The Psychology of Signage

Enhancing Road Worker and Road User Safety through Behaviourally Informed Signage

Roads Australia Fellowship Group Project
SA & Victoria Team

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1. Executive Summary

Despite existing law, regulations, various safety campaigns and signage options available, driver non-compliance with speed limits in roadwork zones remains a critical safety issue for both workers and other road users.

Current signage and speed limits in roadwork zones often fail to elicit compliant speed reduction from drivers, thereby posing significant risks to road workers and other road users. Traditional and overly familiar signage may not sufficiently engage drivers' attention or evoke an emotional response, leading to non-compliance and unsafe driving behaviours.

This study focuses on the 'Safe Speeds' and 'Safe People' pillars of the Safe Systems Approach to road safety.[1] It will investigate how behavioural science and human factors can inform the design and deployment of signage to influence driver behaviour and reduce risks to road workers, and by extension road users. This also aligns to outcome 2 of Road Australia's 'Raising the bar' National Road Worker Safety Action Plan.[3]

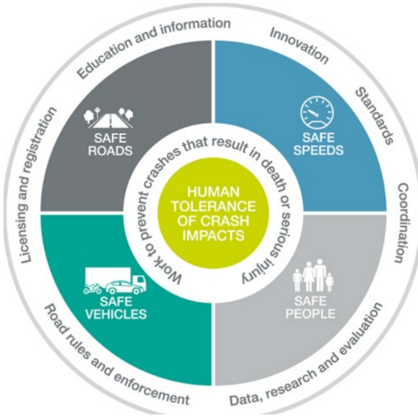

Figure 1 The Safe Systems approach and targeted pillars by this project.[1]

Figure 2 Raising the Bar National Road Worker Safety Action Plan and targeted outcome by this project[3]

Project Objective

To evaluate the effectiveness of psychologically-informed signage (e.g. images, empathetic messaging, dynamic displays) in influencing driver behaviour and improving compliance with speed limits (i.e. reduced speeds) in active workzones.

The study explores the psychology of signage through the following:

1. **Provides a literature review** of the existing data, guidelines & standards, past studies and recommended actions regarding workzone traffic control devices and summarises the key Human Factors and psychology behind traffic speed compliance in workzones.

2. **Evaluate the outcomes of live site trials at the Fleurieu Connections Alliance (FCA) project site.** A significant opportunity was identified by the group to develop a pilot trial at a live major project site with active workzone traffic management. The FCA project site is located just south of Adelaide on Main South Road, and currently the vehicle speeds are monitored through the work site via Bluetooth technology. The group was therefore able to interrogate existing data and use as a baseline for any proposed trial.

3. **Use a number of innovative, non-standard supplementary workzone traffic control signage solutions and test driver responses in real-time.** Utilising existing and readily available traffic control devices, the signage solutions tested (as supplementary signage to standard regulatory signage) included:
   - Variable Message Signs (VMS) with messaging highlighting worker safety
   - Radar speed signs providing real-time feedback to drivers on speed compliance
   - Signage highlighting the potential risk of enforcement

- A strong and simple visual prop to elicit an emotional reaction and reinforce safety messages (VMS with use of colour for effect).

4. **Summarises the findings and lessons learned from our research and site trials**

5. **Offers Recommendations to Roads Australia for taking these findings to the next step in making impactful industry change for workzone safety.**

Trial Summary

Our site Trial revealed that of the four signage trials that were tested at the FCA project site, the VMS message of "*"Police presence,* ***slow down"*** delivered the most consistent and statistically significant reduction in vehicle speeds through the project worksite, indicating that the potential for police speed enforcement, and the risk of punitive and monetary impact, resulted in the most consistent and statistically significant behavioural change.

The impact observed represents about 7,380 additional vehicles (870 daily on average) travelling at or below the posted speed limit, which is a meaningful improvement in compliance rate and a reduction in worksite speed-related risk exposure. It is well-documented that even small reductions of 1km/hr result in substantial decreases in crash severity, these outcomes demonstrate clear practical safety benefits.[18-20]

Conclusions and Recommendations

With the site trials revealing that enforcement-focussed messaging having the most significant impact on driver behaviour, an opportunity is presented for a partnership program between the state Police force, state transport authorities and industry bodies such as Roads Australia to develop a targeted worker-safety campaign, leveraging other speed compliance pilot programs being rolled out across Australia.

Our team found that support from senior stakeholders was key to success in implementing non-standard signage solutions on an active project worksite, enabling approval and process cut-through for the trial implementation.

As with any time-limited trial, further research is recommended. Additional field trials of other VMS message variations (e.g. more personal/emotive, site-specific, project-specific), as well as line-marking/lane modifications and other traffic-calming devices, across a variety of workzones would provide a greater dataset on the effectiveness of various traffic management measures to inform future investment decisions.

An industry toolkit could also be developed to assist practitioners with informed, research-based decisions on implementing innovative work zone site design and traffic control devices.

