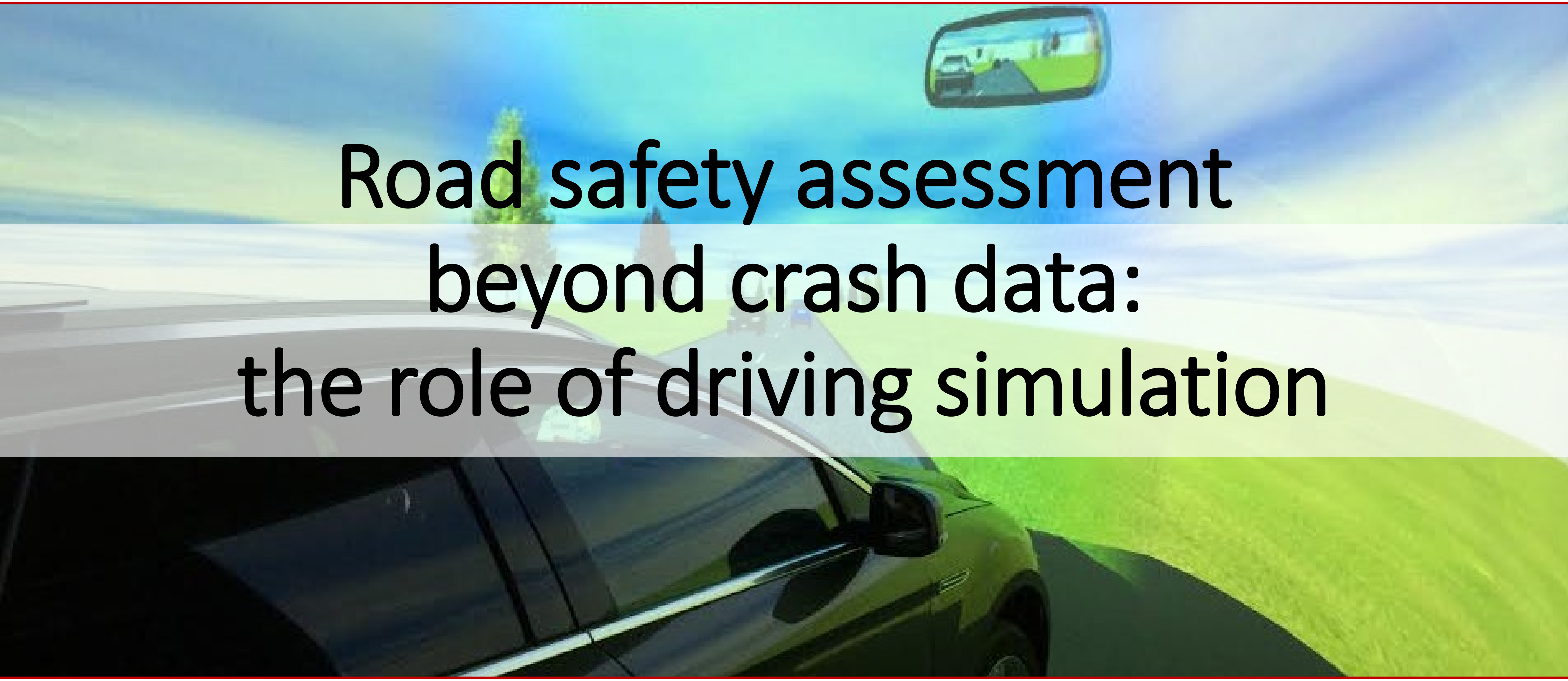
Road safety assessment beyond crash data: the role of driving simulation



Prof. dr. Tom Brijs – Transportation Research Institute (IMOB)

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Overview

- 15 years of driving simulation @ Hasselt University
- Driving simulation and road design
- Driving simulation and human factors
- Driving simulation and vehicle technology / ADAS
- New developments and future outlook

15 years of driving simulation @ Hasselt University


Inacopia
Inacopia office
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In the past: geospecific database modelling

Replica of real-wold driving environment

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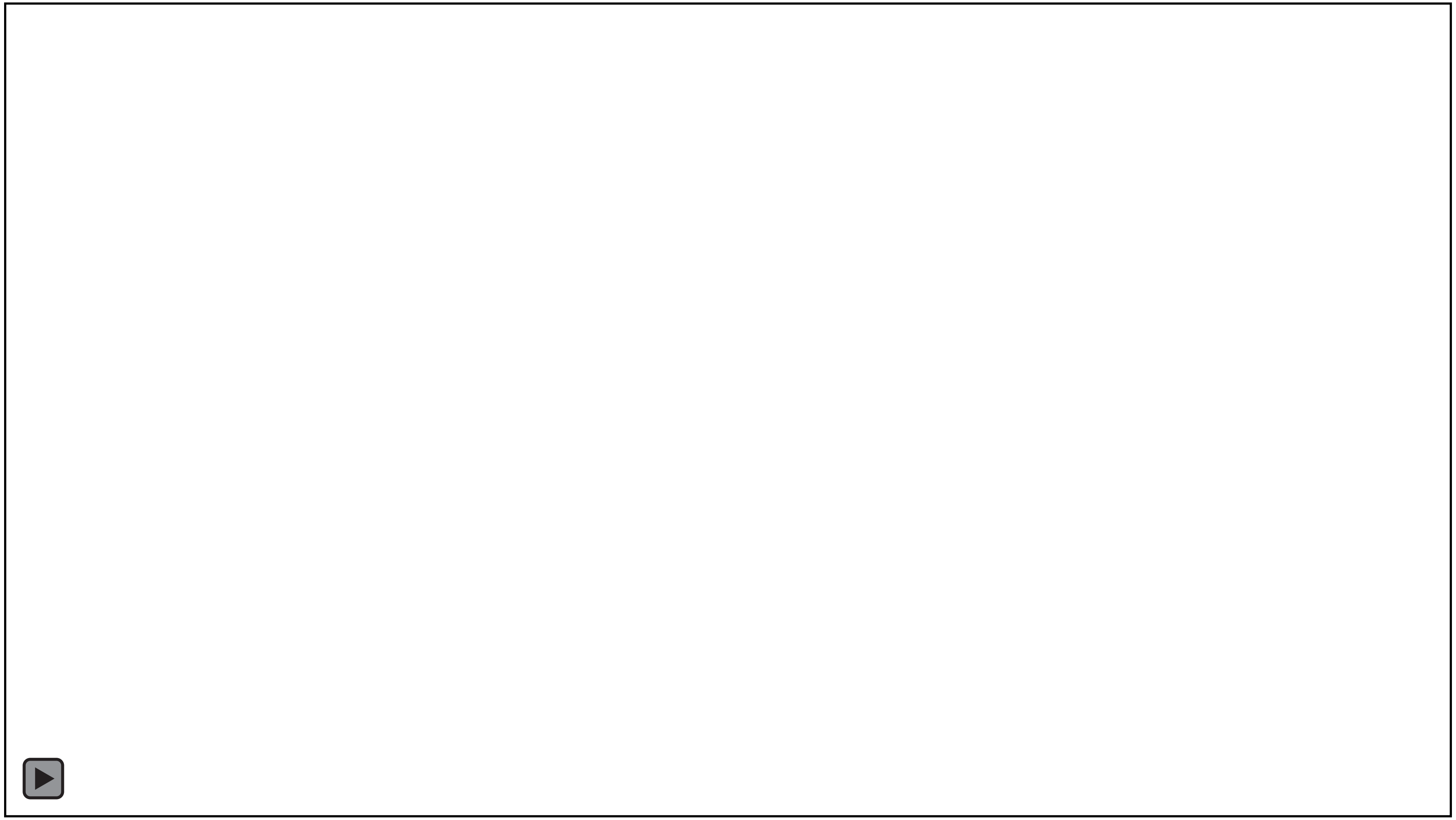
Today: use of digital road and terrain data



