





**The 30th Annual Conference** of The Research Institute of Human Factors in Road Safety Department of Management with Bar-Ilan Center of Smart Cities - **Thursday, July 28th, 2022** 

#### Interactions between Autonomous Vehicles & Vulnerable Road Users

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### Advent of automated vehicles

When considering vehicle automation, usually two approaches are distinguished:

- 1. Smart infrastructure with a non-intelligent vehicle
- 2. Non-smart infrastructure with an intelligent vehicle

By means of the **cooperative driving** approach, developments towards full automation will be implemented in stages.

An **increasing number of tasks** being automated until finally the fully automated traffic system becomes a reality.





### VRU safety worldwide

Share of road fatalities per transport mode in different world regions (WHO, 2018)





## VRU safety issues to note

- Many pedestrian and cyclist fatalities on urban intersections (80% of pedestrians are at fault for intersection crashes)
- Most pedestrian and cyclist fatalities in collisions with single vehicles
- Most pedestrian and cyclist fatalities are males
- Highest fatality risk for older pedestrians and cyclists





## Vehicle Automation Algorithms

When a cyclist approaches an intersection (Wickens et al., 2004):

- IF a car approaches from the right, and I cannot pass in front without obstructing its free passage
- THEN I have to yield and give priority

Or, when a car approaches a pedestrian crossing:

- IF a pedestrian is about to cross,
- THEN I have to yield

However, there are many reasons for this type of algorithms not to be so straightforward in practice





#### Present research

There can be no other arrangement than the recognition of VRUs under all reasonable circumstances, with **no specific adaptations on their part** (such as reflective clothing).

If VRUs display different behaviors against AVs compared to conventional vehicles, then current knowledge might be ineffective for the development of algorithms that would enhance safety

The present research is a **review study** aiming to investigate the issues of **interaction between AVs and VRUs**.





## Methodology of the study

Studies published between 2010-2020 were mainly considered.

The topic is **very complex** to define in research:

An initial separation was conducted between AV side and VRU side, then further for levels 1/2/3 and levels 4/5.

Rather than an exhaustive review, a **sample-based** approach was adopted

14 high-quality journal studies were reviewed in-depth





## **Review synopsis**

- Investigated sides are about equal in terms of perspective (AV side vs VRU side)
- Several studies manage to use field data under various approaches (e.g. Wizard of Oz)
- Most studies conducted in highly advanced and motorized countries

Study characteristics			Investigated side		Data used			Parameters examined	
Author(s)	Year	Country	AV	VRU	Field data	Simulated data/ Questionnaire	No data	VRU recognition / warning from AV	AV trust/ acceptance from VRU
Bandyopadhyay et al.	2013	Singapore	•		•	•		•	•
Banks et al.	2014	United Kingdom	•				•	•	
Brar & Caulfield	2017	Ireland		•		•			•
Christie et al.	2015	Switzerland		•	•				•
Clamann et al.	2017	United States		•	•				
Dehais et al.	2012	France		•	•			•	
Habibovic et al.	2016	Sweden		•	•				•
Katrakazas et al.	2015	United Kingdom	•						
Krotosky & Trivedi	2007	United States	•		•			•	
Liu & Khattak	2016	United States	•		•			•	
Millard-Ball	2016	United States		•			•		•
Palmeiro et al.	2018	Netherlands		•	•				•
Rosen	2013	Sweden	•			•		•	
Rothenbucher et al.	2016	United States		•	•			•	



# Main findings [1/2]

Major limitations of AVs include accurate navigation, efficiency and reliability issues, as well as the absence of a robust legal framework; lack of social acceptance is a factor as well.

VRUs are not yet critical in present frameworks of HMI (human-machine interaction), which are rather based on social norms that have been established with human drivers controlling the vehicles.

Thus the interactions of AVs are a justified source of skepticism and hinder the onset of AVs.





# Main findings [2/2]

On the other hand, if VRUs have the knowledge that AVs are more safely operated, this would lead to **improved confidence** and overall quality of life.

Past research has shown pedestrians to be **at fault in 80% of pedestrian crashes at intersections**, which demonstrates the need to safeguard them despite any possible improper behaviour on their part.

It appears very challenging to **predict behavioral intentions** of pedestrians and cyclists by current technology.





## Further issues [1/2]

- Low-level (2 or less) automation-ADAS technologies provide positive impacts on road safety
- In automation levels of 3 or higher, there is still a lot of uncertainty when trying to predict AV-VRU interactions from the present state of affairs
- VRU-AV interaction can happen independently of weather, road class, lighting, traffic conditions and several different outcomes will be observed, at least during the initial phase of full automation.





## Further issues [2/2]

- Considerable knowledge gaps and lack of analyses of some of the existing VRU categories (road users with mobility impairments).
- No hard evidence until AVs roll out of the factory and operate on real-world conditions.
- Any malfunction against VRUs will generate negative outlook to the public which will be disproportionately high compared to crashes between conventional vehicles and VRUs.
- Research is lacking on the detection of mobility-impaired VRUs such as manual/electric-powered wheelchair users.





# Conclusions [1/2]

- Many car manufacturers, supported by scientific research, are developing safety and communication systems that aim to avoid collisions with VRUs.
- Nevertheless, many difficulties are yet to be overcome (e.g., reliable operation in adverse weather conditions).
- It is even more challenging to develop technology that can reliably predict intentions and behaviour of **pedestrians and cyclists**.





# Conclusions [2/2]

- So far, systems have been mainly developed from the **perspective of the vehicle** and it is not clear to what extent these systems can deal with the often unsystematic behaviour of VRUs.
- Moreover, it cannot be excluded that the behaviour of pedestrians and cyclists changes if they have to interact with automated vehicles.
- Further changes are likely in the transition period, with a combination of fully automated vehicles, partly automated vehicles and manually-driven vehicles in overall traffic.











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