An assessment of LTE-V2X (PC5) and 802.11p direct communications technologies for improved road safety in the EU

A study by the 5GAA

Cellular-V2X Technology: Paving the road to 5G, delivering for connected and automated vehicles in Europe

Brussels
5 December 2017

Introduction to the study[1]

- A quantitative analysis of 3GPP LTE-V2X (PC5) and IEEE 802.11p technologies for short-range *ad hoc*/direct communications in reducing fatalities and serious injuries caused by motoring accidents in the EU.

- Additional reductions in fatalities and serious injuries are possible via longer-range communications enabled through interactions with a LTE cellular network.
  But these are outside the scope of this study.

- Modelling underlying this report has been peer-reviewed and validated in detail by the technology and policy consultancy, Ricardo.

1 The report: “An assessment of LTE-V2X (PC5) and 802.11p direct communications technologies for improved road safety in the EU”, 5 December 2017, is available at: www.5gaa.org.

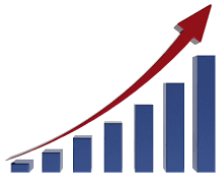
Study framework

- Study examines two independent counter-factual scenarios: one where LTE-V2X (PC5) is the only deployed C-ITS technology, and the other where 802.11p is the only deployed C-ITS technology.

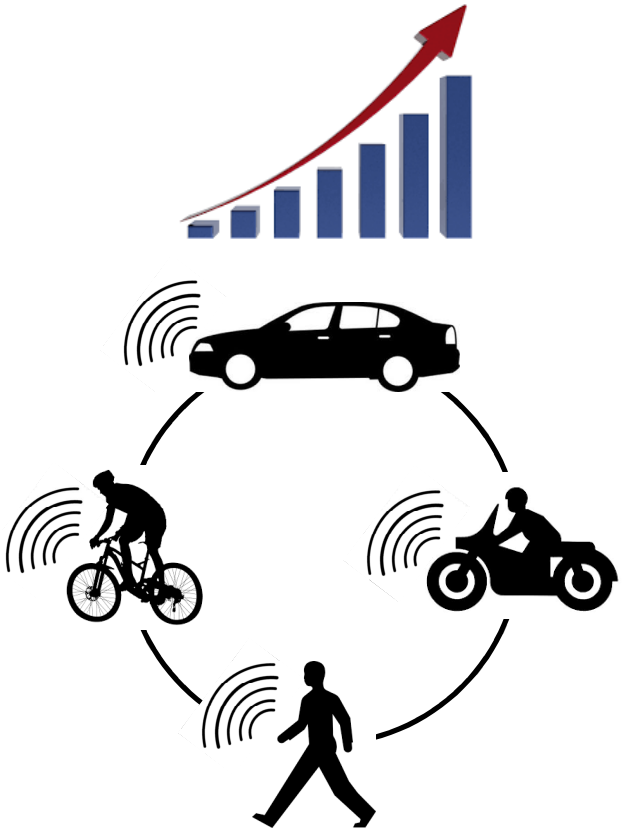
- We consider, as a baseline, the existing and future projected statistics for road traffic fatalities/injuries in the EU. We then evaluate the reduction in fatalities/injuries which may occur by modelling

  - expected take-up of LTE-V2X (PC5) and 802.11p among road users over time (including vehicles, motorcycles, bicycles and pedestrians), and

  - radio link performance of LTE-V2X (PC5) and 802.11p.



Study framework



Inputs

Penetration input

- ❑ Fleet size/turnover rate;
- ❑ Smartphone population;
- ❑ 802.11p in vehicles;
- ❑ LTE in vehicles/phones;
- ❑ LTE-V2X (PC5) in vehicles/phones;

Accident data (fatalities and serious injuries)

% by road type
- ❑ Urban;
- ❑ Rural;
- ❑ Motorway;

% by transport mode
- ❑ Pedestrian and Bicycles;
- ❑ Motorcycles;
- ❑ Vehicles;

% by type of accident
- ❑ At junction;
- ❑ Not at junction;

Calculation modules

Model: Technology penetration

LTE-V2X (PC5)/802.11p
- ❑ By mode of transport;

Model: Avoided accidents

LTE-V2X (PC5)/802.11p
- ❑ By technology;
- ❑ By mode of transport;
- ❑ By type of accident;

