

Adaptive cruise control for standing e-scooters. A camera and radar watch the road ahead. The system holds a safe distance by limiting the motor, caps speed at the legal 20 km/h, and warns the rider before a collision. It never brakes on its own.

Status proof of concept in simulation, v0.2 **October 2026**



time	speed	gap	time to collision	status
0.8 s	14 km/h	16.0 m	>12 s	Following

The short version

e-scooter accidents with injuries in Germany in 2025, up 38.1 % in one year. 38 people died.

of warning before contact in our hard-braking scenario. The previous version gave none.

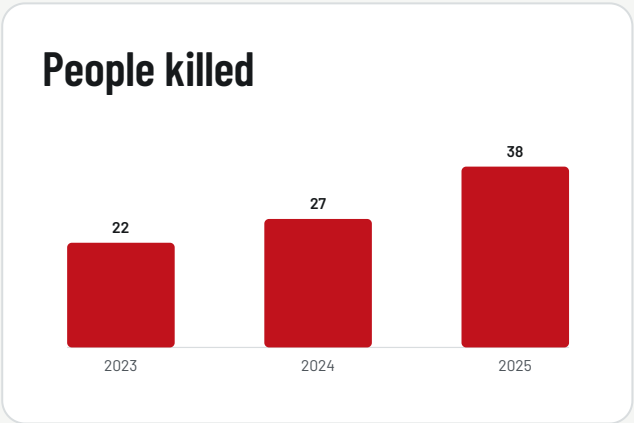
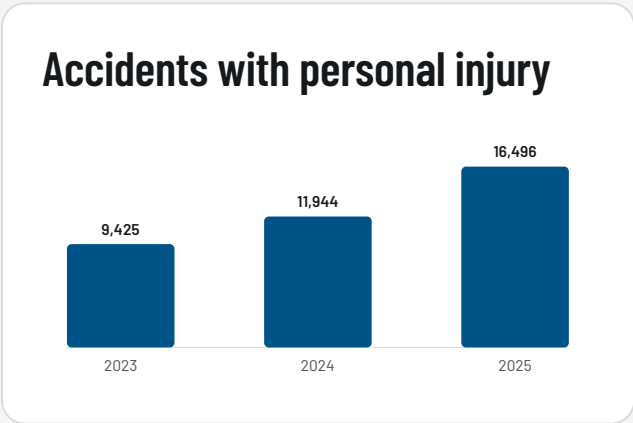
safety tests pass, run automatically on every change. The three safety gaps found earlier are fixed.

In the sources we reviewed, no product documents forward distance keeping on a standing kick scooter. Standing scooters offer cruise control and riding assistance, Chinese makers fit radar to two-wheelers for rear warnings, and researchers have tested forward safety filters. Our design adds forward distance keeping with the rider always in command, supervised by an independent safety chip that is planned for the hardware stage.

02

More scooters, more crashes

Police-recorded e-scooter accidents in Germany grew 75 % from 2023 to 2025. Excessive speed and errors in dense traffic are among the leading causes.



53.6 %

of injured riders in 2025 were under 25.

8.4 %

of rider misconduct was excessive speed. 21.6 % was improper use of road or sidewalk.

49.1 %

of accidents happened in cities with 100,000+ inhabitants.

Source: Statistisches Bundesamt (Destatis), press releases N049 (July 2026) and N040 (July 2025).

What the system does

03

Three behaviours, each tested in software, and one rule above them all: the rider's brake always wins.

Keeps a safe gap

The gap grows with speed: 3 m plus 2 seconds of travel. Inside that gap the motor gets no extra power.

REQ-002 · tested

Stays legal

Set speed is capped at 20 km/h, the German limit for e-scooters. At or above it, the motor gets no extra power.

REQ-012 · tested

Warns early

When time to collision drops below 3 seconds, the rider hears and sees a warning. It works even after the rider has braked.

REQ-014 · tested, threshold provisional

How it is built

Sensors

Forward camera, FMCW radar, GNSS, IMU, wheel encoder

Raspberry Pi 5 + AI HAT+

Object detection, radar-camera fusion, logging. Not trusted with the motor.

