

How do autonomous buses and VRU interact? Evidence from Leuven

Independent monitoring as a
building block for ultra-safe AV
deployment

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Ultra-safe systems are built, not hoped for

What makes aviation ultra-safe



Safety management system

Safety as a managed, audited process



Report incidents and near misses

Learn from precursors, not only from crashes



Independent investigation

Decoupled from blame and liability (ICAO Annex 13)



Just culture and accountability

Those who design and operate carry the culture

Why it will not happen by itself



“They’ll insure it away”

Settling damages can be cheaper than sharing data



Belgium: Art. 29bis WAM

Compensation regardless of fault:
crashes become a cost item, not a learning opportunity



EU 2022/1426: in-service monitoring exists

But data are self-reported by the party at stake

After Amalberti (2001); B. Ciuffo, keynote MFTS 2026

Needed: independent eyes + a framework that makes sharing non-incriminating

Self-reported versus independent: three layers of evidence

SELF-REPORTED

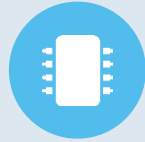


THE REPORTING SYSTEM

In-service monitoring and reporting

Mandatory under EU type approval.
Self-reported by the manufacturer.

INDEPENDENT EYES



THE FLIGHT DATA RECORDER

On-board monitoring

Independent logging aboard the vehicle: built in (like a flight data recorder) or by spot audits (e.g. IVEX).



THIS PROJECT

THE AIR TRAFFIC RADAR

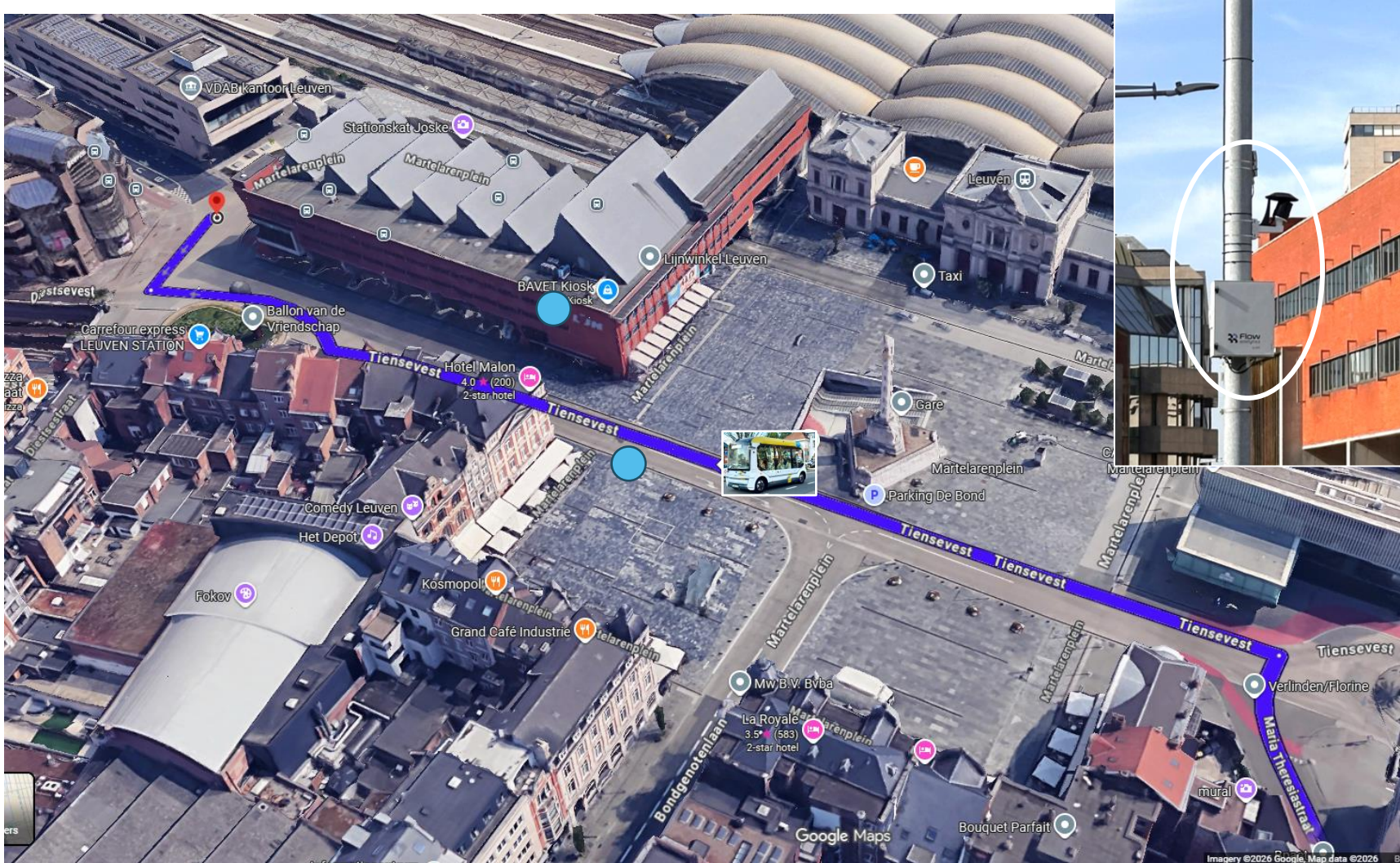
Roadside monitoring

Measures all road users with the same yardstick, independent of what operators disclose.



