety benefits
    - Combined visualisation of VSL(, DR, FAR) and detected speeds
      - Adds perspective to global indicators
      - Shows local mismatches between traffic conditions and VSL response

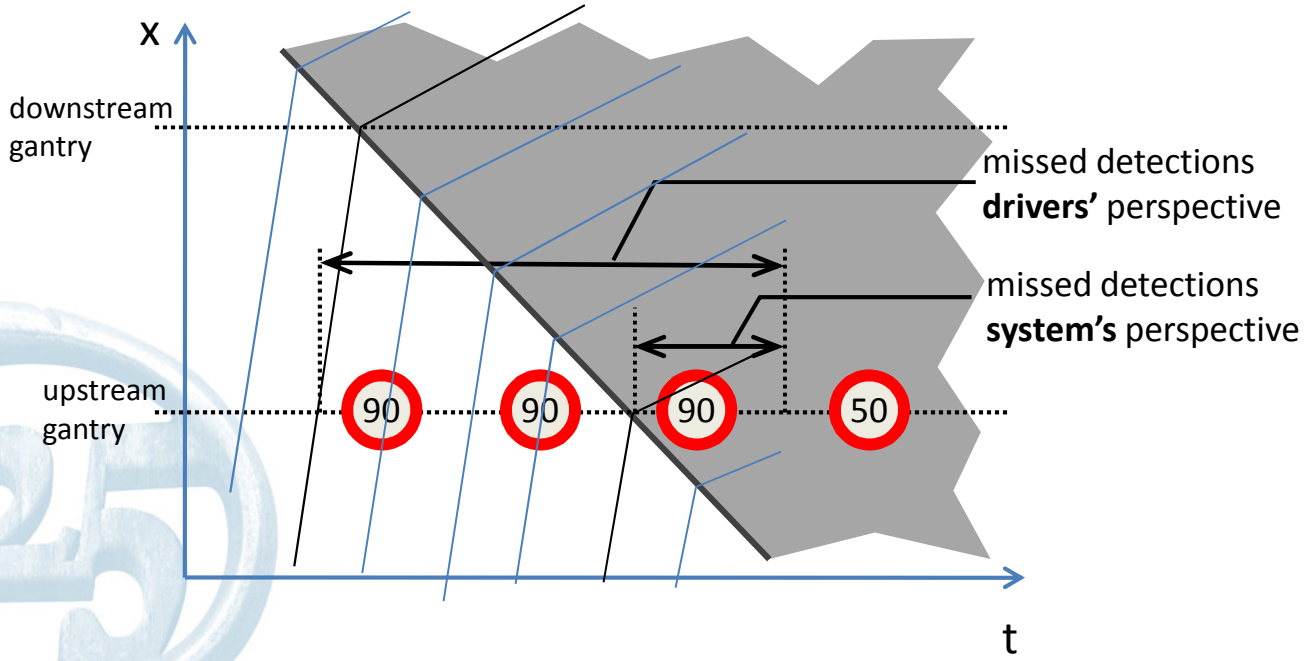
Assessment from the drivers' perspective

- DR and FAR are derived from vehicle trajectories (from speed data)
- *Missed detection:* speed drop on a trajectory that driver was not warned for at the upstream gantry
- *False alarm:* low VSL that is not followed by a (corresponding) speed drop