Model: Radio performance and effectiveness

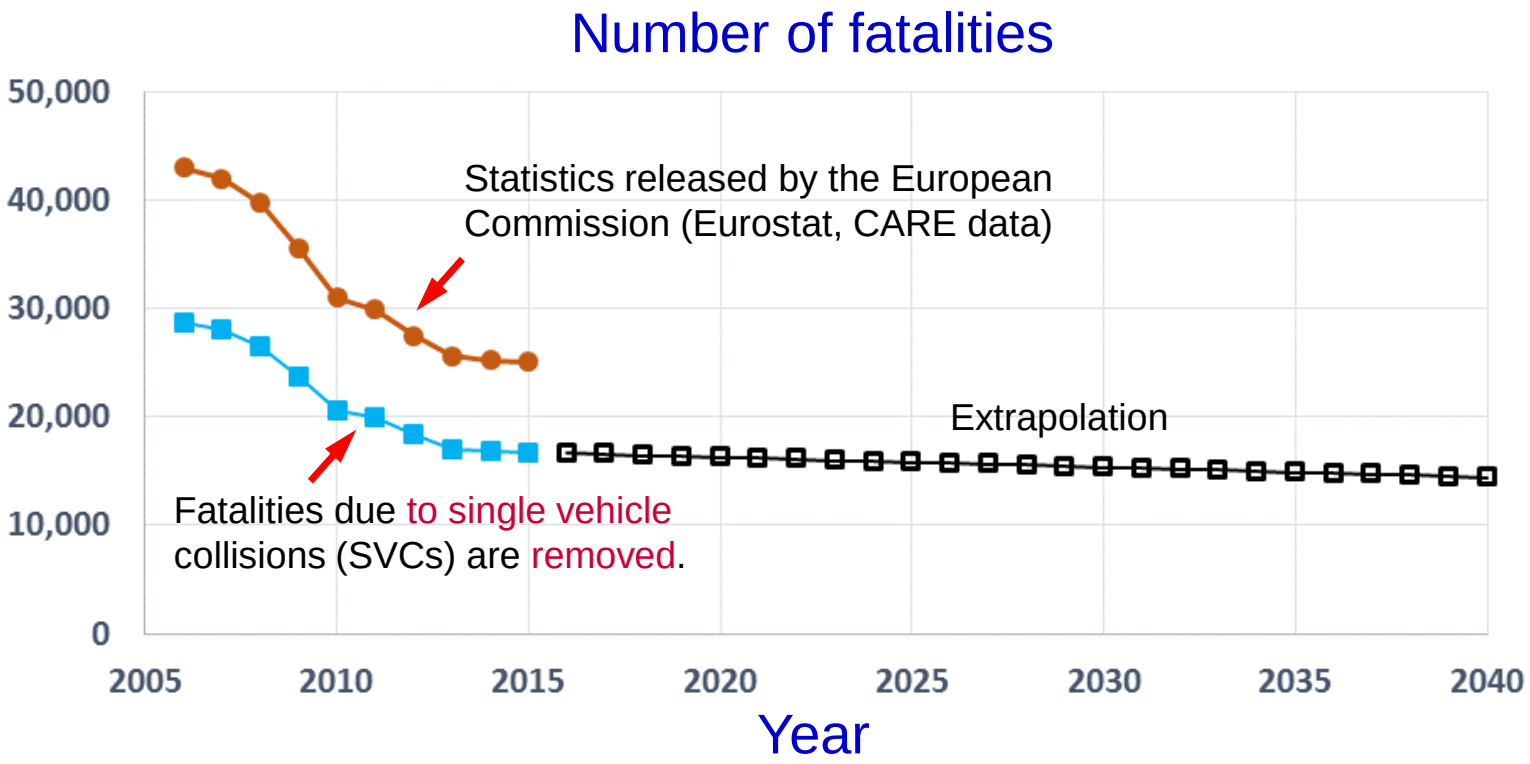
Alert delivery rates LTE-V2X (PC5)/802.11p
- ❑ By road type;
- ❑ By mode of transport;
- ❑ By type of accident;

Impact of alert on driver behaviour
- ❑ By road type;
- ❑ By mode of transport;
- ❑ By type of accident;

Outputs

Accidents avoided (fatalities and serious injuries) projected to 2040
- ❑ % of accidents avoided;
- ❑ Absolute number of accidents avoided;
- ❑ Cumulative number of accidents avoided;
- ❑ Societal cost of accidents avoided;