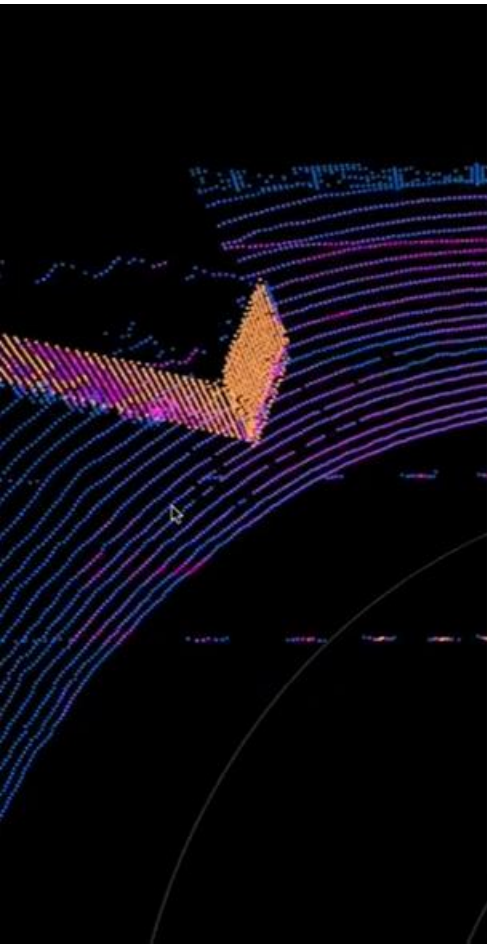
Shared learning → **ultra-safe culture:** confirm safety in operation, detect precursors, anticipate threats

Leuven: roadside monitoring of VRU-automated shuttle interactions



- since 19 May 2026 (and counting)
- 229 shuttle visits analysed so far
- >3000 buses & 228 vans for comparison

From lidar to traffic analysis: existing pipeline by AGC



ANALYTICS

- Counts
- Speeds
- Mobility
- Trajectories
- Replay

TOOLS

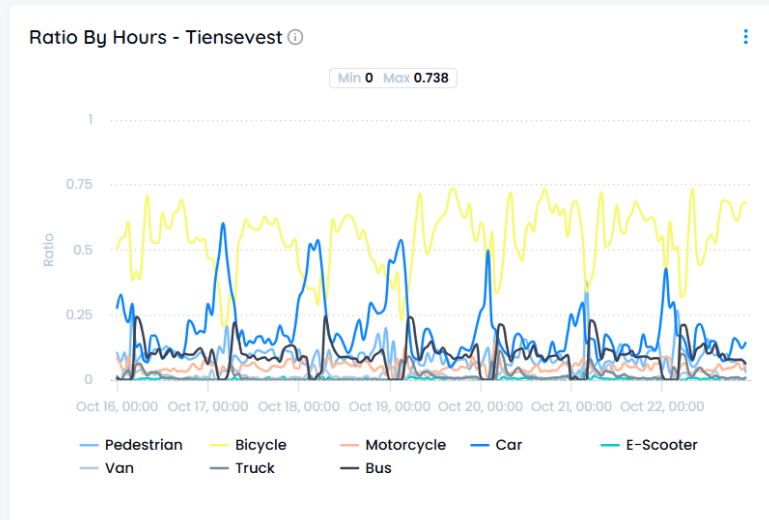
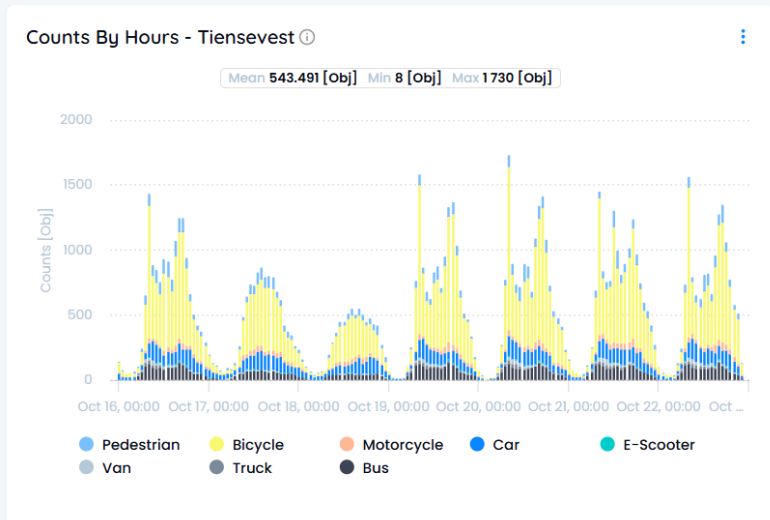
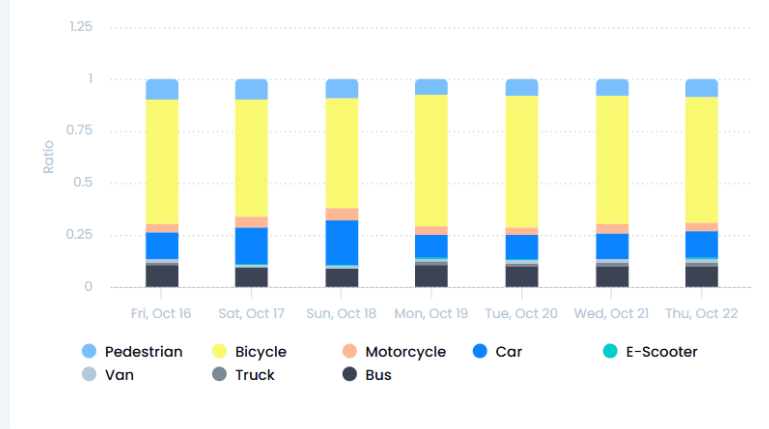
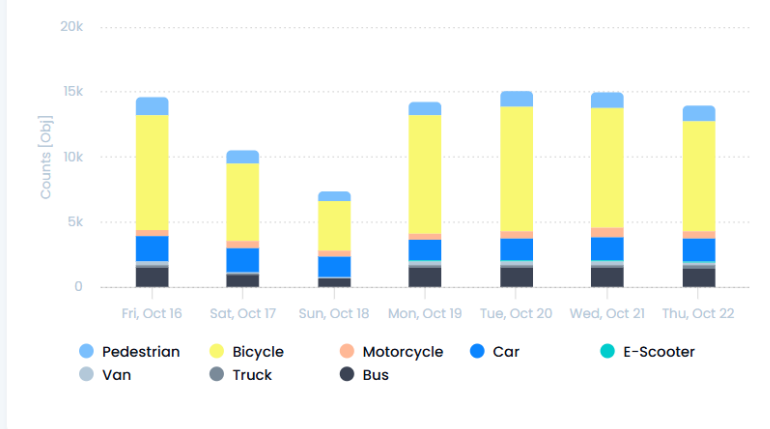
- Zones
- Tables