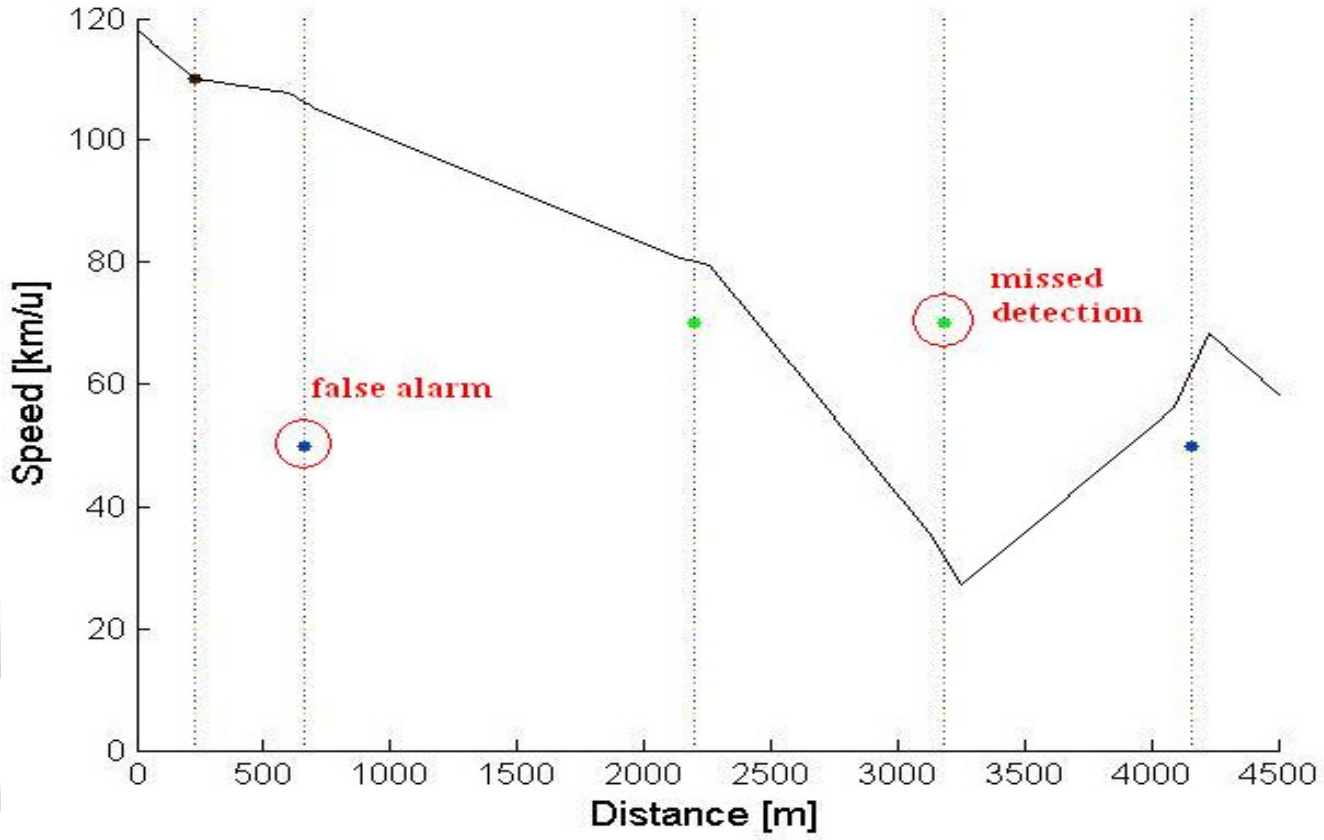
- *DR:* the rate of successful (not missed) detections over all situations to be detected.
- *FAR:* the rate of false alarms over all alarms.

Assessment from the drivers' perspective

- DR and FAR defined from system's perspective in state-of-the-art
- We define DR and FAR from the drivers' perspective



Assessment from the drivers' perspective



- Missed detection and false alarm on trajectory visualized

Analysis of the RSS system

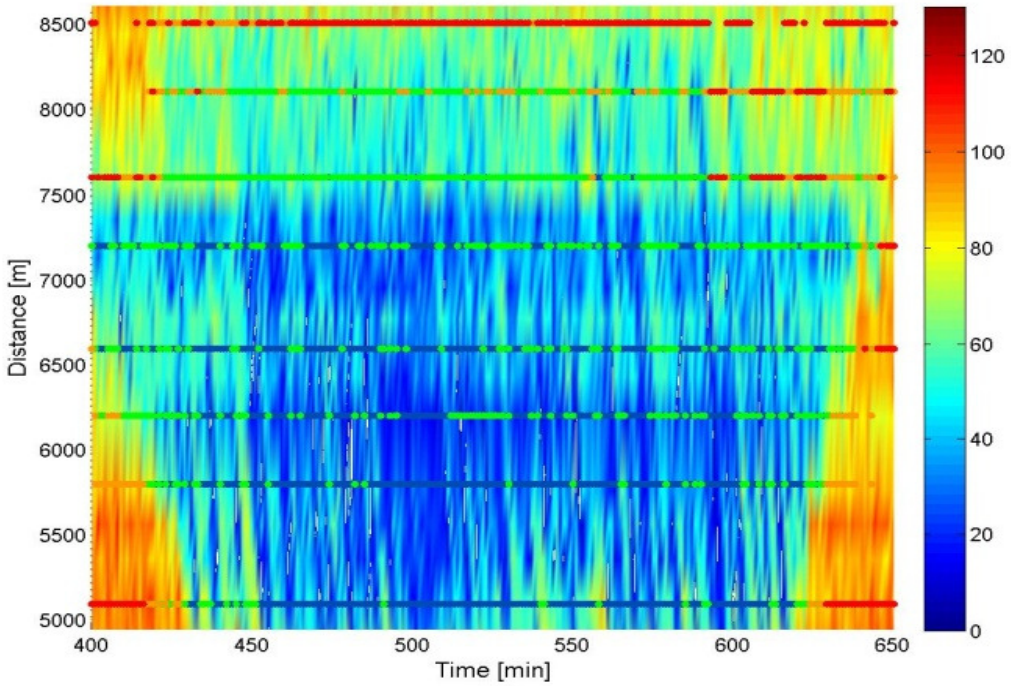
- Global performance of the current system:

	DR (%)	FAR (%)
R1	80.4	10.4
E313	60.5	7.6

- DR reasonably high for R1 but substantially lower for E313
- FAR very low (high credibility)
- Imbalance between DR and FAR, since DR is more important (direct safety benefits)
- Volatile behavior in congestion: > 40% of VSL < 1 min

Analysis of the RSS system

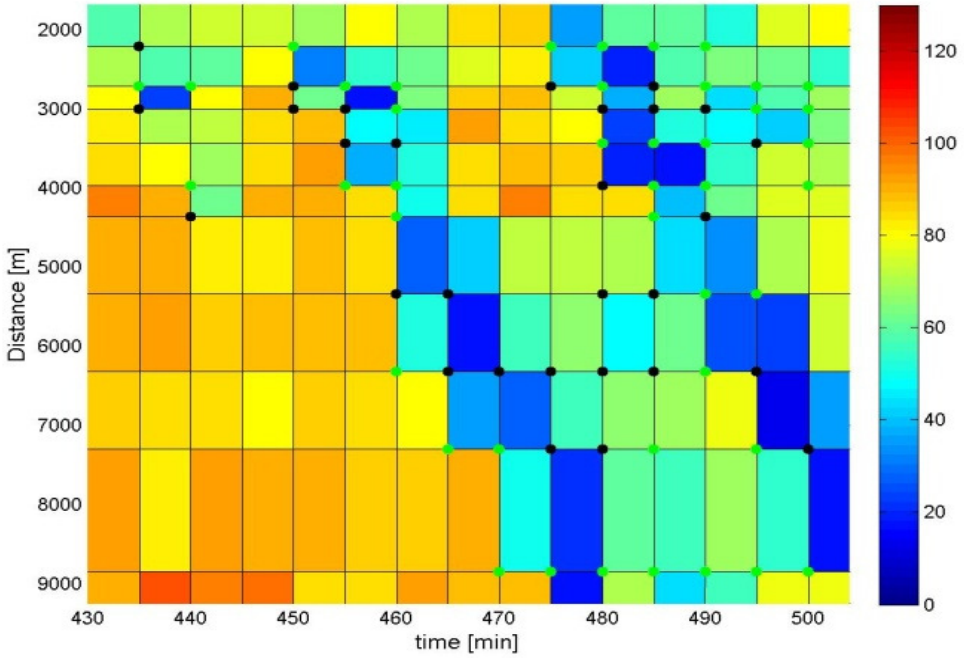
- R1 daily morning congestion and VSL response



- VSL too volatile in stable congested zone
  - Negative effect on credibility
- High VSL (some missed detections) at queue head not undesirable => encourages drivers to accelerate