2. Roadmap for Study

The key stages, timeline and expected outcomes of the study were mapped out by the RA Project team and detailed in our Project Scoping Paper. A summary of the project Roadmaps is provided below.

Table 1. Project Roadmap

Project Stage	Activities
Stage 1 **Problem Definition, Background Research & Literature Review** *May - July*	- Review and summarise existing literature on behavioural psychology, human factors, and signage design in road safety. - Identify signage techniques (colours, messages, images, placement) that may be effective and worth investigating further. - Engage with specialists in the industry to gain further insights into innovations in this field and a better understanding of the potential gaps, and challenges, to developing solutions.
Stage 2 **Industry and Stakeholder Engagement** *July*	- Key Stakeholder identification - Invite stakeholder feedback with an engagement survey.
Design Site Trial Approach & Evaluation Framework *July*	- Undertake Multi-Criteria Analysis to assist in determining which interventions to implement for the Site Trial. - Work with the FCA project team to define a safe and suitable test zone. - Confirm signage treatments and specific VMS messaging - Establish baseline data: typical speeds, compliance rates, near-miss incidents. - Define success metrics: % reduction in average speed, % increase in compliance, observational driver behaviour.
Stage 3 **Pilot Trial on Active Construction Site** *August - October*	- At the FCA trial site, 4 signage treatments were deployed under controlled conditions. - Baseline traffic conditions were monitored prior to the installation of any new signage and the site was returned to baseline conditions in-between each trial for at least 4 days to ensure data clarity. - Data on vehicle speeds, compliance rates, and driver behaviour was collected using radar devices, Bluetooth data, traffic counters, and/or observational methods. - The intention was to implement trials at two project sites but trials were not undertaken at 'The Stuart Highway Flood recovery works - at Lake Windabout' project', the reasons for which are further discussed in Section 5.2.
Stage 4 **Analyse Results & Refine Concept** *September – October*	- Compare data across different signage types. - Analyse statistical changes in driver speed and compliance. - Assess feasibility, constructability, and stakeholder acceptability. - Gather anecdotal feedback.
Stage 5 **Summarise results, Present to Stakeholders & Plan next steps** *October - November*	- Findings compiled into this research paper, feedback from industry stakeholders, our site trial outcomes and opportunities for further research and development with industry
Stage 6 **Integrate into Policy and Practice** *Future*	- Work with the Department for Infrastructure and Transport (DIT), South Australia Police (SAPOL) and industry to incorporate signage findings into partnership programs and large-scale trials across different states and road environments.

3. Literature Review: Key Research Areas and Outcomes

3.1. Crash and Incident Data

It is well documented that speed is one of the main factors which can influence the probability and potential severity of a crash. Anecdotally, speed in road workzones increases the risks to road workers, although from this literature review it appears that in South Australia, it is difficult to correlate captured road crash data with roadwork zone presence or causation. There is a potential gap in data collection due to a difference in thresholds of reporting requirements when an incident is a ‘workplace incident’ reported to SafeWork SA and when a road crash incident is reported to or attended by the SAPOL.

Research[4] in Queensland showed that almost all drivers (77-98%) drove over the posted speed limits when approaching a roadwork zone, while many (19-45%) drove at 20 km/h or more over the posted limits. Baseline speed compliance data collated from the FCA project site (80 km/h posted speed limit) demonstrated that compliance varied from 79.6% (north/city-bound at night) to 97.9% (southbound AM peak).

Notwithstanding this data gap in South Australia, Austroads has published data[2] in 2022 that found over a ten-year period, 18 fatal worksite crashes were recorded annually, along with 245 serious injury crashes. Considering around 1,200 fatal road crashes are recorded annually in Australia, this data suggests 1.5% of national fatalities occur in workzones.

PIARC (World Road Association) are currently running a special project to investigate the best practices in worksite and traffic disruption management around the world, with the aim to build a practical, risk-based toolkit that could be used across countries and associations including major cities and low-resource environments. This highlights that safety of road workers and road users around worksites is a global issue.

3.2. Human Factors and Driver Psychology

The technical discipline of Human Factors examines the underlying causes of errors by focusing on the characteristics and behaviours of road users that influence road safety. These factors include emotional, cognitive, and perceptual aspects of individuals, as well as the effects of sign clarity, familiarity, and emotional resonance. Several studies have shown that human factors have the most significant contribution (around 93%) to an accident[5] and are crucial for developing effective strategies to prevent accidents and improve overall road safety.

Research[6] exploring how signage can be used as a tool for influencing behaviour highlighted the importance for designers and implementers to prioritise both familiarity and clarity of a sign. The study proposed a two-stage process for how signs are processed: either through *direct recognition* (i.e. comprehension though familiarity) or *indirect inference* and thus their effectiveness (i.e. prompting a decision and action). It was concluded that to effectively communicate to a broad audience, an ideal sign should be highly familiar to enable quick, intuitive understanding (i.e. direct processing), but at the same time unambiguous in its intended message, clearly indicating what actions are expected.