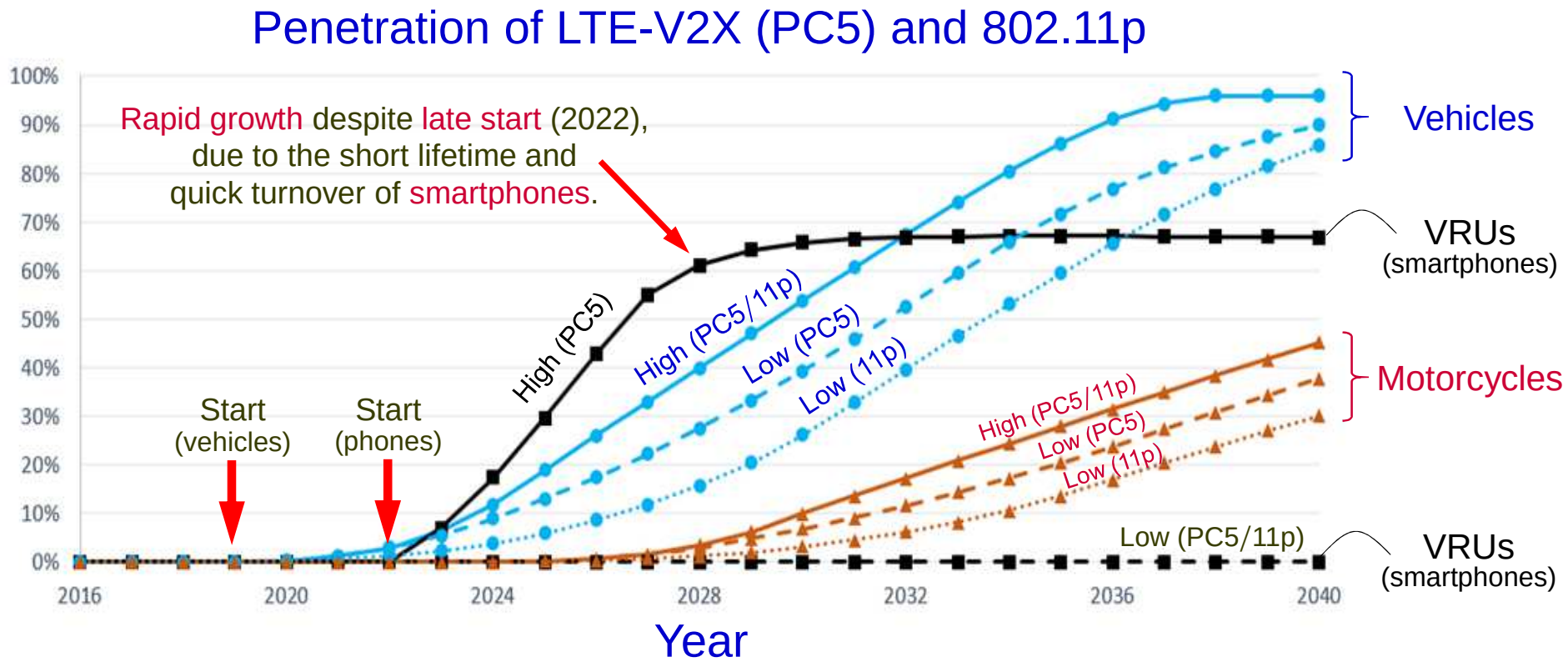
Baseline: Fatalities/injuries in the EU



Extension: 12 serious injuries per fatality.

Note: Baseline does not account for impact of long-range cellular communications (or technologies other than C-ITS), in reducing the number of accidents. For this reason, the results of this study are an upper bound on number of accidents avoided.

Technology penetration: High/low scenarios



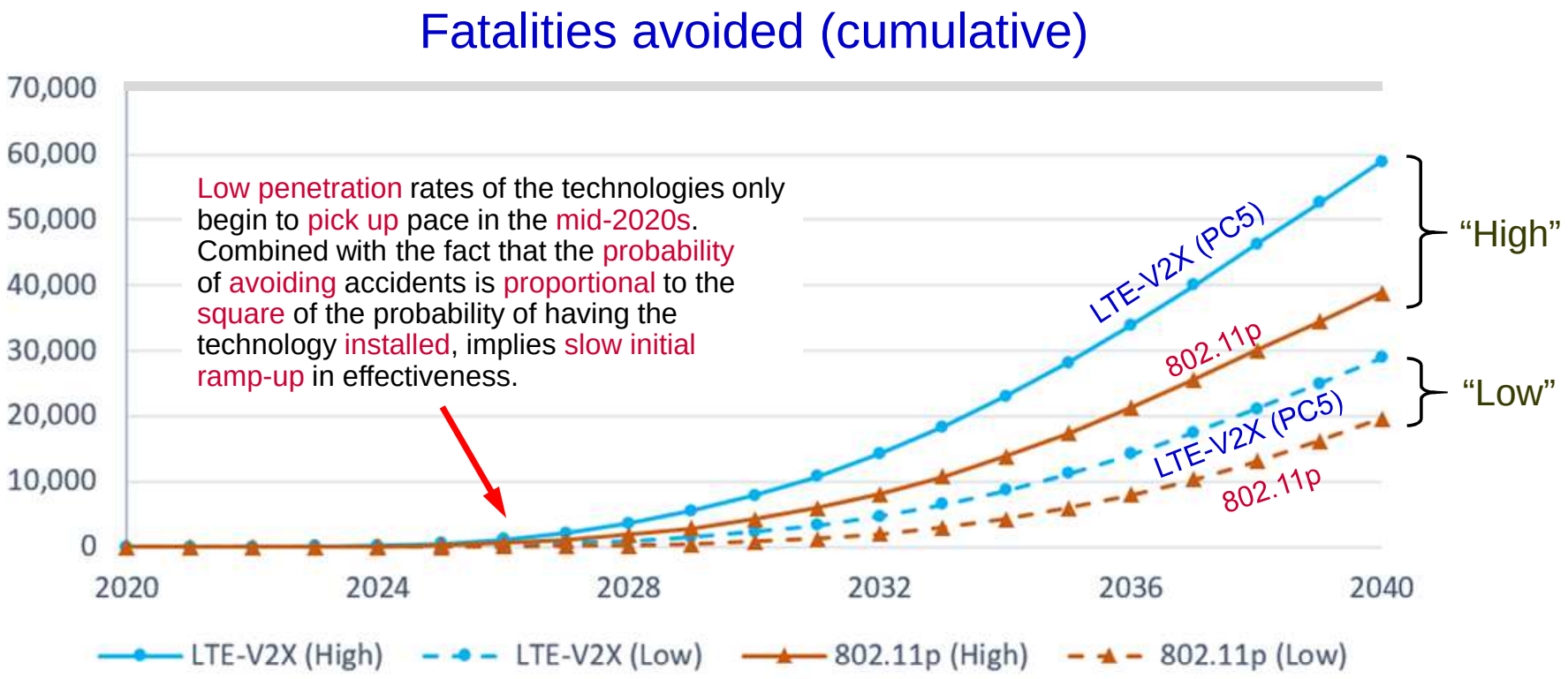
"High" scenario: Assumed aggressive deployment.
"Low" scenario: More pessimistic deployment based on literature.

