CETRA2026 27-30 May 2026, Bol, Island Brač, Croatia
9th International Conference on Road and Rail Infrastructure

REAL-TIME AI MONITORING: ADVANCING SUSTAINABLE AND SAFE ROAD NETWORKS – BRIDGING SUSTAINABILITY AND ROAD SAFETY THROUGH INTELLIGENT INFRASTRUCTURE SOLUTIONS

David Homola[1], Samo Čarman[2], Bismarck Ledezma Navarro[3]
[1]Transoft Solutions Inc, Hungary
[2]CGS Labs d.o.o., Slovenia
[3]Transoft Solutions Inc, Canada

Abstract

Throughout Europe, climate action and road safety are often addressed separately, but East Riding of Yorkshire Council (ERYC), UK, demonstrates how real-time AI monitoring can integrate both. Backed by the UK Department for Transport's "Live Labs 2, " ERYC utilized an AI-driven thermal camera system to track key safety and operational data before, during, and after lighting changes. Strategies included removing streetlights in some areas and adding in-pavement lighting at crossings. The system's analytics guided energy-saving measures while maintaining user safety. This project highlights that decarbonization and road safety can advance together, offering a model for smarter, safer, and greener mobility.

Keywords: road safety, decarbonization, street lighting, thermal imaging, AI, computer vision, surrogate road safety, PET, TTC, privacy, GDPR, Live Labs 2, Transoft Solutions

1 Introduction

This study evaluates the safety impacts of large-scale road-lighting de-illumination using a before-and-after analytical framework based on continuous thermal-video monitoring and AI-derived surrogate safety metrics. The objective is to quantify changes in road user behavior and conflict risk across baseline, transition, and steady-state phases of lighting interventions implemented in East Riding of Yorkshire, UK. Road safety must remain central to sustainability efforts. Neglecting safety, such as delaying considerations during lighting changes, can raise risks for vulnerable road users like pedestrians and cyclists. Inadequate visibility and overlooked behavioral shifts may cause preventable injuries or fatalities, emphasizing the need to prioritize safety throughout planning and implementation. Implementing the safe system principle and Vision Zero from the start prioritizes eliminating serious road injuries and deaths. Ultimately, decarbonization efforts rely on public trust and safety. Prioritizing road safety from the start ensures environmental improvements do not compromise lives, making change both responsible and fair.

2 Program background and testbed context

The UK Department for Transport's Live Labs 2 program funds local authority-led trials to decarbonize local roads while maintaining service outcomes. Within this program, ERYC leads the "Future lighting testbed", [1] a systems-based examination of lighting for local roads to reduce lifecycle carbon while preserving or enhancing safety.

DOI: https://doi.org/10.5592/CO/CETRA.2026.1996

The testbed includes interventions such as de-illumination on selected corridors, enhanced conspicuity via solar road studs and highly reflective markings, and pedestrian-focused in-pavement lighting at crossings. A continuous monitoring system was established to quantify safety and operational effects before, during, and after change.

3 System architecture and deployment

3.1 Sensing hardware and system architecture

A network of 30 fixed thermal cameras was deployed across multiple locations in and outside of East Riding's jurisdiction, to ensure reliable detection accuracy and robust data collection, regardless of ambient lighting conditions. These cameras stream footage in real time via a secure cellular network to a centralized traffic management center. At this center, the video feeds are continuously analyzed using Transoft Solutions' proprietary AI tool for live safety monitoring, TrafxSAFE Connect, which operates on-premise servers to deliver high-precision object detection and classification. The use of thermal imaging not only eliminates privacy concerns by avoiding personally identifying visual details but also ensures consistent detection performance across both day and night, as well as during adverse weather conditions.

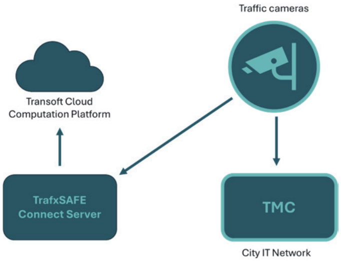

Figure 1 Schematic deployment architecture

3.2 Analytics

Computer vision models underpin the safety analytics, using algorithms to detect, classify, and track road users in thermal camera video streams. Each detected object is categorized – such as pedestrian, cyclist, car, LGV, or HGV – enabling detailed risk analysis and targeted interventions. Multi-object tracking algorithms preserve the identity of each road user across frames, building continuous trajectories that capture position, velocity, and movement patterns. Thermal imagery ensures reliable tracking in all lighting conditions. The resulting data estimates individual speeds and aggregates turning counts at key junctions, supporting operational and safety assessments.