SETTINGS

- Export
- Preferences

SUPPORT

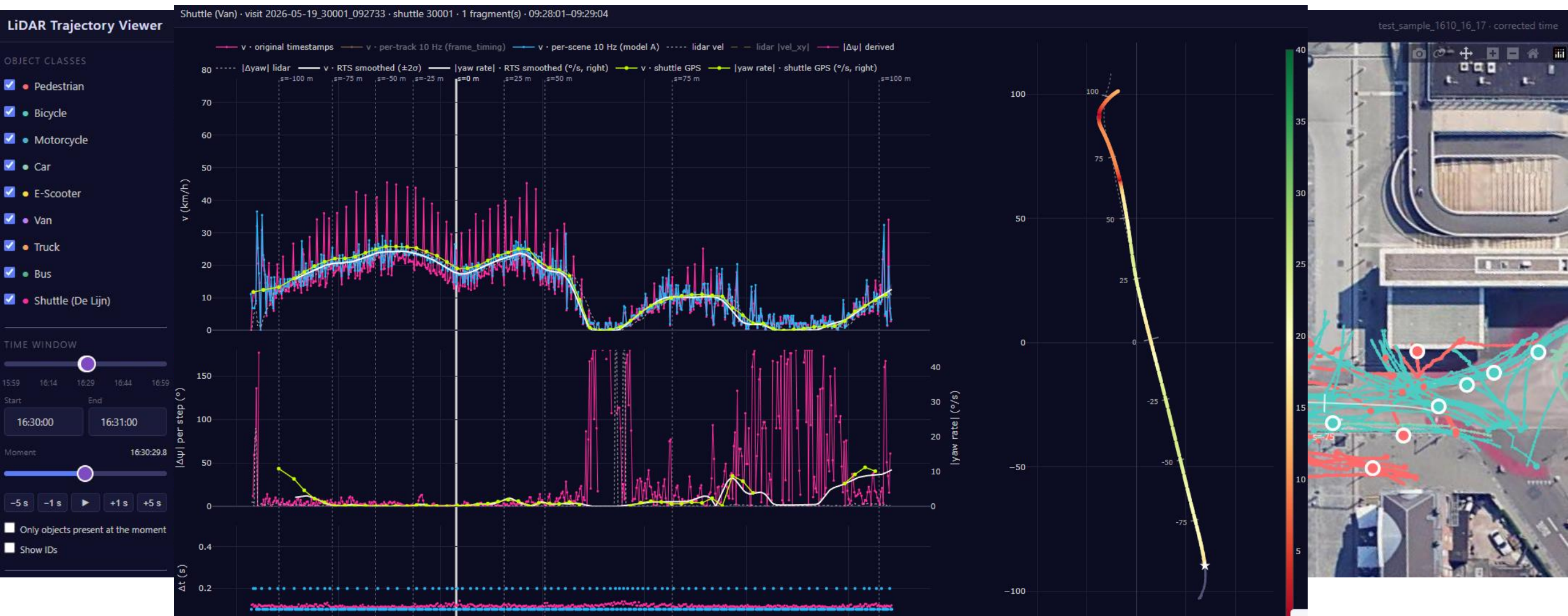
- API
- Contact



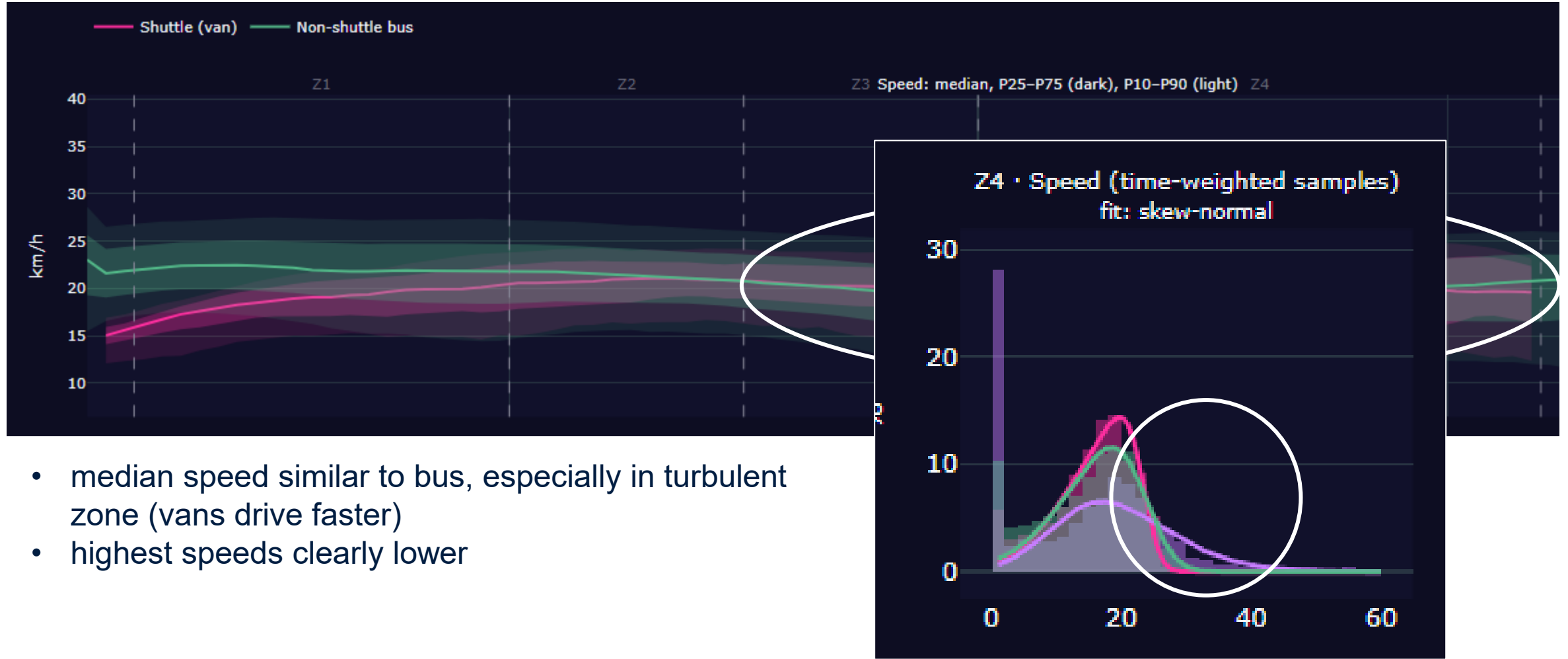
Pedestrian #455175 4.4 km/h

Pedestrian #455175 4.4 km/h

From lidar to traffic analysis: development at KU Leuven



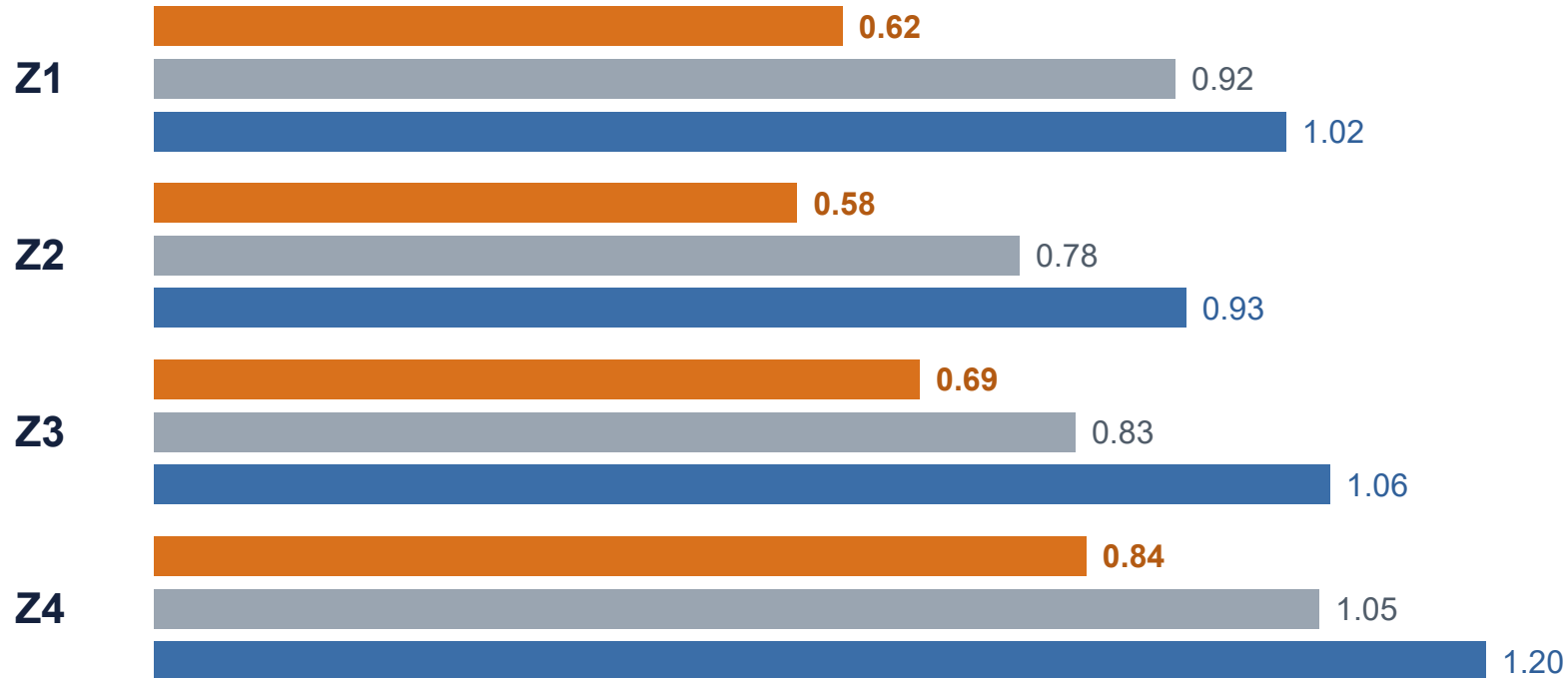
Preliminary results: speeds of shuttle vs. buses and vans



