Smart Connected Bikes

Final Report

Conclusions and Recommendations

for Researchers, Policy Makers, and Industry

Smart Industry 2019 – SI2019

SMART CONNECTED BIKES

Smart Connected Bikes

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https://www.smartconnectedbikes.nl

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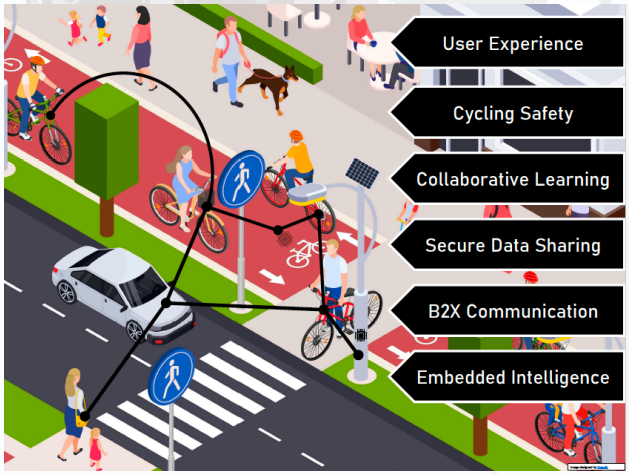
https://www.utwente.nl/en/eemcs/ps/

SMART CONNECTED BIKES

The Smart Connected Bikes project

Cycling is popular in the Netherlands and still growing in popularity, in particular the use of e-bikes has grown across young, middle-age and older population groups. Currently, about 40% of all cycling kilometres are made on e-bikes and e-bike use is expected to increase further. E-bikes have many advantages but at the same time the number of traffic accidents with e-bike users have grown steadily. At the same time new business concepts are emerging. E-bikes with integrated sensors and intelligence could give rise to many new opportunities, increased user experience, safety and better quality. The Smart Connected Bike project aimed to develop and test a novel connected vehicles ecosystem which combines the capabilities of sensing, wireless technology and data science to make bicycle transportation more safe, more reliable, and more comfortable.

The project was a collaboration between the University of Twente, Accell Group, TNO, Delft University of Technology and Saxion University of Applied Science, and funded by the Smart Industry programme of the Dutch Research Council (NWO) and Accell Group. The project ran from January 2021 to January 2026.



The Smart Connected Bike project structure centred the project around field trials organised in Enschede (WP5- Living Lab), based on research conducted in four work packages.

Work packages:

- WP1: Secure data Sharing focussed on how to gain insights from smart bicycles and disseminate information between cyclists and other stakeholders in a privacy-preserving manner. Second, research in the work package
- WP2: Product Realisation addressed human-machine interactions, investigating how to best communicate with cyclists while they are cycling. A context aware smartphone-based app road safety 'warning system' prototype, communicating potentially dangerous locations to cyclists, has been designed, implemented and tested.
- WP3: Design conducted a number of studies with a 360-degree video collection system for capturing e-bikes journeys and contextual factors (e.g. traffic, safety incidents).
- WP4: User Experience developed and investigate a sensor-based method to evaluate the impact of smart cycling technologies on positive and negative cycling experiences.

This report presents the main conclusions and recommendations for researchers, policy makers and cycling industry from the Smart Connected Bike project. The conclusions and recommendations are structured along the topics of Secure Data Sharing (recommendation 1), Product, Sensor and Communication Technology (recommendations 2-6), Design (recommendations 7-9), and User Experiences (recommendations 11-16).

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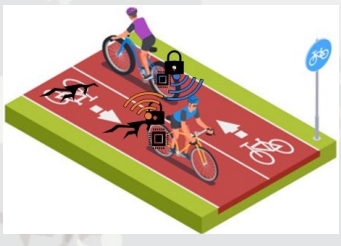
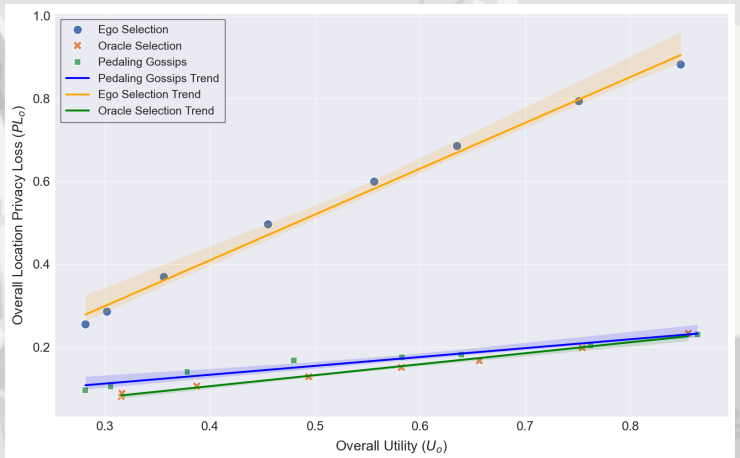
1 Adopt Gossiping-Based Data Sharing to Preserve Location Privacy

Secure Data Sharing

Enabling bicycles to strategically share information through bicycle-to-bicycle (B2B) communication, balancing location privacy and utility without relying on centralized infrastructure.

Smart bicycles collect valuable data through on-board sensors, such as road quality information, but sharing location-tagged data raises privacy risks, as attackers could reconstruct trajectories or movement patterns. While most solutions focus on securing data collectors or infrastructure, an alternative is to protect location privacy directly on the cyclist's device. On-device privacy mechanisms keep sensitive location information concealed, ensuring safety even when data is shared with untrusted entities or exposed to eavesdroppers.





Pedalling Gossips shows that privacy can be ensured by design using decentralized data sharing. By avoiding central servers and limiting information spread, gossiping provides a scalable and resilient way to share data privately.

Did you know?

- The proposed gossiping strategy enhances location privacy by up to 75% compared to a baseline, and approaches the performance of an oracle.
- Even when enforcing a minimum utility threshold, Pedaling Gossips produces significantly lower amd more stable privacy loss values compared to baseline.

