@HFE_UOS

Drivers' Reactions to Automated Vehicles:

why do partially automated vehicles crash?

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Driving simulator (2016)


12:34

Overview

- Vehicle automation rather than autonomy?
- What goes wrong?
- Why do automated vehicles crash?
- What can be done?
- Conclusions and warnings

SAE J3016™ LEVELS OF DRIVING AUTOMATION

	SAE LEVEL 0	SAE LEVEL 1	SAE LEVEL 2	SAE LEVEL 3	SAE LEVEL 4	SAE LEVEL 5
ADAPTIVE CRUISE CONTROL		●	●	●	●	●
PARKING HELPER-L1		●				
ACTIVE LANE CENTERING		●	●	●	●	●
PARKING HELPER-L2			●	●	●	●
HIGHWAY PILOT-L2			●	●	●	●
TRAFFIC JAM PILOT				●	●	●
AUTOMATED DRIVING SYSTEM-L3				●		
AUTOMATED DRIVING SYSTEM-L4					●	
PARKING VALET					●	●
AUTOMATED DRIVING SYSTEM-L5						●
		ASSISTED		AUTOMATED		

LEVELS

0 NO DRIVING AUTOMATION
You drive; vehicle can provide driving assist features

1 DRIVING AUTOMATION ASSISTANCE
Either steering or braking assist but not at the same time

2 PARTIAL DRIVING AUTOMATION
Steering AND braking assist together as support feature only; human driver must supervise

3 CONDITIONAL DRIVING AUTOMATION
Automation of full driving task with human fallback; driver must respond promptly when alerted

4 CONDITIONAL DRIVING AUTOMATION
Full automation but only in pre-determined conditions; human must drive when system is not engaged

5 FULL DRIVING AUTOMATION
You never have to drive anywhere unless you want to

INTERNATIONAL

SAE J3016™ LEVELS OF DRIVING AUTOMATION

	SAE LEVEL 0	SAE LEVEL 1	SAE LEVEL 2	SAE LEVEL 3	SAE LEVEL 4	SAE LEVEL 5
ADAPTIVE CRUISE CONTROL		●	●	●	●	●
PARKING HELPER-L1		●				
ACTIVE LANE CENTERING		●	●	●	●	●
PARKING HELPER-L2			●	●	●	●
HIGHWAY PILOT-L2			●	●	●	●
TRAFFIC JAM PILOT				●	●	●
AUTOMATED DRIVING SYSTEM-L3				●		
AUTOMATED DRIVING SYSTEM-L4					●	
PARKING VALET					●	●
AUTOMATED DRIVING SYSTEM-L5						●
		ASSISTED		AUTOMATED		

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Fatalities

Date	Country	City, State	OEM	Model	Fatality
20th January 2016	China	Handan, Hebei	Tesla	Model S	Driver
7th May 2016	USA	Williston, FL	Tesla	Model S	Driver
18th March 2018	USA	Tempe, AZ	Uber/Volvo	XC90	Pedestrian
23rd March 2018	USA	Mountain View, CA	Tesla	Model X	Driver
1st March 2019	USA	Delray Beach, FL	Tesla	Model 3	Driver
25th April 2019	USA	Miami, FL	Tesla	Model S	Pedestrian

Be prepared to take control….

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Banks, V. A., Plant, K. L. and Stanton, N. A. (2018) Driver error or designer error: Using the Perceptual Cycle Model to explore the circumstances surrounding the fatal Tesla crash on 7th May 2016. Safety Science, 108, 278-285.

Autopilot ‘Upgrade’

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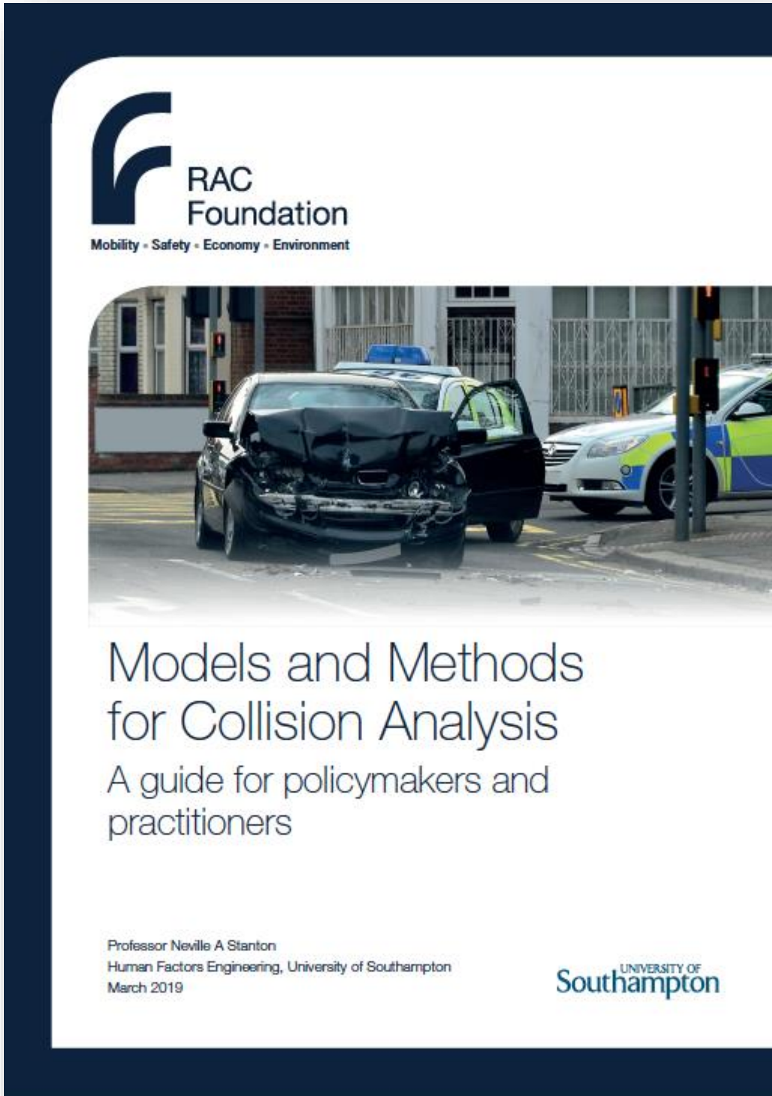
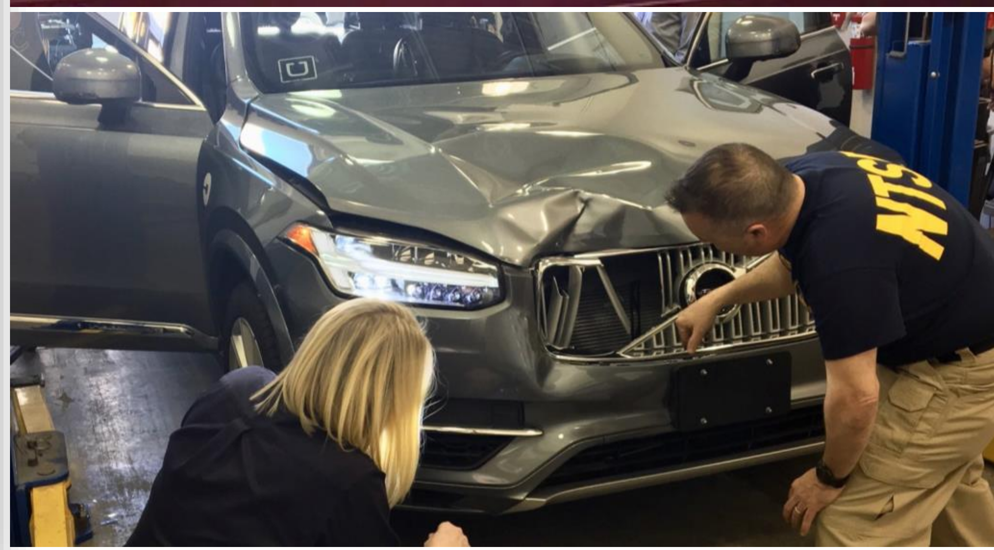
Banks, V. A., Eriksson, A., O’Donoghue, J. and Stanton, N. A. (2018) Is partially automated driving a bad idea? Observations from an on-road study. Applied Ergonomics, 68, 138-145.

Collision analysis





https://www.racfoundation.org/research/safety/models-and-methods-for-collision-anaylsis

Timeline 18th March 2018

- **6:30 p.m.**: 44-year-old Rafaela Vasquez arrives for work at the Uber facilities in Tempe, Arizona.
- **9:14 p.m**.: Vasquez leaves the Tempe facilities in a self-driving 2017 Volvo XC90 operated by Uber to run an established test route through downtown Tempe.
- **9:39 p.m**.: The vehicle is switched to autonomous mode.
- A report from Tempe police states Vasquez begins streaming "The Voice" on the Hulu app on a cellphone. During this time, the Tempe police state that Vasquez can be seen frequently looking down at the lower center console area near her knee and frequently smirking and laughing. Her hands are not visible in the frame of the surveillance footage. Police determine she looks down 204 times over the course of 11.8 miles. Her eyes were off of the road for 6 minutes and 47 seconds during this period (i.e., over 25% of time). ***This report is not yet substantiated by NTSB.***
- **9:58 p.m.**: Vasquez looks up while driving northbound on Mill Avenue toward Curry Road, approximately 0.5 seconds before the crash. She attempts to swerve left before striking 49-year-old Elaine Herzberg at 39 mph (speed zone posted at 45 mph) as she crosses the street mid-block. Hulu's records also show the streaming of the show ended at this time.
- Vasquez calls 911 and is released later that night after speaking to police. She stated she was monitoring the self-driving system interface and neither her business or personal phones were in use.

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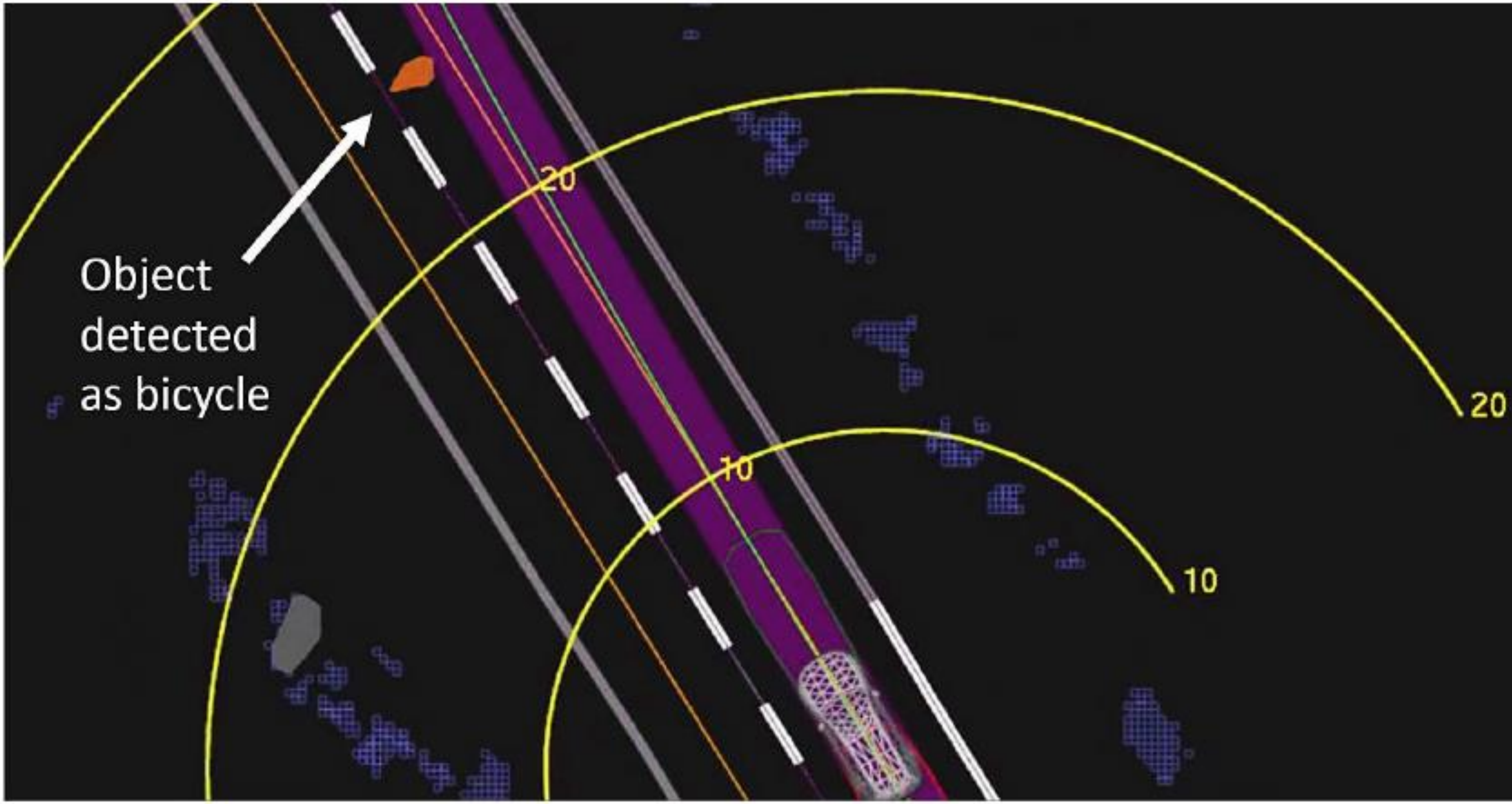

Figure 2. View of the self-driving system data playback at about 1.3 seconds before impact, when the system determined an emergency braking maneuver would be needed to mitigate a collision. Yellow bands are shown in meters ahead. Orange lines show the center of mapped travel lanes. The purple shaded area shows the path the vehicle traveled, with the green line showing the center of that path.

