

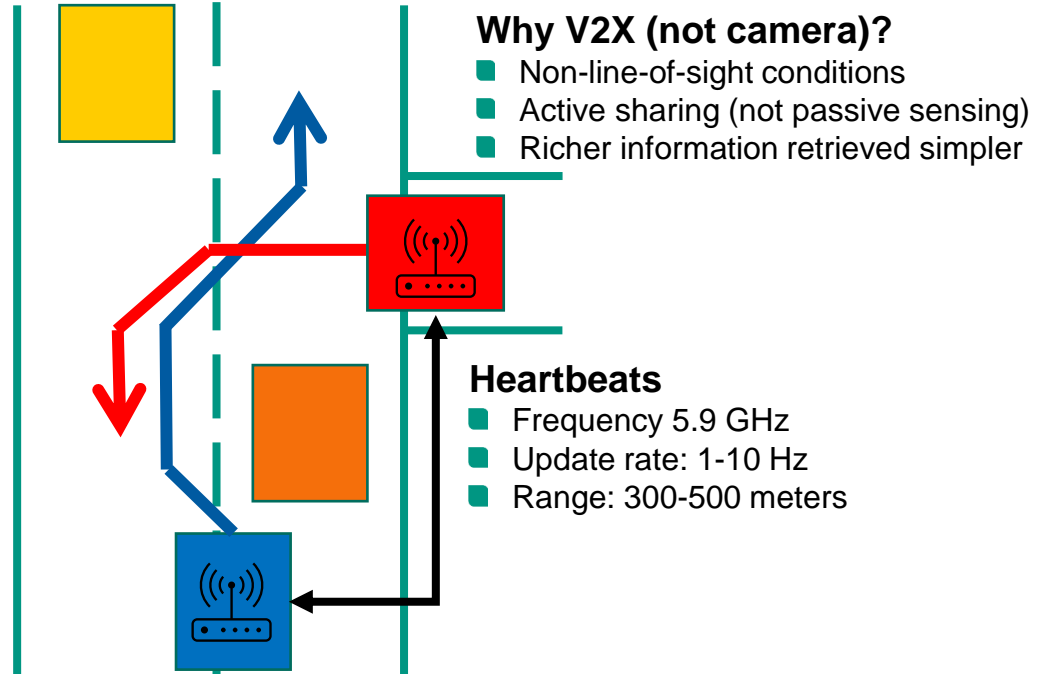
# **Invited lecture - Autonomous Networks and Systems**