Studies[7-11] have found that the psychology of driver compliance hinges on two fundamental principles:

- **social proof:** if surrounding traffic is speeding through a workzone, individuals are more likely to conform, even if they know it’s unsafe; and
- **fear of punishment:** drivers reduce speed when obvious speed enforcement devices are present.

This is further supported by a recent study undertaken by Deakin University[13] in partnership with Transport for New South Wales, into the effectiveness of temporary traffic control measures at end of queue worksites. Police presence was ranked as one of the most effective treatments. This study also found eSeries signage, narrow gateway treatments, rumble strips and flashing queue warning signs to be among the most effective treatments.

Another factors influencing behaviour was linked to how salient or noticeable the danger appeared. Drivers were found to respond more strongly when they perceived immediate and tangible threats, such as the presence of visible workers or heavy machinery. People are generally more likely to take action when risk cues are both prominent and credible.[10]

3.3. Signage Design and Effectiveness

Signage must be clear and legible. Confusing or cluttered signs reduce compliance because drivers must process too much information too quickly.[12] If signage is inconsistent with the actual risk (e.g. speed signs remain beyond extended workzones), drivers learn to ignore them over time, reducing long-term compliance. In Australia, roadworks signage complies with the Australian Standard AS1742.3 with some additional/supplementary signs as per each state's requirements (e.g. in South Australia this is the SA Standards for Workzone Traffic Management). Any innovative or non-standard traffic controls devices require approvals under the *Road Traffic Act*.

Studies[14] identified that graphics on dynamic message signs and fixed warning signs have been shown to prompt faster responses from drivers and mitigate potential distractions, compared to longer text-based messages, however the difference was not affected by the type of display used to present the message.

Other considerations include:

- **Placement:** with regard to speed-feedback signage in particular, it was found that they were generally effective at reducing workzone speeds, however they tended to be more effective when positioned closer to the work area, including ingress/egress locations.[15]
- **Visual 'Tricks':** utilising road design to make drivers slow down and/or pay attention. Examples include 3D artwork (e.g. speed bumps) painted on the roads, cardboard cutouts of law enforcement, and optical illusions to change driver's perception of decreasing distances leading drivers to think that they're travelling faster than they really are.[16]

3.4. Literature Review Conclusion

This literature review has highlighted the following areas to be further investigated, socialised with stakeholders and tested.

1. Emotional response
2. Readability/graphics that are clear and approachable to a broader audience
3. Ease of implementation across diverse workzones
4. Familiarity of imagery/text
5. Signage placement, avoiding visual clutter and messaging overload

4. Industry and Stakeholder Engagement

4.1. Stakeholder Identification

The following table presents relevant industry stakeholders identified in Stage 1 that the project team directly engaged with.

Table 2. Relevant Project Stakeholders

Third Party Stakeholders:	**Project Stakeholders:**
Department for Infrastructure and Transport (DIT)	Fleurieu Connect Alliance Project
SAPOL	Lake Windabout Project team
SafeWork SA	Local road users
RAA	Workzone Traffic Managers
Technical Experts:	Road Workers
Traffic Engineers	**Industry bodies:**
Transport Safety Technical Advisors	Austroads
Psychologists	Centre for Automotive Safety Research, The University of Adelaide
Road Designers and Human Factors consultants	Traffic Management Association Australia (TMAA)

4.2. Stakeholder Engagement Survey

As part of Stage 2 of the study, we conducted a stakeholder survey (included in Appendix 1) involving both the general public and industry professionals, with a total of 78 respondents. Figure 3 presents the demographic breakdown, showing that most participants were managers, engineers, or supervisors, followed by policy makers, construction workers, and members of the public. This ensured a balanced view with strong input from those directly managing safety on worksites.

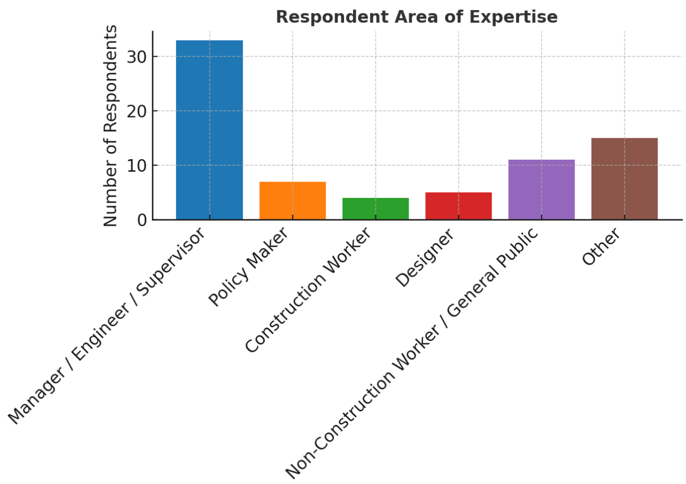

Figure 3. Distribution of respondents by area of expertise

A complete summary of the survey questions and analysis is provided in Appendix 1, the general themes of responses are highlighted below.