Read more on this topic:

- D. Yeleshetty, O. Durmaz, Y. Huang, "Pedaling Gossips: Towards Location-Privacy-Preserved Data Sharing with Smart Bicycles", In Companion of the 2025 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp Companion '25), October 12–16, 2025, Espoo, Finland. ACM, New York, NY, USA. [To be Published]

2 Embed IMUs on Bicycles for Enhancing Cycling Safety and Utility Applications

Product, Sensor and Communication Technology

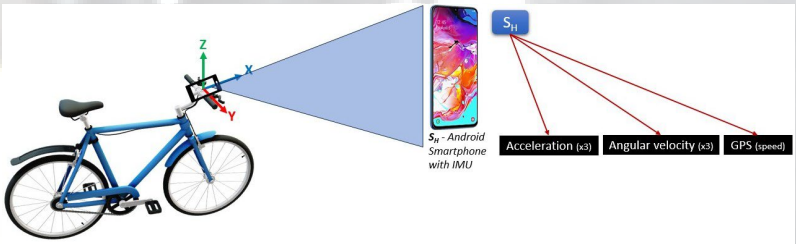
Low-cost, bicycle-mounted Inertial Measurement Units can enable proactive cycling safety applications while supporting infrastructure assessment, comfort analysis, and behaviour understanding.

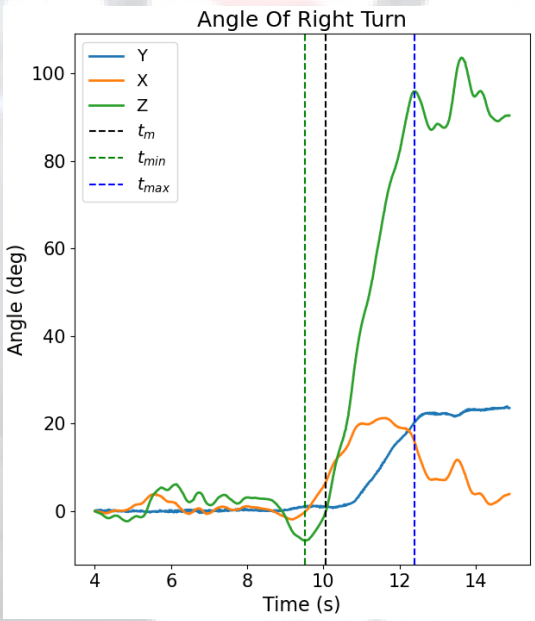
Cycling safety is a major concern, especially in dense traffic, and predicting cyclists' turn manoeuvres can help prevent collisions. Bicycle-mounted IMUs non-intrusively capture key indicators like counter-steering and tilting to accurately predict turns, with additional signals like deceleration, pedalling, and gaze potentially enabling earlier predictions. Beyond safety, IMUs are low-cost and widely deployable, and their motion data can also be used to assess road quality, detect surface irregularities, evaluate cycling comfort, and analyse riding behaviour across different conditions.

Bicycle-mounted IMUs allow safety-critical manoeuvre prediction without intrusive sensors and also provide valuable data for analysing cyclist behaviour and assessing infrastructure.

Did you know?

- The method predicts bicycle turns 0.5 s and 0.25 s ahead using only IMUs, achieving F1-scores of 0.72 and 0.92.
- Counter-steering and cyclist tilting, measured by IMUs, are key indicators for predicting turns.





Read more on this topic:

- G. d. Smit, D. Yeleshetty, P. J. M. Havinga and Y. Huang, "Predicting Turn Maneuvers of Cyclists Using Bicycle-Mounted IMU with CNN-LSTM," 2024 IEEE International Conference on Pervasive Computing and Communications Workshops and other Affiliated Events (PerCom Workshops), Biarritz, France, 2024, pp. 587-592: Available on 10.1109/PerComWorkshops59983.2024.10502681

3 B2X Wireless Communication via low-cost & low-energy technology

Product, Sensor and Communication Technology

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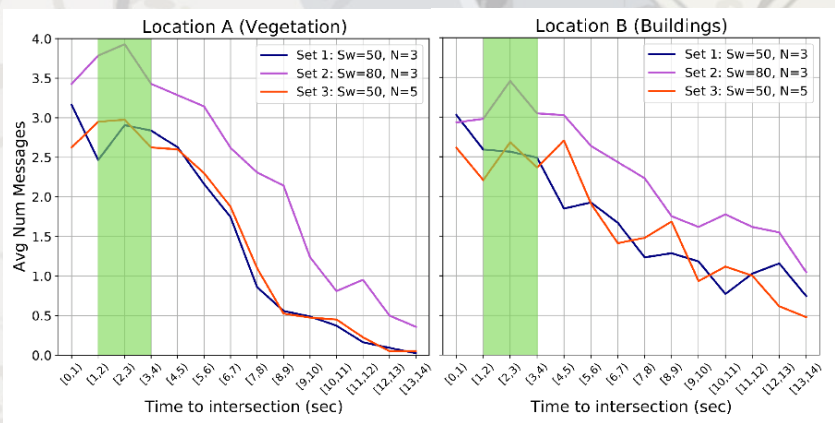
Bluetooth Low Energy (BLE) is a strong candidate for enabling reliable Bike-to-Everything (B2X) communications

Bluetooth Low Energy (BLE) is a widely available, low-cost, and energy-efficient technology ideal for bicycle safety systems, as it integrates easily into smartphones, wearables, and sensor platforms.

With well-chosen BLE parameters, cyclists can reliably receive early warnings, providing enough time to manoeuvre safely before entering a danger zone. These configuration strategies make BLE a strong candidate for future connected urban mobility systems.

Studies show that with targeted parameter tuning, BLE can reliably meet the timing and performance needs of cyclist-safety applications while maintaining low energy use, supporting safer interactions in urban traffic.



Read more on this topic:

- P. H. W. De Alcantara, K. B. Fredj, G. Heijenk and Y. Huang, "Evaluating Bi-Directional Connectionless BLE for Bike-To-Everything Wireless Communications," 2025 21th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob), Marrakesh, Morocco, 2025, pp. 1-7, doi: 10.1109/WiMob66857.2025.11257496.