Analysis of the RSS system

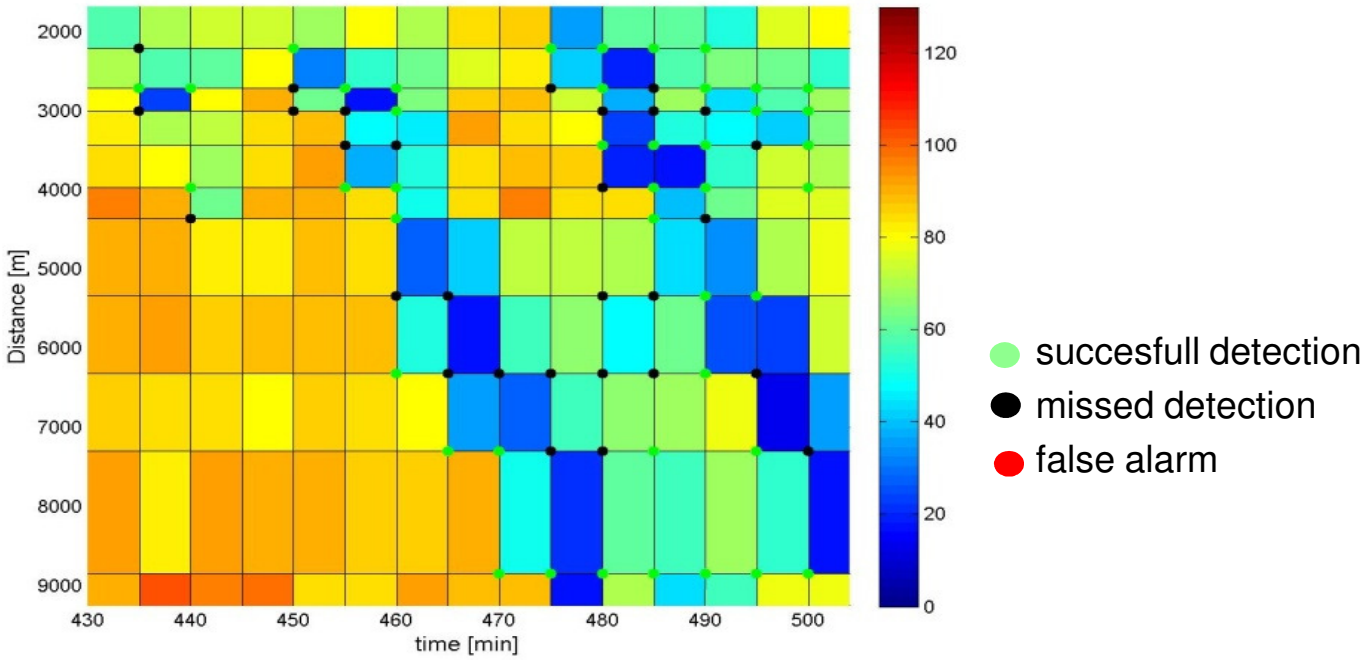
- Trajectory speeds (E313) vs. DR and FAR



- A lot of dangerous missed detections at queue tails
- Imbalance between DR and FAR is clearly visible

Analysis of the RSS system

- Trajectory speeds (E313) vs. DR and FAR



- A lot of dangerous missed detections at queue tails
- Imbalance between DR and FAR is clearly visible

Analysis of the RSS system

- Stability of the VSL messages during peak periods:

	ochtendspits (6u30-10u)		avondspits (15u30-19u)	
duur (min)	#	%	#	%
<1	3474	40.5	3112	43.3
->2	1846	21.5	1462	20.3
->3	1150	13.4	821	11.4
->4	626	7.3	412	5.7
->5	373	4.3	289	4.0
>5	1111	12.9	1099	15.3
totaal	8580	100.0	7195	100.0

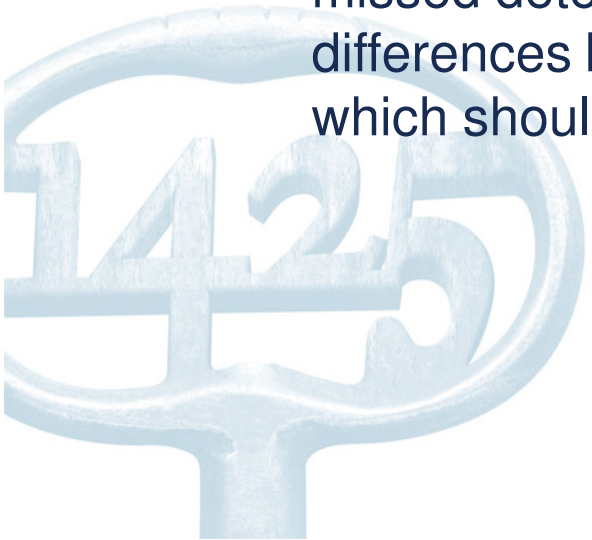
- Volatility is apparent from large number of very short displays

Analysis of the RSS system

- Conclusions:
  - Overall the RSS system performs well
    - VSL correspond to detected traffic conditions
  - DR reasonably high (mainly on R1) and FAR is very low
  - Response to spillback waves is reasonable, but may be improved
  - RSS system responds well to the dissolving of congestion by showing higher VSL to encourage drivers to accelerate
  - In heavy congestion, the VSL are stable
  - Volatile in regular congestion
    - VSL messages change frequently, which negatively affects the credibility
  - Detection is crucial
    - Our study revealed some malfunctioning cameras which caused unjustified VSL activation
    - This has to be checked regularly