The methodology relies on surrogate safety metrics to quantify near-miss events and potential conflicts without using collision data. Key measures include Post-Encroachment Time (PET), which indicates how close encounters were by measuring the time gap between two road users in the same location, and Time-to-Collision (TTC), which assesses the time left before a potential collision if trajectories remain unchanged. These metrics are computed from precise spatiotemporal tracking data, supporting detailed analysis of conflict points and responses to interventions. The safety analytics engine processes these metrics in real time, feeding results into dashboards and alerting systems that flag elevated risk levels based on configurable thresholds.

By continuously monitoring surrogate safety indicators, the system provides actionable insights into the effectiveness of lighting interventions and other measures, enabling rapid iteration and evidence-based decision-making. This methodology not only supports rigorous evaluation of safety impacts but also fosters transparency and accountability in the pursuit of Vision Zero and safe system principles.

3.3 Operations and safety dashboard

A web-based dashboard supports live monitoring, trend analysis, and configurable thresholds that flag elevated risk levels. Role-based access controls enforce least-privilege access; audit logs are retained for governance.

3.4 Operations dashboard and analytics outputs

The web-based dashboard serves as an integral component of the system architecture, supporting live monitoring, temporal analysis, and evidence-based evaluation of interventions. Historical traffic volumes and speed distributions are aggregated from continuous trajectory data, enabling users to conduct trend analysis across baseline, transition, and steady-state periods. These operational metrics are presented via configurable tables and charts, with filtering options by location, time interval, turning movement and road user type.

Road safety data are generated through proactive and predictive methods, utilizing surrogate safety metrics. Conflict indicators are calculated in real time from the spatiotemporal trajectories of detected road users and are visualized in a variety of formats. Heatmaps display the spatial distribution of vehicle speeds and conflict frequencies, allowing users to quickly identify high-risk zones and temporal hotspots. For more granular analysis, scatter plots are available that plot vehicle speed against PET or TTC values (figure 2), following the principles of the Swedish Traffic Conflict Technique [2]. This approach facilitates the differentiation between higher and lower risk conflicts and supports before/after intervention assessments by illustrating changes in risk profiles and behavioral response over time.

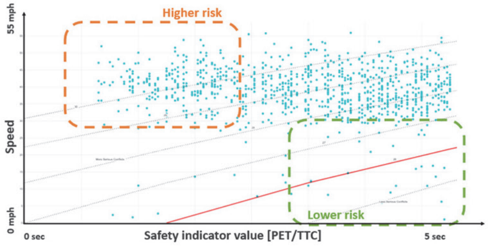

Figure 2 Example of granular report on critical conflicts, based on the Swedish Traffic Conflict Technique

4 Methodology

The study adopts a quasi-experimental before–after design to evaluate the safety impacts of lighting de-illumination and alternative low-carbon visual interventions. Continuous monitoring was conducted across defined baseline (pre-intervention), transition, and steady-state (post-intervention) periods at intervention sites, with additional control sites monitored concurrently to account for broader temporal effects. Thermal-video data were collected continuously using fixed cameras deployed at selected roundabouts, junctions, and crossings.

AI-based computer vision models extracted road-user trajectories, enabling the estimation of speeds, turning movements, and interaction dynamics independent of ambient lighting conditions. Safety performance was evaluated using surrogate safety metrics derived from tracked trajectories, including PET and TTC. Conflict events were identified using predefined threshold values following the principles of the Swedish Traffic Conflict Technique. Vehicle speed distributions were analyzed to assess behavioral adaptation to lighting changes.
For each site, indicator distributions were compared between baseline and post-intervention periods. Changes in median speed, frequency of low-PET/TTC events, and spatial conflict patterns were examined. Control sites were used to contextualize observed changes and support attribution to the interventions.

5 Study sites and interventions

At the time of submission, the monitoring network comprises a total of 29 cameras across multiple jurisdictions – 23 within East Riding while 6 in other councils, project partner locations, contributing further to monitoring and serving as control sites. These additional six cameras were deployed in external regions: Lancashire, Oxfordshire, Derbyshire, Hull, and Aberdeenshire.