Key Challenges and Effectiveness

Stakeholders identified several critical challenges (Figure 4) in ensuring road user compliance and safety in work zones, including:

• Driver distraction (particularly mobile phone use)
• Speeding and complacency when speed limits appear repetitive or unnecessary
• Confusion due to frequently changed conditions

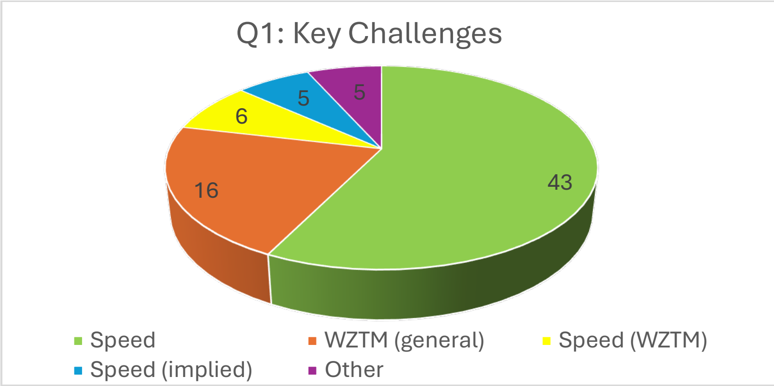

Figure 4. Results for Question 1 – Key Challenges for road user compliance

When questioned regarding effectiveness of current signage (Figure 5, *Rating scale: 1 = Not at all effective, 5 = Very effective*), respondents rated an average of 3.08 out of 5, indicating only moderate influence on driver behavior. Comments revealed that while flashing or dynamic signs captured attention, signage alone did not consistently translate into safer driving behavior. This points to the need for signage strategies that are both more engaging and more personally resonant.

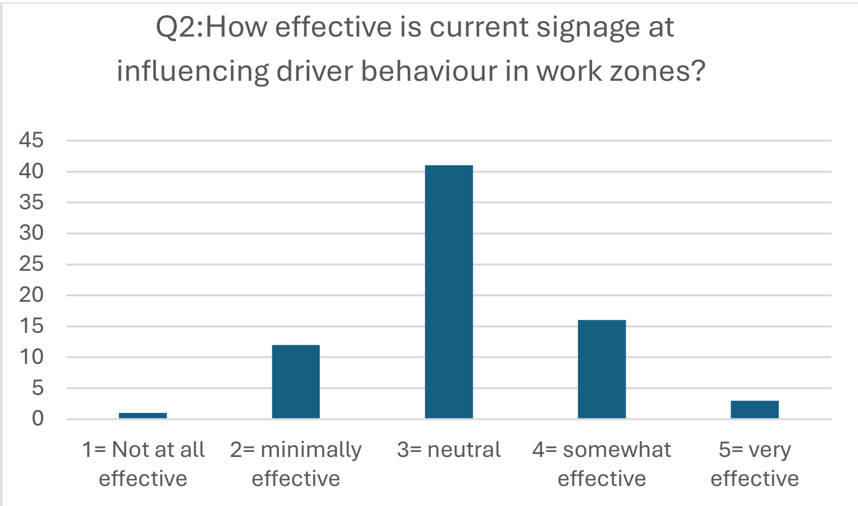

Figure 5. Results for Question 2 - Effectiveness of current signage (number of responses)

Innovative signage strategies and perceived effectiveness

Just over half of respondents (Question 4 - 55%) had encountered innovative signage strategies (Figure 6) such as empathetic messages, colour cues, or emotive symbols (e.g. 'Happy Harry' smiley face signs). The most common of these being dynamic speed signage (42%) and travel time information (22%) with respondents noting their observed impacts included improved awareness and stronger driver responses. Demonstrating empathetic and visual cues can positively influence behavior when thoughtfully applied.