STM32 safety chip

Checks every message, latches faults, enforces limits, gives the brake priority.

Motor controller

Disabled in this version. Only through a documented manufacturer interface.

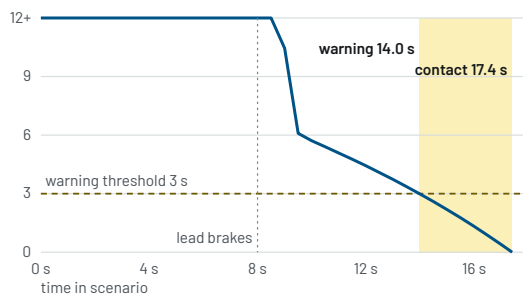
Stale sensor data, a missed heartbeat, low confidence or a rider brake removes motor authority in the same 20 ms control cycle. Status: the control and safety logic runs in simulation today; the sensors, Raspberry Pi and STM32 hardware are planned for the lab stage.

Evidence, not promises

Every number here comes from code that anyone on the team can rerun. Hardware results come later, at the bench-test stage.

The warning window

Time to collision in scenario S2. The yellow band is when the rider is warned.



Before and after the fixes

Scenario	v0.1.0	v0.2 today
Sensor fault, then rider presses brake and engage	Accelerates again	Stays in safe fault mode
Set speed 30 km/h on an open road	Reaches 21.2 km/h	Stays below 20 km/h
Vehicle ahead brakes hard	No warning	Warning 3.4 s before contact
Sensor data goes stale	Motor power cut	Motor power cut at 10.14 s

Simulation with an illustrative vehicle model, not a real-world stopping test. 25 of 25 tests pass in continuous integration on Python 3.11.

05

Gallery

A ride through a small town driven by our real controller, the simulation results behind this exposé, and the hardware components the design is built on.

Ride through a small town



time

2 s

gap ahead

16.7 m

ACC status

Active

speed

13 km/h

time to collision

not closing

Map key: blue dot = e-scooter (yellow ring while warning) · dark box = car · grey dot = cyclist · dashed line = tracked gap · traffic light at the stop line.

Simulation only. The real controller (v0.2) runs at 50 Hz on an illustrative vehicle model.

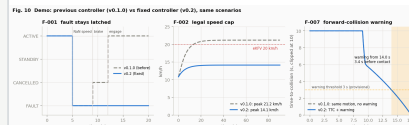
The cyclist, car, traffic light and rider reactions are scripted: the rider brakes 1.0 s after the warning and re-engages when it is safe. Top speed stays near 14 km/h because of the simple vehicle model, not the 20 km/h cap.

Found while building this demo (F-008): with no road user ahead at all, v0.2 treats the missing target as untrusted perception and cancels ACC instead of cruising at the set speed. The ride above always has a cyclist or car ahead. Fixing this is a new task for the team.

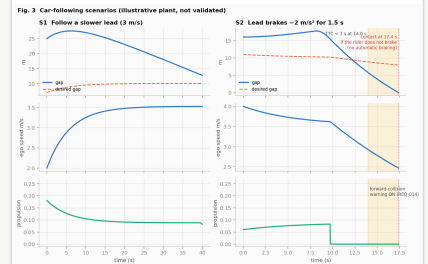
Simulation results



Bird's-eye maps of the six test scenarios: the scooter turns red when it warns.



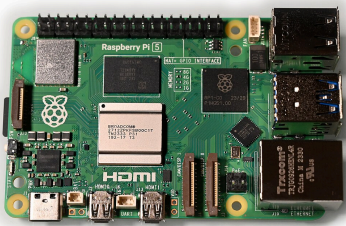
Before and after the fixes: fault latch, 20 km/h cap, warning 3.4 s before contact.



Following a slower vehicle, and a vehicle that brakes hard: gap, speed, motor request.

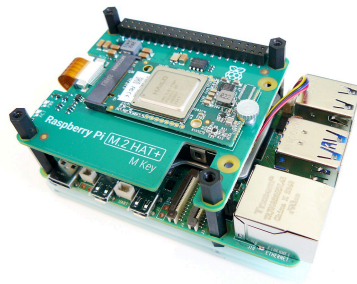
Hardware the design is built on

Photos of the component types in our design, from Wikimedia Commons under free licences. **These are not photos of our prototype**, which does not exist in hardware yet.