Driving simulation & road design

Road user testing

- In depth evaluation and product/user and safety testing has become everyday practice in most industrial sectors
  - Food and cosmetics industry: consumer panels
  - Pharmaceutical industry: clinical trials
  - Car industry: crash testing
  - …
- And what about the design of roads?
  - At best we have guidelines (but which often differ from region to region)
  - In most cases we test for conformity to the guidelines (i.e. safety audits) ≠ user testing

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Need for evaluation and road user testing

- Why to involve the road user in the evaluation? Because:
  - *Road user perception and comprehension*: does the road user understand the infrastructure we intend to build?
  - *Road user behavior*: does the road user behave as expected by the road planners / designers?
  - *Ethics*: Design errors may lead to serious safety consequences (collisions)
  - *Cost*: Correcting for errors after construction of the infrastructure is expensive and causes additional disturbance ("prevention is better than cure")

How to involve the user in the design process?

- As *early as possible* during the design process: the longer we wait, the more difficult / costly to repair errors
- In a *naturalistic setting*, as representative as possible to the real world understood by the road user
- In an *evidence-based* way by means of scientific and verifiable parameters
- In a *cost-efficient* way

-> Solution: driving simulation

Why driving simulation?

- Modern software, graphics capabilities and computer systems enable creation of quasi realistic driving environments
- Different climatological and traffic conditions can be simulated
- Full experimental control
- Easy and detailed user data collection (driving dynamics, visual attention, cognitive processing, decision behavior …)
- Testing under safe conditions (ethics)

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Research topics in infrastructure design

- Road geometric design
  - Innovative intersection designs
  - Motorway design (acceleration / deceleration lanes, weaving zones)
  - Traffic calming measures
- Traffic signals
  - Innovative signaling concepts, signal timing
- Road signs & markings
  - Sign perception, placement and composition (avoiding overload)
  - Sign comprehension (choice of symbols, pictograms)
  - Innovative markings (e.g. LED, coloured markings)
  - Compliance and choice behavior (e.g. speed, right of way, direction)
- Impact of roadside elements
  - (LED) roadside advertising, speed enforcement cameras
  - Beacons, roadworks

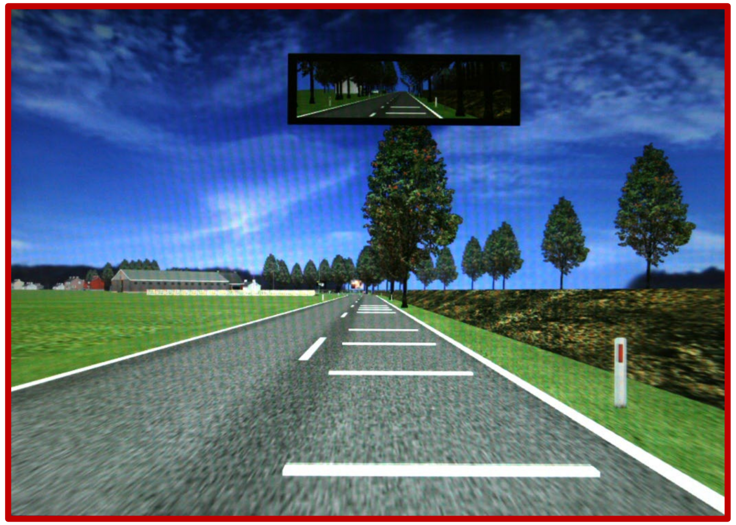
Road markings and curves

Conclusion

- Both markings lower the mean speed
- **TRS:** Delay from 166 m before the curve
- **HB:** Delay from the beginning of the curve

In case of dangerous curves
→ use Transversal rumblestrips

Transversal rumblestrips



Herringbone pattern

Source: Ariën, C.; Brijs, K.; Vanroelen, G.; Ceulemans, W.; Jongen, E. M.M.; Daniels, S.; Brijs, T. & Wets, G. (2016). The effect of pavement markings on driving behaviour in curves: a simulator study. In: Ergonomics, Jul 4, pp 1-13.

Road markings and curves

Conclusion

- Both markings reduce speed before curve
- **HWS:** no effect on lateral control
- **RM:** driving closer to road edgeline

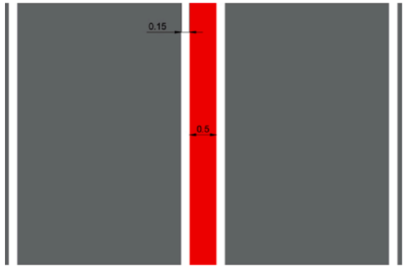
In dangerous curves with head-on collisions

→ Use red median

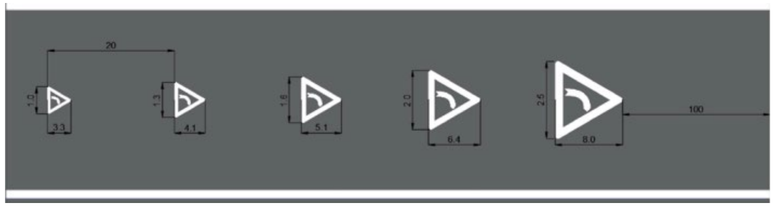
Otherwise

-> use horizontal warning signs

Red median (RM)



Horizontal warning signs (HWS)



Source: Babic, D., Brijs, T. (2021) Low-cost road marking measures for increasing safety in horizontal curves: A driving simulator study. In: Accident Analysis and Prevention, 153 , (Art N° 106013).