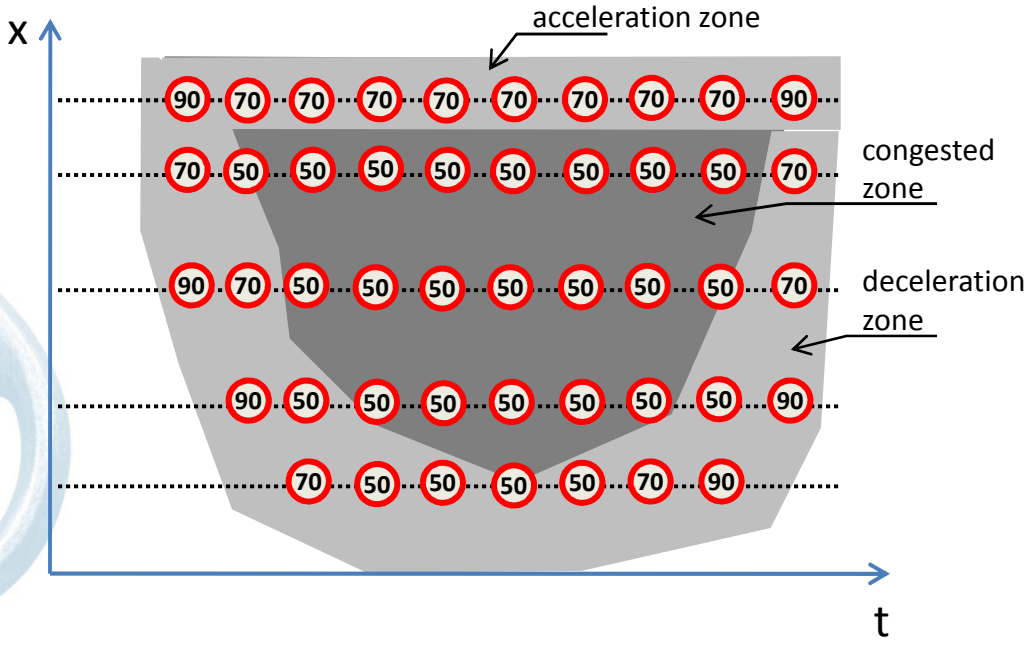
Analysis of the RSS system

- From the in-depth analysis, two suggestions for improving the performance can be made:
  - Stabilization of VSL during congestion. This increases the credibility of the system (and possibly yields indirect safety benefits in result).
  - Short-term spillback wave predictions to avoid dangerous missed detections at queue tails (involving large speed differences between approaching and downstream traffic), which should engender considerable safety benefits.



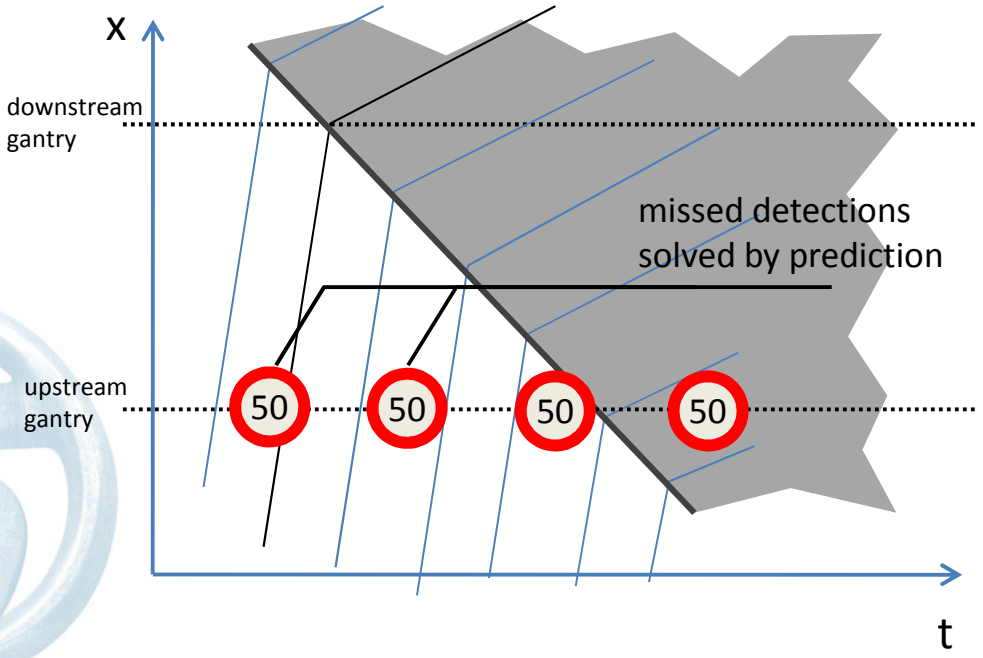
Ex-ante evaluation of modifications

- Stabilizing VSL of 50 km/h
  - By fixing them for a *dominant* period
  - VSL can be further prolonged with *active* period
    - If VSL downstream are high; VSL of 50 km/h is lifted (keeping the desirable properties in the acceleration zone)
  - Intended functionality:



Ex-ante evaluation of modifications

- Short-term spillback wave prediction
  - low VSL are propagated to an upstream gantry even before congestion is detected at that upstream highway section
  - Intended functionality:



Ex-ante evaluation of modifications

- ⟹ Ex-ante evaluation using again the assessment method from the drivers' perspective
- Modifications performed with post-processing algorithms on the VSL loggings
- Effect on the traffic states and drivers' speeds is neglected; the same data set is used
- Parameter values of the modifications are optimized to maximize the anticipated performance

Ex-ante evaluation of modifications

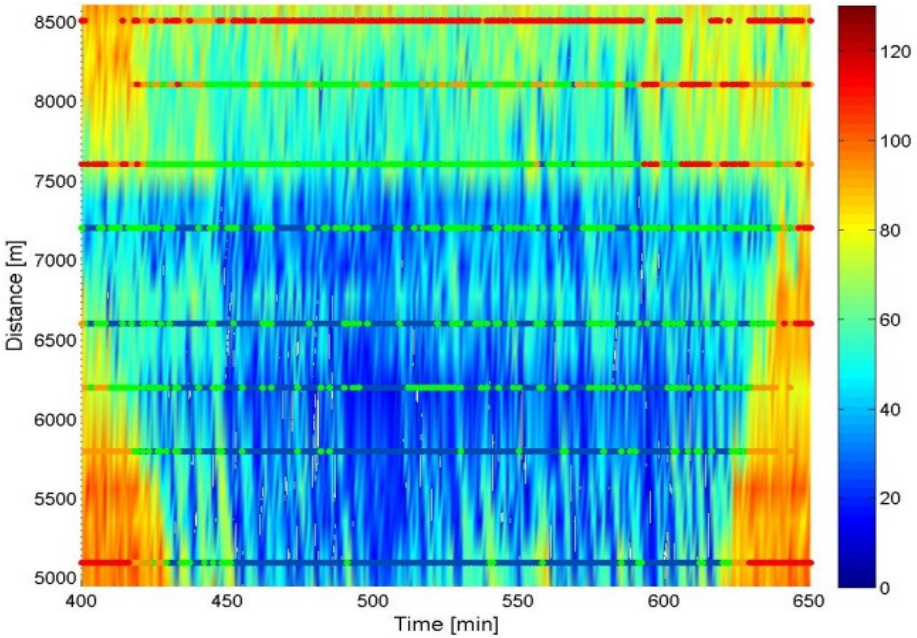
- Ex-ante performance of the modified VSL system

R1	DR (%)	Δ DR (%)	FAR (%)	Δ FAR (%)
stabilization	88.0	+7.6	12.2	+1.8
prediction	81.7	+1.3	12.5	+2.1
both	88.9	+8.5	13.4	+3.0

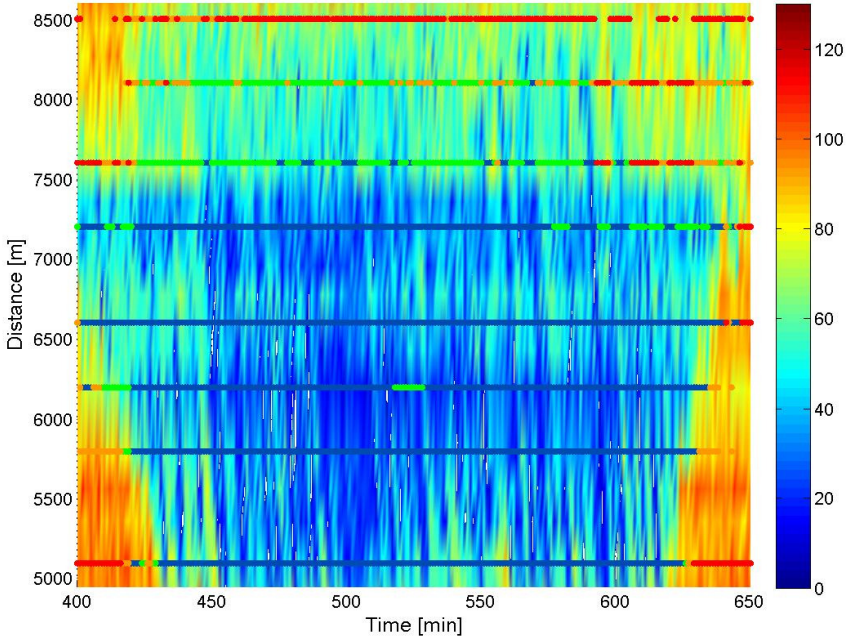
E313	DR (%)	Δ DR (%)	FAR (%)	Δ FAR (%)
stabilization	72.2	+11.7	9.9	+2.3
prediction	67.2	+6.7	10.6	+3.0
both	76.2	+15.7	12.7	+5.1