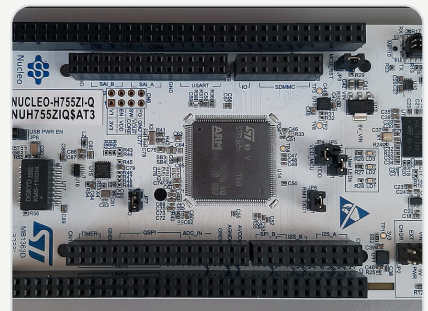
Raspberry Pi 5: perception and decision computer.

Photo: SimonWaldherr, [Wikimedia Commons](#), CC BY 4.0



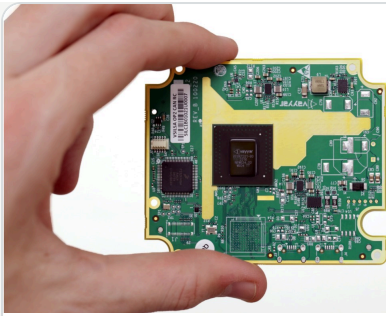
Hailo AI accelerator on a Raspberry Pi 5 (M.2 HAT+ shown): edge AI for object detection.

Photo: RetroEditor, [Wikimedia Commons](#), CC BY 4.0



STM32 Nucleo board (H755ZI-Q shown; our design targets the STM32G474): independent safety controller.

Photo: Frans, [Wikimedia Commons](#), CC BY 2.0



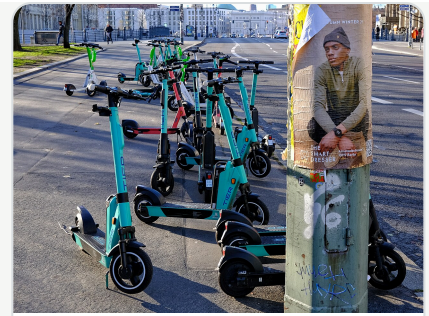
Automotive radar sensor
(60 GHz imaging radar shown; our module is not selected yet): forward distance and speed.

Photo: Amyreed444, [Wikimedia Commons](#), CC BY-SA 4.0



Raspberry Pi camera module
(older board shown): forward camera for object detection.

Photo: ZippeyKeys12, [Wikimedia Commons](#), CC BY-SA 4.0



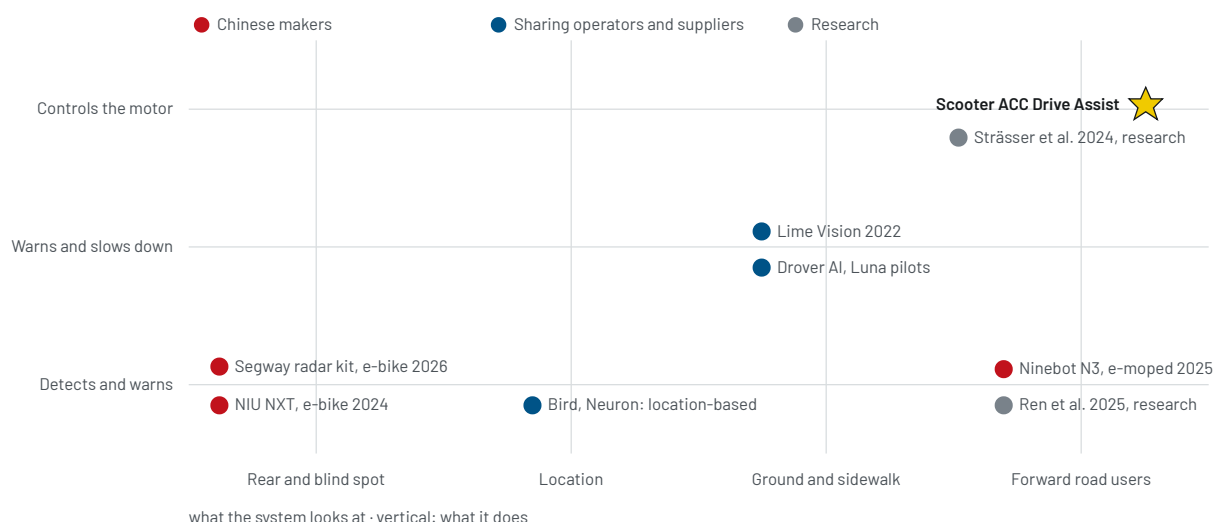
E-scooters in Berlin-Mitte:
the vehicle class we design for.