## **University of Aveiro**

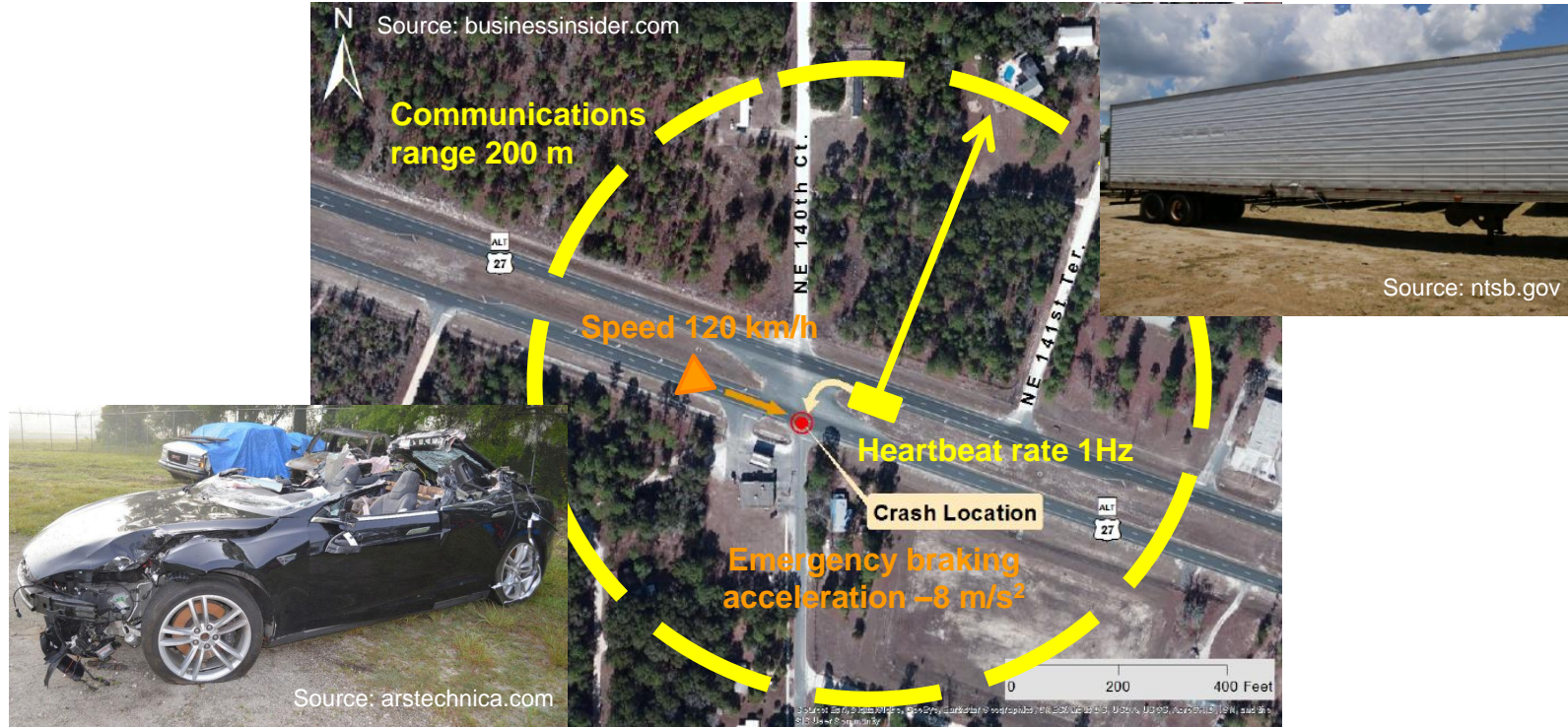
# Do we need vehicular communications (V2X)?



# V2X classics: cooperative awareness



# 7 May 2016 Tesla crash in Florida



# Cooperative awareness: performance evaluation

■ Wi-Fi: Data throughput [802.11 Bianchi 2000]

■ V2X: Heartbeat delivery probability

users      window      deadline

$$P(N, W, T) = \frac{X(N, W, T)}{N}$$

V2X Channel

$$\begin{aligned}
 X(n, w, t) &= q_0(n, w)X(n, w - 1, t - e) && \text{empty} \\
 &+ q_1(n, w)[1 + X(n - 1, w - 1, t - s)] && \text{success} \\
 &+ \sum_{i=2}^n q_i(n, w)X(n - i, w - 1, t - c) && \text{interference} \\
 q_i(n, w) &= \binom{n}{i} \left(\frac{1}{w}\right)^i \left(1 - \frac{1}{w}\right)^{n-i}
 \end{aligned}$$

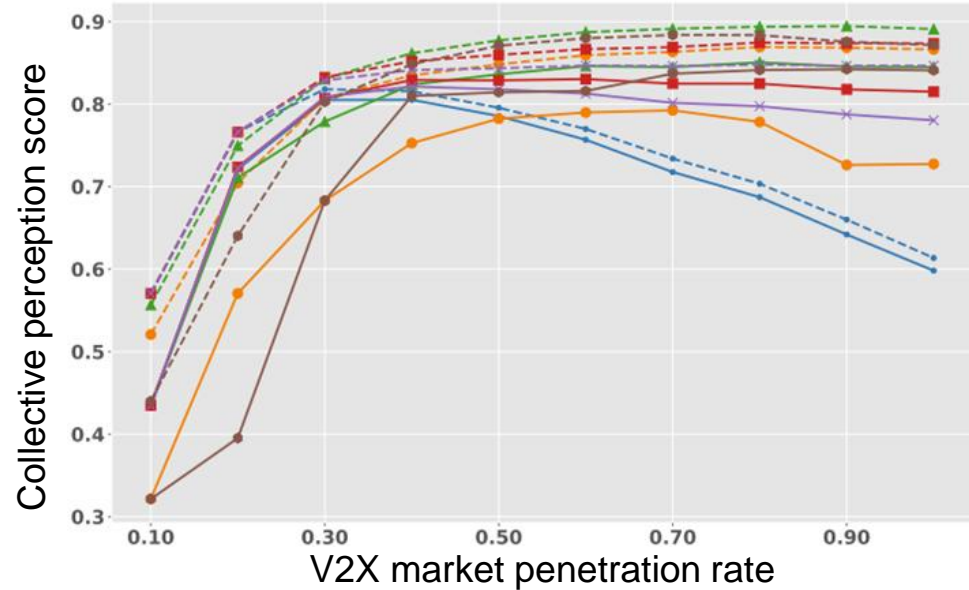
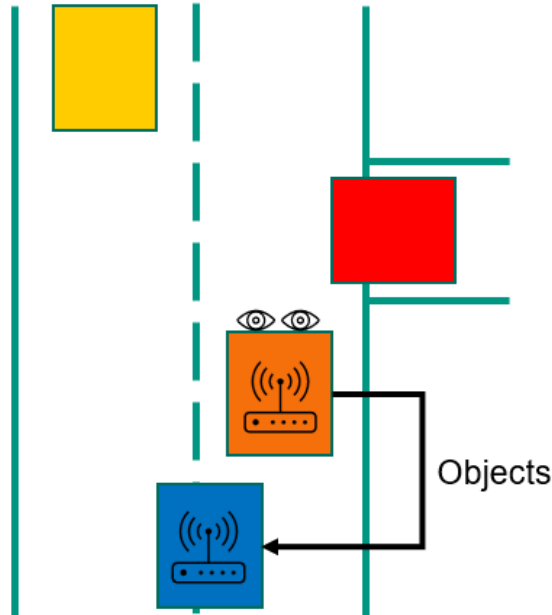