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4 Green-light assistance by optimal and privacy-preserving speed control

Product, Sensor and Communication Technology

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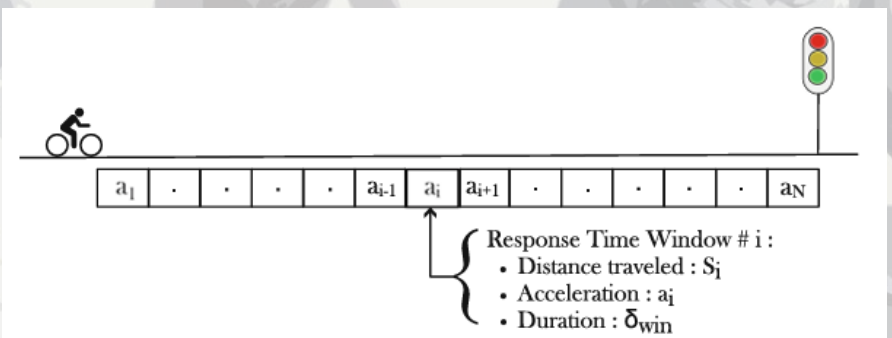
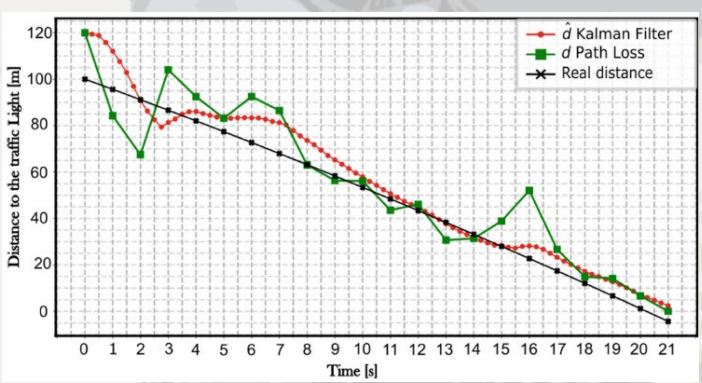
Use lightweight beacon-based distance estimation to guide cyclists safely and comfortably through signalized intersections.

The system uses an optimization-based strategy to recommend smooth speed adjustments, helping cyclists catch green lights without sudden or risky manoeuvres, enhancing comfort, trust, and predictability. It refines distance-to-traffic-light estimates with a Kalman filter and periodic traffic light beacons, ensuring accuracy along the journey. By relying on infrastructure beacons instead of GPS, the system preserves privacy, reduces complexity, and remains lightweight and scalable for urban mobility.



By combining optimal control with beacon-based estimation, cyclists can be guided through intersections in a way that is smooth, safe, and respectful of privacy. This approach bridges advanced optimization theory with practical, deployable smart-cycling assistance.



Read more on this topic:

- Ben Fredj, K., Pallamreddy, A.R., Heijenk, G., Havinga, P., Huang, Y. (2024). E-Go Bicycle Intelligent Speed Adaptation System for Catching the Green Light. In: Zaslavsky, A., Ning, Z., Kalogeraki, V., Georgakopoulos, D., Chrysanthis, P.K. (eds) Mobile and Ubiquitous Systems: Computing, Networking and Services. MobiQuitous 2023. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, vol 593. Springer, Cham. https://doi.org/10.1007/978-3-031-63989-0_10

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5

Predicting the Future: Potential Bicycle Trajectories

Product, Sensor and Communication Technology

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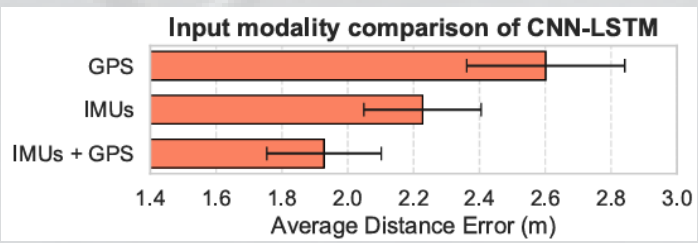
Leverage Lightweight Deep Learning Models and Onboard Sensors for 5-Second Trajectory Foresight.

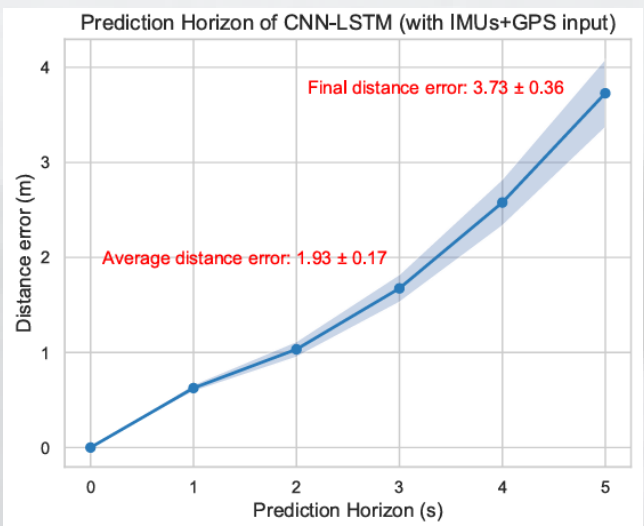
While active transportation offers significant benefits, rising cyclist fatality rates necessitate a shift toward advanced, vehicle-integrated safety systems. Traditional trajectory prediction often relies on stationary, infrastructure-mounted sensors, which are hindered by occlusions and line-of-sight limitations. Predicting Ego Cyclist Trajectories introduces a lightweight, onboard alternative that leverages low-cost GPS and IMUs to capture fine-grained motion cues, including counter-steering and head rotation, which serve as critical indicators of future movement. By implementing a modular CNN-LSTM architecture, the system provides high-precision spatial estimates 5 seconds into the future without requiring manual cyclist input. This foresight enables early feedback to the rider and V2X-based collision-avoidance systems, facilitating timely interventions and potentially reducing collision risk by up to 98%.

Implementing edge-AI transforms the bicycle from a passive vehicle into an intelligent vehicle. By processing multi-modal data at the edge, the system enables the bicycle to anticipate hazardous situations and communicate its intended path to the wider traffic ecosystem. This is essential for the next generation of active safety systems.

Did you know?

- A 4-second advance warning, powered by this trajectory prediction, can yield a potential safety benefit of up to 98%.
- An IMU on the handlebar provides the most accurate single-sensor data for trajectory prediction.