Preliminary results: shuttle accelerates more gently

95th percentile of |acceleration| while moving (m/s²) · strongest acceleration per passage, P90:
shuttle 0.52–0.83, others up to 1.34

■ Shuttle ■ Bus ■ Van



Preliminary results: Fewer hard brakes, more moderate (not more frequent) braking where conflicts occur

Strongest deceleration per zone passage (m/s²)

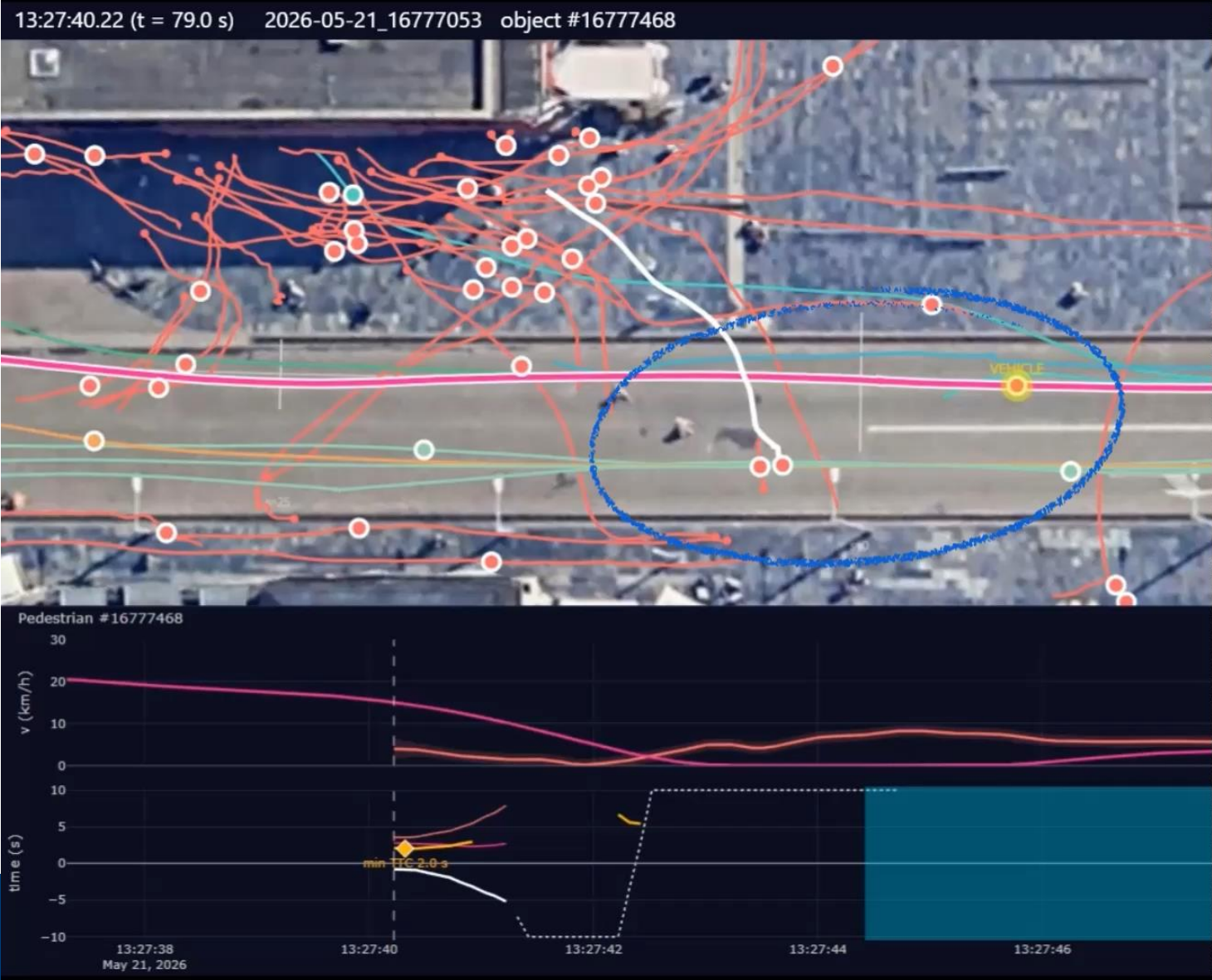
Zone	Hard braking (P10 of passages)			Typical passage (median)		
	Shuttle	Bus	Van	Shuttle	Bus	Van
Z1	-0.61	-0.85	-0.64	-0.11	-0.28	-0.20
Z2	-0.55	-0.68	-0.89	-0.16	-0.28	-0.25
Z3	-0.79	-0.92	-1.23	-0.41	-0.36	-0.35
Z4	-1.17	-1.27	-1.48	-0.72	-0.54	-0.53