Paths of pedestrian and vehicle

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Junction approach (daytime)

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Actor Map

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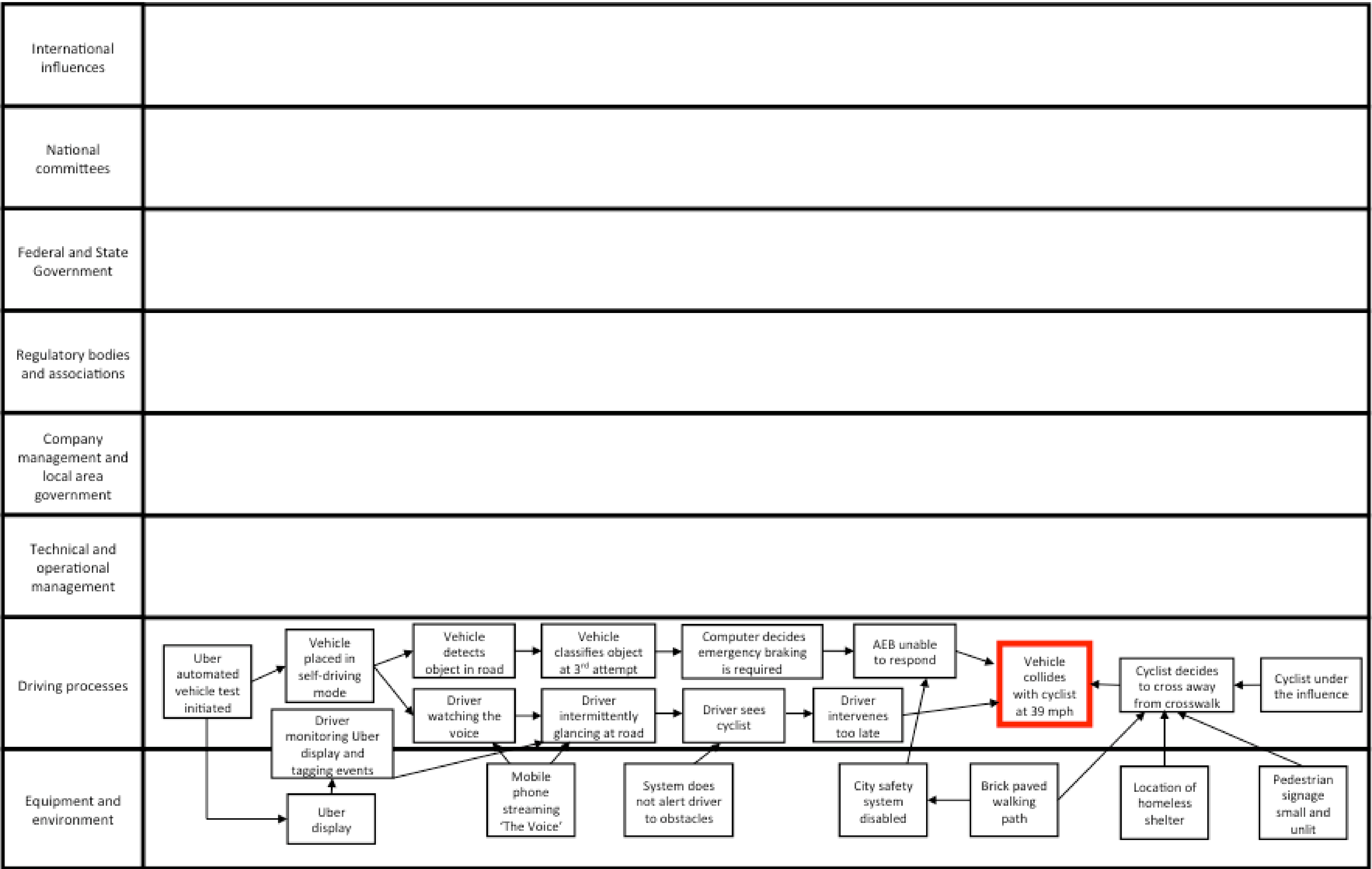
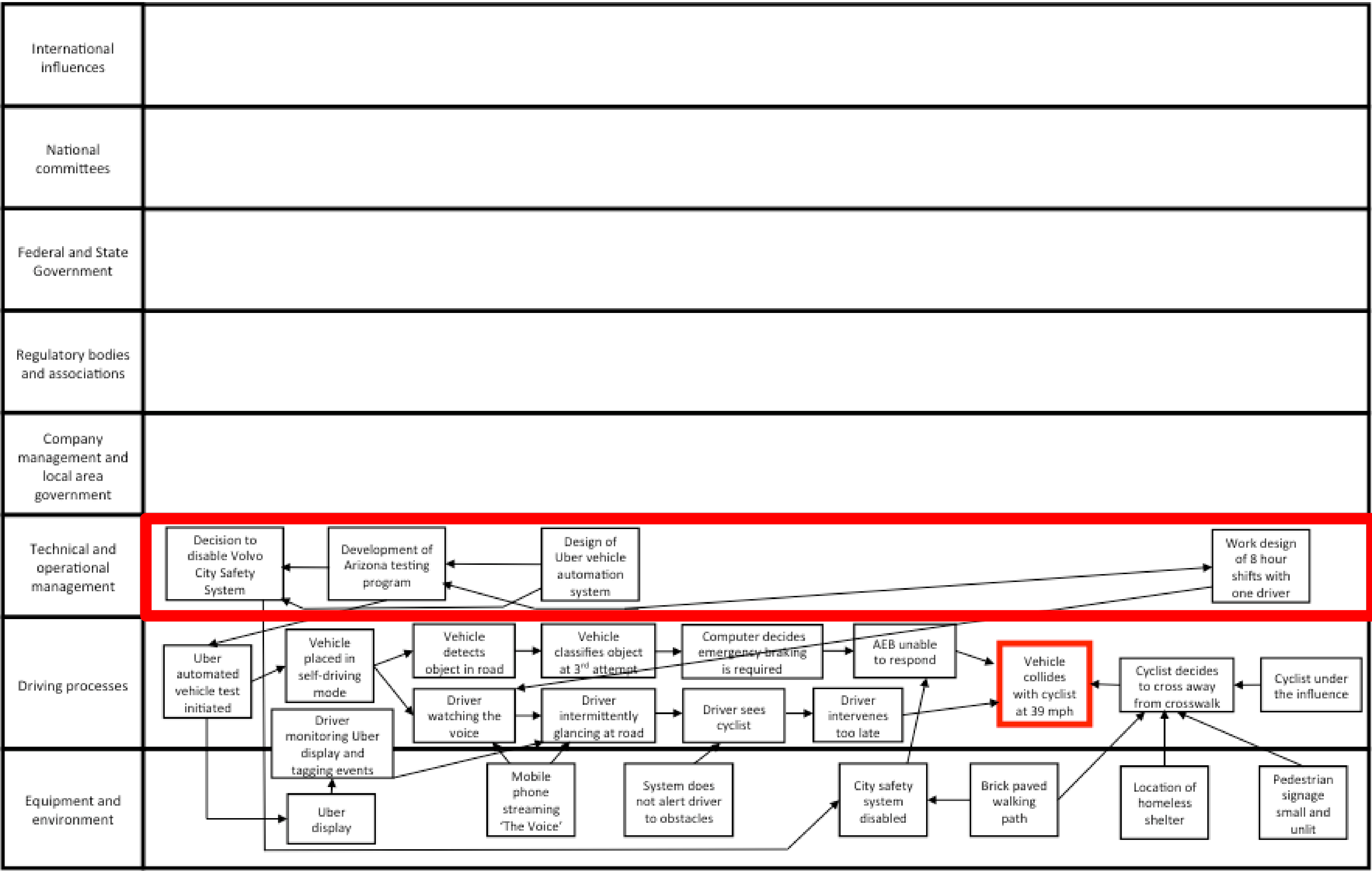
International influences	International Standards Organisation					
National committees	Society of Automotive Engineers					
Federal and State Government	Federal Government	California State Government	Arizona State Government			
Regulatory bodies and associations	California regulators	Arizona regulators				
Company management and local area government	Uber	Volvo	Urban planners			
Technical and operational management	Uber engineers					
Driving processes	Driver	Cyclist				
Equipment and environment	Automated vehicle	Road	Median	Junction	Bicycle	Signage