Read more on this topic:

- Gijs de Smit, Akhil Pallamreddy, Ilja Kaniščev, and Yanqiu Huang. 2026. Predicting Ego Cyclist Trajectories Using Bicycle-Mounted Sensors with CNN-LSTM. In Companion of the 2025 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp Companion '25). Association for Computing Machinery, New York, NY, USA, 1463–1468. https://doi.org/10.1145/3714394.3756285

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6 Riding the Green Wave: Privacy-Preserving Speed Adaptation

Product, Sensor and Communication Technology

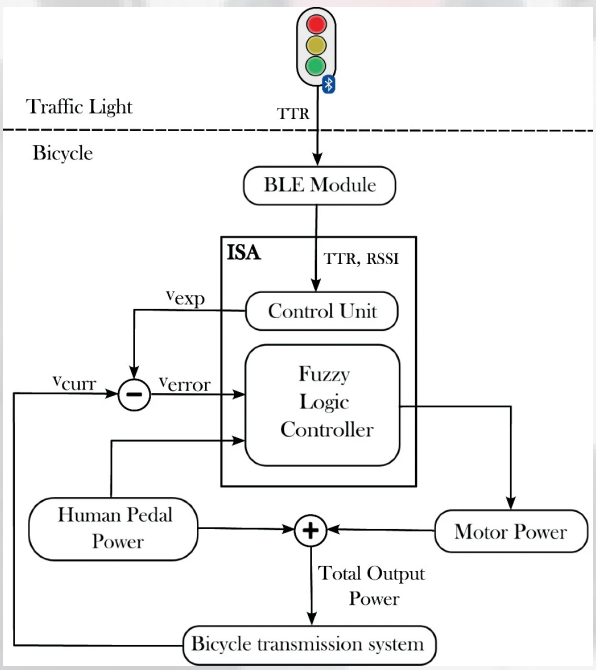
Catch the Green Light with Smooth, Optimization-Based Motor Intelligence Speed Assistance (ISA)

Signalized intersections are the most stressful and physically demanding segments of an urban journey, frequently disrupting cyclists. E-Go Bicycle ISA transforms this experience by enabling a seamless "Green Light" for e-bikes, moving beyond passive advice to active, intelligent intervention. By leveraging lightweight Bluetooth Low Energy infrastructure instead of privacy-invasive GPS tracking, the system provides a decentralized way to guide cyclists through traffic intersections while preserving privacy. At the core of this system, a fuzzy logic controller serves as a "tactical brain," dynamically blending motor assistance with human pedaling effort to achieve optimal speeds calculated via optimization. This intelligent adaptation eliminates the cognitive and physical load of constant stop-and-go cycling, preserving momentum caused by frequent accelerations. Ultimately, this smooth control loop improves the probability of catching a green light by 77%, and makes the e-bike a more predictable, comfortable, and competitive alternative to motor vehicles in dense city environments.

By integrating real-time traffic light data into the e-bike's motor control, the bicycle becomes an active participant in urban traffic management. This intelligent speed adaptation ensures riders catch the green lights, reducing friction in city travel and making e-bikes a more competitive alternative to motor vehicles.

Did you know?

- Using this system increases your chances of catching a green light by 77%.



Read more on this topic:

- Ben Fredj, K., Pallamreddy, A.R., Heijenk, G., Havinga, P., Huang, Y. (2024). E-Go Bicycle Intelligent Speed Adaptation System for Catching the Green Light. In: Zaslavsky, A., Ning, Z., Kalogeraki, V., Georgakopoulos, D., Chrysanthis, P.K. (eds) Mobile and Ubiquitous Systems: Computing, Networking and Services. MobiQuitous 2023. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, vol 593. Springer, Cham. https://doi.org/10.1007/978-3-031-63989-0_10

7 Holistic Data is Key to Predicting and Preventing Cycling Crashes

Design

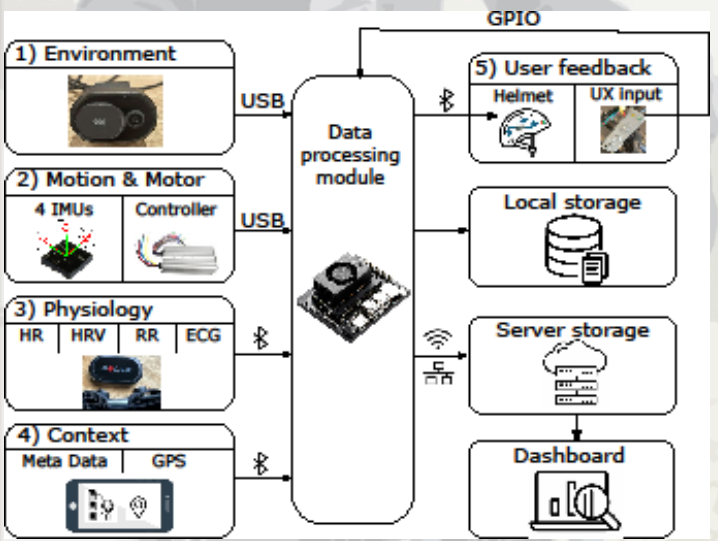
Adopt Multi-Modal Synchronization to Capture the Full "Human-Bicycle-Environment" Interaction

Designing truly intelligent and safe bicycles requires moving beyond isolated data collection to a holistic, real-world understanding of the cyclist-bike-environment ecosystem. BicycleSense360 provides this foundation by unifying five critical functional domains, including perception, physiology, motion, context, and bidirectional feedback, into a synchronized data. While traditional research often relies on post-hoc analysis or controlled simulators, this system captures the complex, multi-factorial precursors of crashes as they happen in naturalistic settings. By orchestrating heterogeneous sensors through a lightweight, real-time architecture, we enable the bicycle to not only log data but to perform edge-AI inference. This shift is vital for developing proactive safety interventions, such as fall prediction and hazard alerting, that can intervene in the critical moments before a collision or single-bicycle crash occurs.

Transitioning from passive data logging to active safety requires an on-bike "central nervous system". BicycleSense360 enables real-time edge inference by feeding synchronized, multi-modal data directly into edge AI models for immediate action.

Did you know?

- Only 10% of single-bicycle crashes ever reach police records.
- BicycleSense360 handles data streams ranging from 1 Hz to over 100 Hz simultaneously. This allows AI models to detect subtle precursors that unsynchronized systems would miss.