Ex-ante evaluation of modifications

Original response



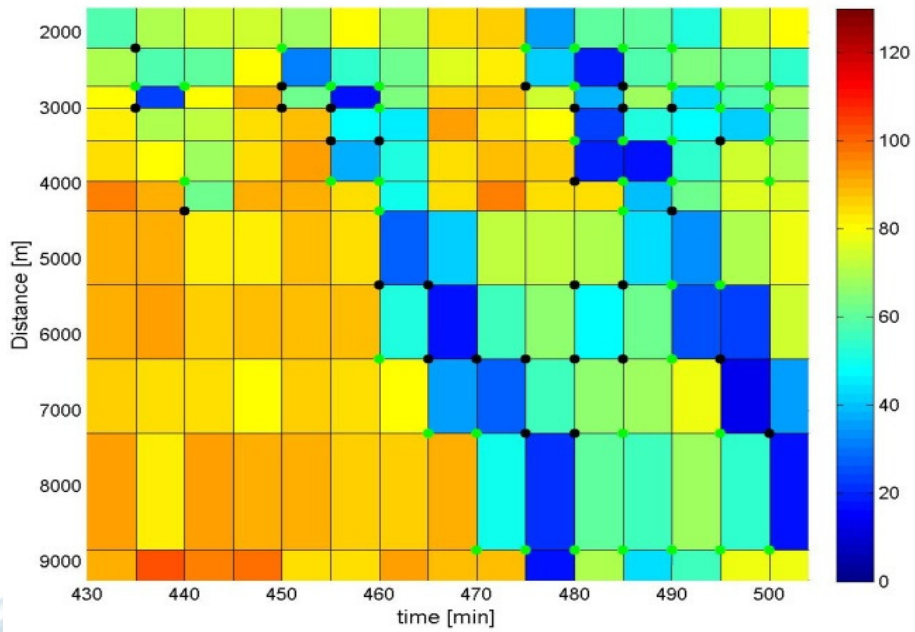
Modified response



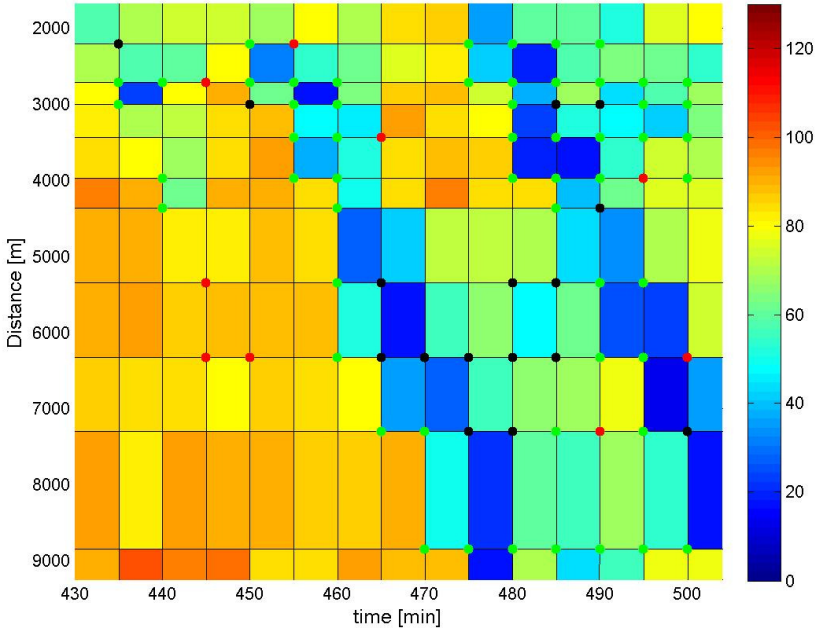
- VSL in congestion effectively stabilized
- At the queue head, drivers are encouraged to accelerate as in the original situation