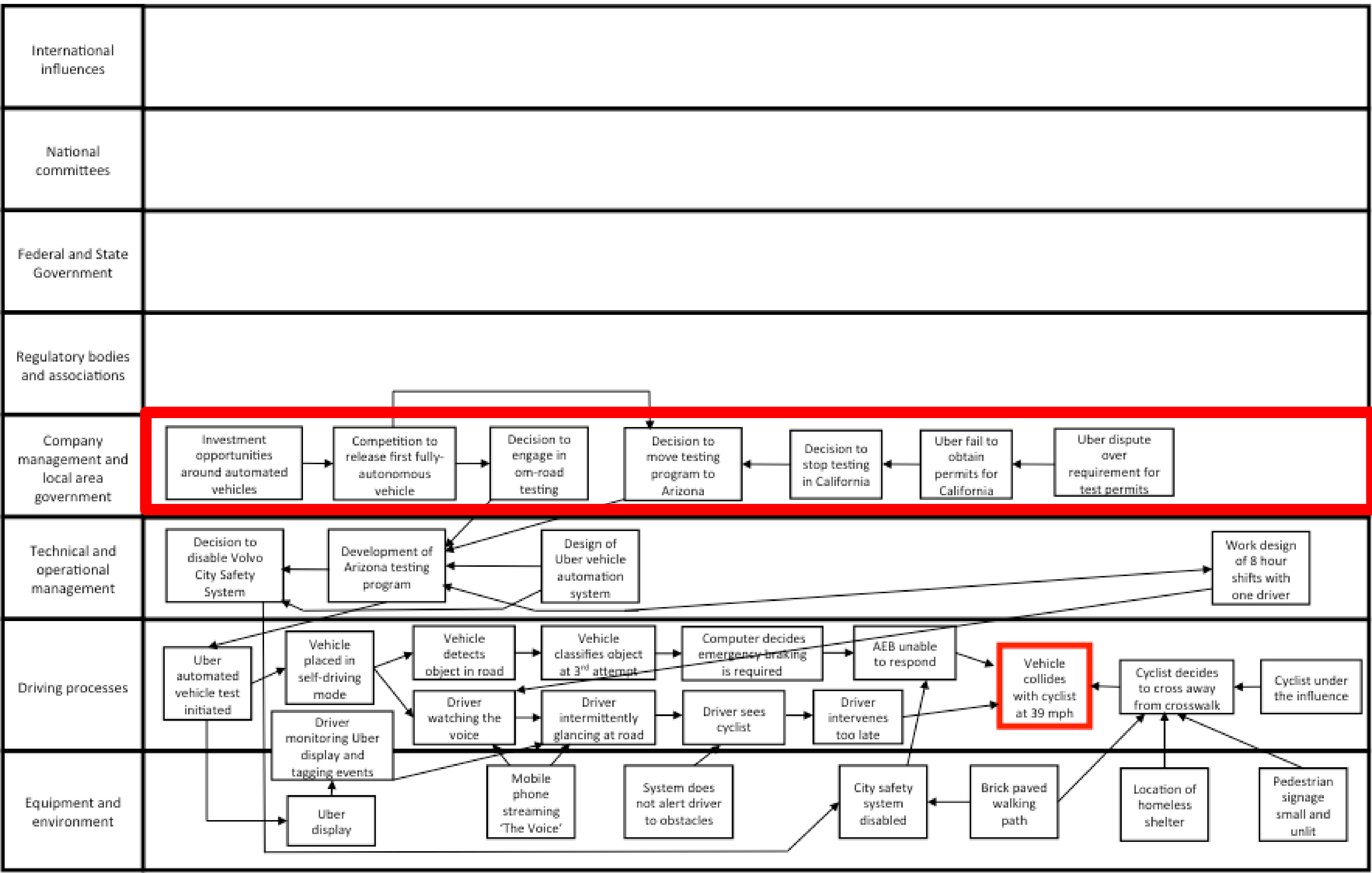
Driver and pedestrian



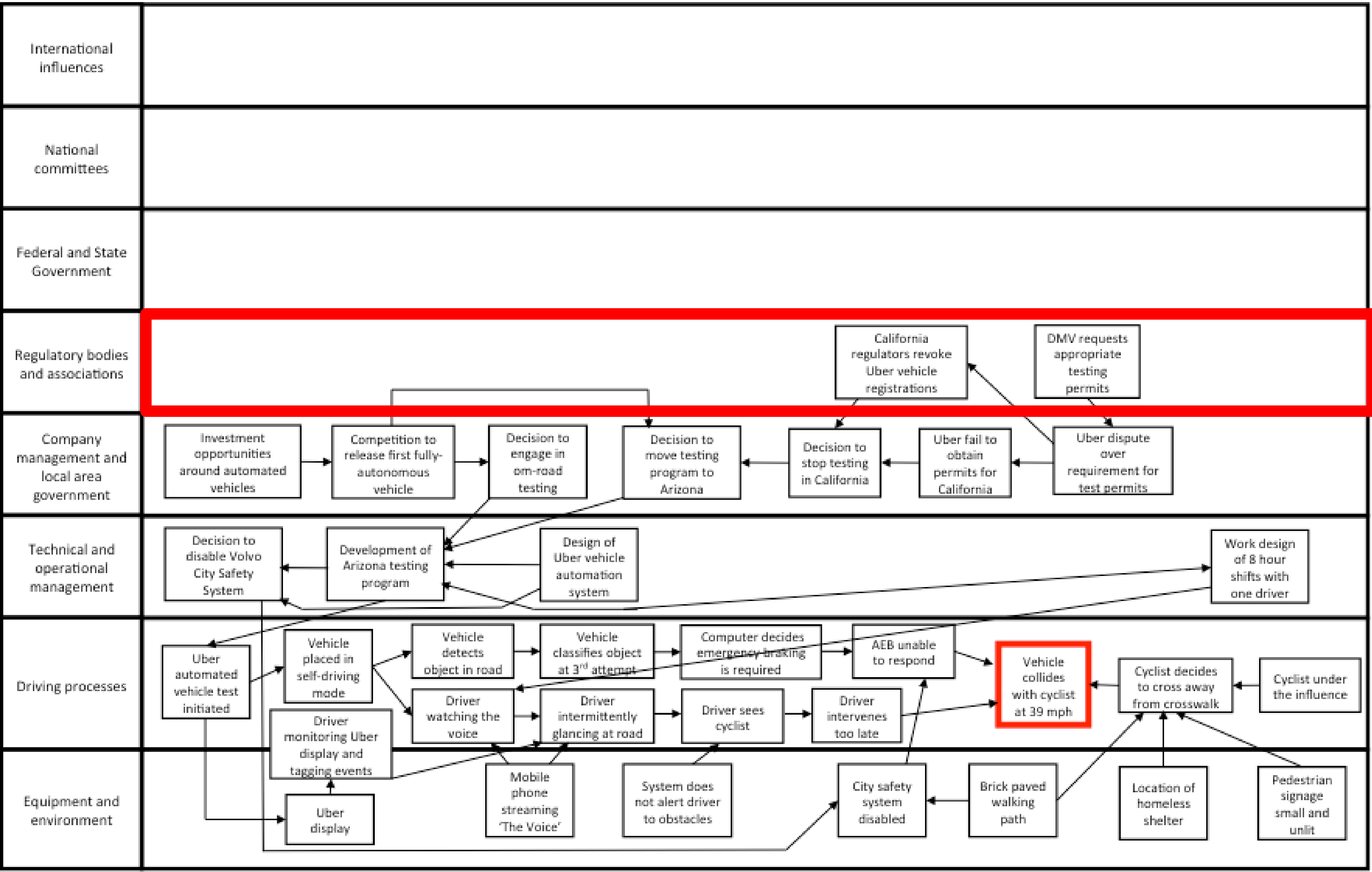
Uber tech/op management



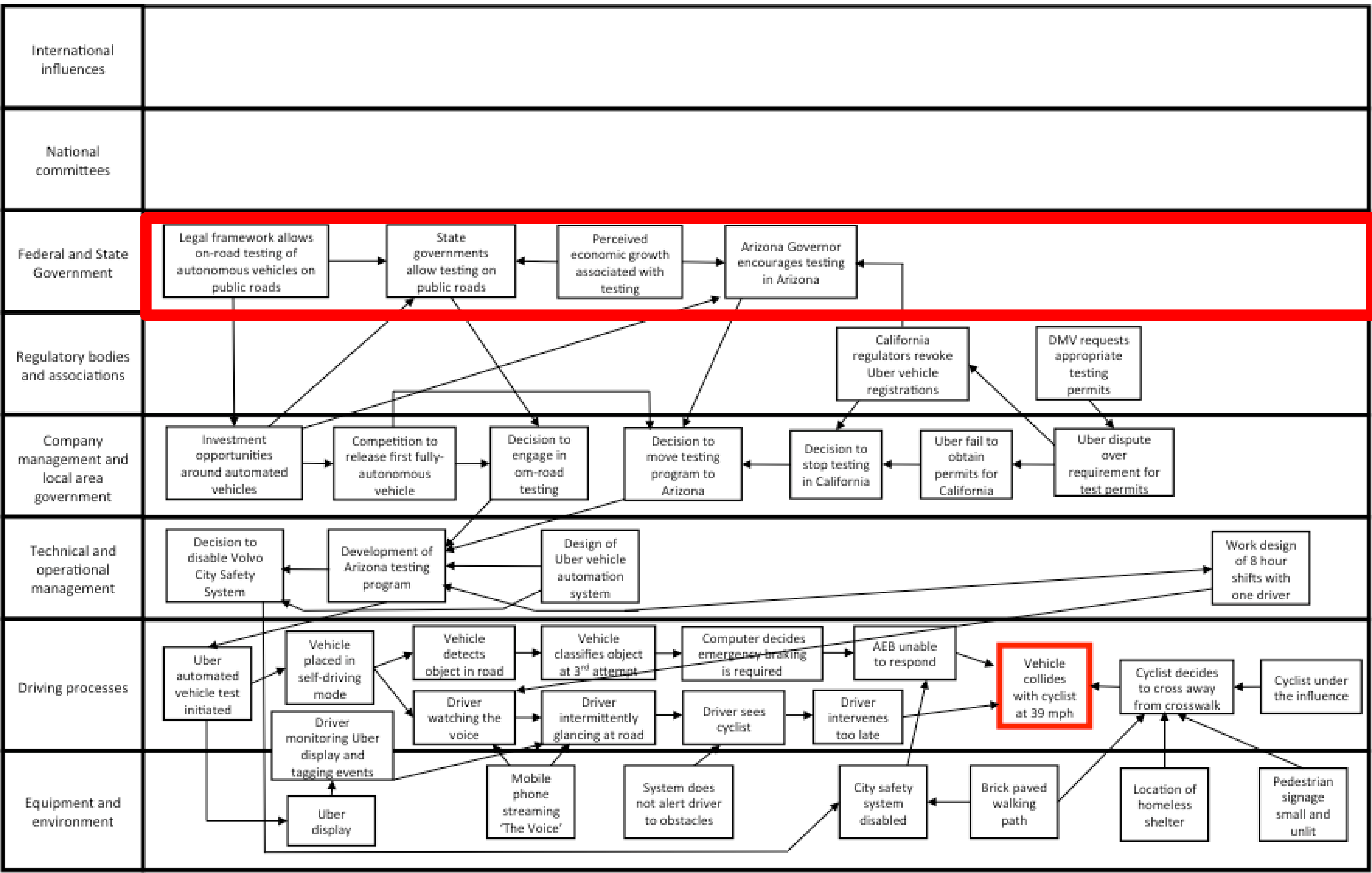
Uber company management



Reguator


International influences
National committees
Federal and State Government
Regulatory bodies and associations
Company management and local area government
Technical and operational management
Driving processes
Equipment and environment
California regulators revoke Uber vehicle registrations
DMV requests appropriate testing permits
Investment opportunities around automated vehicles
Competition to release first fully-autonomous vehicle
Decision to engage in om-road testing
Decision to move testing program to Arizona
Decision to stop testing in California
Uber fail to obtain permits for California
Uber dispute over requirement for test permits
Decision to disable Volvo City Safety System
Development of Arizona testing program
Design of Uber vehicle automation system
Work design of 8 hour shifts with one driver
Uber automated vehicle test initiated
Vehicle placed in self-driving mode
Vehicle detects object in road
Vehicle classifies object at 3rd attempt
Computer decides emergency braking is required
AEB unable to respond
Vehicle collides with cyclist at 39 mph
Cyclist decides to cross away from crosswalk
Cyclist under the influence
Driver monitoring Uber display and tagging events
Driver watching the voice
Driver intermittently glancing at road
Driver sees cyclist
Driver intervenes too late
Uber display
Mobile phone streaming 'The Voice'
System does not alert driver to obstacles
City safety system disabled
Brick paved walking path
Location of homeless shelter
Pedestrian signage small and unlit

Federal and state government



Governor Ducey's executive order released in March 2018 that opened the door to AV testing in Arizona. The order states in Section 3:

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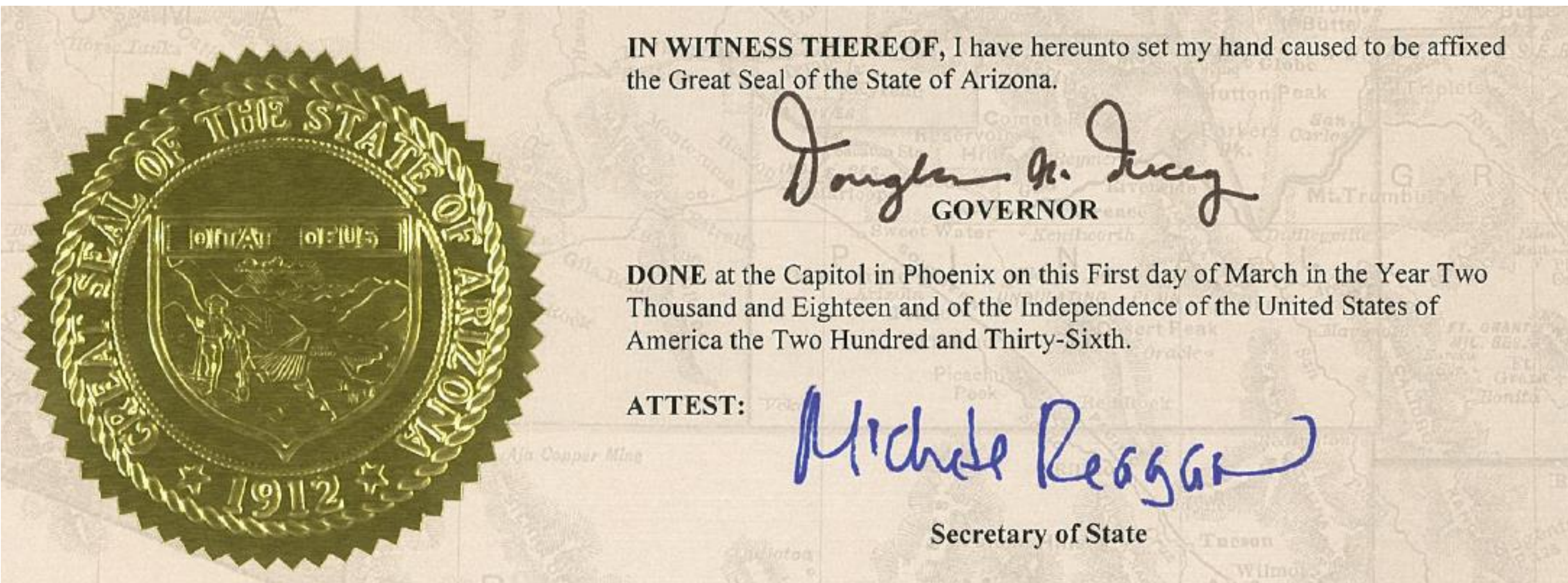
Testing of autonomous vehicles on public roads that do not have a person present in the vehicle shall be allowed only if such vehicles are fully autonomous, provided that a person prior to commencing testing or operation of fully autonomous vehicles, has submitted a written statement to the Arizona Department of Transportation, or if already begun, has submitted a statement to the Arizona Department of Transportation within 60 days of the issuance of this Order…

Elsewhere, the EO goes on to describe a requirement for a law enforcement interaction protocol, also required within 60 days of testing. The EO was released on the 1st March 2018 and Elaine Herzberg was killed on the 18th March 2018, well within the 60 day window.

Phoenix metro area has one of the highest pedestrian fatality rates in the US


IN WITNESS THEREOF, I have hereunto set my hand caused to be affixed the Great Seal of the State of Arizona.

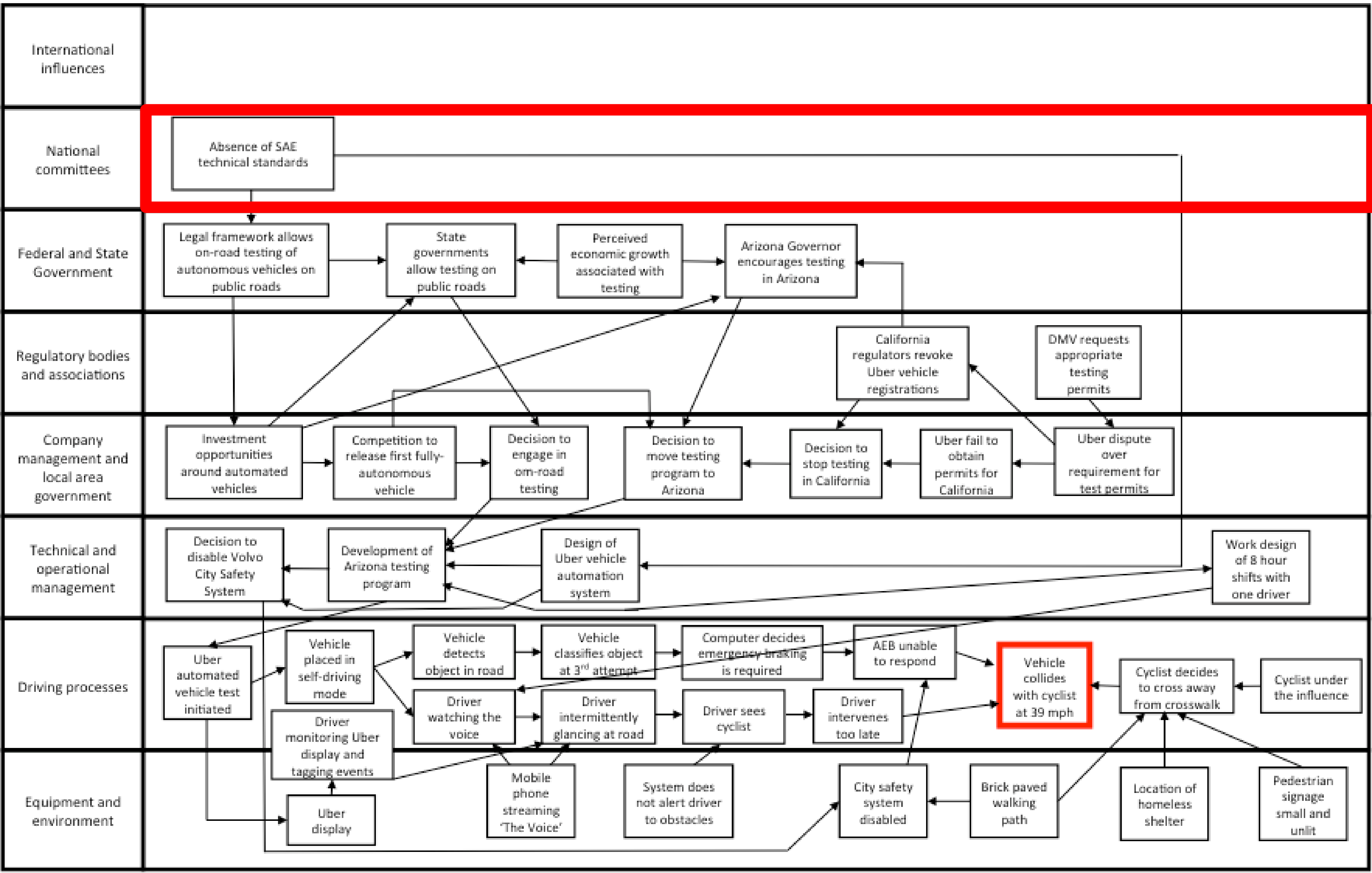
GOVERNOR

DONE at the Capitol in Phoenix on this First day of March in the Year Two Thousand and Eighteen and of the Independence of the United States of America the Two Hundred and Thirty-Sixth.

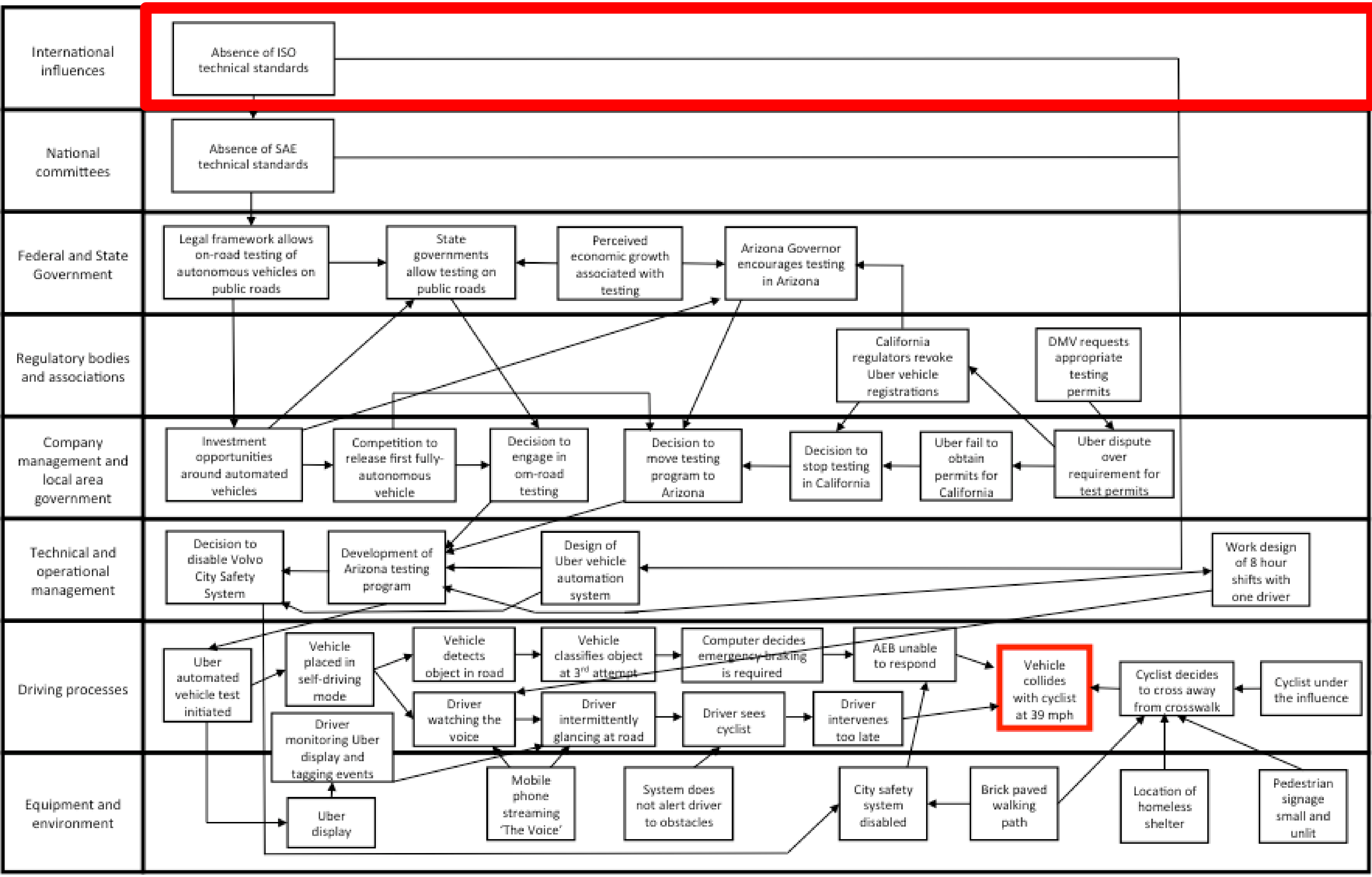
ATTEST:

Secretary of State

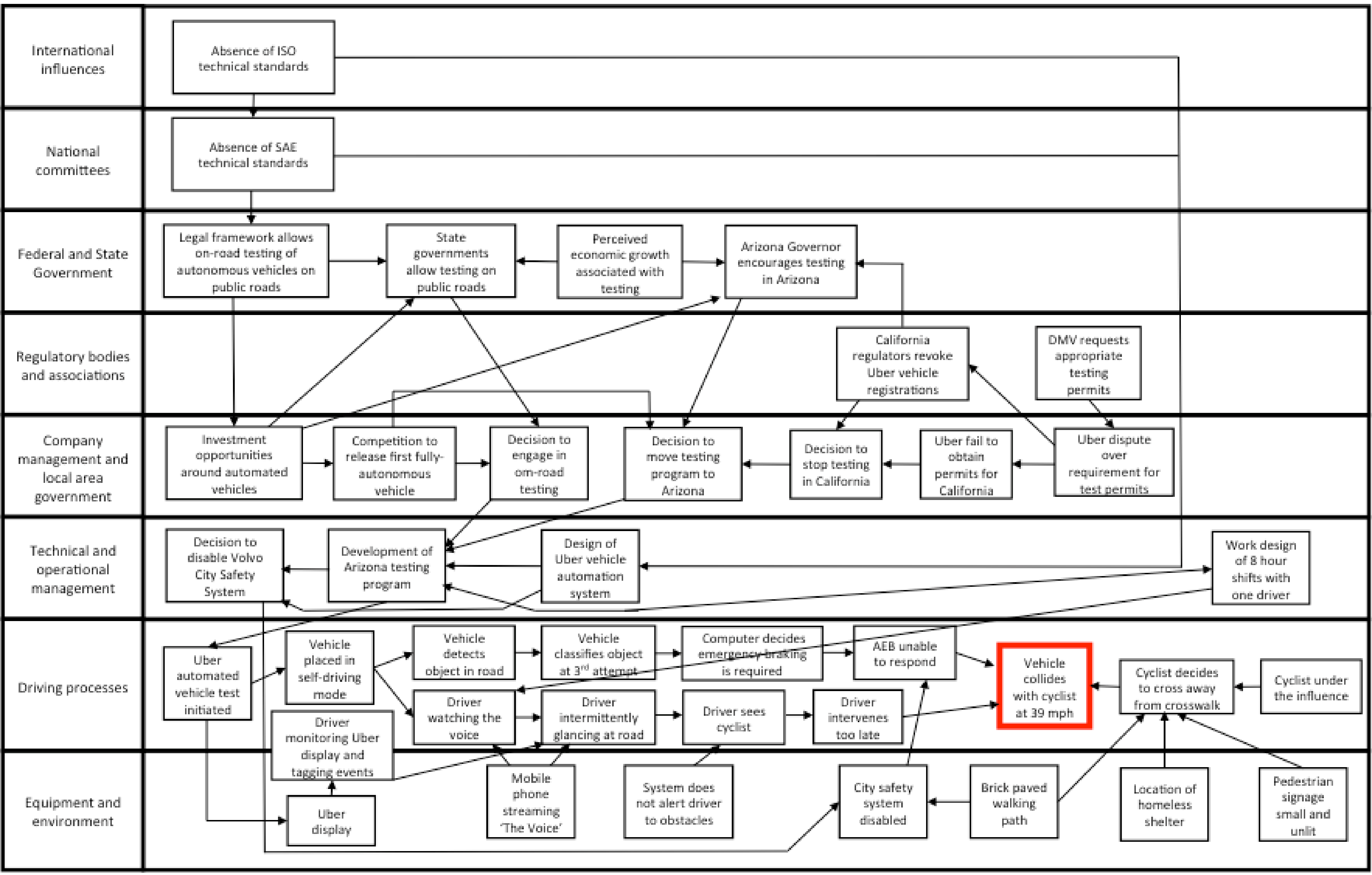
National committees



International committees



AcciMap



International influences
National committees
Federal and State Government
Regulatory bodies and associations
Company management and local area government
Technical and operational management
Driving processes
Equipment and environment
Absence of ISO technical standards
Absence of SAE technical standards
Legal framework allows on-road testing of autonomous vehicles on public roads
State governments allow testing on public roads
Perceived economic growth associated with testing
Arizona Governor encourages testing in Arizona
California regulators revoke Uber vehicle registrations
DMV requests appropriate testing permits
Investment opportunities around automated vehicles
Competition to release first fully-autonomous vehicle
Decision to engage in om-road testing
Decision to move testing program to Arizona
Decision to stop testing in California
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Driver intervenes too late
Uber display
Mobile phone streaming 'The Voice'
System does not alert driver to obstacles
City safety system disabled
Brick paved walking path
Location of homeless shelter
Pedestrian signage small and unlit

Q. Can we improve the design of the testing regime?

A. Yes, but we need to address all of the system levels simultaneously

Stanton, N. A., Salmon, P. M., Walker, G. H and Stanton, M. (2019). Models and Methods for Collision Analysis: A Comparison Study based on the Uber collision with a pedestrian. Safety Science, 120, 117-128.

System levels	Potential recommendations
International influences	Develop new standards for vehicle automation (e.g. head-up interface) Develop new standards for on-road testing of vehicle automation (e.g. two testers in vehicle)
National committees	Develop new standards for vehicle automation Develop new standards for on-road testing of vehicle automation
Federal and state government	Develop new laws on vehicle automation Develop new laws for on-road testing of vehicle automation Require permits for on-road testing of vehicle automation
Regulatory bodies and associations	Enforce new laws on vehicle automation Enforce new laws for on-road testing of vehicle automation Enforce permits for on-road testing of vehicle automation
Company management and local area government	**Uber**: Undertake comprehensive driver task analysis Undertake comprehensive analysis of human and technical risks Analyse the workload of human driver with automation **City Planners**: Fence off central reservations that are not part of pedestrian crossings Improve highway lighting
Technical and operational management	Conduct pilot studies with human drivers to discover potential problems Share tasks between two drivers to ensure sufficient rests (eyes-out versus eyes-in tasks) and swap tasks regularly Leave safety systems intact (including the AEB) Fit dual controls to vehicle so that both drivers can drive the vehicle manually if required
Driving processes	Ensure that one driver is eyes-out at all times and swap tasks between drivers regularly
Equipment and environment	Place all nomadic devices (such as phones) in glovebox before the vehicle is driven

Self-reported workload

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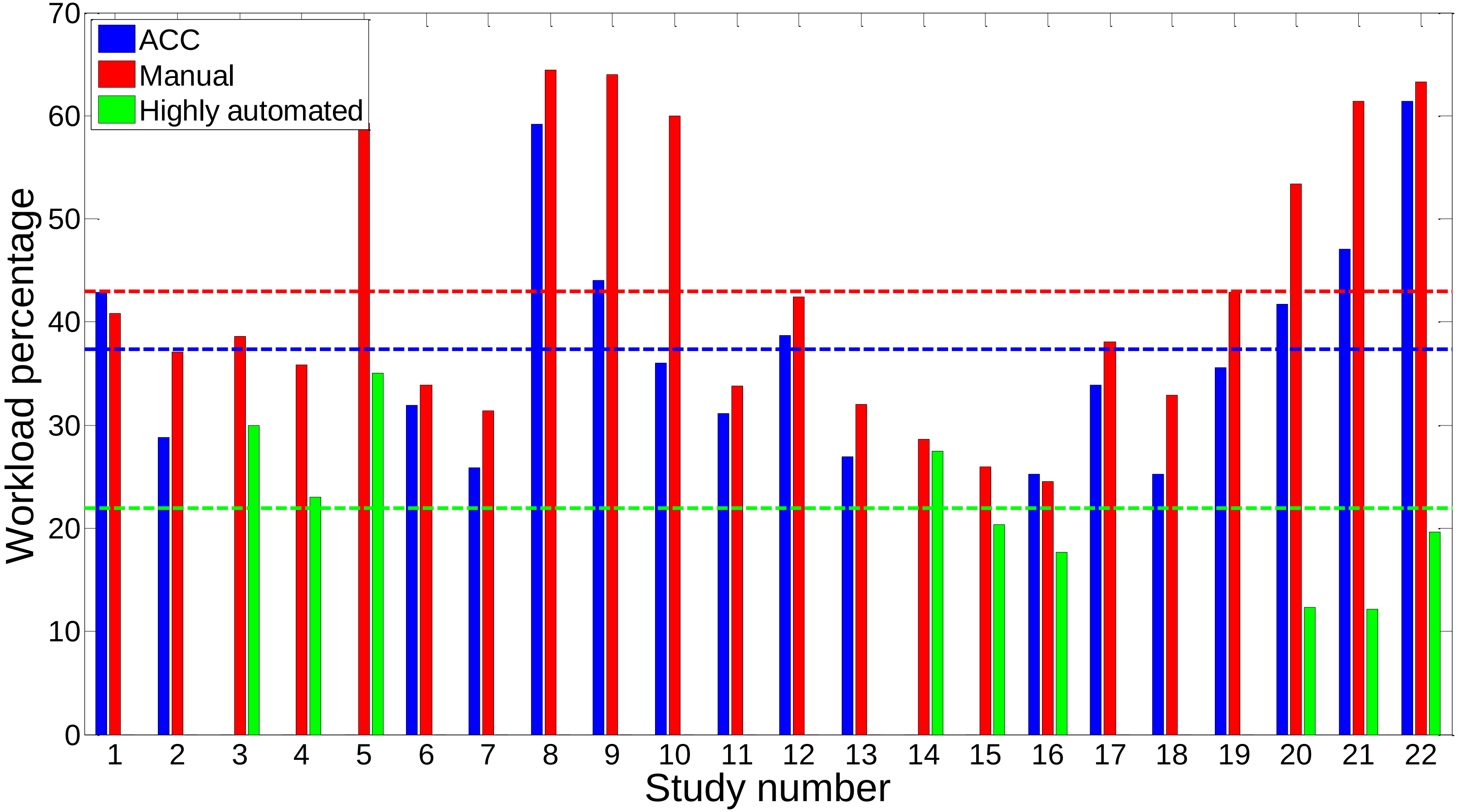
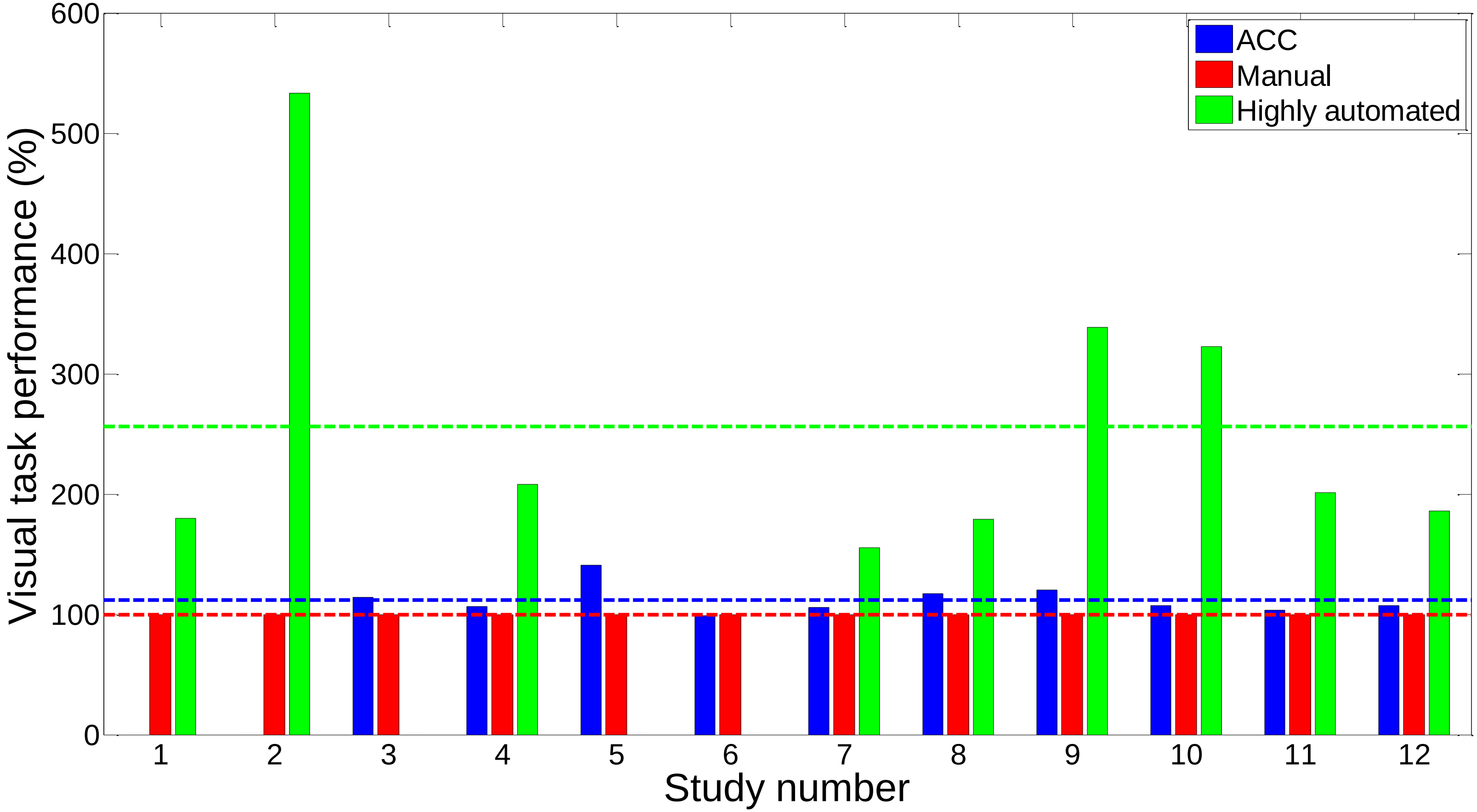


de Winter, J. C.F., Happee, R., Martens, M. H. and Stanton, N. A. (2014) Effects of ACC and highly automated driving on workload, situation awareness, and uptake of secondary tasks: A review of the empirical evidence. Transportation Research Part F: Traffic Psychology and Behaviour 27 (B), 196-217.