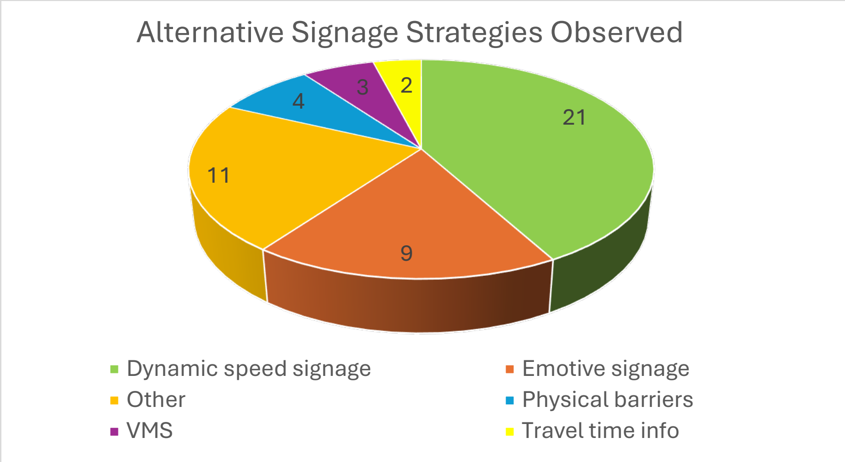

Figure 6. Alternative Signage Strategies observed

When asked in Question 6 (Figure 7), which signage elements hold the greatest potential to positively influence driver behaviour, respondents identified both physical and behavioural approaches. The strongest support was for physical interventions and Variable Message Signs (VMS), but there was also notable recognition of the role of empathetic and visual cues:

- Physical road layout changes (60 votes) were seen as unavoidable interventions that force drivers to reduce speed.
- Variable message signs (57 votes) were valued for their adaptability and visibility, with the ability to display context-specific messages.
- Visual cues (39 votes), such as colour and lighting, and empathetic messaging (38 votes) were recognised as softer but important nudges that engage drivers emotionally and reinforce compliance
- Graphical imagery (28 votes) and other approaches (12 votes) were mentioned less often but demonstrate an appetite for continued innovation.

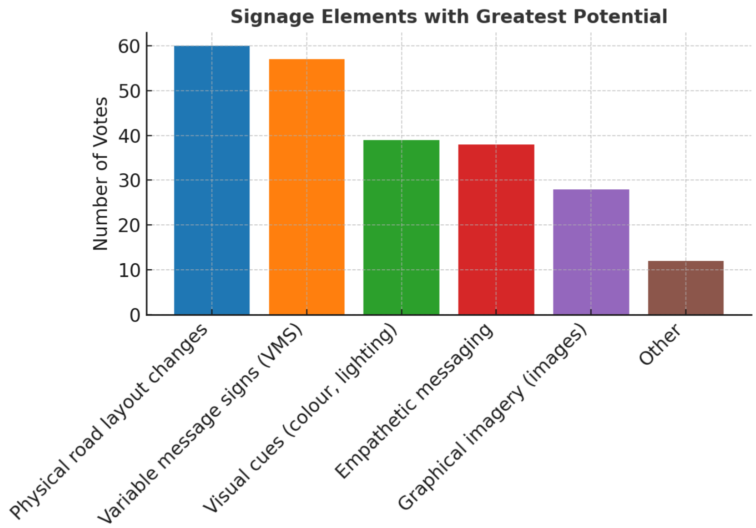

Figure 7. Signage Elements with Greatest Potential Impact

When asked about advice or considerations offered for ensuring the success and safety of signage trials on active worksites (Question 7), respondents emphasised the importance of ensuring visibility and driver engagement in any new signage trial. Recommendations included:

- Increase visibility (larger, brighter signs)
- Collect continuous driver and site feedback
- Use adaptive or dynamic speed limits depending on site conditions.

These suggestions reinforce the industry's support for innovative but practical, driver-focused solutions.

4.3. Survey Conclusion & Next Steps

The findings of the survey generally support the fundamental assumptions of the study being:

- Speeding vehicles is one of the dominant challenges *in ensuring road user compliance and safety in and around road work zones.*
- Current signage is somewhat effective, but could be improved.
- Drivers often disengage from existing signage, reducing compliance and increasing risks.
- Dynamic speed signage and emotive signage and other examples of alternative signage have been observed, but their effectiveness is unclear.
- After physical road layout changes, VMS dynamic signage was considered the most effective signage method, followed by empathetic signage to positively influence driver behaviour in work zones.

The results of the consultation demonstrated that while current signage has moderate impact, stakeholders see clear potential in innovative approaches.

Variable Message Signs were viewed by respondents as one of the most effective strategies, especially when paired with empathetic messaging. These findings were used to inform our VMS messaging selection discussed in Section 5.

5. Site Trial design

5.1. Multi-Criteria Assessment to Determine Trial Options

Introduction to Multi-Criteria Assessment

Multi-Criteria Assessment (MCA) is a structured decision-making process used to evaluate project options against a range of performance, safety, social and deliverability criteria. Unlike a cost benefit analysis which is primarily financial focused, MCA enables both quantitative and qualitative factors to be considered in a transparent and balanced approach.

This approach has been used by transport agencies in Australia and overseas to prioritise infrastructure upgrades and to support Safe Systems Assessments. By assessing performance, safety and social outcomes alongside cost and deliverability, an MCA helps decision makers to identify which treatments are most likely to achieve the desired outcomes.

For this project, the MCA process has been adopted to assess a series of potential trial interventions aimed at improving driver compliance with reduced speeds in work zones. The process ensured that each option was considered consistently, scores documented and the interventions with the highest potential identified for site testing.