Radio link performance: Alert delivery reliability

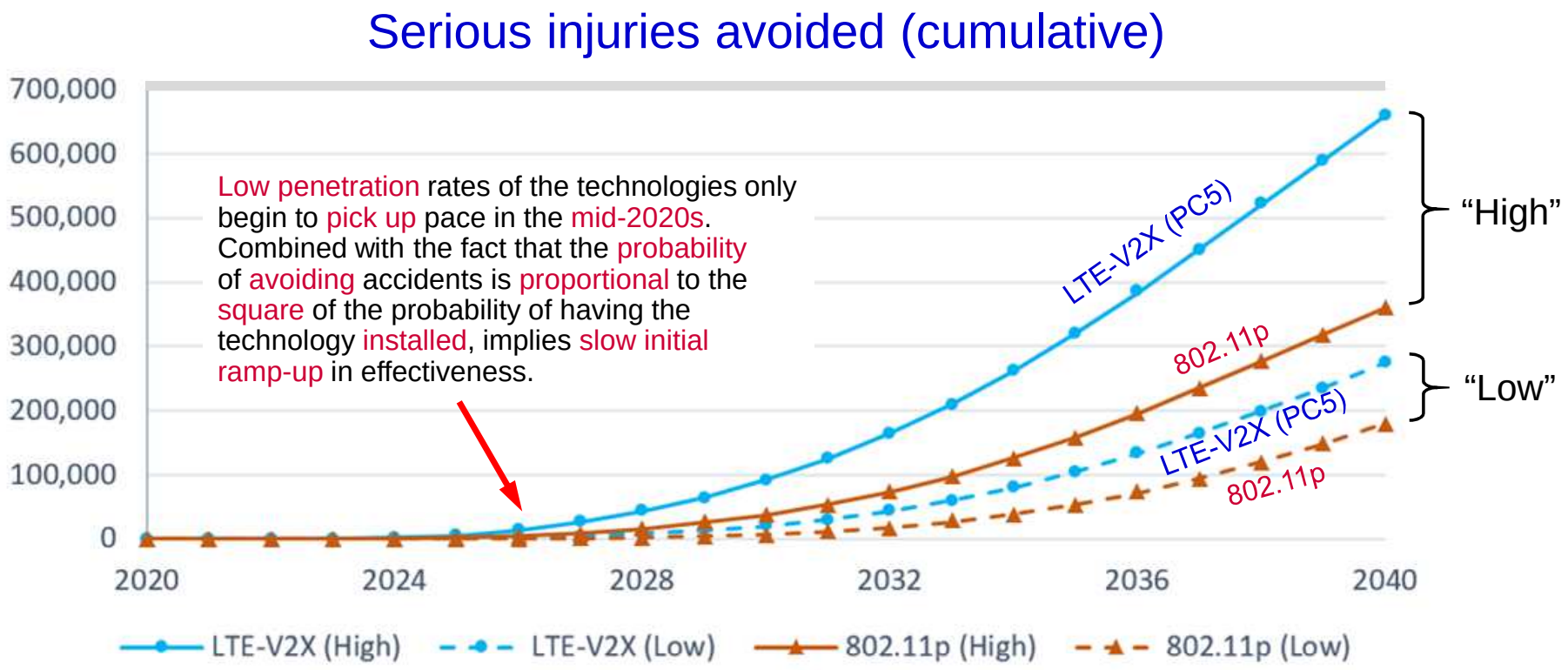
LTE-V2X (PC5) [802.11p]	At junction			Not at junction		
Vehicle to...	**Urban**	**Rural**	**Motorway**	**Urban**	**Rural**	**Motorway**
... pedestrian or bicycle	96% [78%]	67% [59%]	N/A	88% [75%]	98% [97%]	97% [63%]
...vehicle or motorcycle	96% [78%]	83% [66%]	N/A	96% [81%]	99% [98%]	94% [86%]

- Likelihood of successful delivery of warning messages between two road users equipped with LTE-V2X (PC5) is greater than it is for two road users equipped with 802.11p.
- LTE-V2X (PC5) has greater transmit power spectral density (frequency-domain multiplexing), more power-efficient SC-FDM waveform, better (Turbo) channel coding gain, physical layer packet re-transmissions, and better (deterministic) management of radio resources.

Cumulative statistics: Fatalities



Cumulative statistics: Serious injuries



Summary

Time-frame: 2018-2040	Avoided fatalities		Avoided serious injuries	
	High	Low	High	Low
LTE-V2X (PC5)	**59,000**	**29,000**	**660,000**	**275,000**
802.11p	39,000	20,000	360,000	180,000

- Deployment of LTE-V2X (PC5) would avoid greater numbers of fatalities and serious injuries on the EU's roads than would be the case for 802.11p.
- Expressed in terms of external costs avoided, this amounts to total avoided costs of **€61 billion** and **€22 billion** for LTE-V2X (PC5) compared to 802.11p in the "high" and "low" scenarios, respectively.