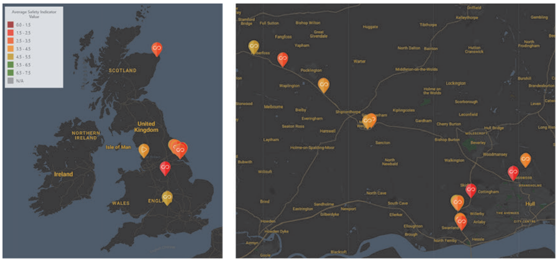

Figure 3 Monitoring locations across the UK (left) and within East Riding (right)

Interventions for this project span two major A roads in East Riding of Yorkshire, the A1079 and A164, as well as at additional sites nationwide. The work includes targeted de-illumination and the installation of pedestrian-focused lighting at key crossings, supported by enhancements such as solar-powered road studs and improved retroreflective markings for better nighttime visibility. These upgrades are being implemented in distinct phases: baseline (pre-change), transition, and steady-state periods. Below is an example of the de-illuminating intervention implemented at one of the roundabouts, where besides the street light switch off, solar power road studs and high reflectivity markings and signs were installed.

Figure 4 Riplingham Road Roundabout A164 pre street lighting switch off (left) and post street lighting switch off (right)

6 Results

At the time of writing, the project remains in an active operational phase, with several intervention sites still transitioning toward steady-state conditions. Consequently, a full before - after statistical comparison is not yet appropriate. This paper therefore focuses on (i) the monitoring methodology, (ii) baseline and early post-intervention observations, and (iii) the feasibility of continuous surrogate-safety assessment during lighting transitions.

6.1 Operational safety outcomes during the initial postintervention period

The initial operational monitoring period provides evidence on the safety performance of road lighting de-illumination when combined with alternative low-carbon visual interventions and continuous AI-based monitoring. Results are reported based on comparisons between baseline, transition, and steadystate periods across monitored intervention sites.

6.2 Collision trends, behavioral insights and lighting assumptions

These observations are based on continuous monitoring during the postintervention period. Early operational evidence reveals that no nighttime collisions have occurred at high-risk locations such as roundabouts, junctions, and priority intersections. Comparison between baseline and post-intervention conditions indicates no deterioration in overall safety performance following de-illumination. Analysis of vehicle speed distributions derived from tracked trajectories shows a reduction in average vehicle speeds of approximately 10% during nighttime conditions in the post-intervention period compared with baseline. No increase in conflict risks or safety incidents attributable to the lighting switchoff was observed. Behavioral patterns including lane keeping, approach speeds remained consistent with baseline conditions. Safety performance was further evaluated using surrogate safety metrics, including PET and TTC, derived from continuous trajectory data, enabling ERYC engineers to validate the safety of de-illumination in live operational settings.

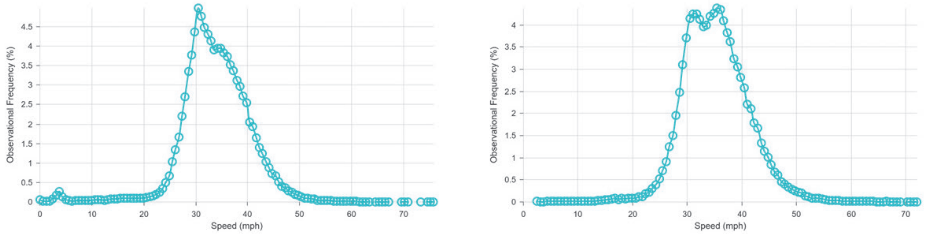

Figure 5 Speed distribution of an arbritarily chosen site before (left) and after (right) de-illumination

Overall, the before–after comparison across intervention sites indicates that reduced conventional lighting, when accompanied by lowcarbon visual enhancements and continuous AIbased monitoring, did not result in measurable deterioration of safety performance during the initial operational period.