Source: www.t-online.de

A. Vinel, "3GPP LTE Versus IEEE 802.11p/WAVE: Which Technology is Able to Support Cooperative Vehicular Safety Applications?," IEEE Wireless Communications Letters, 2012.



# V2X state-of-the-art: collective perception



$$\text{Score} = (1 - \text{Channel Busy Ratio}) * \text{Environmental Awareness Ratio} * \text{Redundancy Valuation}$$

Q. Delooz, A. Festag, A. Vinel and S. C. Lobo, "Simulation-based Performance Optimization of V2X Collective Perception by Adaptive Object Filtering," IEEE Intelligent Vehicles Symposium, 2023.

# V2X vision: cooperative maneuvering



GCDC 2016



Black Sheep Production

# A social robot as a mediator of mixed traffic

Function 1: Perception

Function 2: Planning

Function 3: Interaction

Digital  
Communication

Social  
Interaction

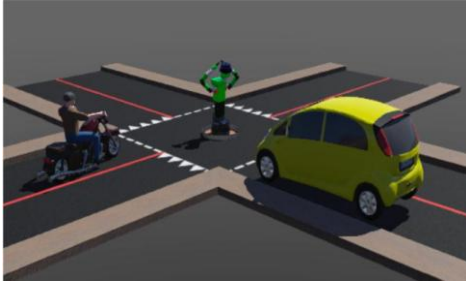
Benchmark Scenarios (Intersection, Roadworks)





# How new is the idea of the “robot-policeman”?

## A. No vehicle-robot connectivity



F. Ghaffar, *Controlling Traffic with Humanoid Social Robot*, arXiv 2022

## B. No real-world experiments



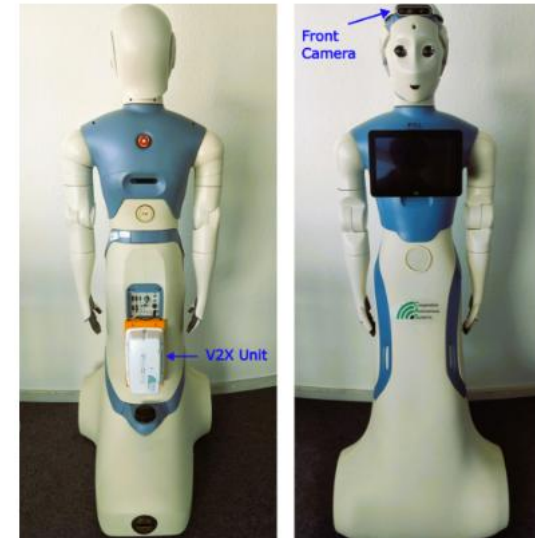
S.C. Kumaran et al., *To Cross or Not-to-Cross: A Robotic Object for Mediating Interactions Between Autonomous Vehicles and Pedestrians*, RO-MAN 2023

## C. No social interactions in traffic



EU Project IPA2X 2022 <https://ipa2x.eu>

## D. Our approach



# 1<sup>st</sup> Attempt: Pedestrian Crossing

## ■ Gesture set of the social traffic robot



A: the robot is in the initial state

B: the robot blocks the path by spreading the arms

C: the robot moves slightly to the side and indicates to give way by opening the right hand

M. Schrapel, M. Bied, B. Bruno, A. Vinel, "Experiencing Social Robots for Traffic Guidance using Virtual Reality Videos," MuC 2024, Karlsruhe, Germany.