Even the "low" 802.11p penetration is expected to be overly optimistic: at the time of writing only one European car vendor has announced an intention to deploy 802.11p, expected in 2019. Whereas, the "low" LTE-V2X (PC5) penetration is based on on-going growth of LTE modems in vehicles (for telematics/infotainment), and what we consider to be a realistic future projection of PC5 functionality in such LTE modems.

Conclusions and recommendations (1/2)

- An absence of interoperability at radio link level between LTE-V2X (PC5) and 802.11p is unlikely to present a substantive barrier to reduction of road accidents in the EU in the short to medium term.

- This is because the relatively low penetration of C-ITS technologies in vehicles in the first half of the next decade means that a vehicle equipped with LTE-V2X (PC5) or 802.11p is far more likely to collide with a vehicle that is not equipped with C-ITS technologies at all.

- Any regulations which mandate LTE-V2X (PC5) to be backward interoperable with 802.11p will

  - have only a limited effect in the early years of deployment pre-2025;
  - run the risk of unnecessarily distorting the market in favour of 802.11p, thereby obstructing the adoption of LTE-V2X (PC5);
  - resulting in greater road fatalities and injuries in the longer term.

Conclusions and recommendations (2/2)

- The study indicates that LTE-V2X (PC5) outperforms 802.11p in reducing fatalities and serious injuries on the EU's roads.

- This is due to a combination of the superior performance of LTE-V2X (PC5) at the radio link level for *ad hoc*/direct communications between road users, and the market led conditions which better favour the deployment of LTE-V2X in vehicles and in smartphones, and include a clear evolutionary path towards 5G-V2X.

- For these reasons, it is essential that EU regulations remain technology neutral and do not hinder the deployment of LTE-V2X (PC5) in favour of 802.11p for the provision of direct communications among vehicles and between vehicles and vulnerable road users.

Thank you

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ANNEX

Breakdown by mode of transport

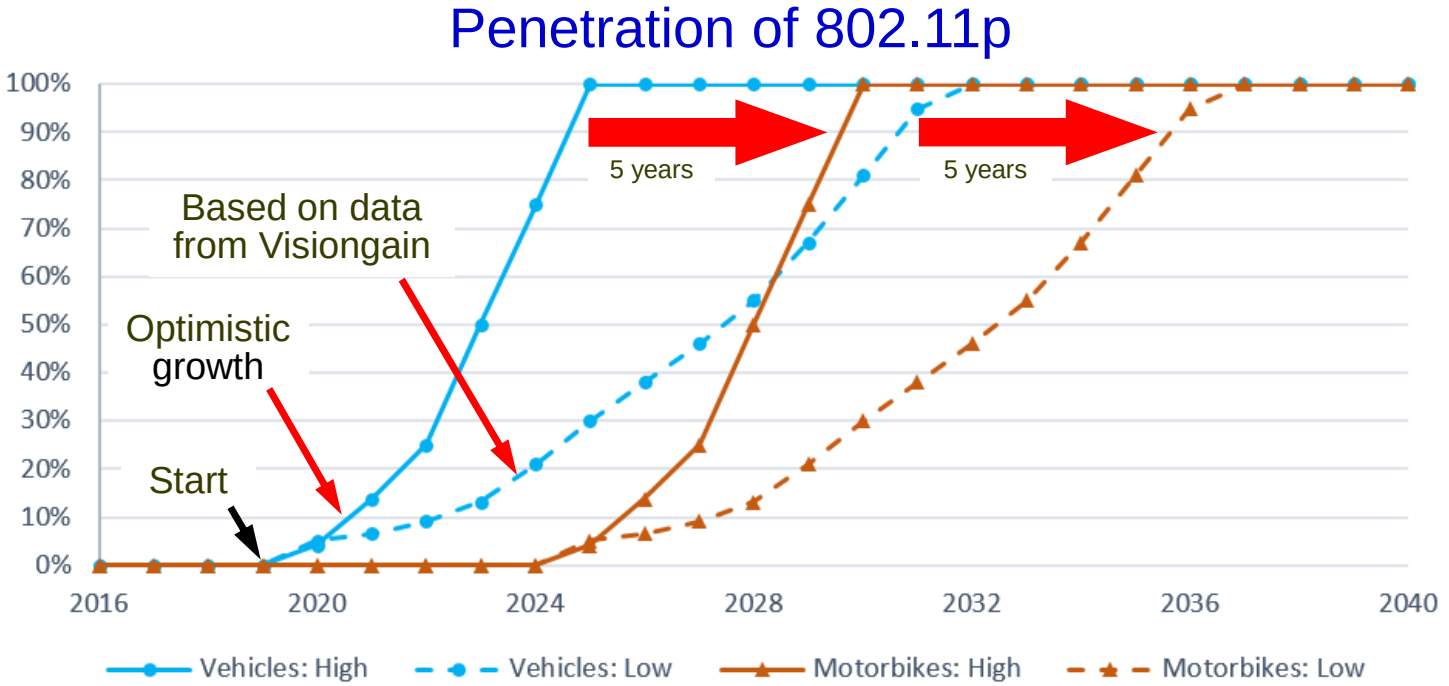
LTE-V2X (PC5)
2018 - 2040

	Fatalities		Serious injuries	
	High	Low	High	Low
Pedestrians	12,700	N/A	164,828	N/A
Bicycles	5,014	N/A	102,159	N/A
Motorcycles	3,854	2,567	59,477	39,611
Vehicles	37,353	26,403	333,449	235,704
Total	**58,921**	**28,970**	**659,913**	**275,315**