Photo: Jörg Fuhrmann (Intermerker), [Wikimedia Commons](#), CC BY-SA 4.0

06

Where we fit

Others warn about what is behind the rider, hold a set speed, or catch riders on the sidewalk. None of the products we reviewed documents keeping the gap ahead on a standing kick scooter.



Why now

- Accidents are rising fast, and cities and insurers want them down.

Market size, handled with care

Commercial reports put micromobility in 2025 anywhere between USD 42 bn and 198 bn, and e-scooters alone at

- Edge AI has become efficient: a 2026 benchmark measured Hailo-8 as the most energy-efficient accelerator for large YOLO models on a Raspberry Pi 5.
 - Chinese makers have industrialised two-wheeler radar on e-bikes since 2024, so components exist at scale.
 - Sharing operators already pay for camera-based rider safety.
- USD 47.4 bn. These numbers disagree by a factor of 4.7, so we use them as context only. The business case below is built bottom-up from units and prices you can change.

Sources: Segway press release (CES 2026); NIU Q4 2023 earnings call; The Paper, 14 Mar 2025; TechCrunch, 13 Jul 2022; Suchý & Turčaník, Sci. Rep. 2026; IMARC and Grand View Research listings, accessed 17 Oct 2026.

Commercial products we compared

Three products, checked against their official product pages on 17 October 2026. Each card lists what the page states; anything the page does not mention is marked as not documented, which is not proof that the feature is missing.

Segway Ninebot F3 Pro D

Type	Standing e-kick-scooter, about 20 km/h, 500 W rated, German insurance plate: yes
Stated	SegRide Intelligent Riding Assist (real-time support by detecting the road and riding behaviour), uphill acceleration and downhill deceleration assistants, traction control (off by default), stability system
Not documented	Cruise control, radar, camera, forward obstacle detection, distance keeping

Riding assistance on a standing scooter. No forward radar-based distance keeping documented.

[de-de.segway.com · F3 Pro D](https://de-de.segway.com/F3-Pro-D), verified 17 Oct 2026

NIU NQiX 300

Type	Seated electric moped (L3e), up to 80 km/h. Not a standing scooter
Stated	Rear blind-spot detection that warns of approaching traffic (new for 2026), ABS, traction control, auto-hold on slopes, reverse assist
Not documented	Camera, forward collision warning, cruise control, adaptive cruise control

Radar-based rear warning on a seated moped. Rear blind-spot warning is not forward ACC.

global.niu.com · [NQiX 300](#), verified 17 Oct 2026

LAMAX S7500 Plus

Type	Standing e-kick-scooter, 25 km/h, 350 W (600 W peak); page states legal operation in the Czech Republic and Slovakia
Stated	Automatic cruise control: after ten seconds above the set speed it holds the speed so the throttle can be released; can be switched off in the app
Not documented	Obstacle detection, distance monitoring, radar, camera, collision warning

Conventional speed-holding cruise control. Not adaptive cruise control.

lamax-electronics.com · [S7500 Plus](#), verified 17 Oct 2026

Research that came before us

Collision Avoidance Safety Filter for an Autonomous E-Scooter using Ultrasonic Sensors

R. Strässer, M. Seidel, F. Brändle, D. Meister, R. Soloperto, D. Hambach Ferrer and F. Allgöwer. 17th IFAC Symposium on Control in Transportation Systems (CTS 2024); IFAC-PapersOnLine 58(10), 22–28, 2024. arXiv:2403.15116, submitted 22 March 2024.