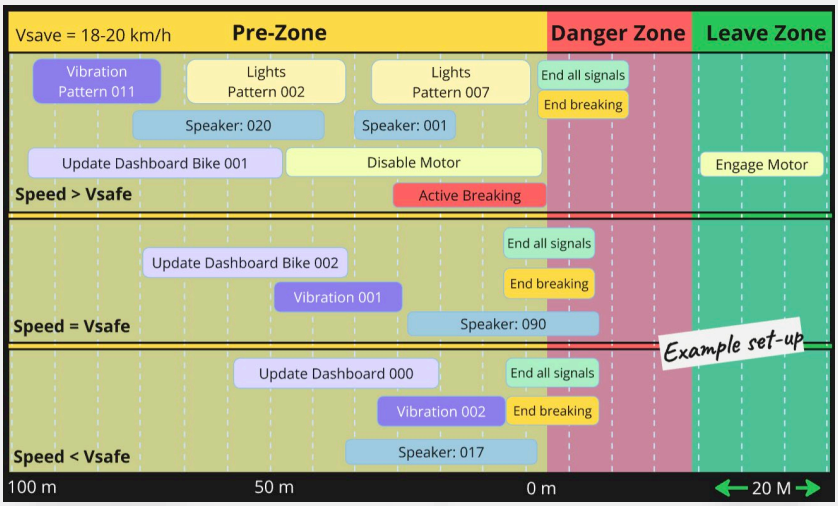
Read more on this topic:

- Akhil Pallamreddy, Noah Van Maare, Dany Shalhoub, Ozlem Durmaz Incel, and Yanqiu Huang. 2026. BicycleSense360: Real-World Multi-Modal Naturalistic Cycling Data Acquisition and Synchronization System. In Companion of the 2025 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp Companion '25). Association for Computing Machinery, New York, NY, USA, 1443–1449. https://doi.org/10.1145/3714394.3756286

Warning Signal Time management by swim lanes

Design

Type, timing and modality of system signals for the bike rider



Swim lanes: Since there is no clear guide for when warning signals should start or end in dense traffic situations, in field trials it would be very useful to real-time adjust the timing and intensity of the signalling peripheral. The piece of peripheral time management should be quick and easily adjustable. Clarity, content & intensity of the specific warning should also be quick adjustable since signals may vary from a mild buzzing sensation to a possibly all out red flashing rotating beacon and loud siren. Not only the signalling but, most important, the automated braking system should be easily adjusted in the system when executing in the live tests.

A Time-management Swim lanes: The solution is a graphic user interface in the form of a swim lane system where these variables can easily be added, edited, moved and removed. See example image below.

Did you know?

- Higher speed means less time within pre-zone
- Warning signals can also be distracting
- Many people combined with many signals make it a challenge to determine the correct set of signals and their variables

Layout & grouping of the bike route - Introducing the Pre-Zone: Another issue was that we needed an extra zone. Defining when and where signalling should start and end obviously describes a need for defining the safe and unsafe zone. But that's not enough. The missing part is when approaching the danger zone, where the biker needs to focus on traffic and not be distracted by warning signals, hence we introduced the **Pre-zone.** This should be adjustable in size (distance or time) according to the complexity of the danger zone.

9 On-bicycle feedback can urge cyclists to slow down in unsafe situations

Design

On-bicycle feedback has the potential to reduce speed and increase perceived safety.

During field trials, participants rode on e-bikes equipped with or without a safety support system. This system provided on-bicycle feedback to urge cyclists to slower speeds in dangerous zones. Participants received warnings via a combination of visual and either tactile or audio warnings. It was found that participants rode with lower speeds when cycling with the safety system. Additionally, participants felt safer when driving with the system. Participants did indicate lower trust in the system, potentially due to the lower-fidelity prototype. This asks for more technologically advanced tests in the future.

Enhancing e-bikes with continuous on-bicycle feedback can increase traffic safety.

Did you know?

- Cyclists reduced speed when receiving visual warnings combined with tactile or audio signals.
- Female participants tended to approach dangerous zones slower, while male participants reduced their speed more after receiving a warning.

Read more on this topic:

- Kapousizis, G., Jutte A., Ulak, M. B., Geurs, K. (2025). How do cyclists experience a context-aware prototype warning system? Assessing perceived safety, perception and riding behaviour changes through a field study. Journal of Cycling and Micromobility Research, 3, 100051. doi: https://doi.org/10.1016/j.jcmr.2024.100051
- Boot, M., Jutte, A., Ulak, M. B., & Geurs, K. (2025). Feel the Warning? Using Wearable Sensor Data to Measure Pleasantness with a Safety Warning System for Cyclists. Manuscript revised after external peer review. Available for preprint. Retrieved from https://dx.doi.org/10.2139/ssrn.5344791

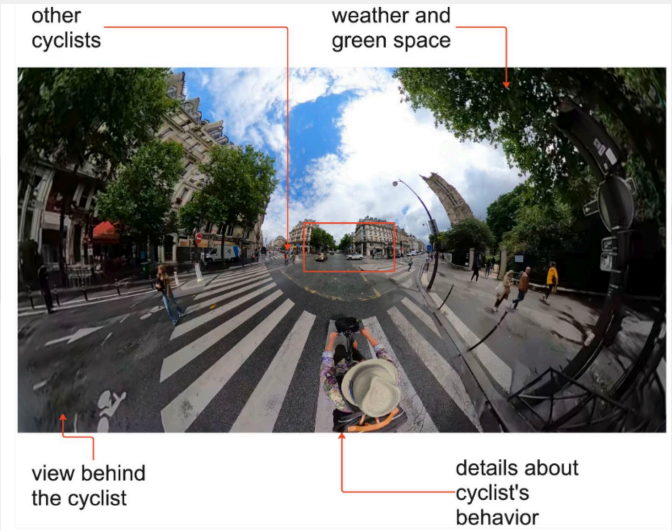
10 Use 360° video to inform safer and more effective cycling design

User experience

SMART CONNECTED BIKES

Onboard cameras capture both the cyclist's viewpoint and their surroundings, providing context that observation, interviews, and sensors cannot

Designing safer bicycles and cycling infrastructure requires a full understanding of cyclists' real-world context. Onboard 360° video provides a unique approach by recording a complete, real-time view of the cyclist's surroundings, combining first-person and surround perspectives. Designers and policymakers explore critical moments from multiple angles, revealing safety issues that fixed observations often miss. Research shows that this method fosters appropriate empathy, helping designers understand cyclists' situations without assuming exact experiences.