## 2<sup>nd</sup> Attempt: Pedestrian Crossing



# V2X in cooperative driving safety

ISO 26262  
Functional Safety



V2X  
radio  
failed

ISO 21434  
Cybersecurity  
Engineering



V2X  
network  
attacked

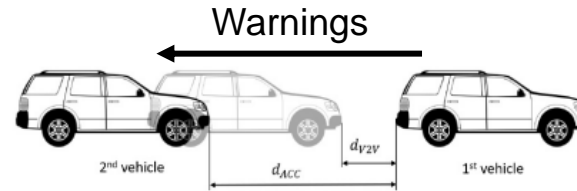
ISO/DIS 21448  
Safety of  
Intended  
Functionality



V2X  
environment  
changed



# Cooperative automated driving safety



## ■ Autonomous case

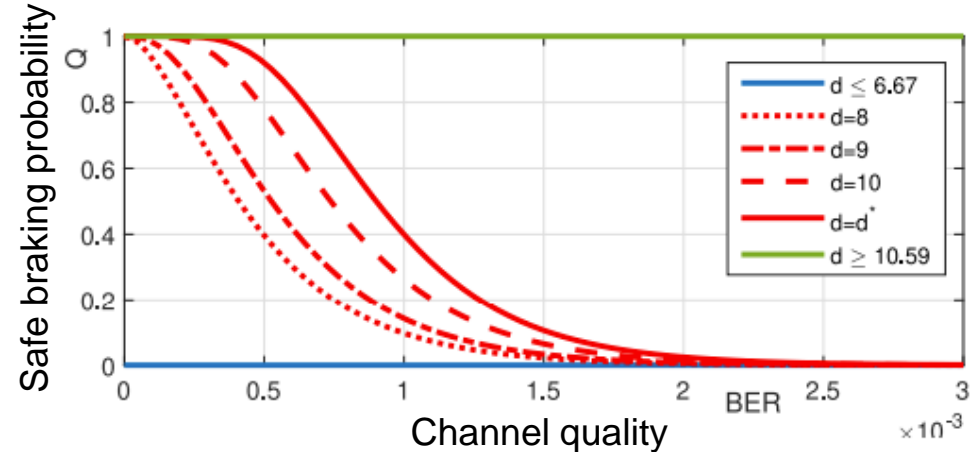
The AV, on the other hand, can be programmed to create and operate within a safe following distance, based on the formula below.

$$d_{min} = \left[ v_r \rho + \frac{1}{2} a_{max} \rho^2 + \frac{(v_r + \rho a_{max})^2}{2\beta_{min}} - \frac{v_f^2}{2\beta_{max}} \right]_+$$

The moment the distance between the two cars is less than  $d_{min}$ , the AV brakes until a safe following distance is restored, or until the vehicle comes to a complete stop, whichever occurs first.

**Does not work when ego vehicle has a higher decelerating capacity than its preceding vehicle [we extended the model accordingly]**