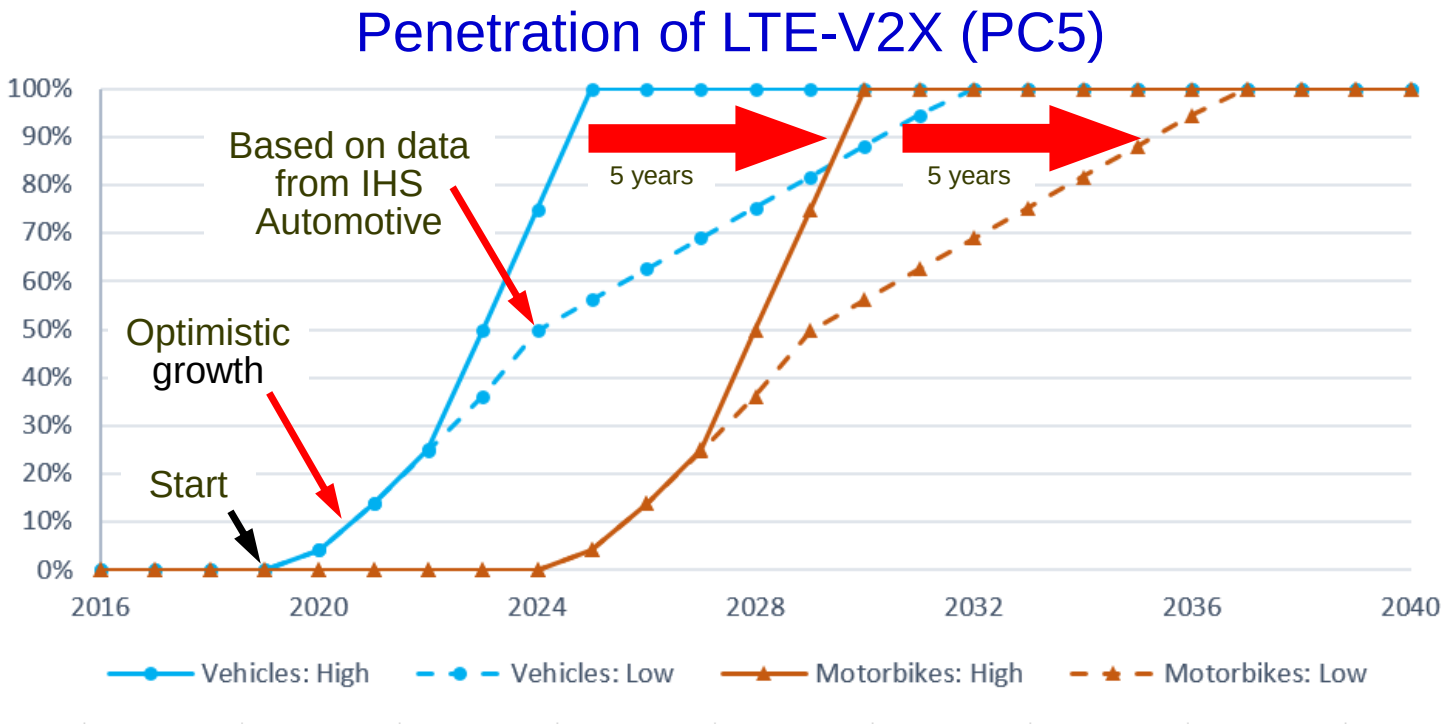
802.11p
2018 - 2040

	Fatalities		Serious injuries	
	High	Low	High	Low
Pedestrians	N/A	N/A	N/A	N/A
Bicycles	N/A	N/A	N/A	N/A
Motorcycles	3,569	1,504	53,462	22,534
Vehicles	35,318	18,105	307,013	157,385
Total	**38,887**	**19,609**	**360,474**	**179,918**