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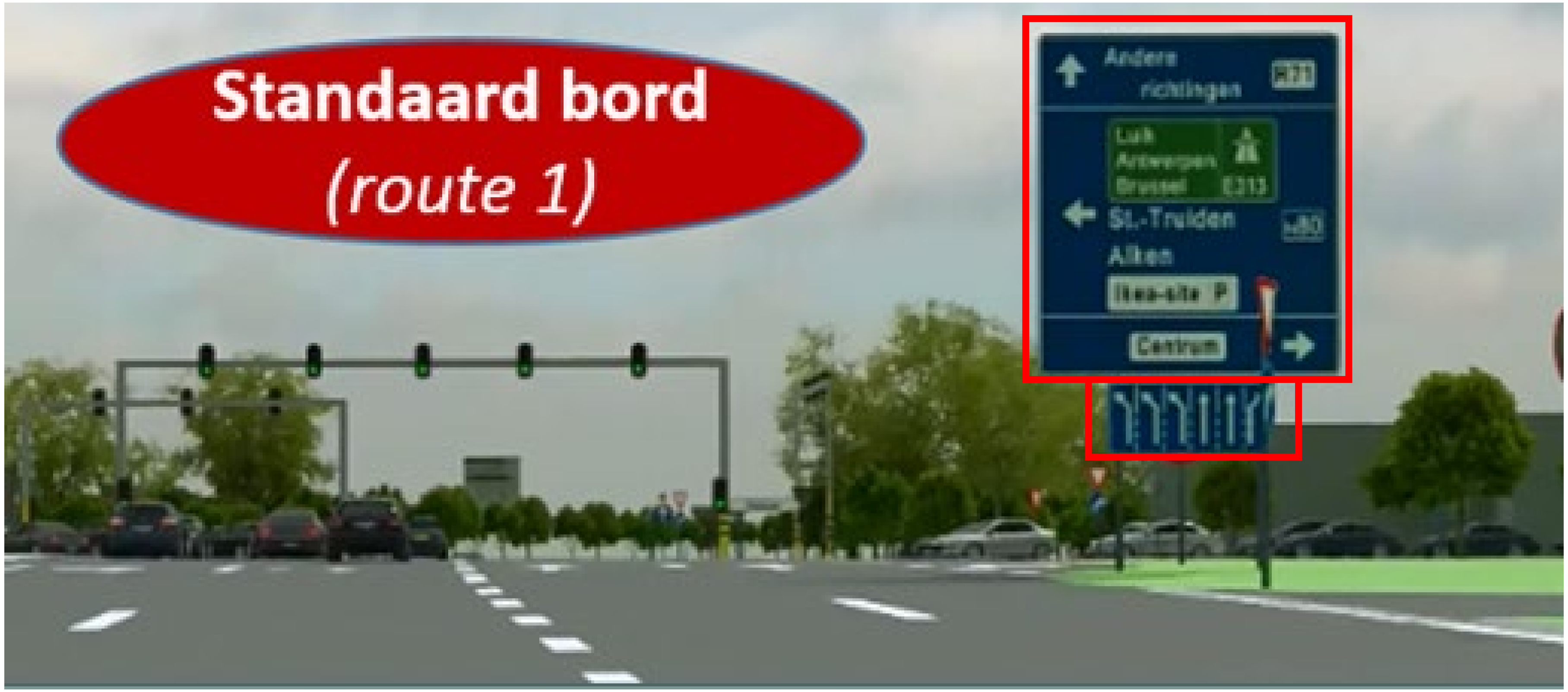
Case: R71 - N80 in city of Hasselt