Several low-cost ultrasonic sensors detect obstacles in front of an autonomous e-scooter. A filter handles measurement noise and missing values, and a gain-scheduled controller limits the commanded velocity to a reduced safe value that keeps a sufficient safety distance. The approach was validated in real-world experiments.

arxiv.org/abs/2403.15116, checked 17 Oct 2026

How our concept differs

- Their vehicle drives autonomously and the filter limits its own commanded speed. Ours keeps a human rider in charge: the system only withholds extra motor power and warns.
- They sense with ultrasonic sensors at short range. We plan forward FMCW radar plus camera detection, for longer range and object classification.
- They validated on real hardware. We are at the simulation stage.

Forward collision avoidance and speed reduction on e-scooters have already been studied. Our contribution is the rider-in-command combination, not the idea of collision avoidance itself.

Capability comparison

Confirmed

stated on the official page

Not documented

not mentioned; not proof of absence

Research prototype

Simulation validated

Planned

Hardware validated

Capability	Segway F3 Pro D	NIU NQiX 300	LAMAX S7500 Plus	Academic research (Strässer et al. 2024)	Scooter ACC Drive Assist
Standing scooter platform	Confirmed	No, seated moped	Confirmed	Research prototype autonomous e-scooter	Planned target platform
Forward obstacle detection	Not documented	Not documented	Not documented	Hardware validated ultrasonic	Planned sensors · logic Simulation validated
Radar sensing	Not documented	Confirmed rear blind spot	Not documented	No, ultrasonic	Planned forward FMCW
Camera-based object detection	Not documented	Not documented	Not documented	Not documented	Planned
Radar-camera sensor fusion	Not documented	Not documented	Not documented	Not documented	Planned
Conventional cruise control	Not documented	Not documented	Confirmed speed holding	Not applicable autonomous vehicle	Simulation validated set-speed tracking
Adaptive distance keeping	Not documented	Not documented	Not documented	Hardware validated safe velocity for safety distance	Simulation validated
Forward collision warning	Not documented	Not documented (rear warning only)	Not documented	Not documented	Simulation validated REQ-014
Motor torque or propulsion limitation	Confirmed slope assistants, traction control (not distance-based)	Confirmed traction control (not distance-based)	Not documented	Hardware validated velocity limit	Simulation validated distance- and speed-based
Independent safety microcontroller	Not documented	Not documented	Not documented	Not documented	Planned STM32G474
Offline edge AI	Not documented	Not documented	Not documented	Not documented	Planned Pi 5 + AI HAT+
Hardware validation status	Confirmed series product	Confirmed series product	Confirmed series product	Hardware validated real-world experiments	Simulation validated no hardware yet

Scroll the table sideways on small screens. "Confirmed" for a product means stated on its official page on 17 Oct 2026, not independently tested by us.

Technology gap: forward distance assistance for standing e-scooters

Standing scooters already offer cruise control and intelligent riding assistance. Other electric two-wheelers use radar for warnings. Researchers have explored obstacle avoidance and safety filters on e-scooters.

The sources we reviewed do not yet show a commercially available standing scooter that combines all six capabilities on the right. This is a preliminary research observation, not proof of market exclusivity.

- Forward radar sensing
- Camera-based object detection
- Radar-camera sensor fusion
- Adaptive forward distance assistance
- Independent safety supervision
- Offline edge processing

Our proposed architecture

Status per layer: the decision and safety logic is **Simulation validated**; all hardware is **Planned**. Nothing below is hardware validated yet.

Perception

- Forward FMCW radar
- Camera
- IMU
- Wheel speed encoder
- GNSS

Planned

AI and decision

- Raspberry Pi 5 + edge AI accelerator
- Object detection
- Sensor fusion
- Relative distance and speed
- Time-to-collision estimation

Planned

TTC logic simulated

Safety

- Independent STM32 safety controller
- Brake priority
- Watchdog supervision
- Fault detection and latch
- Motor torque limitation
- Fail-safe behaviour

Logic simulated

STM32 planned

Control philosophy

- No automatic braking in the current scope
- The rider keeps braking responsibility
- Progressive propulsion limitation, only where validated as safe
- Forward collision warnings

Simulation validated

Regulation and prior art

Engineering disclaimer. This is an R&D prototype concept. Compliance, functional safety and road legality have not been demonstrated.