7 Discussion

While the project will continue to closely monitor driver behavior and safety performance, these findings are encouraging and potentially could challenge the longstanding belief that artificial lighting is the principal tool for nighttime risk reduction. The project aims to serve with further evidence-based analysis to test how lighting is implemented and challenge the current practice that lighting alone is the decisive factor in safety at high-risk sites [3].
The findings underscore that aligning decarbonization initiatives with road-safety objectives demands continuous, transition-period evidence, particularly in contexts such as large-scale de-illumination where conventional visibility cues are diminished. In this regard, thermal analytics offer a resilient, illumination-independent modality capable of maintaining uninterrupted observational coverage. At the same time, surrogate safety indicators remain indispensable for generating early, actionable insights ahead of collision-based evidence. Finally, the replicability of such monitoring systems across jurisdictions rests on standardizing deployment parameters enabling methodological comparability and accelerating wider adoption.

7.1 Effectiveness of low-carbon visual enhancements

Instead of traditional lighting, the corridors featured a range of low-carbon visual aids: solar-powered road studs, upgraded high-retroreflective road markings, enhanced signage, and color-coded visual cues. Results show that these elements supply sufficient navigational guidance to help drivers intuitively interpret road alignments and conflict areas at night. This demonstrates that thoughtfully designed visual systems can uphold operational safety standards without relying on high-intensity luminaires, raising questions about current national design practices for road lighting [3].

7.2 Ecological responses to reduced lighting

Simultaneous environmental surveys at the Hayton site recorded frequent nocturnal wildlife activity via camera traps and acoustic sensors. The data set documented presence of bats, moths, foxes, roe deer, badgers, and various birds. While the long-term ecological implications require further study, early evidence confirms more activity of nocturnal species and supports the idea that reduced artificial light may lessen disturbance for sensitive wildlife [4].

7.3 Broader and strategic Implications

Collectively, these early findings indicate that, when paired with advanced monitoring and low-carbon visual interventions, de-illumination can maintain road safety while achieving significant carbon reductions. Should these results persist through subsequent phases, the program could inform revisions to British lighting standards – or potentially influence a broader, international practice – and support widespread reductions of street lighting in rural settings – potentially affecting over a million luminaires [5].

8 Conclusion

Real-time, thermal-video-based AI monitoring can furnish the evidence needed to decarbonize lighting assets while maintaining – or improving – road safety. The ERYC testbed illustrates how integrated sensing and analytics provide visibility during transitions, support targeted mitigations, and build institutional confidence.

Future work will include further analysis, comparing results with similar sites for stronger conclusions, and improving guidelines for deployment in different regions.

It is essential that road safety remains the foremost consideration in any design or decarbonization decision, particularly when interventions have the potential to alter established visibility cues or affect driver behavior. Decisions made without prioritizing safety risk undermining public trust, increasing the likelihood of collisions, and potentially reversing the environmental gains achieved through decarbonization efforts.

By ensuring that safety objectives are at the heart of design and operational choices, especially during transitions such as large-scale de-illumination, authorities can strike the necessary balance between sustainability and user protection. Advanced monitoring technologies, such as thermal analytics, enable rigorous evidence gathering that does not rely on traditional lighting, thereby allowing for innovation without sacrificing safety. Furthermore, prioritizing road safety supports regulatory compliance, aligns with public expectations, and reinforces the legitimacy of sustainability initiatives, paving the way for broader adoption and long-term success.

Acknowledgments

The authors thank East Riding of Yorkshire Council (ERYC), Local Transport Projects (LTP), and the UK Department for Transport Live Labs 2 program for their collaboration. Any views expressed are those of the authors and do not necessarily reflect official policy.

References

[1] ADEPT Live Labs 2 - ERYC (ADEPTNET), www.adeptnet.org.uk/news/live-labs-2-blog-%E2%80%93-east-riding-yorkshire-council%E2%80%99s-decarbonising-street-lighting-project-1, 30.01.2026.

[2] Hydén, C.: The development of a method for traffic safety evaluation: The Swedish Traffic Conflict Technique, First edition, Lund Institute of Technology, 1987.

[3] East Riding of Yorkshire Council (EASTRIDING), www.eastriding.gov.uk/environment/roads-streets-traffic-and-parking/roads-pavements-and-traffic/live-labs-2/, 30.01.2026.

[4] North and East Yorkshire (NEYEDC), www.neyedc.org.uk/updates-insights/2025/9/1/project-spotlight-live-labs-2, 30.01.2026.

[5] Highways Magazine (HIGHWAYSMAGAZINE), www.highwaysmagazine.co.uk/news/local-road-network/live-labs-east-riding-ready-big-switch, 30.01.2026.