Cantilever + traffic lights



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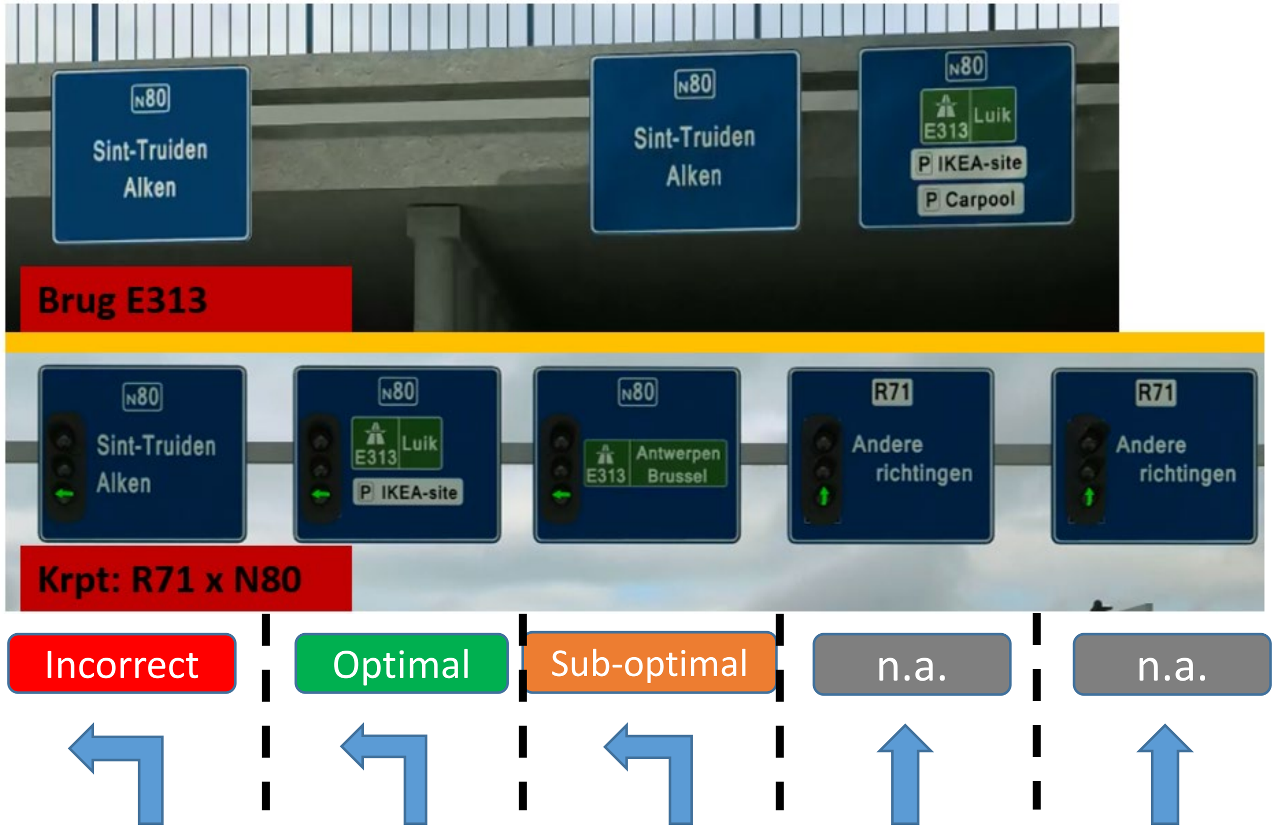
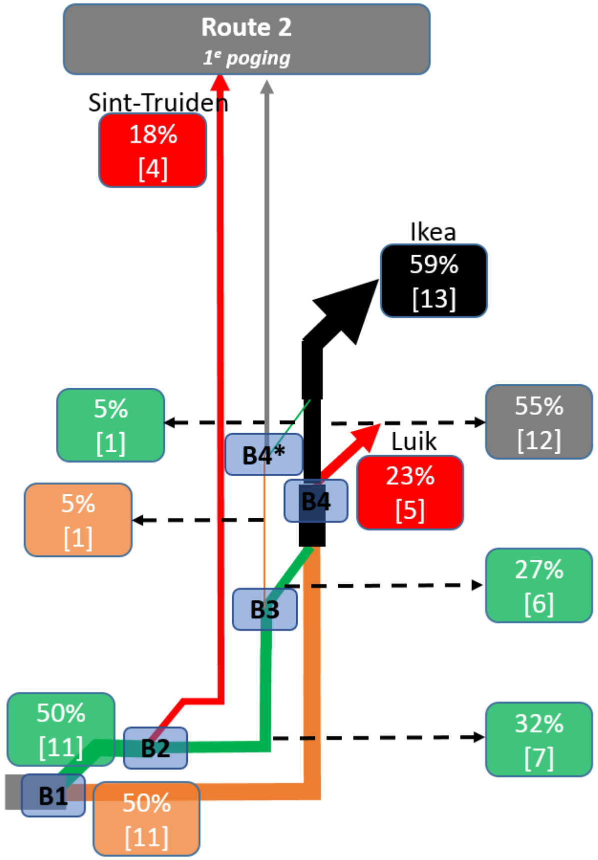
Gantry with integrated traffic lights

Case: R71 - N80 in Hasselt





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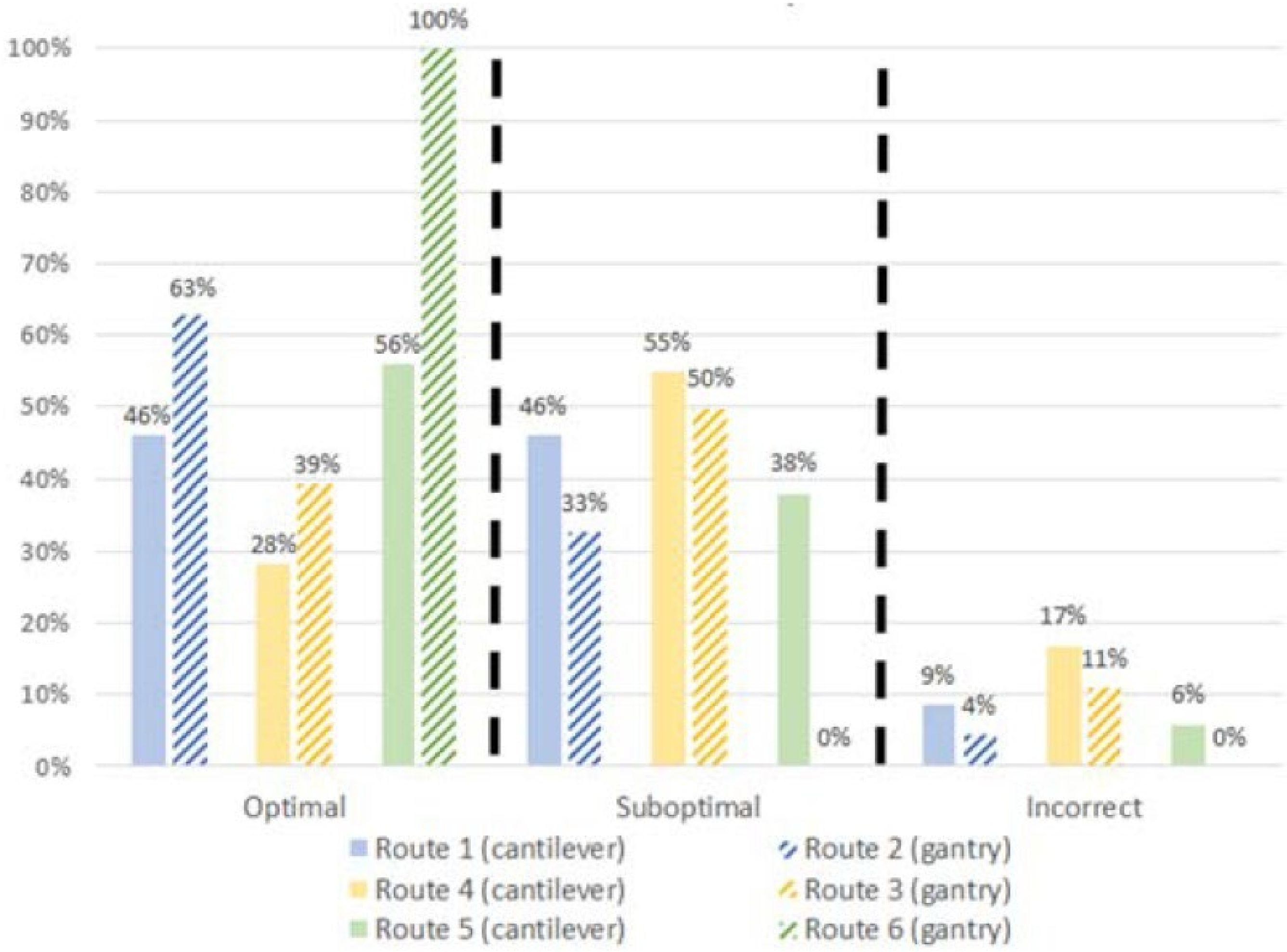
Case: R71 - N80 in Hasselt



Current situation

Source: Mollu, K.; Cornu, J.; Declercq,K.; Brijs, K. & Brijs, T. (2017). The Use of Gantries and Cantilevers at a Redesigned Intersection: a Simulator Study on Route Choice and Visual Search Behavior. In: Advances in transportation studies, 42(A), p. 55-68.