Its hardest brakes are **milder in every zone**.

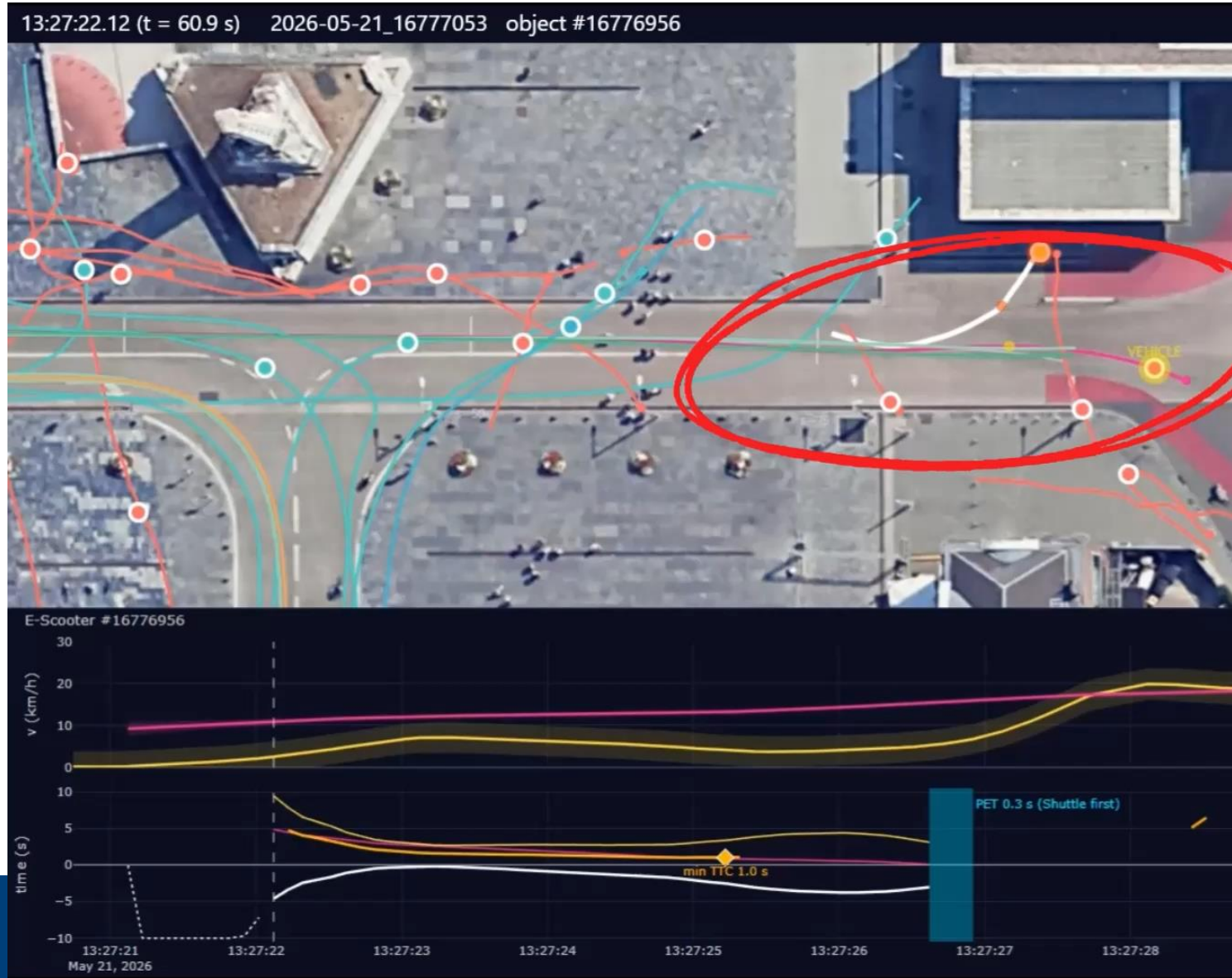
In the conflict zones Z3–Z4 its **typical passage brakes harder** than a bus or van passage.