360° video provides rich contextual insights that complement lab tests, surveys, traffic counts, and crash data by revealing when and why cyclists experience difficulty or feel unsafe

Did you know?

- Professional designers using 360° video frequently pause and explore multiple viewpoints: behind the cyclist, blind spots, and road surfaces, revealing contextual conditions that cyclists often cannot articulate in interviews.
- The D360 annotation tool enables collaborative analysis that builds on traditional workshop methods by allows design teams to return to the exact moment and viewing angle where an insight was captured.

Read more on this topic:

- Meijer, W. et al. (2024). Sphere Window: Challenges and Opportunities of 360° Video in Collaborative Design Workshops. NordiCHI 2024. DOI: 10.1145/3679318.3685407
- Meijer, W. et al. (2025). D360: a Tool for Immersive, Iterative, and Collaborative Design Ethnography using 360° Video. DIS 2025. (Conditionally Accepted)
- Meijer, W. (2025). 360° Video for Design, by Design. PhD Dissertation, TU Delft.
- D360 Tool: Available as open-source software.

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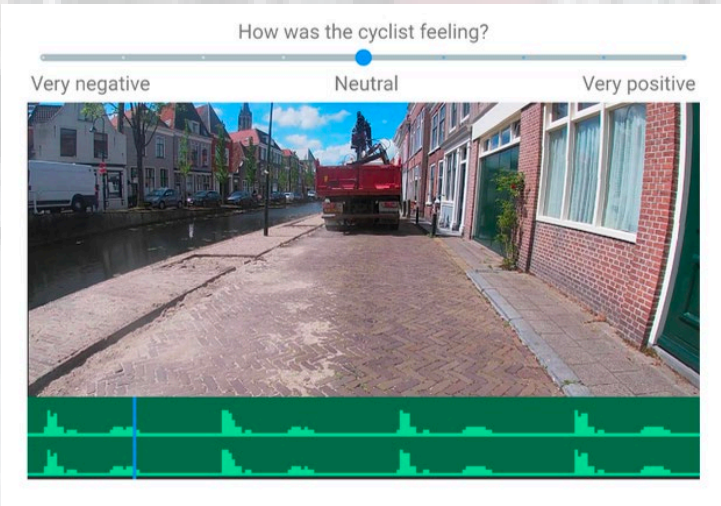
11 Use bio-signals to complement objective safety assessments

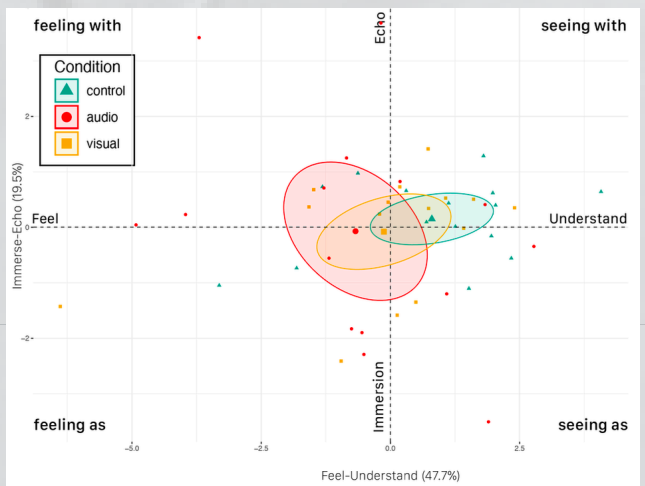
User experience

SMART CONNECTED BIKES

Physiological data reveals how cyclists experience safety—not just whether they are safe

For e-bike manufacturers, bio-signals offer a way to evaluate how riders experience product features beyond performance metrics—understanding emotional responses to motor behaviour, braking feel, or interface design. For municipalities, bio-signal mapping can identify stress hotspots that traditional safety audits miss, enabling targeted improvements that address both objective risk and felt experience that determines whether people cycle. Combined with existing methods, bio-signals provide a complete picture of cycling safety.





Did you know?

- Heart rate data collected during a single bike ride can identify stress hotspots that years of crash statistics might miss.
- Bio-signals collected using smartwatches make physiological measurement practical for field trials, route assessments, and product evaluations.
- Adding heart rate as audible heartbeats was significantly more effective than visual graphs at helping observers understand cyclist stress

Read more on this topic:

- Meijer, W. et al. Can you Hear(t) me? Using Expressive Biosignals to Change Observer's Empathy While Watching PoV Ethnographic Video. (Manuscript in preparation)

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12 Mobile sensors contribute to evaluating impacts of Smart Cycling Technologies

User experience

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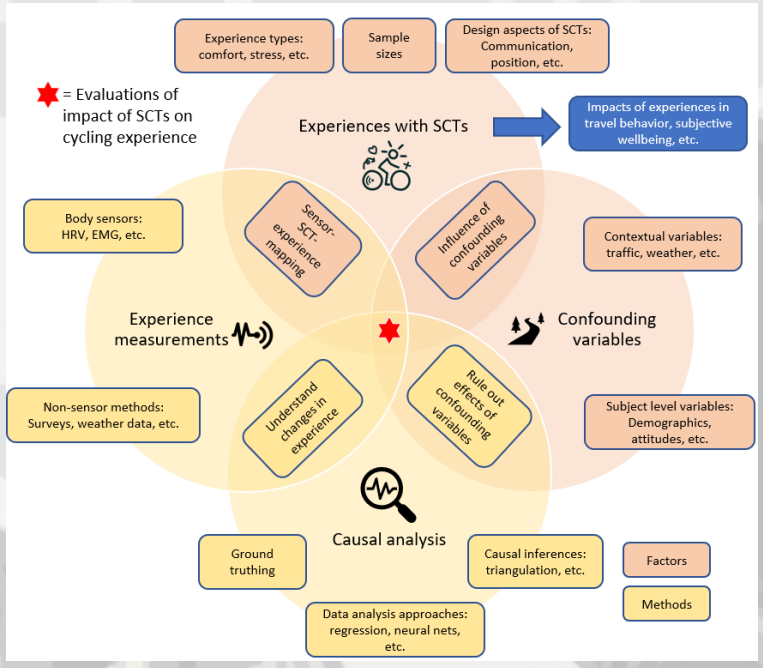
Mobile sensors can provide valuable insights into how cyclists experience SCTs in real-world conditions

Mobile sensors offer valuable insights into how cyclists experience Smart Cycling Technologies (SCTs) in real-world settings. Combining data from smartphones, wearables, and e-bike motors with self-reports and contextual information helps capture cycling experiences in their richness. Rich environmental and real-time contextual data such as information about nearby events show strong potential for evaluating the impact of cyclist technologies. A proposed evaluation framework helps guide the use of mobile sensors in future analyses of effects of SCTs.