Long List Development

A long list of eleven potential interventions was developed for the MCA (Table 3). These were informed by current practice, behavioural psychology and examples of interventions in work zone safety both locally and internationally. Each treatment seeks to influence driver behaviour through visibility, enforcement, perception or emotional response.

Table 3. Long list options

ID	Option	Description	Example
1	Police Presence	Deployment of visible police vehicles or officers near work zones as a deterrent.	
2	Enforcement Signage	Static or electronic signage warning of police activity, e.g. “Police presence – slow down”.	
3	VMS with Emotive Messaging	Messages on Variable Message Signs emphasising worker safety, such as “People work here – slow down”.	
4	VMS with Real Time Feedback	Radar-based displays providing drivers with immediate feedback on their travel speed.	
5	Lane Width Restrictions	Narrowing of lanes within the work zone to create a stronger perception of constraint and encourage slower speeds.	
6	Pavement Markings	3D or converging line markings designed to alter drivers’ perception of speed and distance.	
7	Gateway Treatment	Enhanced entry treatments combining narrowing, signage and lighting to reinforce a transition into the work zone.	
8	Highlighted Speed Signs	Speed signs supported by personalised elements such as corflute worker cutouts.	

ID	Option	Description	Example
9	Bespoke Human Element Campaign	Campaign material highlighting the personal impact of speeding on road workers and their families.	
10	Bespoke Educational Campaign	Campaigns explaining why reduced speeds are important even when workers are not physically present.	
11	High Impact Props/Signage	For example, a wrecked vehicle or strong visual prop to elicit an emotional reaction and reinforce safety messages.	

Criteria Development

To evaluate the long list of potential treatments and inform a short list for trial assessment, a set of MCA criteria were developed. These criteria were chosen to reflect the project objectives of improving safety and compliance in roadwork zones, while also considering deliverability, community expectations and broader sustainability outcomes.

The final set of nine criteria, grouped under five categories, is summarised below:

- Performance/Effectiveness
    - **Emotional Response:** The likelihood of the treatment influencing driver behaviour through an emotional reaction.
    - **Ease of Interpretation:** Clarity and readability of the treatment, ensuring messages are intuitive and easily understood.
- Safety
    - **Road User Safety:** The potential extent to which the treatment improves safety outcomes for drivers.
    - **Road Worker Safety:** The potential extent to which the treatment improves safety outcomes for workers within the construction site.
- Deliverability
    - **Ease of Implementation:** Practical considerations such as resource availability, compliance with standards and time to implement.
    - **Scalability/Repeatability:** The potential for the treatment to be expanded or replicated at other worksites beyond the trial.
    - **Cost:** The relative financial feasibility of delivering the treatment.
- Social
    - **Community Acceptance:** The likely level of support from the community and key stakeholders.
- Environmental and Sustainability
    - **Sustainable:** The environmental footprint of the treatment including materials, energy usage and whether the installation is temporary or permanent.

The final criteria were discussed and agreed with the project team prior to progressing with the MCA assessment.

MCA Process and Outcomes

The long list options were assessed against the nine criteria outlined above. Scores were allocated on a scale of 1 to 5, where 1 indicated limited or no positive effect, and 5 indicated a strong positive effect. The scoring was undertaken collaboratively within the project team, with scores determined from professional judgement, available evidence from literature, and outcomes from the stakeholder questionnaire.

The MCA was first conducted on an unweighted basis (Table 1 in Appendix 2) which gave each criterion equal importance. This provided the project team a starting point to investigate trial options that yielded the highest result with no influence from weighting.

The highest scoring treatments were Option 3 'VMS with Emotive Messaging', Option 4 'VMS with Real Time Feedback' and Option 11 'High Impact Props/Signage'. These options performed well across the performance and safety criteria, particularly with evoking an emotional response. The lesser performing options were Option 6 'Pavement Markings' and Option 7 'Gateway Treatment'. These scored poorly in providing an emotional response and the deliverability criteria. Most other options had relatively good scores suggesting moderate potential but without a distinct advantage that the top 3 options showed.

Following the unweighted assessment a weighting process was applied to reflect the relative importance of each of the criteria. The weightings were derived using the pairwise method, which involves comparing and prioritising each of the criteria against each other sequentially (Table 2 in Appendix 2). This resulted in development of a pairwise matrix, which is used to generate a series of weightings for each criterion.

The pairwise assessment indicated Road Worker Safety (20%) and Road User Safety (18%) as the most critical factors, aligning with the project's focus on reducing risks to roadworkers in construction sites. Ease of Implementation (16%) and Emotional Response (14%) also scored highly, highlighting the importance of practical deployment and the potential to influence driver behaviour. While the remaining criteria were weighted lower, they remain important factors in the selection of the short list trial options.