Stops: 8.5–9.6 % of Z4 passages for all three types.

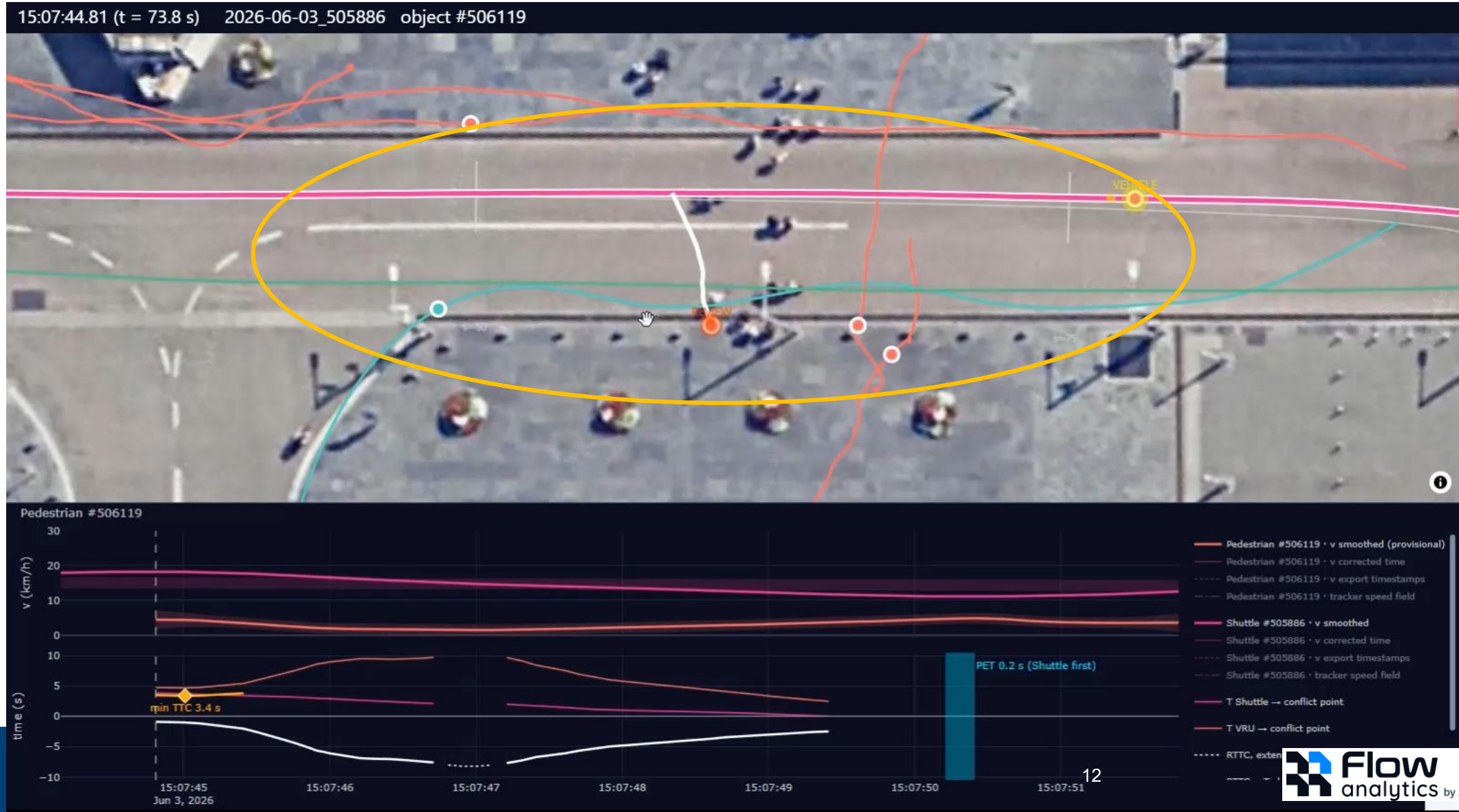
Pedestrians on critical collision course: shuttle brakes and yields; other peds taking advantage of stop