Ex-ante evaluation of modifications

Original response



Modified response

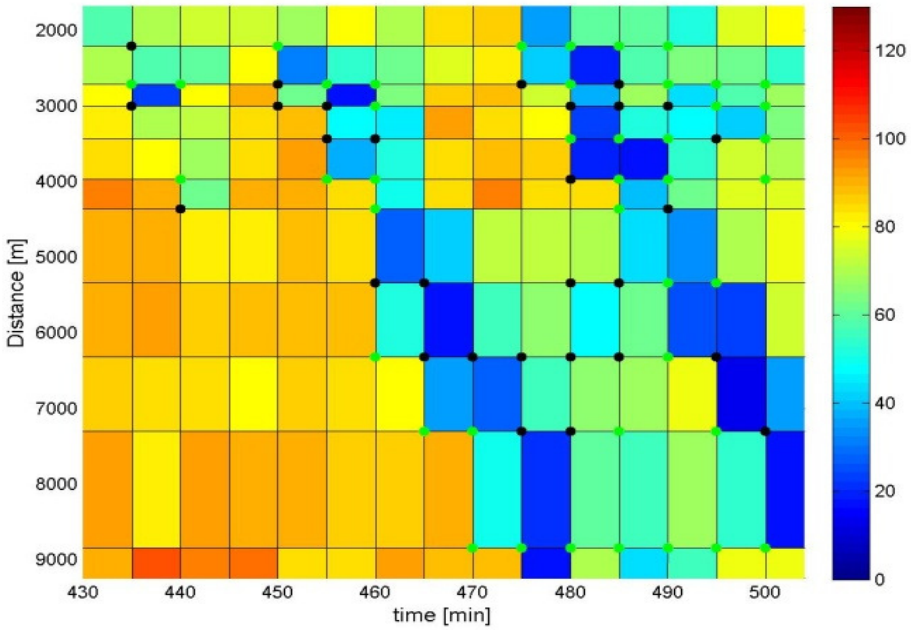


- successfull detection
- missed detection
- false alarm

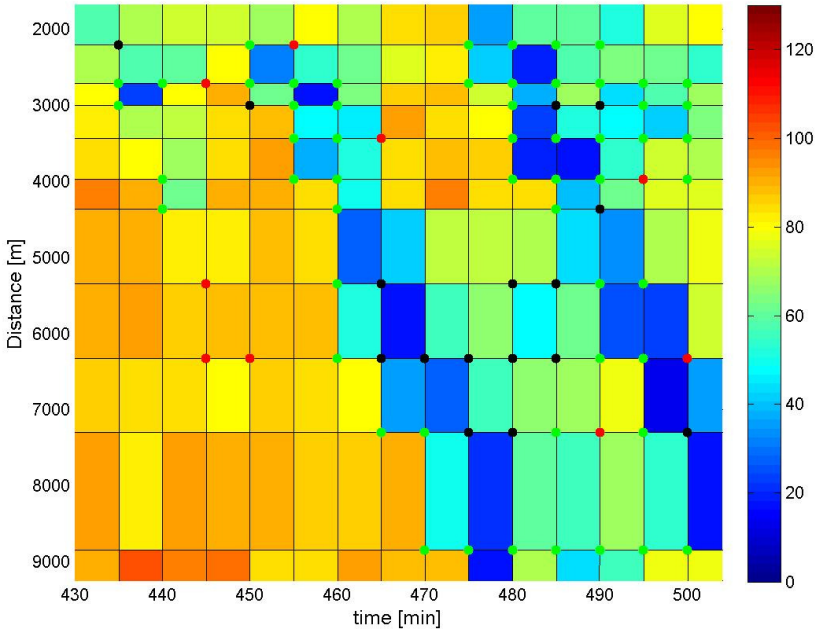
- Most dangerous missed detections at queue tails solved; some other (less dangerous) remain

Ex-ante evaluation of modifications

Original response



Modified response



- successfull detection
- missed detection
- false alarm

- Some false alarms are generated by the modification, but overall effect is positive

Conclusions

- Assessment of safety and credibility of VSL from DR and FAR defined from the drivers' perspective
- In-depth analysis with visualizations of VSL, detections and alarms in comparison to detected traffic states allows to identify (local) weaknesses and suggest targeted improvements
- Performance of the warning function of the current RSS system is good:
  - Relatively few missed detections
  - Very few false alarms
  - Good response to accelerating traffic

Conclusions

- With the presented assessment method, the current VSL implementation around Antwerp is evaluated and two improvements are suggested:
  - Stabilization of VSL during congestion to increase the system's credibility.
  - Short-term shockwave predictions to increase the safety benefits
- Ex-ante analysis of the modified system predicts an improvement of 8-15% in DR at the cost of an increase of the FAR of only 3-5%

Thank you for your attention