The MCA was then conducted using the weighted criteria, with results replicating the unweighted analysis (Table 3 in Appendix 2) indicating the top three options were:

1. Option 3 'VMS with Emotive Messaging' - 3.98
2. Option 4 'VMS with Real Time Feedback' - 3.61
3. Option 11 'High Impact Props/Signage' - 3.41.

The results suggest that these options offer the most balanced performance across the nine criteria and are likely to be the most feasible to deliver the greatest improvements in both Road Worker and Road User safety and therefore form the basis of the signage to be trialled.

5.2. Site Selection

Two live construction sites, Lake Windabout Project and Fleurieu Connections Allicance Project, in South Australia were identified by the project team as opportunities to test a number of innovative signage solutions in real-time.

Lake Windabout Project

The Stuart Highway, Lake Windabout Flood Remediation Works is a part of the Improve National Supply Chain Resilience program. The initiative focuses on improving flood resilience and repairing road sections damaged by previous weather events along the Stuart Highway at Lake Windabout, near Pimba, about 425km north of Adelaide.

The team made every effort to implement trials at the Lake Windabout site; however, due to time constraints within the project, implementation was not achieved. The challenges encountered during this process provided valuable insights and led to several key recommendations.

Construction projects in remote areas present a unique set of challenges, especially when it comes to ensuring the safety of both workers and the travelling public. It is well established that effective traffic management is critical not only for the safety of construction personnel but also for minimising disruptions to road users. In metropolitan areas, innovative technologies become standard practice. However, remote projects remain under-explored. The Lake Windabout trial aimed to address this gap, offering valuable insights into both the potential and the pitfalls of implementing new traffic management strategies in challenging environments.

Methodology

The trial was designed to leverage the existing project boards for messaging, supplemented by the installation of 'happy harry' boards—devices equipped with speed recording technology—at both the entry and exit points of the work zone. This approach aimed to not only inform but also actively engage motorists, encouraging compliance through real-time feedback. The data gathered would then be analysed to determine the extent to which these interventions modified driver behaviour, providing an evidence base for future deployments.

Planning and Approval Process

From the outset, meticulous planning was required to adapt standard traffic guidance schemes (TGS) for the unique context of the Lake Windabout project. The process began with the drafting of a new TGS plan that incorporated the proposed VMS and speed feedback boards. This documentation was then submitted to DIT for initial approval—a step that can present challenges especially when introducing novel interventions.

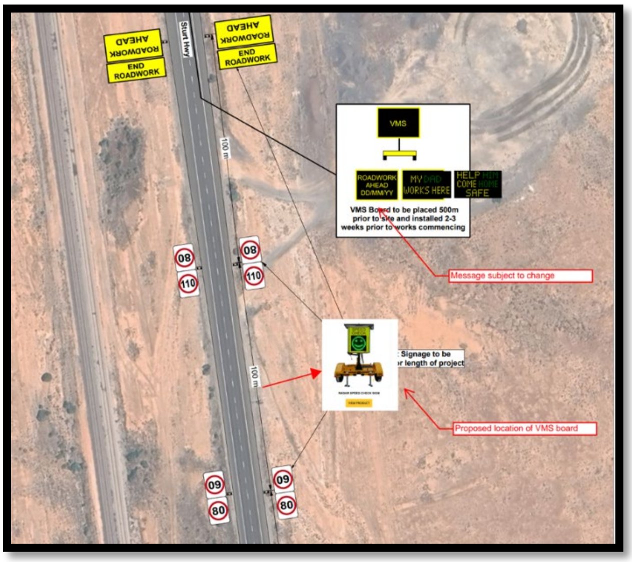

Figure 8. Lake Windabout Trial TMP

Once preliminary approval was sought, the next phase involved finalising the Traffic Management Plan (TMP) and securing a Memorandum of Agreement (MOA) from the relevant authorities. Only then could procurement and installation of the happy harry boards proceed. Each of these steps required close coordination among project teams, contractors, and government stakeholders. In theory, such a process is designed to ensure both compliance and safety; in practice, it can introduce significant delays, especially in the context of smaller, resource-constrained projects.

Implementation Challenges in Remote Settings

The Lake Windabout project, valued at under $20 million and located in a remote region, exemplifies the logistical and operational hurdles faced by teams working outside metropolitan centres. While there was clear alignment between the contractor and DIT regarding the trial's intent, the realities of limited resources and competing priorities became the primary obstacles to successful implementation.

One of the most persistent challenges was the timely acquisition of approvals. The approval process, while essential for governance and safety, can be protracted, particularly when the trial in question falls outside the original project scope. In remote areas, where personnel and equipment are often stretched thin, aligning rosters to install devices and coordinate activities added further complexity. As a result, by the time approvals were obtained and resources marshalled, the window for data collection had effectively closed, leaving insufficient evidence to inform the final report.

Reflecting on similar projects, the intersection of innovation and resource constraint is where many promising initiatives falter. Remote projects, in particular, lack the redundancy and flexibility found in larger, urban undertakings. This reality underscores the importance of integrating trial activities into the planning and tendering process from the outset, rather than treating them as afterthoughts or optional extras.