Mobile sensors can support evaluations of experiences with Smart Cycling Technologies, but only when combined with data about context, behaviour, and self-reports.

Did you know?

- In-ride pleasantness ratings can enable machine learning classification of sensor data.
- Our evaluation framework guides the use of mobile sensors in future evaluations of experiences with SCTs.

Read more on this topic:

- Boot, M., Ulak, M. B., Geurs, K. T., & Havinga, P. J. M. (2024). European Transport Research Review. DOI: http://doi.org/10.1186/s12544-024-00635-3

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13 Smart Cycling Technologies can enrich cycling experiences

User experience

Cyclists can benefit from improved flow and alertness with intelligent warnings and motor interventions.

Smart Cycling Technologies (SCTs) affect not only ride performance but also cyclists' experiences and emotions. Fieldwork shows that digital features like safety warnings, geofenced motor control, and tailored motor support for paired cyclists can enhance pleasantness, flow, and sociability when well designed. However, SCTs may reduce enjoyment if interventions are poorly timed or abrupt, highlighting that cyclists' subjective experience often matters more than the systems' technical effectiveness.

Smart cycling technologies can shape experience in subtle and diverse ways: enriching experiences when smooth and helpful, but disruptive if intrusive or inaccurate.

Did you know?

- More intrusive interventions were experienced less pleasantly than more subtle interventions.
- Cyclists who evaluated warnings as noticeable and alerting reported more pleasant rides overall.

Read more on this topic:

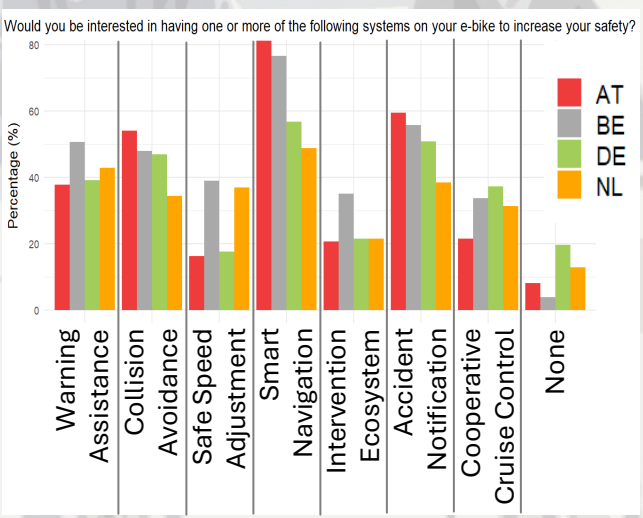
- Boot, M., Jutte, A., Ulak, M. B., & Geurs, K. (2025). Feel the Warning? Using Wearable Sensor Data to Measure Pleasantness with a Safety Warning System for Cyclists. Manuscript revised after external peer review. Available for preprint. Retrieved from https://dx.doi.org/10.2139/ssrn.5344791
- Boot, M., Kahnt, L., Postma, D., Ulak, M. B., Geurs, K., & Havinga, P. (2024). Are We in Flow? Measuring and Supporting Simultaneous Flow in Duos of Elderly Cyclists. 2024 IEEE International Conference on Pervasive Computing and Communications Workshops and other Affiliated Events (PerCom Workshops), 255-260. doi: http://doi.org/10.1109/PerComWorkshops59983.2024.10503119

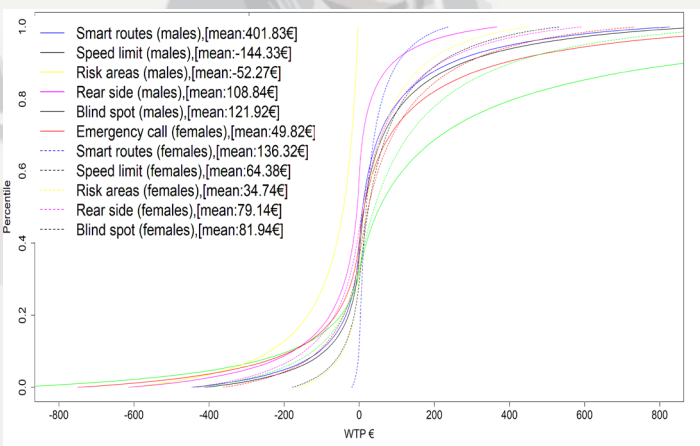
14 Dutch consumers are willing to pay for Smart Connected Bicycle technologies

User experience

Smart bicycle technologies should be deployed selectively, prioritising simple, high-value features while avoiding intrusive interventions for cost-sensitive users.

Evidence shows that cyclists are not a homogeneous group. While a substantial segment of e-bike users is willing to pay for advanced safety technologies, a slightly larger group remains technology-cautious and highly cost-sensitive. Dutch consumers have a positive attitude toward smart bicycle technologies, with Assistance smart routes, Assistance emergency call, and Collision avoidance rear side being the most preferred, and they are willing to pay up to 259 € to use technologies on e-bikes to increase their cycling safety.





Results indicate significant heterogeneity in individuals' preferences, which several variables partially explain.

Did you know?

- Males and older individuals are reluctant towards automatic speed control and active intervention systems.
- Smart cycling technologies are most likely to succeed when they enhance perceived safety through supportive, low-intrusion features, while giving cyclists choice and control over more advanced interventions.