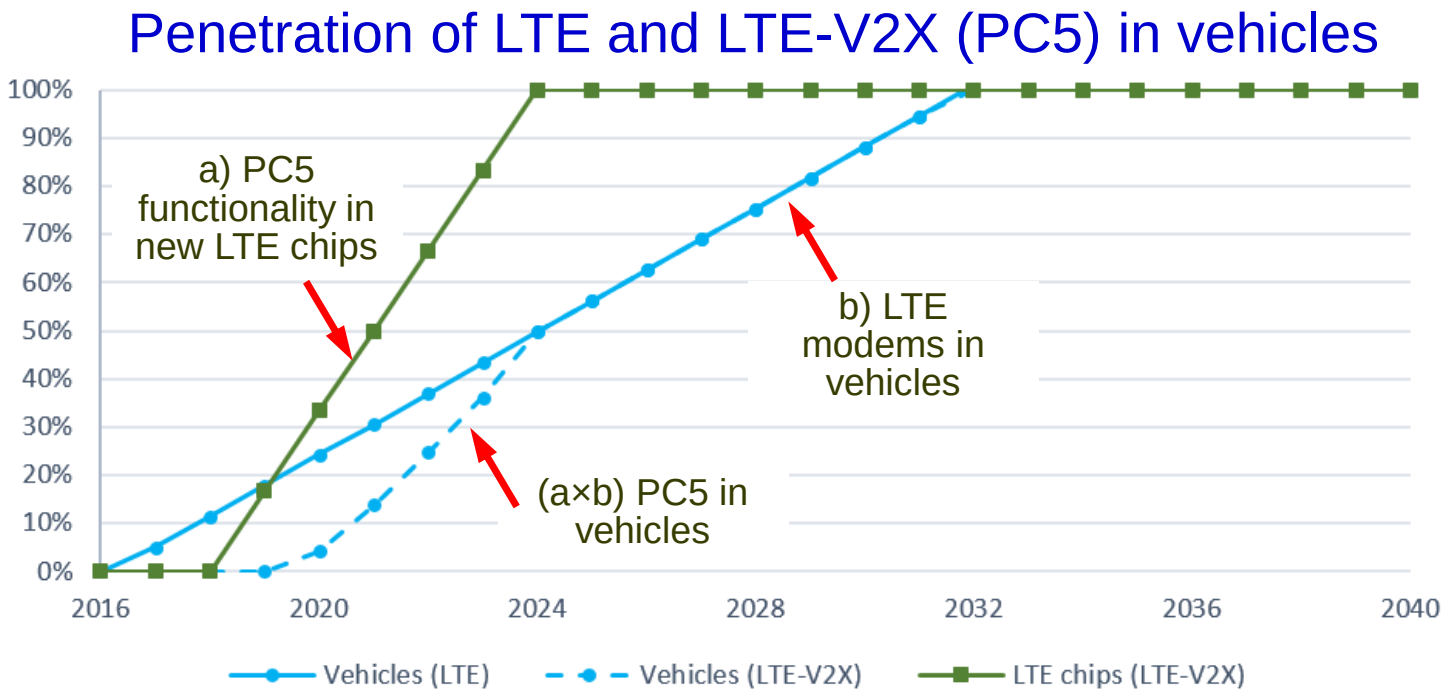
802.11p in new vehicles/motorcycles



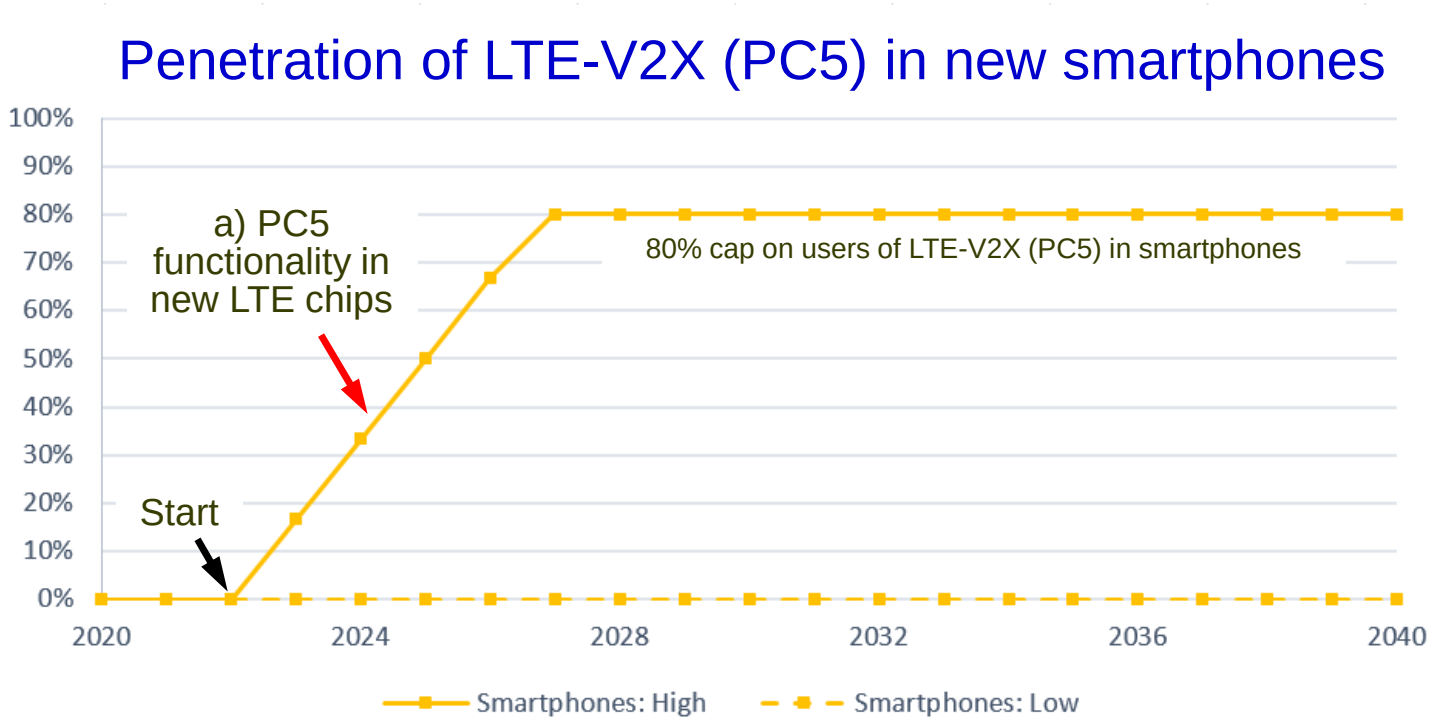
LTE-V2X (PC5) in new vehicles/motorcycles