Secondary task performance



de Winter, J. C.F., Happee, R., Martens, M. H. and Stanton, N. A. (2014) Effects of ACC and highly automated driving on workload, situation awareness, and uptake of secondary tasks: A review of the empirical evidence. Transportation Research Part F: Traffic Psychology and Behaviour 27 (B), 196-217.

Malleable Attentional Resources Theory (MART) – why low task demand may be a problem

Young, M. S. and Stanton, N. A. (2002). Malleable Attentional Resources Theory: A new explanation for the effects of mental underload on performance. Human Factors 44 (3), 365-375.

Young, M. S. & Stanton, N. A (2004) Taking the load off: investigations of how Adaptive Cruise Control affects mental workload. Ergonomics 47 (8), 1014-1035.

Workload and performance

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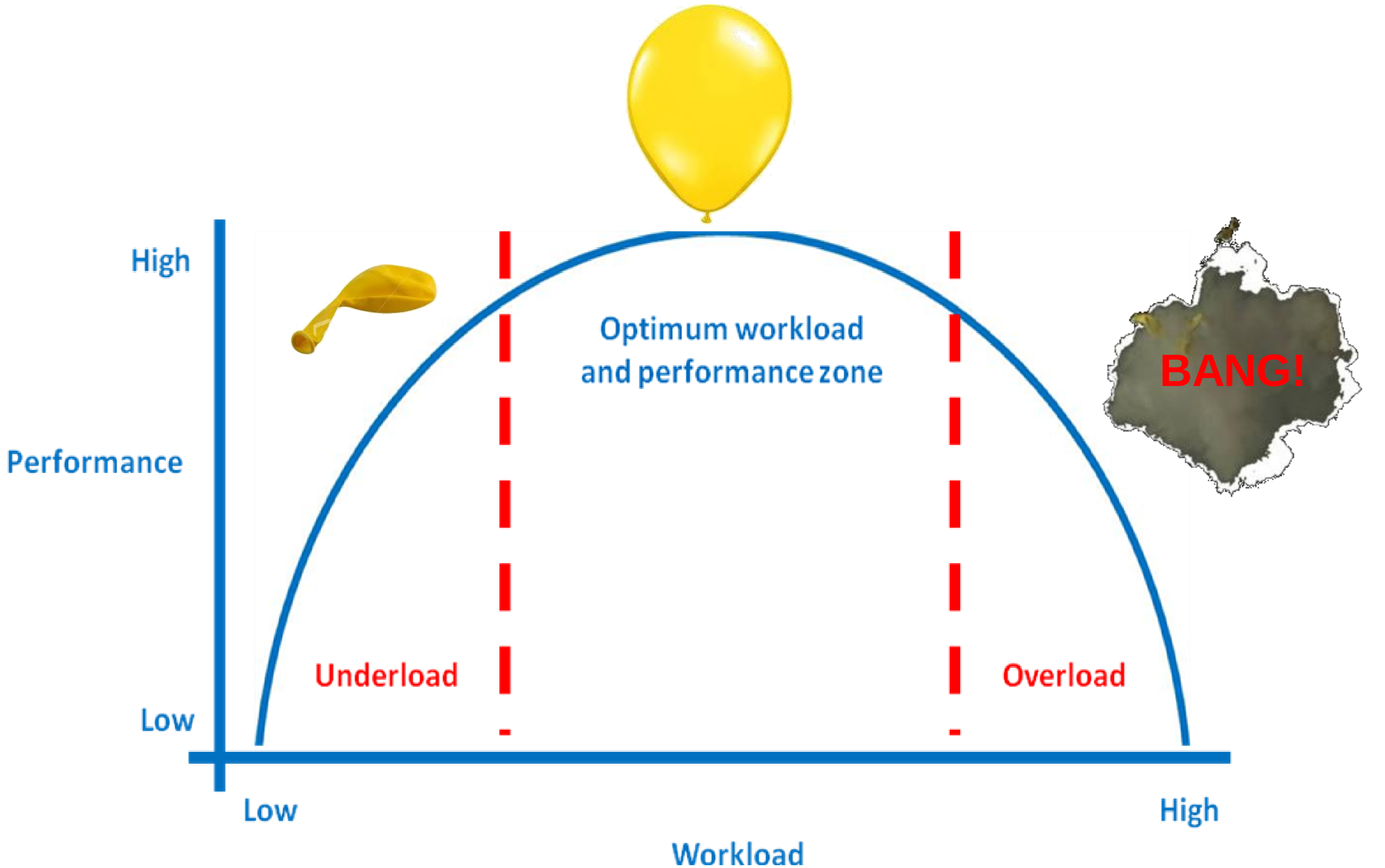

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Young, M. S. & Stanton, N. A (2004) Taking the load off: investigations of how Adaptive Cruise Control affects mental workload. Ergonomics 47 (8), 1014-1035.

Take over requests

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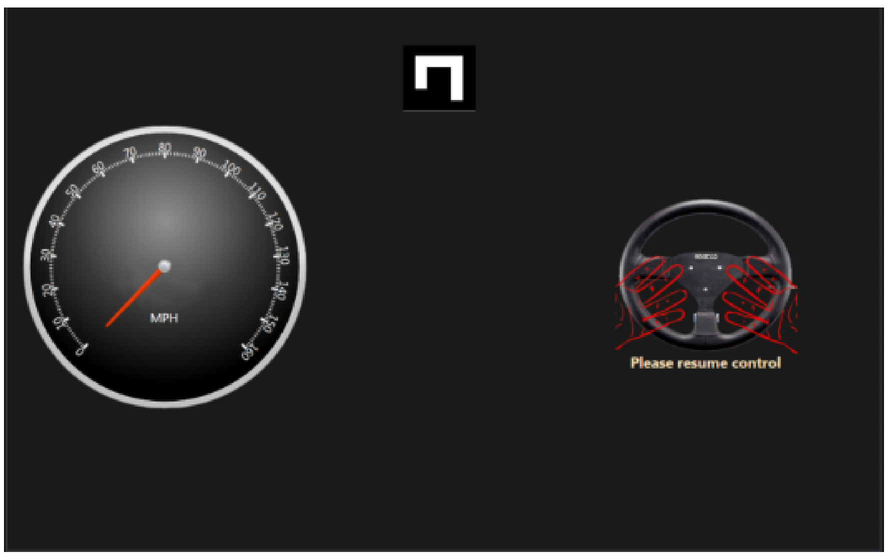
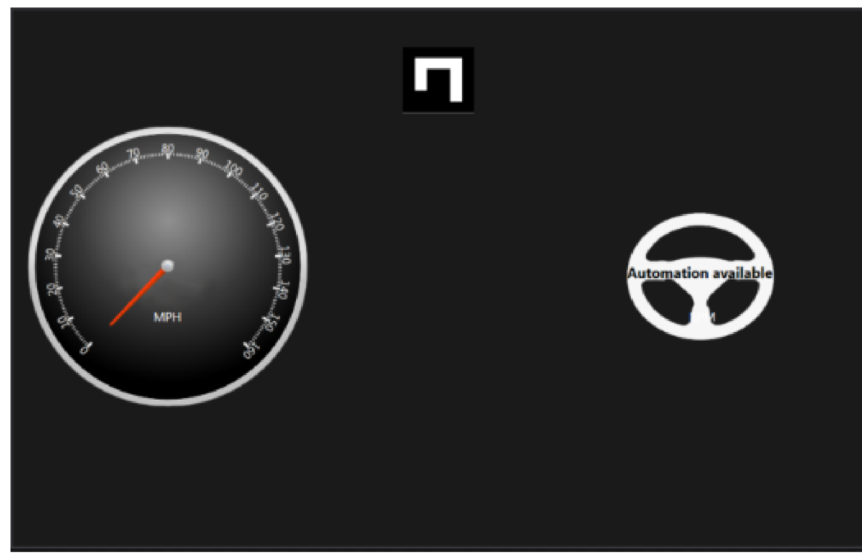
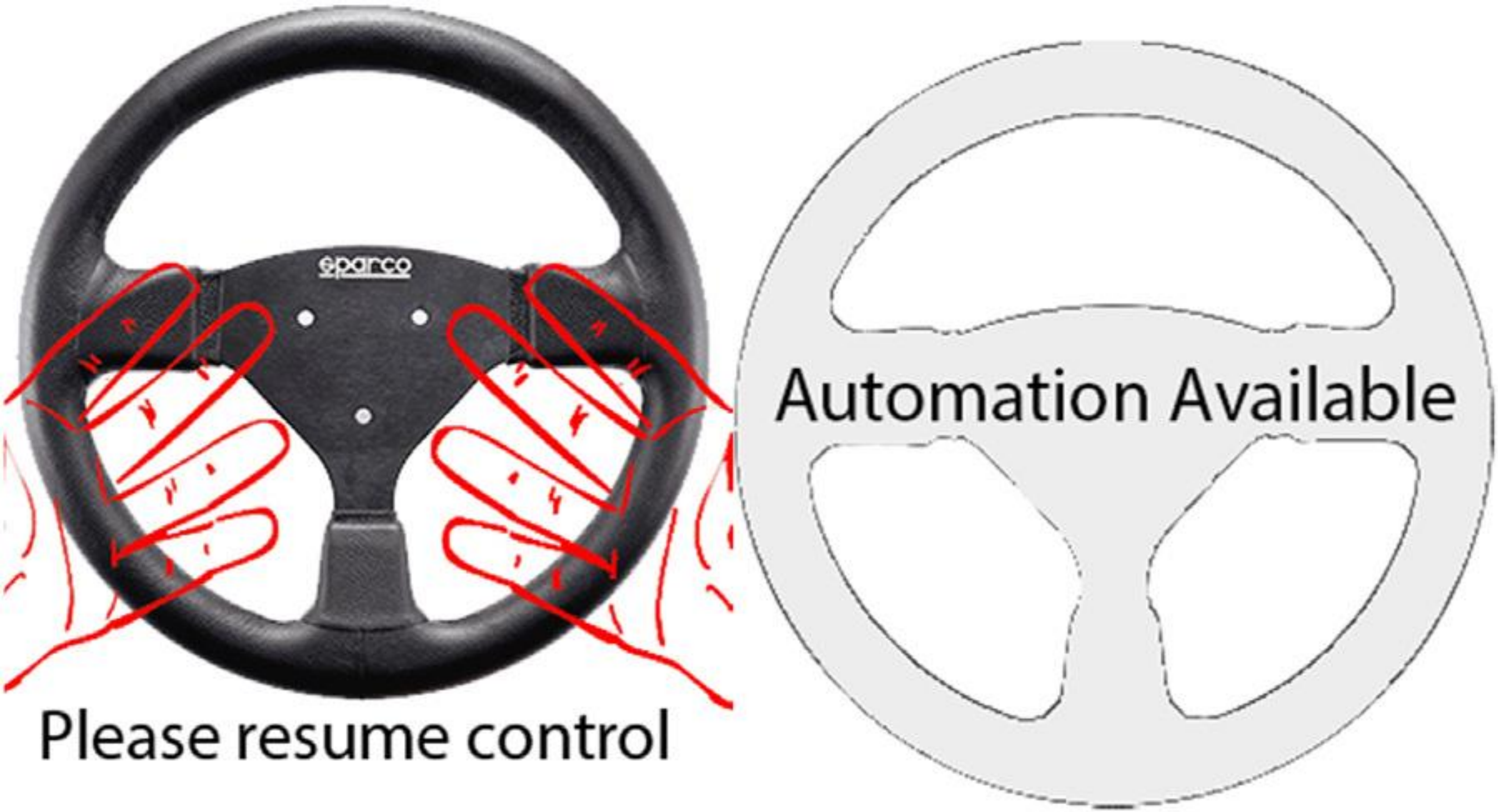
“Please resume control”

“Automation available”





Eriksson, A. and Stanton, N. A. (2017) Take-over time in highly automated vehicles: transitions to and from manual control. Human Factors 59 (4), 689 –705.