Read more on this topic:

- G. Kapousizis (2024). Smart Connected Bicycles: User Acceptance and Experience, Willingness to Pay and Road Safety Implications. https://doi.org/10.3990/1.9789055843541

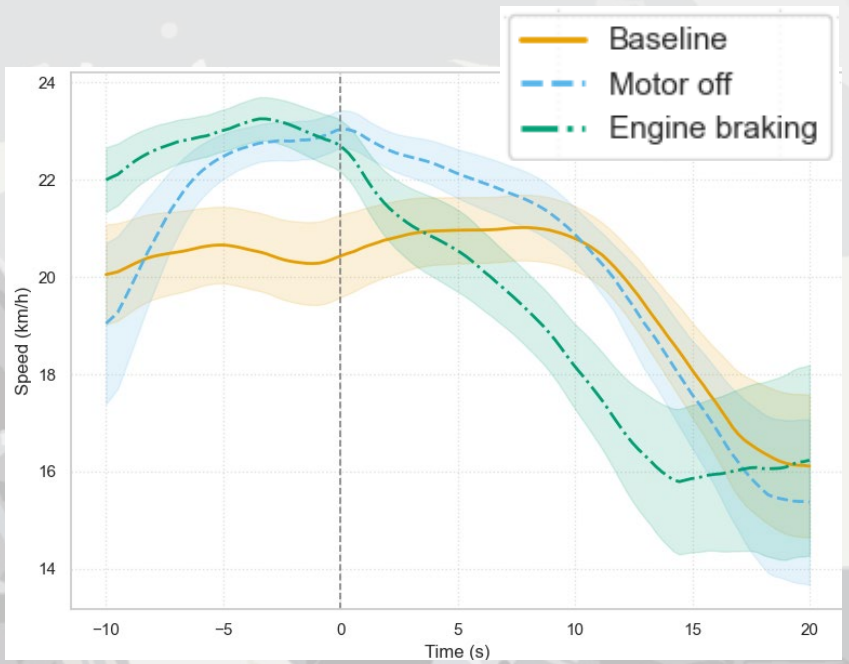
15 E-bikes can “talk” to riders through intelligent e-bike motor interventions

User experience

SMART CONNECTED BIKES

Smart Cycling Technologies can achieve more than safer cycling behaviour: systems can also “talk” to riders.

E-bike motor interventions can influence cycling speed while also communicating cues to the rider. Even if motor interventions do not cause substantial speed changes, switching off motor support can be perceived as a meaningful signal. This highlights the need to design and evaluate motor control systems based on both objective performance and subjective interpretation.



Did you know?

- Engine braking lowered speed by 3 km/h within 10 seconds.
- Switching off motor support had no significant effect on cycling speed within 10 seconds but was perceived as a meaningful signal.
- Communicating cues to riders through switching e-bike motors on and off is a promising interaction mechanism.

Motor interventions can change rider speeds, while alerting riders on potential risks.

Read more on this topic:

- Boot, M., Pallamreddy, A., Ulak, M. B., & Geurs, K. More Safe, Less Pleasant? Effects of Intelligent E-bike Motor Control on Riding Dynamics and Cycling Experiences. Submitted (2025) to the Journal of Urban Mobility.

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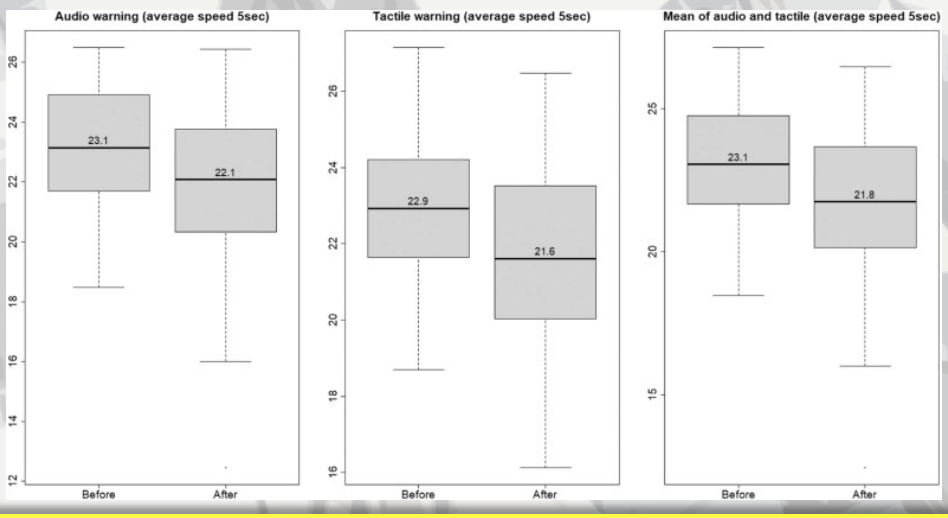
16 Context-aware warning system increases experience and perceived safety

User experience

Design cyclist warning systems to prioritise trust, clarity, and minimal intrusiveness - while still encouraging speed reduction at high-crash-risk locations.

Field evidence indicates that context-aware warning systems can increase perceived safety of cyclists and lead to measurable reductions in speed at high-crash-risk locations. Moreover, individuals favour tactile warnings during safety-critical moments and respond best to systems that are easy to use, predictable, and well integrated into the bicycle. Allowing personalisation (volume, intensity, modality) is beneficial for accommodating different riders, speeds, and environments.



The context-aware prototype warning system can influence cyclist riding behaviour and perceived safety.

Did you know?

- Individuals were found to have a higher perceived safety for the e-bike equipped with a safety support system than a conventional e-bike
- Individuals reduced their speed when receiving warnings in high-crash-risk locations by almost 2km/h (15%).

Read more on this topic:

- G. Kapousizis, A., Jutte, M. B., Ulak, K., Geurs. (2025). How do cyclists experience a context-aware prototype warning system? Assessing perceived safety, perception and riding behaviour changes through a field study. Journal of Urban Mobility. https://doi.org/10.1016/j.jcmr.2024.100051

Colophon

Project Title
Smart Connected Bikes - enjoyable, safe, reliable, and comfortable.

Timeline
2021-2026

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User Committee
Netherlands Organisation for Scientific Research (NWO), Accell Group, Institute for Road Safety Research (SWOV), TNO, BAM Infra Nederland

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Final deliverable of Smart Connected Bikes project

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Final Report

Conclusions and Recommendations for Researchers, Policy Makers, and Industry

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