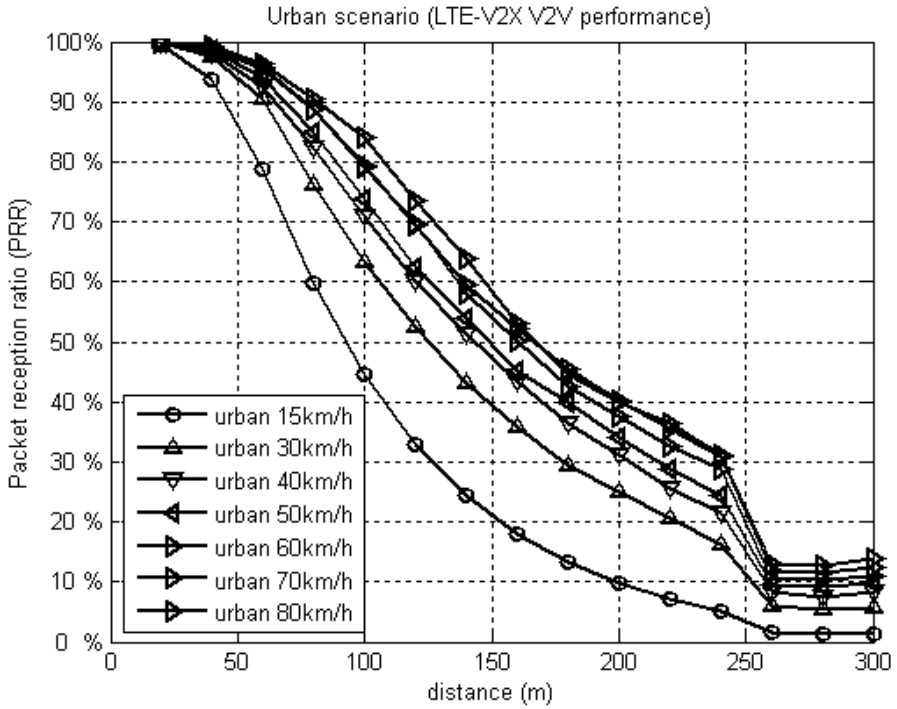
Derivation of LTE-V2X (PC5) low scenario

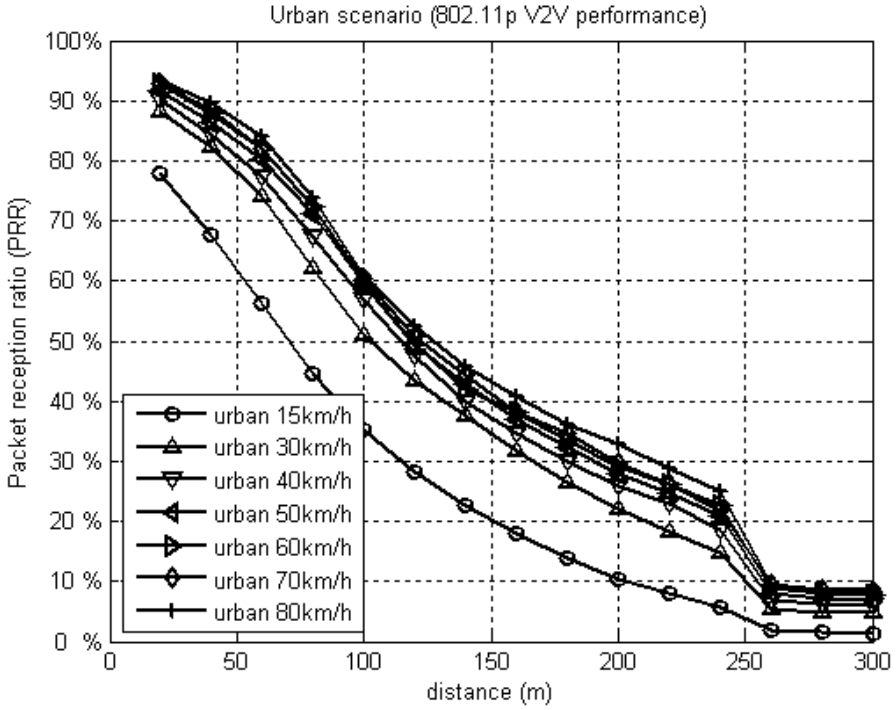


LTE-V2X (PC5) in new smartphones



Radio link performance





For each scenario, the range of assumed road user speeds maps to a corresponding range of alert delivery reliability rates. The *average* reliability rate over this range is then calculated as the alert delivery reliability associated with the said scenario.