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Augmented reality video simulation

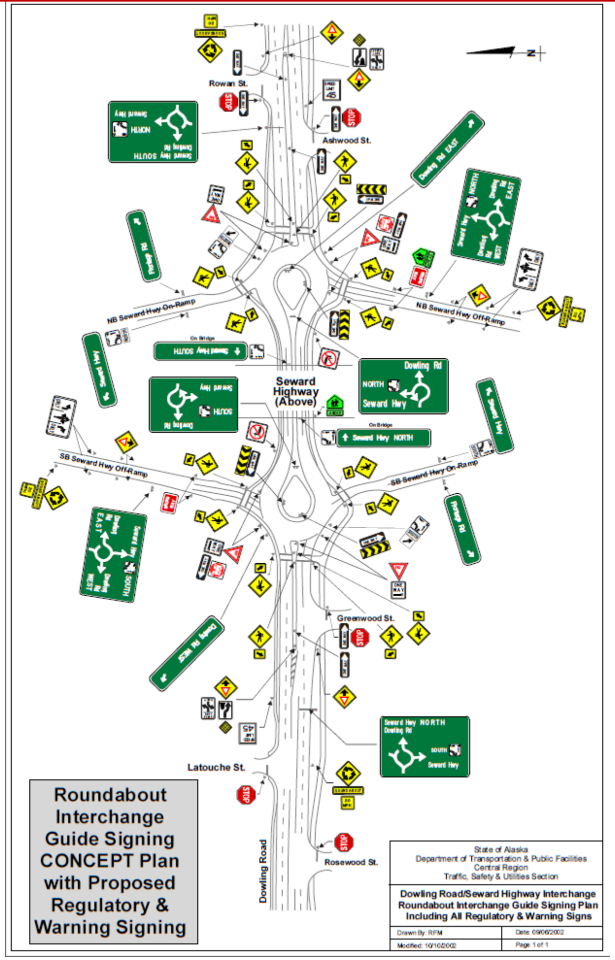
- Technique developed to use video footage for driving simulation and ‘enrich’ it with signs, markings and roadside objects that are not physically present in the real world
- Applications:
  - Signage and markings in roadworks situations
  - Signage for temporary route diversions (emergency divergence routes)
  - Signage for urban parking routing
  - Signage for route guidance to industrial zones

Source: De Ceunynck, T.; Arien, C.; Brijs, K.; Brijs, T.; Van Vlierden, K.; Kuppens, J.; Van der Linden, M. & Wets, G. (2015). Proactive Evaluation of Traffic Signs Using a Traffic Sign Simulator. In: European Journal of Transport and Infrastructure Research, Vol. 15 (2), p. 184-204.

Approach

The case of roadworks:

1. Analyse proposed signage plan and signage concept
2. Video recording of existing infrastructure
3. Integration of virtual signs and markings
4. Develop test scenarios
5. Select test panel, perform tests
6. Analyse, report results



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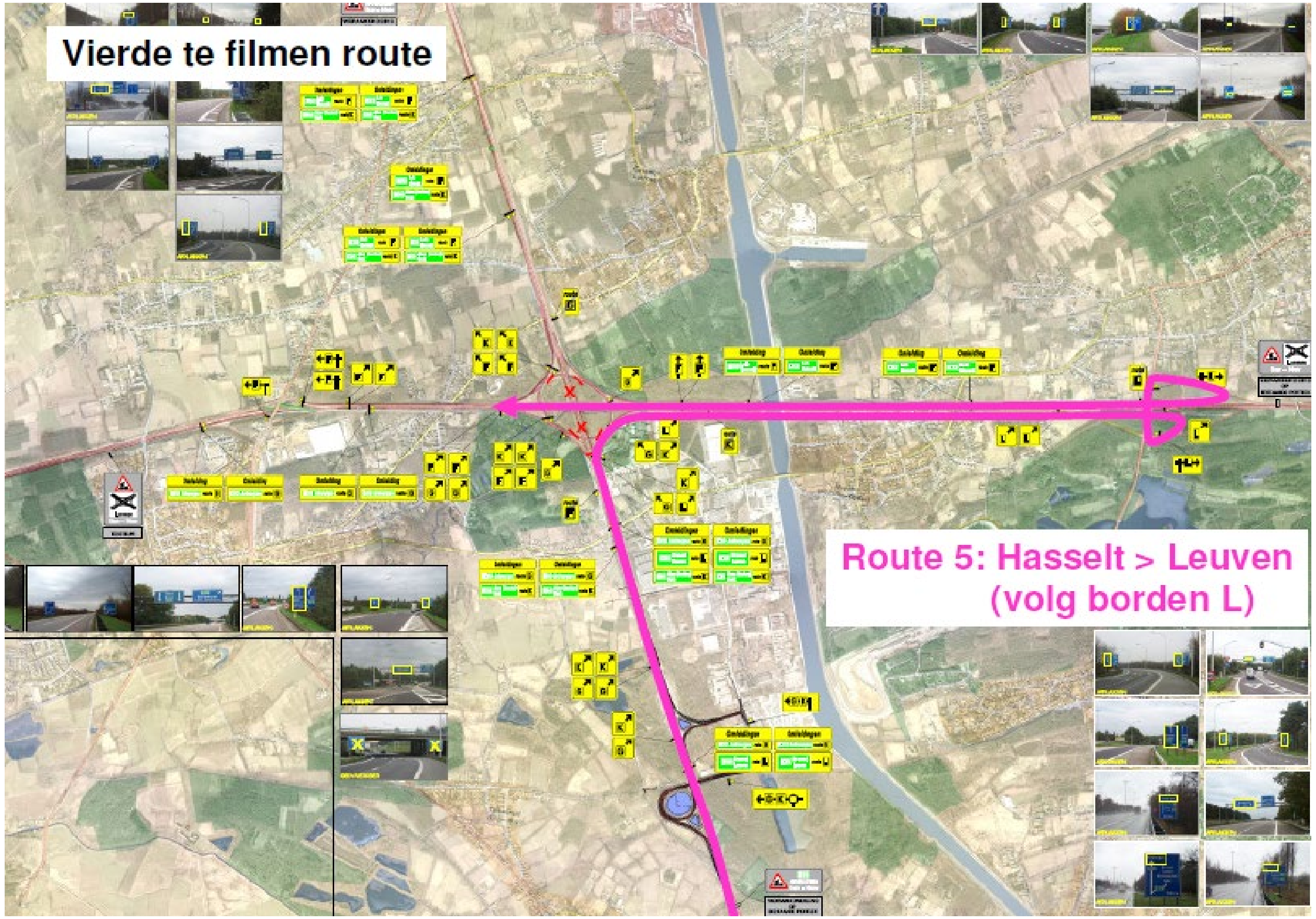
Step 1: study divergence routes & signs