Germany (eKFV). E-scooters need a design speed above 6 and up to 20 km/h, an operating permit (ABE) or individual permit, and a valid insurance plate (eKFV §1 and §2). Adding sensors and propulsion control to an approved scooter may affect its permit; this needs assessment with a technical service.

EN 17128:2020. The European standard for personal light electric vehicles up to 25 km/h. It is not tied to a specific EU law, and countries including Germany apply their own national rules. Its test methods are relevant to our validation plan; class definitions are taken from secondary summaries and must be checked against the standard text.

[gesetze-im-internet.de/ekfv](https://www.gesetze-im-internet.de/ekfv), checked 17 Oct 2026

Prior-art search still to do

We make no claim of patentability or freedom to operate. A dedicated search is recommended before any filing or product decision:

- [Google Patents](#)
- [Espacenet](#) (European Patent Office)
- [WIPO PATENTSCOPE](#)
- [IEEE Xplore](#)
- [Google Scholar](#)

Help build the next generation of scooter safety

We are looking for contributors who want to take this from simulation to a working prototype. Useful experience:

Embedded C/C++ and STM32

Raspberry Pi and edge AI

Computer vision

Radar signal processing

Sensor fusion

Control systems

Functional safety

Hardware integration and testing

Request to join the team

Sign in to GitHub and submit the short form. Every request is reviewed by the project owner.

07

Business model

We start where safety already has a budget: shared fleets in the EU. Germany first, because its rules are clear and strict.

Sharing operators

A retrofit kit plus a yearly software and data service. Fewer crashes and less damage, proof of speed compliance for city permits.

first customers

Scooter makers

License the controller, safety-chip logic and test evidence. The maker builds the hardware at volume, often in China.

scale

Insurers and cities

Anonymised warning and near-miss statistics for risk pricing and hot-spot maps. No raw video leaves the scooter.

later

Getting into the EU market

Requirement	What applies	Our status
Vehicle rules, Germany	eKFV: 6–20 km/h, operating permit (ABE) and insurance plate	20 km/h cap done in software. Permit impact to assess.
Radio and CE	Radio Equipment Directive 2014/53/EU for the radar	Module selection
Battery	Regulation (EU) 2023/1542, battery passport from Feb 2027	Scooter maker's duty
Camera data	GDPR (EU) 2016/679	Processing on the device, no raw video stored by default
Product law	GPSR 2023/988, Product Liability Directive 2024/2853, AI Act 2024/1689	Legal assessment before road tests

China supplies technology and partners, not customers: kick scooters are banned from public roads in Beijing and other major cities (Beijing rules reaffirmed from 1 May 2026).

08

Profit model

A scenario, not a forecast. Move the sliders to test your own assumptions. Every default is a placeholder until supplier quotes and operator interviews replace it.

Kit price per scooter

€420



Retrofit kit sold to a fleet operator.

Kit cost per scooter at volume

€260



Target with a custom board. The prototype parts list costs €715–1,420.

Software and data service per scooter and year

€36



Billed on every installed kit.

Fixed costs per year

€650 k



Team, testing, certification, in thousand €.

Volume ramp

100 %



100 % = 500, 3,000, 10,000, 20,000 and 30,000 kits in years 1–5.

€160

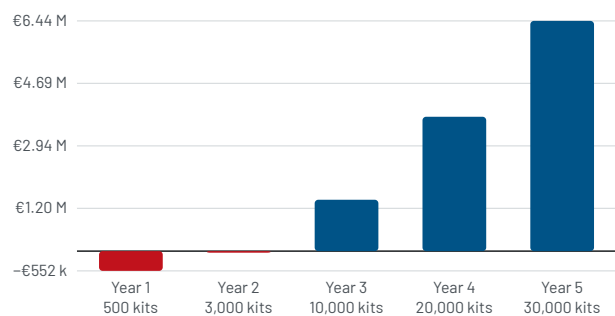
gross margin per kit

4,063

kits per year to break even

€6.44 M

operating result in year 5



Model: result = kits sold × (price – cost) + installed kits × service – fixed costs. Installed kits accumulate with no attrition. Excludes taxes, financing and working capital. These are illustrative assumptions to be tested in hypotheses B1 (willingness to pay) and B3 (cost-down).