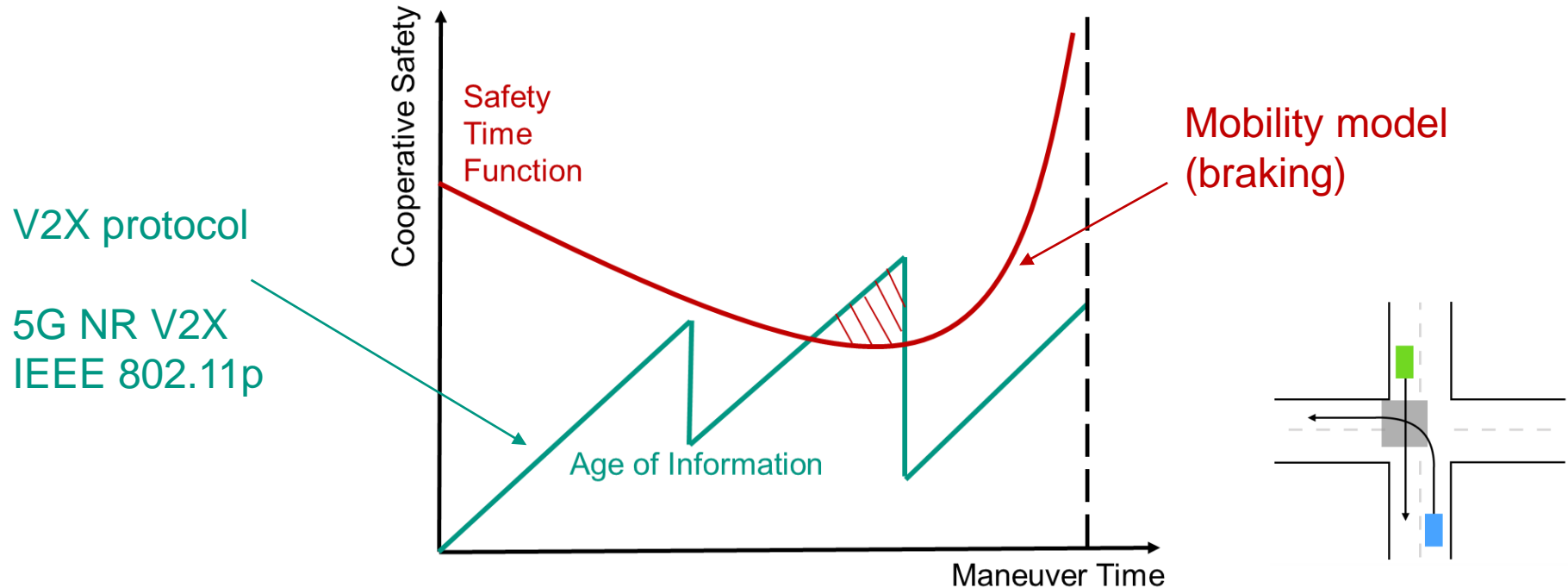
## ■ Cooperative case



G. Sidorenko, A. Fedorov, J. Thunberg and A. Vinel, "Towards a Complete Safety Framework for Longitudinal Driving," IEEE Transactions on Intelligent Vehicles, 2022.

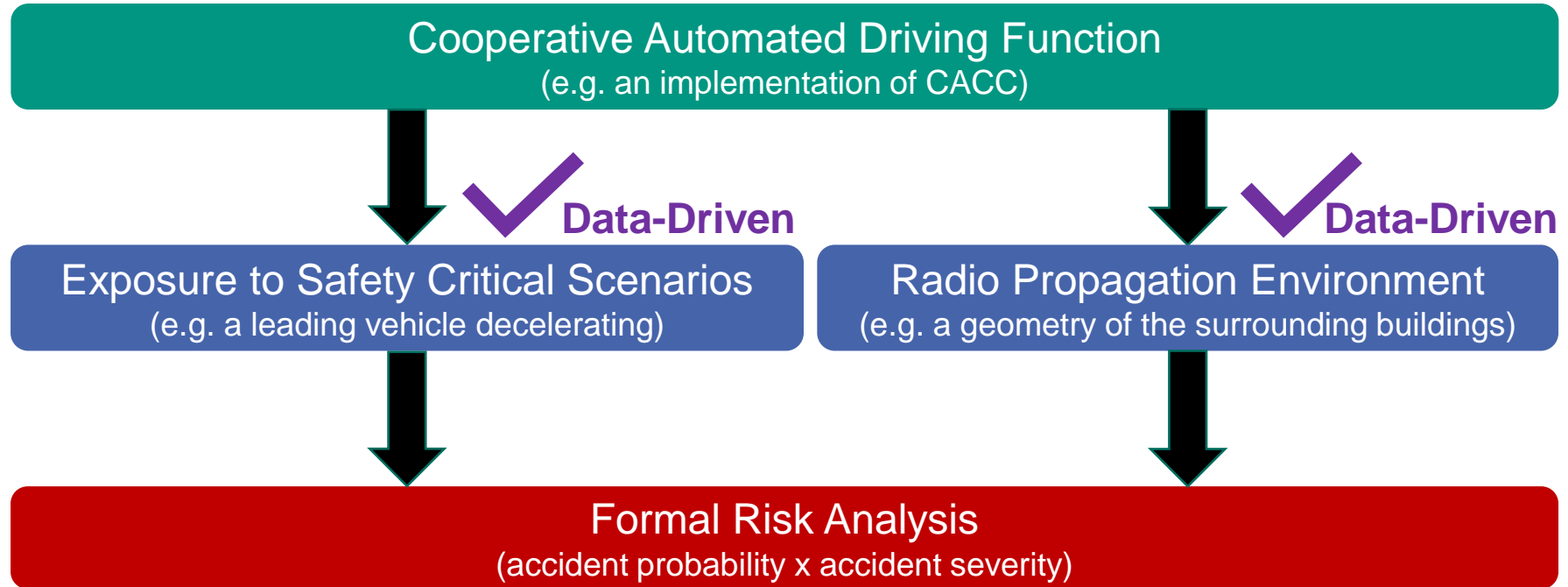
G. Sidorenko, D. Plöger, J. Thunberg and A. Vinel, "Emergency Braking With ACC: How Much Does V2V Communication Help?," in IEEE Networking Letters, 2022.