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Step 2: video recording of infrastructure

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Step 3: integration of virtual signs and markings

> By adapting camera-tracking/matching techniques

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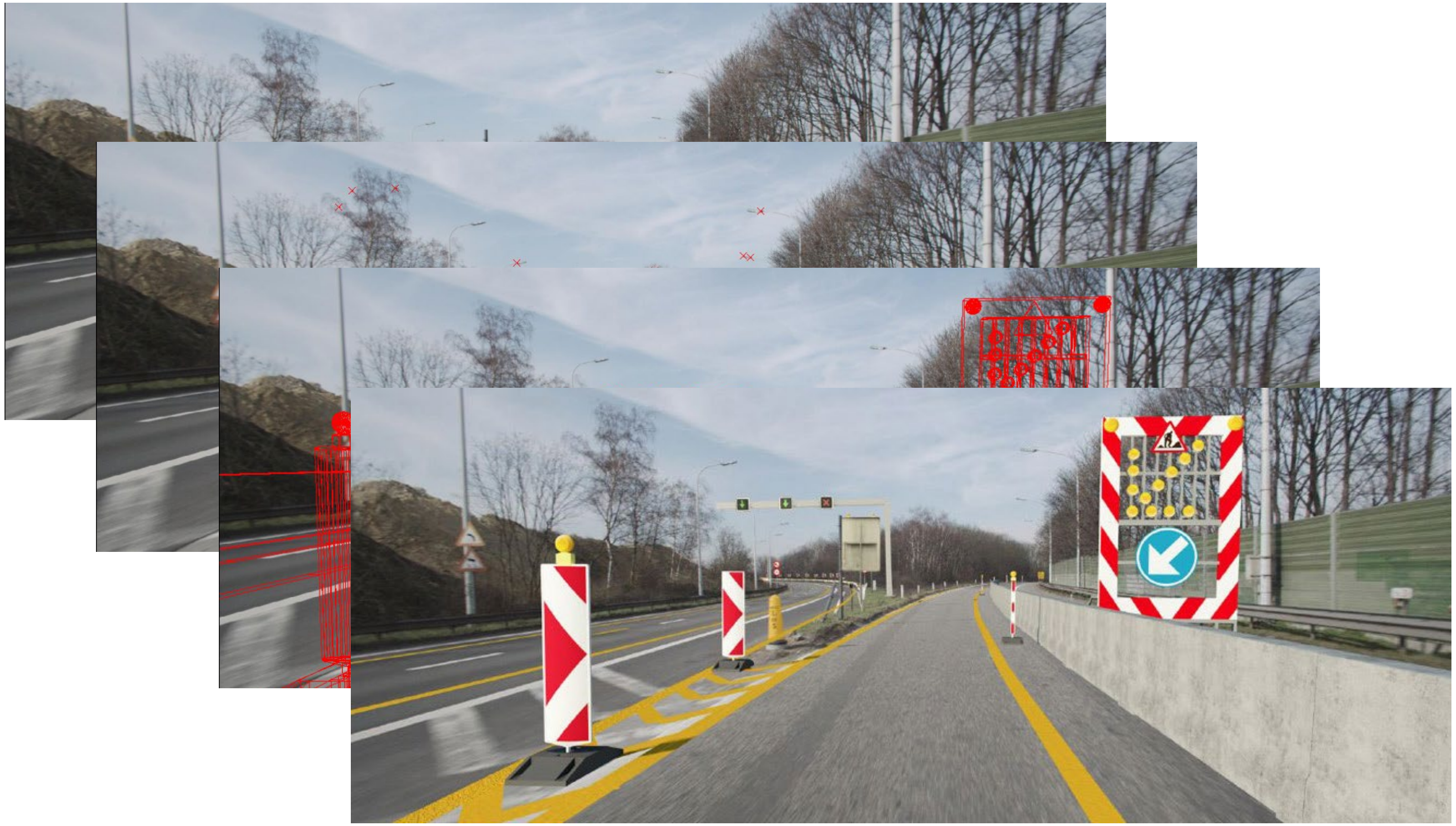
Step 3: integration of virtual signs and markings



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Result before-after integration of virtual objects

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Testing: traffic diversion signage on motorway

Source: Mollu, K.; Cornu, J.; Brijs, K.; Van der Linden, M.; de Boer, J. & Brijs, T. (2016). Gantries or cantilevers for route guidance on a reorganized arterial road? A before study of route choice effectiveness using a traffic sign simulator (case study). In: Rafalski, L.; Zofka, A. (Ed.). Transportation Research Procedia (TRPRO), ELSEVIER SCIENCE BV,p. 4277-4285. (Transportation Research Procedia (TRPRO), 14)

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Testing: traffic diversion signage on motorway

Comparison

Virtual reality versus augmented reality driving simulation

	Virtual Reality	Augmented Reality
Driving scene graphical realism	Medium	High
Scenario development effort	Low – medium	Medium - high
Free movement	High	Medium
Freedom of scenario development	High (new + existing infra)	Low - medium (existing infra)
Traffic integration	Easy	Medium - difficult
Extensive data logging	Easy	Medium