09

Impact

The goal is fewer injuries without taking control away from the person on the scooter.

Safety

Distance keeping and early warnings address speed and reaction errors in dense

Rider authority

No automatic braking, because a standing rider can lose balance. The system only

traffic. The real effect has to be measured in a pilot with a control fleet. We will not claim a crash reduction before that.

Young riders

More than half of injured riders are under 25. A speed cap and early warnings help the least experienced riders most.

withholds extra power and warns. Brake and cancel always win.

Privacy

Images are processed on the scooter. Only object lists and statistics leave it, so city and insurer data contain no faces.

10

Scope and the road to production

Each stage ends at a gate with evidence. We are at stage one.

1 Concept	2 Lab	3 Field	4 Pilot	5	6 Series
Simulation, tests, requirements	Safety chip, emulated motor, fault injection	Closed test track only	Custom board, small fleet with a partner	Industrialise	Production and field monitoring
now	gate: timing measured	gate: safety review + site approval	gate: reliability data	Design for manufacture, end-of-line test	gate: field KPIs
				gate: yield	

In scope now

Control logic, simulation, safety requirements and tests, sensor-data replay, bench test with an emulated motor, offline model training.

Out of scope now

Real motor commands, automatic braking, public-road tests and certification. These need a documented safety review first.

11

Engineering challenge: can you build it better?

Our architecture is a reference implementation, not the required solution. If you can meet the same requirements with simpler, safer or cheaper

hardware, algorithms or software, we want to hear it.

Fixed

Standing e-scooter, forward obstacle detection, adaptive motor power limit, at most 20 km/h commanded speed, early collision warning. No automatic braking: the rider brakes.

Open

Sensors, processors, algorithms and software architecture. One chip instead of two? Radar only? Tell us how and how you would prove it.

How

Answer three short questions and share your idea on GitHub. If you like, an AI model on your own computer helps turn it into a full engineering proposal. The project owner reviews every proposal.

Karim Samy eng.karimsamy11@gmail.com

This exposé describes a research prototype in simulation. It makes no claim of road legality, ISO compliance, certified safety or validated stopping performance. Market figures are third-party estimates; the profit model is an illustrative scenario.

Sources

1. Destatis, "38,1 % mehr E-Scooter-Unfälle mit Personenschaden im Jahr 2025," press release N049, Jul. 2026.
2. Destatis, "26,7 % mehr E-Scooter-Unfälle mit Personenschaden im Jahr 2024," press release N040, Jul. 2025.
3. eKFV (Elektrokleinstfahrzeuge-Verordnung), §1 and §2, [gesetze-im-internet.de](https://www.gesetze-im-internet.de).
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5. NIU Technologies, Q4 2023 earnings call (NXT e-bike with rear mmWave radar).
6. The Paper (澎湃新闻), Ninebot and NIU smart riding features, 14 Mar 2025.
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11. Segway, "eKickScooter Ninebot F3 Pro D," official product page de-de.segway.com, verified 17 Oct 2026.
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13. LAMAX, "E-Scooter S7500 Plus," official product page lamax-electronics.com/en-de, verified 17 Oct 2026.
14. R. Strässer et al., "Collision avoidance safety filter for an autonomous e-scooter using ultrasonic sensors," IFAC-PapersOnLine 58(10), 22–28, 2024 (CTS 2024); arXiv:2403.15116.
15. EN 17128:2020, Personal light electric vehicles (PLEV): requirements and test methods (scope summarised from secondary sources; to verify against the standard text).
16. EU legal acts: 2014/53/EU, (EU) 2023/1542, (EU) 2016/679, (EU) 2023/988, (EU) 2024/2853, (EU) 2024/1689.
17. Project evidence: internal project documentation (project document and China/EU market analysis), available to team members on request.