# Goal-oriented communications: safety in focus

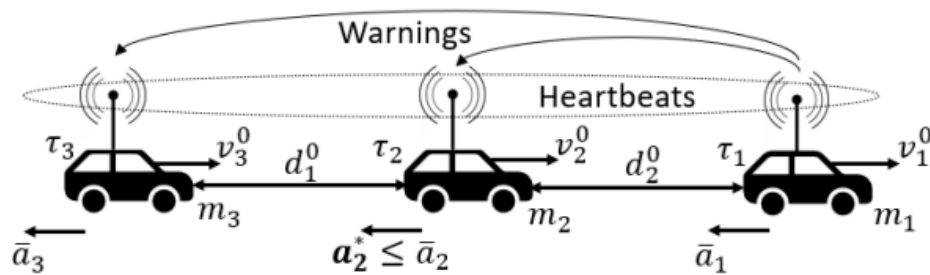


J. Thunberg, D. Bischoff, F. A. Schiegg, T. Meuser and A. Vinel "Unreliable V2X Communication in Cooperative Driving: Safety Times for Emergency Braking," IEEE Access, 2021.

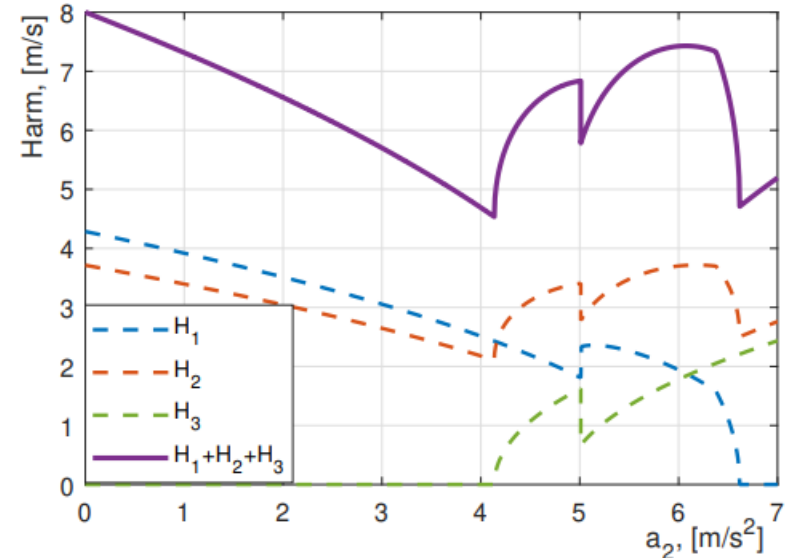
# Risk assessment framework



# Ethical V2X: moral cooperative driving



- The situation of an **unavoidable accident**
- Actions to **distribute harm** between vehicles
- V2X supports:
  - Risk assessment
  - Trajectory planning



G. Sidorenko, J. Thunberg and A. Vinel "Ethical V2X: Cooperative Driving as the Only Ethical Path to Multi-Vehicle Safety" IEEE VTC-Fall Workshops, 2023.

G. Sidorenko, J. Thunberg and A. Vinel "Cooperation for Ethical Autonomous Driving" IEEE WiMob, 2024.