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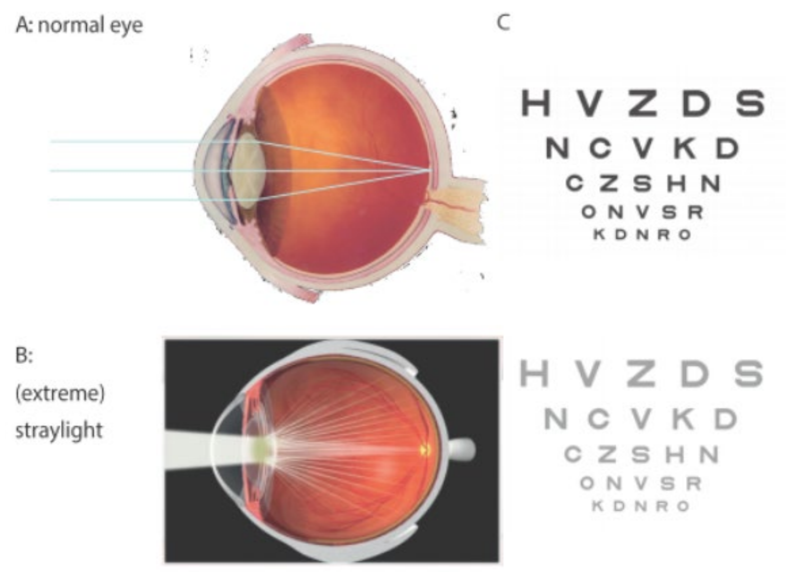
Driving simulation & human factors

Research topics

- Evaluation of fitness-to-drive, i.e. situation and time dependent ability to drive, such as influenced by:
  - Fatigue, sleepiness
  - Psychoactive substances (alcohol, medication, drugs)
  - Distraction
- Evaluation of driving aptitude, i.e. determined by physical and psychological traits and functions that are stable over time:
  - Drivers with physical disabilities
  - Elderly drivers
  - Medical conditions: visual impairments, dementia, Parkinson's disease, sleep apnea, epilepsy, multiple sclerosis
  - Personality disorders (anti-social, paranoid, narcissistic, …)
  - Drivers with ASS, ADHD
- Evaluation and training of driving skills
  - Young novice drivers, driving experience & education

Straylight (glare sensitivity) and driver aptitude

- Visual acuity is the only indicator widely adopted in driver aptitude evaluations
- Research shows that straylight can also affect driver abilities in traffic (and is largely independent from visual acuity)
  - Stray light reduces contrast sensitivity
  - More difficult to adapt to intense light sources (vehicle headlights)
  - More difficult to detect other objects / road users
  - Driving in twilight and dark becomes more difficult: some drivers decide to stop driving in these conditions
- Straylight increases with age, the intensity of the light source, and its impact can further increase with cataract
- Limited research available of straylight on driving abilities
- Need for limit values for straylight for clinical practice



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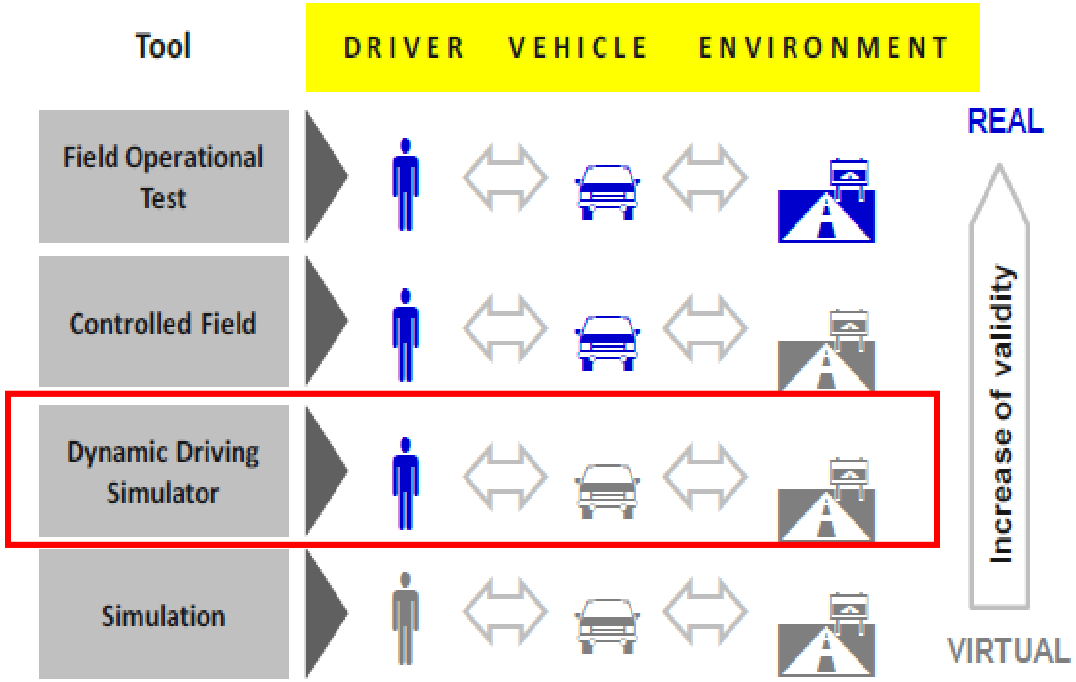
Straylight (glare sensitivity) and driver aptitude

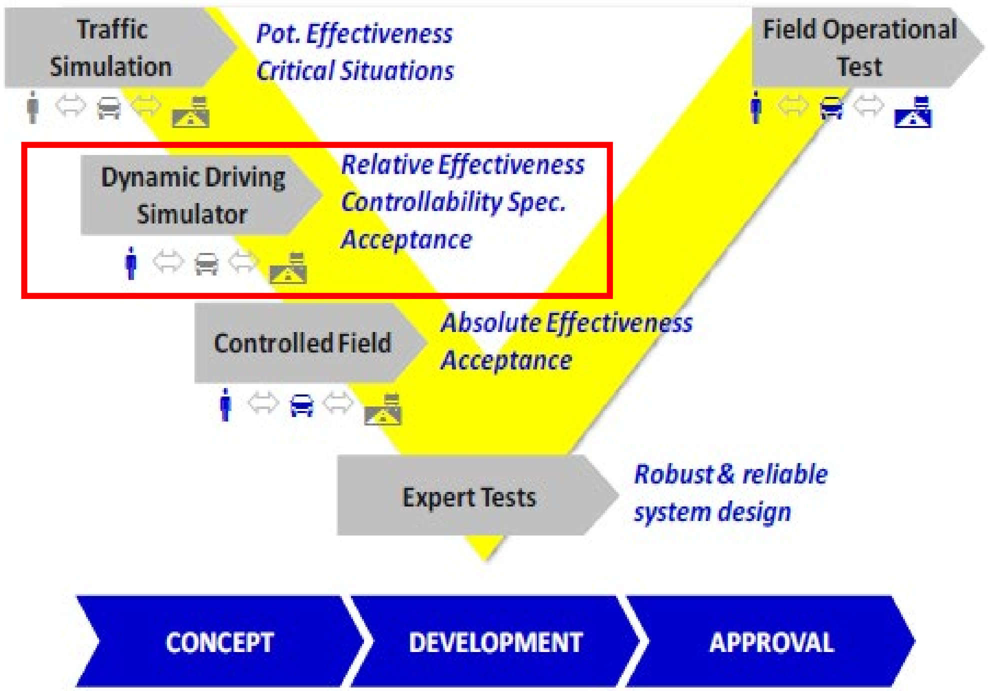
When exposed to straylight source and with increasing levels of simulated cataract (using special filter glasses):