Eriksson, A. and Stanton, N. A. (2017) Take-over time in highly automated vehicles: transitions to and from manual control. Human Factors 59 (4) 689-705.

Transitions to and from manual

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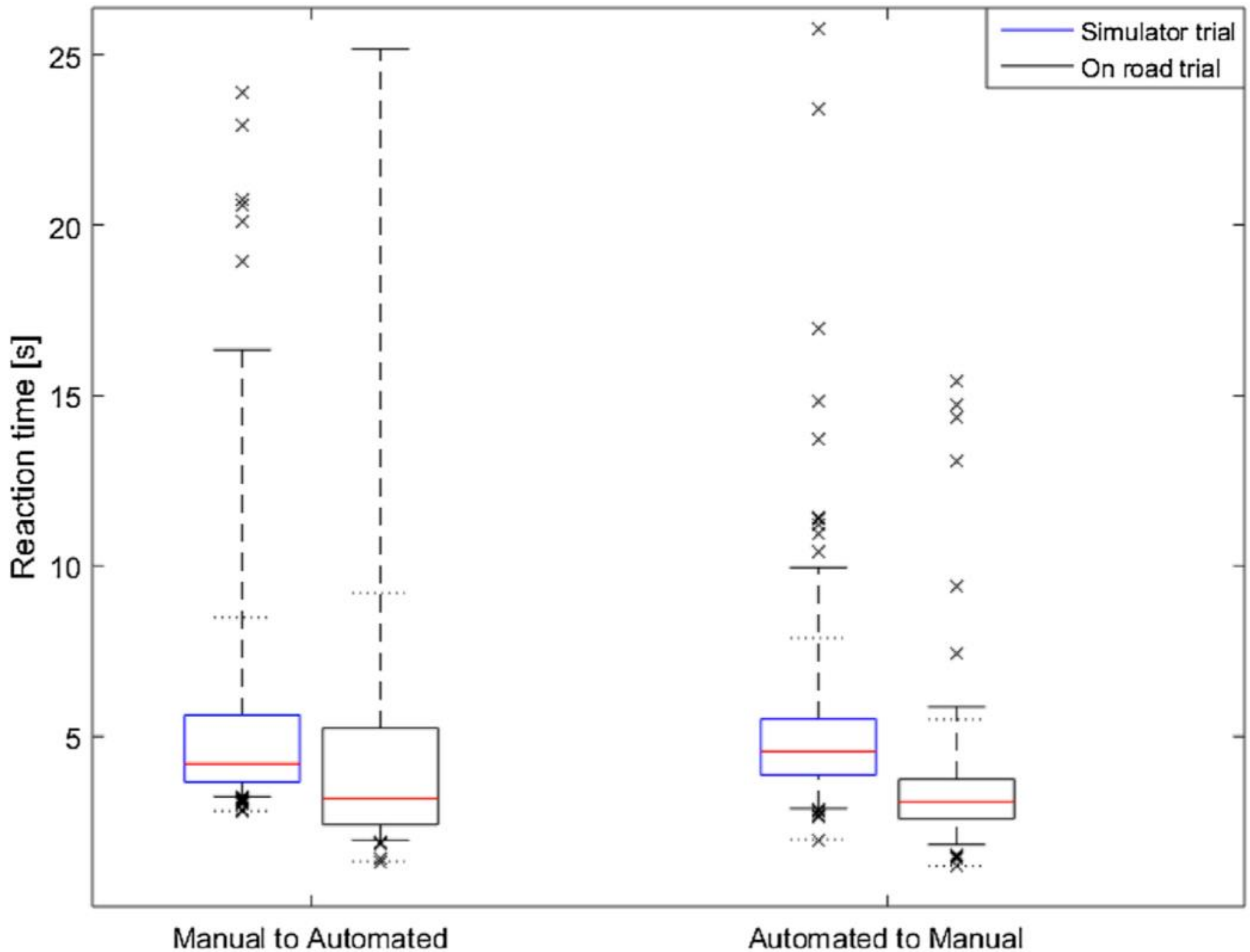

Eriksson, A., Banks, V. and Stanton, N. A. (2017) Transition to Manual: comparing simulator with on-road control transitions. Accident Analysis and Prevention, 102 (2017) 227–234.

Validation of simulator

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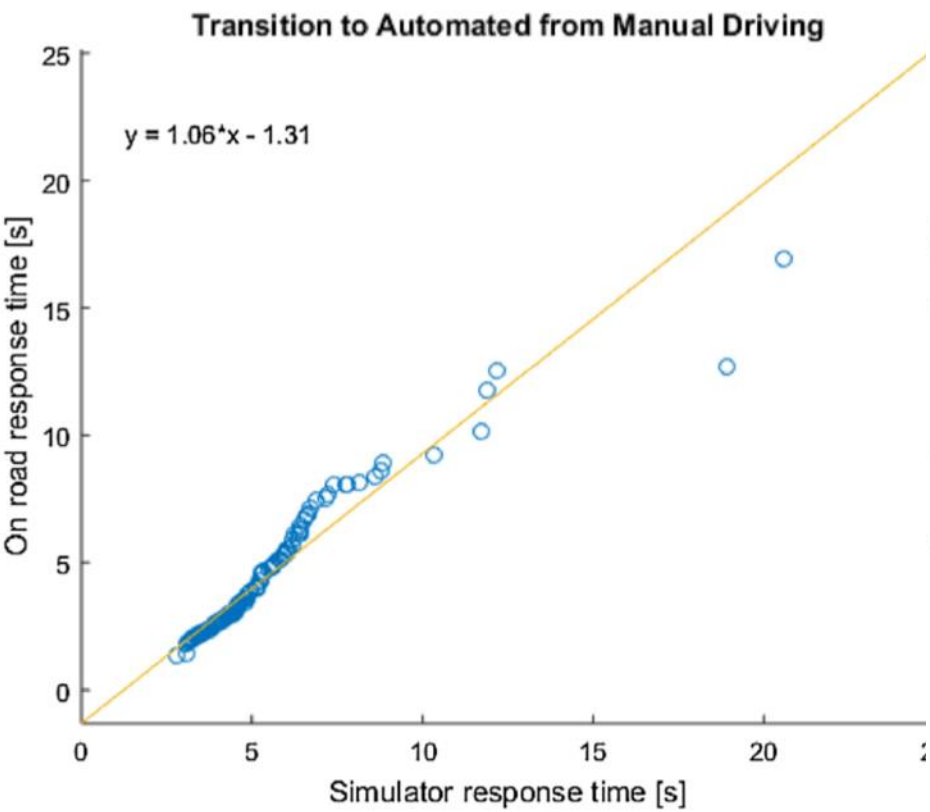

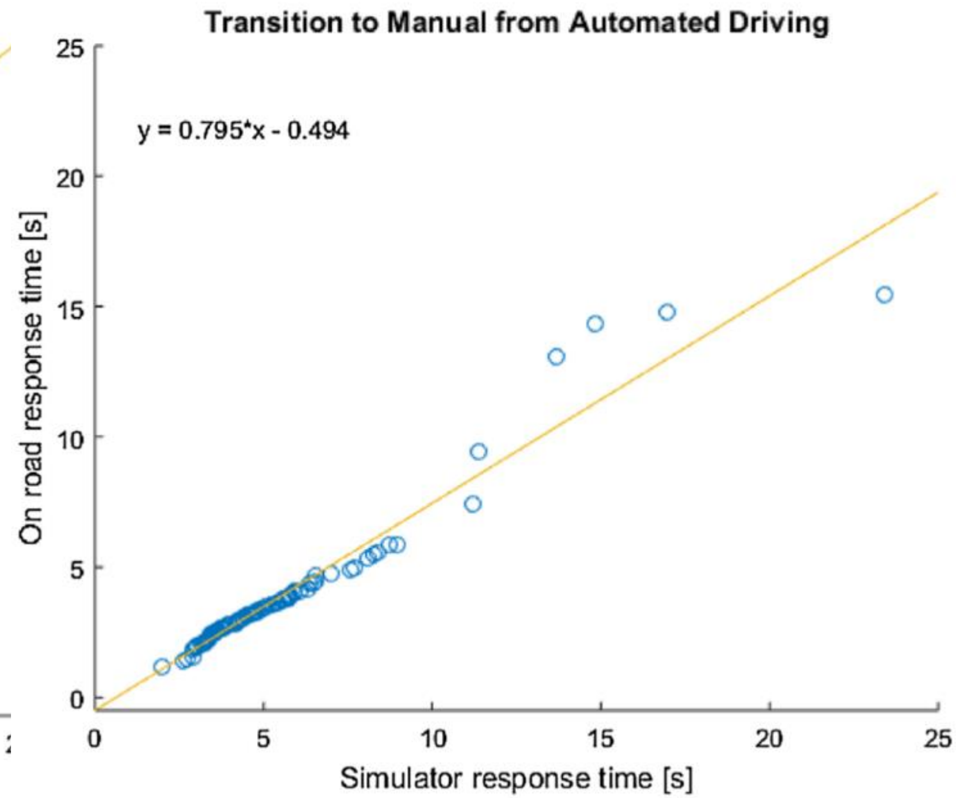

Eriksson, A., Banks, V. and Stanton, N. A. (2017) Transition to Manual: comparing simulator with on-road control transitions. Accident Analysis and Prevention, 102, 227–234.

Mercedes Distronic Plus

Route driven manual and auto

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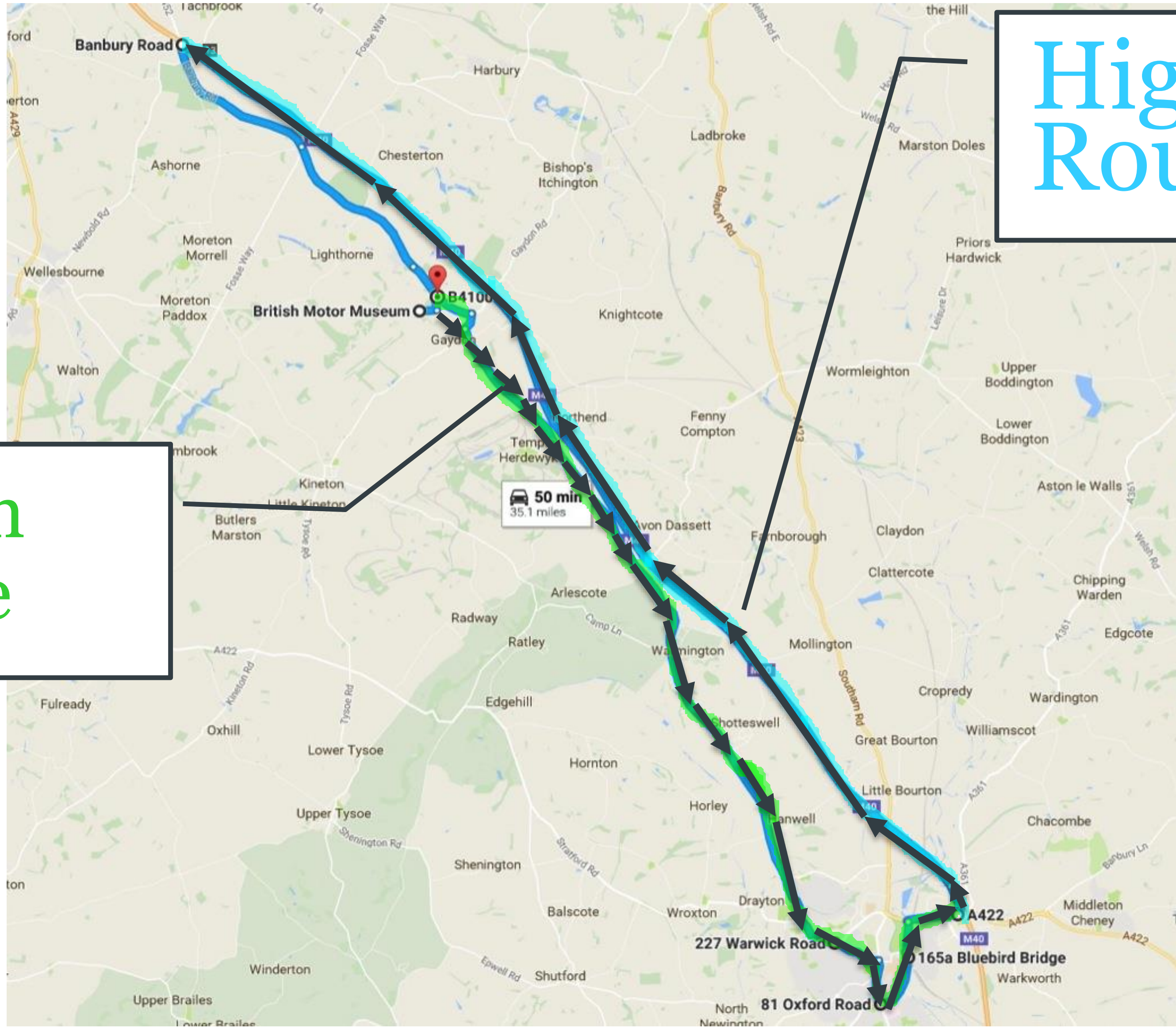