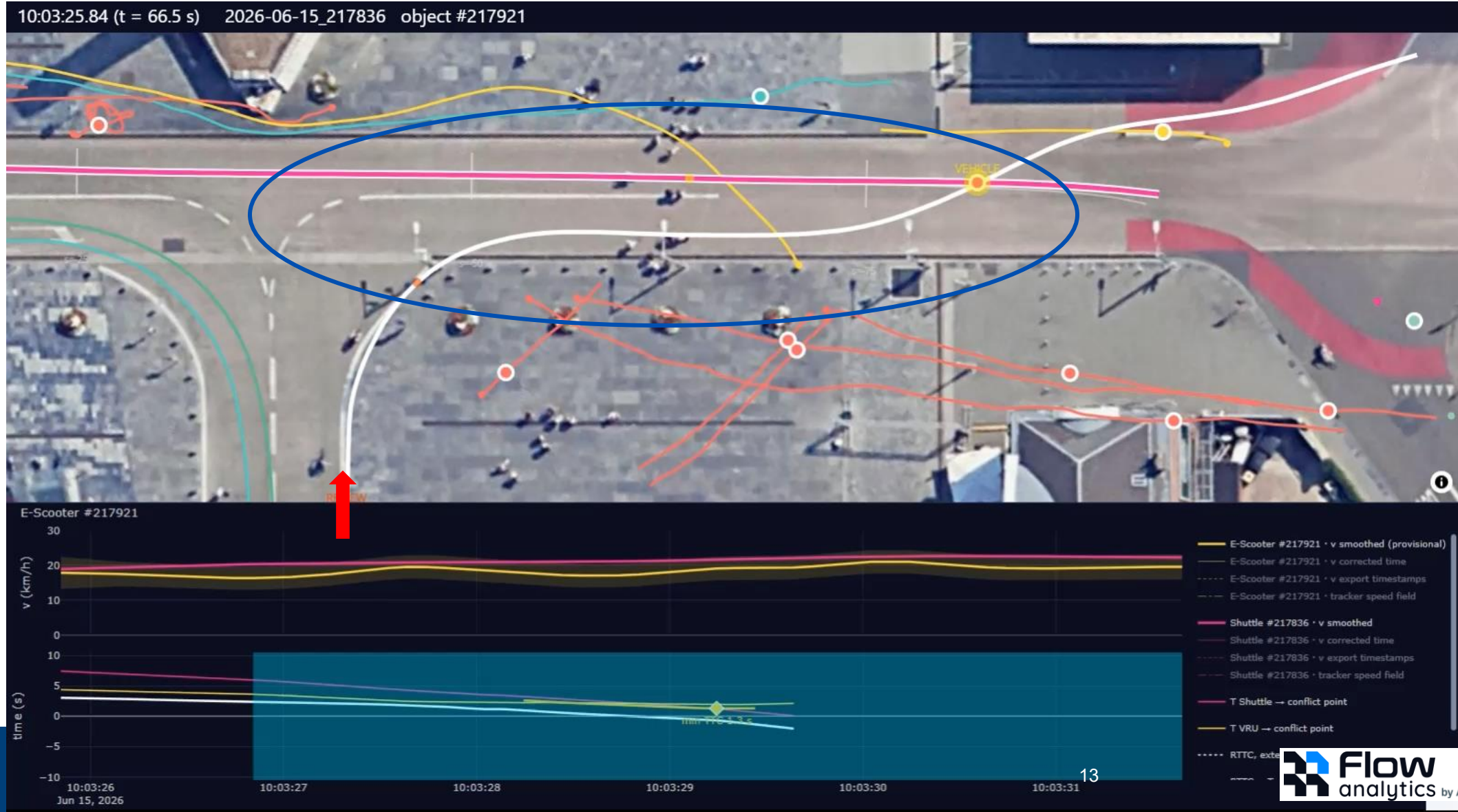
Bicycle on critical collision course (no shuttle reaction)



Pedestrian on critical collision course: ped backs up (vague shuttle reaction)



Same start of right bike turn: actual turn right (no shuttle reaction)



Same start of bike right turn: actual crossing after shuttle (no shuttle reaction)



Same start of right bike turn: actual turn left before shuttle (shuttle brakes and yields)



Preliminary results summary

PRELIMINARY

Autonomous shuttle behaviour appears not that different from human driving (bus, van)

What we observe



Speed and acceleration

Differ subtly; clear cap on maximum speeds



Conflict handling

A

Shuttle must yield: seems somewhat more careful

B

Shuttle has priority: no evidence (yet?) of more careful driving

Is that desired?

Speculative extrapolation would expect...



No dramatic traffic flow disruptions



No dominance of cyclists and pedestrians that blocks driving



May bring less safety gain than technologically possible

A choice, not a fault



Status quo by design

The regulatory reference is the competent and careful human driver. The shuttle meets exactly that bar.



A real trade-off

Anticipating every possible manoeuvre means congestion in Leuven — and always yielding invites exploitation by other road users (Millard-Ball, 2018).



Not only the vehicle

Safe System thinking: design the conflict out, e.g. the access to the cycle bridge, concentration of crossings by barriers.

*Without a thorough debate and deliberate choice, AVs may become merely a saving on the driver cost — **not a safety leap.***

What's next

RESEARCH (my homework)



Quantify the trade-off

Delay cost versus critical conflicts avoided



Human-driven baseline

Same locations, same yardstick



Scale up

More locations, longer observation



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Ahmed Nasr · Flow Analytics (AGC)

CALL TO ACTION

Make independent monitoring a structural part of AV deployment

— combined with a just-culture framework that makes sharing safe for those who share.