- Drivers show compensatory behavior (keep longer headway, driver at lower speed)
- Nevertheless:
    - Longer detection and reaction times to critical events
    - Shorter distance to danger

Driving simulation & ADAS

Role of driving simulation in ADAS development





Source: Eckstein L. and Zlocki A. (2013), Safety potential of ADAS – Combined methods for an effective evaluation, in: Proceedings of the 23rd International Technical Conference on the Enhanced Safety of Vehicles (ESV-2013), Seoul, Korea, May 27-30.

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Research topics

- Behavioural reactions to in-vehicle assistance technologies
- Hardware in the loop testing
- Parameter tuning of ADAS systems (warning levels)
- Early user technology acceptance testing
- Augmented reality (e.g. 3D windshields)
- Transition of control between driver and vehicle in higher levels of automation (SAE>2)
- The potentially distracting role of (touchscreen) displays to control ADAS and driving comfort functions

Augmented reality
Source: Eyelights & AGC

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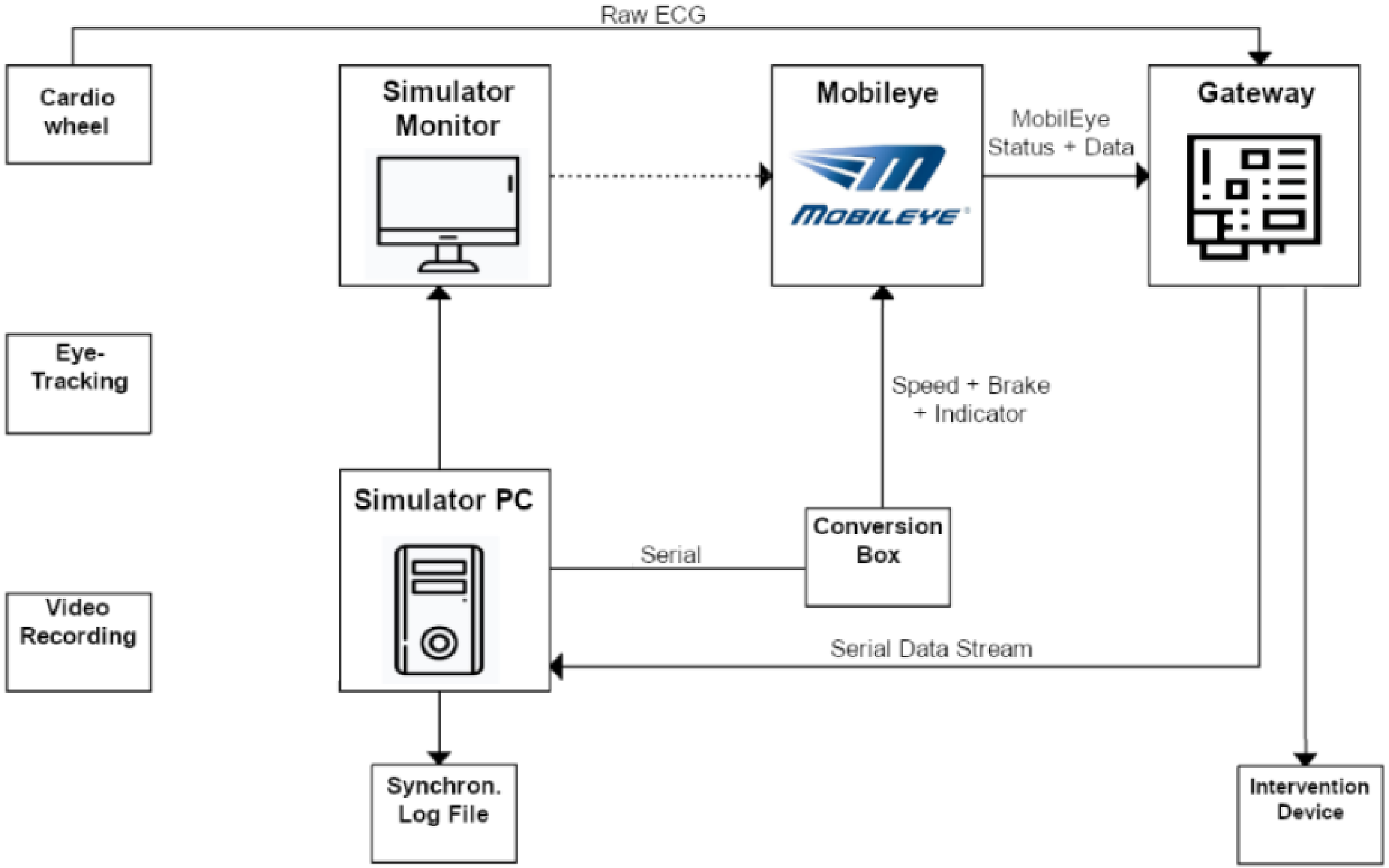
500 ft
25 min
Kuratorium für Verkehrs

Hardware in the loop simulation

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New developments & Future outlook

New developments & Future outlook

- Increasing attention for other (VRU) modes
  - Bicycle simulation
  - Scooter simulation
  - Pedestrian simulation
- Co-simulation / multi-driver simulation
- Integration of simulation tools: vehicle sensors, vehicle dynamics, road environment, surrounding traffic
- 3D goggles (with integrated eye-tracking)
- Out-of-the-box environment creation from open data
- Connected, Cooperative and Automated Mobility (CCAM)
  - V2V, V2I, V2X
  - Transition of control
  - Interaction between different road users

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