Urban Route

Highway Route

NASA TLX – overall workload

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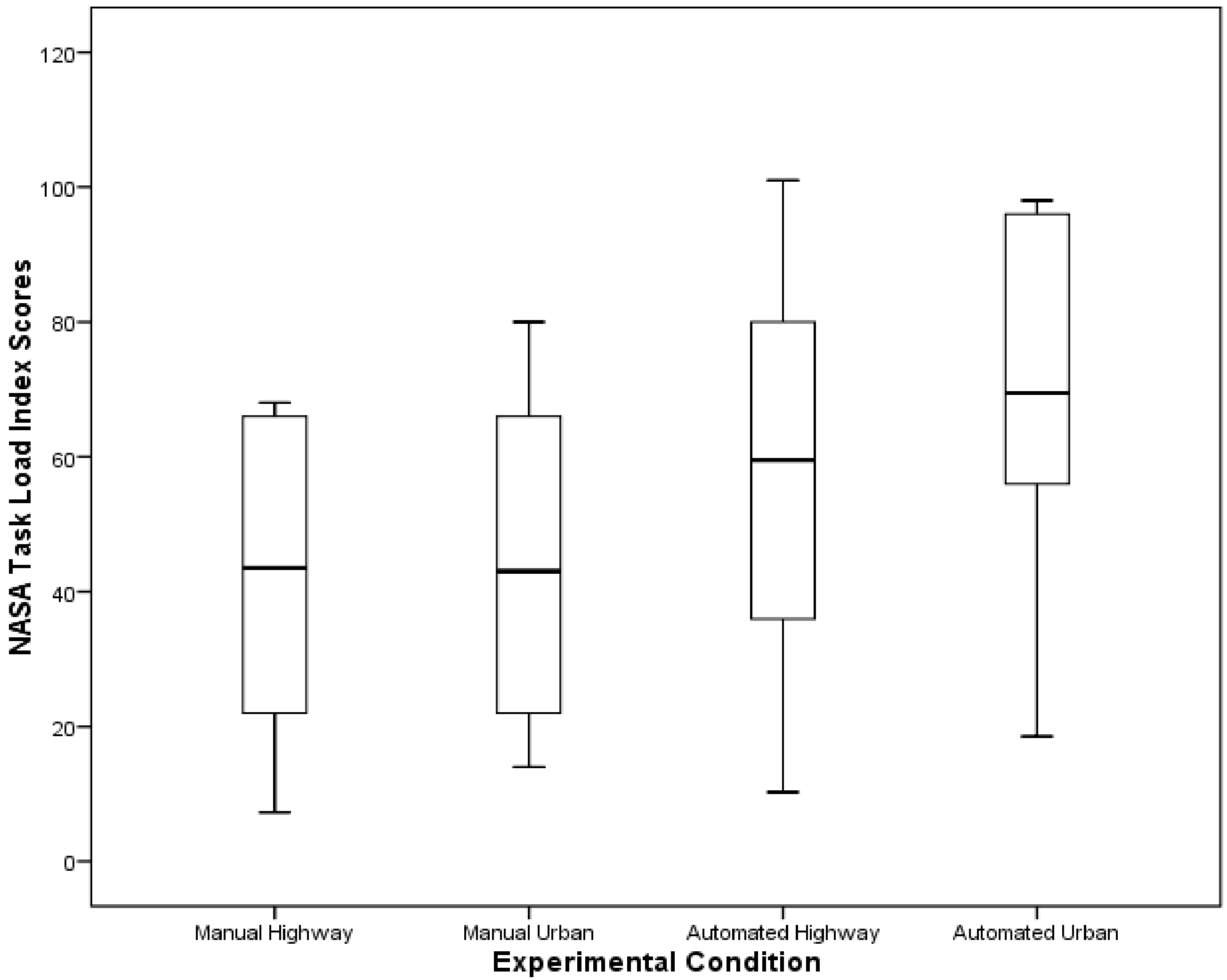

Highway Auto – PCM

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SCHEMA

5) I'm thinking about doing an overtake now
7) So, I get past this lorry,
11) oh, no. Blimey! [we're going to crash]
13) And I didn't trust it
15) …that was scary
[safe headway breached]
20) if I hadn't had grabbed it back then
It would have ploughed into that lorry

ACTION

4) – another bit of input,
it wants– okay, just given it.
8) and I'll try indicating.
9) Check behind me
12) Brake.
14) I'm pulling out now
16) So, I think I'm going to
have put that back on again.
17) Distronics on 70
19) hands off the wheel

WORLD

1)…there's vehicles all around me.
It feels quite heavy traffic.
2) So, we've dropped down to …
3) Icon observed
[Put hands on steering wheel]
6) [Lorry observed]
10) ooh..we're speeding up
18) We're doing 60

The catch 22 of vehicle automation

Take away all of the driving tasks from the driver

BUT

The catch 22 of vehicle automation

Take away all of the driving tasks from the driver

BUT


The catch 22 of vehicle automation

Take away all of the driving tasks from the driver

BUT

Tell the driver they must be vigilant and be prepared to intervene as they are legally responsible for the vehicle

What have we learnt?

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- **Automated automobiles are nearly upon us.....**
- **Problems with automation.....**
  - Not powerful enough (yet) to render driver redundant
  - Requires driver to monitor (continuously) and intervene (occasionally)
  - Attentional resources are yoked to task demand (which is substantially reduced in highly automated vehicles)
  - Reduced drivers readiness and timeliness to intervene
- **There maybe a design solution.....**
  - Only automate what you have to and when you have to
  - Support the driver rather than replace driver
  - 'Background' automation <u>not</u> 'foreground' automation
  - Design a 'chatty' co-pilot <u>not</u> a 'silent' auto-pilot
  - Gradual and graceful degradation in system failure

Automobile automation books….

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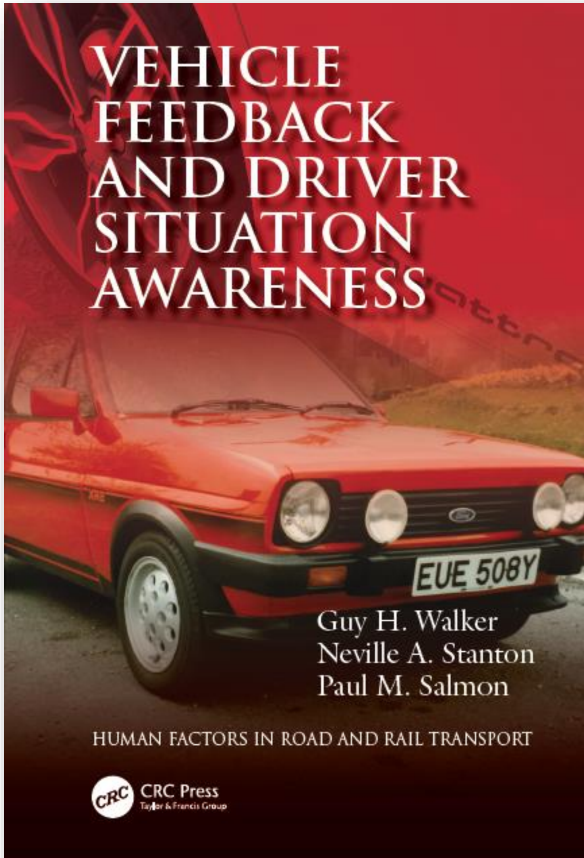

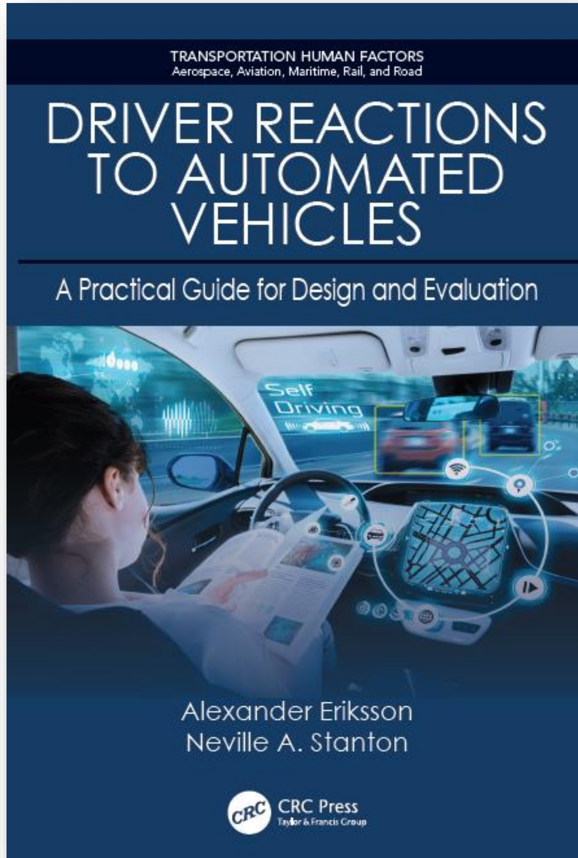

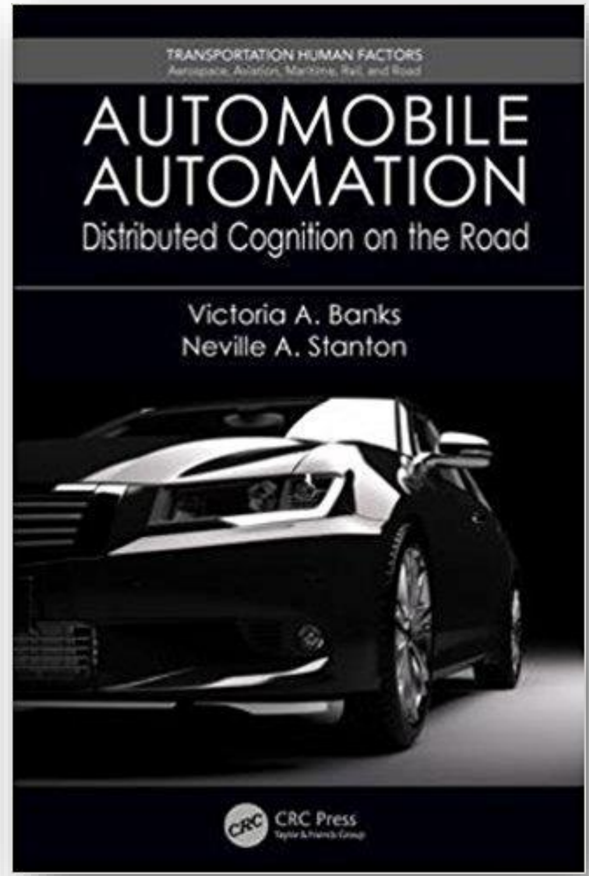


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If you have any further questions please contact me at:

n.stanton@soton.ac.uk

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