Lessons Learned

Several key insights emerge from the Lake Windabout experience. First, the value of innovation in traffic management must be balanced against the practicalities of project delivery in remote settings. While the intent to trial new technologies is commendable, success depends on early integration into project planning, adequate resourcing, and streamlined approval pathways.

Second, trials that sit outside the contracted scope are particularly vulnerable to delay or abandonment. Unless explicitly included in tender documents and project schedules, such initiatives are unlikely to receive the sustained attention and resources they require. Embedding trial activities within the core scope not only clarifies responsibilities but also ensures that they are properly costed and prioritised alongside other deliverables.

Finally, the tendency for innovation to concentrate in metropolitan areas must be addressed. Regional and remote projects face distinct risks—long travel distances, limited emergency response, and variable driver behaviour—that make robust traffic management all the more critical. Neglecting these contexts not only undermines worker and public safety but also limits the industry's capacity to generate data-driven insights applicable to the full spectrum of project environments.

Fleurieu Connections Alliance

The Fleurieu Connections Alliance (FCA), involves the duplication of Main South Road between Seaford and Sellicks Beach (Figure 9). The project location in regional South Australia, 45km from Adelaide city, currently has 19,000 vehicles through the site each day.

Figure 9. FCA overview

Within the Project footprint, State government data (Link) indicates there were 93 recorded traffic accidents that resulted in 52 injuries, between 2020-2024. The project resides predominantly on flat terrain, with a built-up commercial area at the Northern extremity and greater density of housing at the Southern end of the alignment. During trial location assessments, it was deemed preferable to situate both signage and speed detection devices in locations that had minimal other variables that could impact the driver (intersection, corners, steep incline/declines, short sight distances etc.). Additionally, the signage and speed detection systems had to be located in locations where the designated speed was fixed- not transitioning from 60-80 or vice versa. There were no significant differences in the speed environment between Northbound and Southbound lanes.

Trial Measurement Devices

Data on vehicle speeds and compliance rates were collected using radar devices and traffic counters.

Pre-trial, there were 5 No. Bluetooth probes installed along the alignment to measure vehicle speeds throughout the project footprint, with an Alliance Key Performance Indicator (KPI) being vehicle speed impact due to works. An additional 2 No. Probes were installed (Figure 10) so as to measure vehicle speeds in close proximity to the signage in the trial. The distance between the two trial probes of approximately 1.9 km also provided sufficient time for drivers to process the signage information and alter their speeds accordingly.

A key requirement in the trial design was for the devices to be readily available and affordable across the industry, so that learnings from the trial are transferable to other industries and authorities such as local councils. VMS are widely used across the industry and Local Government Authority's (LGAs) often have their own VMS devices to deploy. As compared to static signage, VMS are low maintenance once installed and can have the message altered remotely, providing maximum flexibility to the user.

Figure 10. FCA Trial site probe locations

Whilst bluetooth radar probes used in the trial can be cost prohibitive to smaller projects and LGA's at circa $35,000 for a standalone speed monitoring system, portable VMS with radar is a much cheaper alternative at circa $2,000 per month rental whilst providing accurate speed and data capture, as discussed further in Section 6.1.

Other Considerations

For trial No. 4, a separate risk assessment was conducted due to the nature of the messaging and suitability of locations. State road authority regulations on VMS messaging and placement of perceived hazards in the road corridor meant that the crushed car had to be situated inside the project work site. A recent article[17] also indicated that the wrecked cars should be placed at accident prone zones where drivers have the time to absorb the message and alter their driving behaviour. A viewing platform inside the project compound at Aldinga Beach Road intersection also provided an elevated platform to display the vehicle and accompanying VMS to drivers at the intersection. With a favourable footprint at this location, light towers were also positioned to illuminate both the car and VMS at night, providing a greater contrast to the surrounding area as compared to the days (Figure 11).

To implement such a trial in other settings across the industry is considerably harder, with significant barriers in addition to the above including cost, craneage, duration, road authority reticence due to driver and reputational risks, willingness of emergency services to source an appropriate vehicle (must be drained of flammable fluid) and community appetite for messaging that can be triggering for some members of the community.

Figure 11. Establishment considerations for Trial

5.3. FCA Message Selection

Following the MCA process, the overall top-rated signage options as Option 3 'VMS with Emotive Messaging', Option 4 'VMS with Real Time Feedback' and Option 11 'High Impact Props/Signage' were used to inform the selection of a number of innovative signage solutions to trial in real time at the FCA project site.

Further supported by our stakeholder survey results, VMS were viewed by respondents as one of the most effective strategies, especially when paired with empathetic messaging.

As such, the project team selected several VMS messages to test the impact of different messages on driver speed compliance. A combination of standard signage and these experimental signage treatments (empathetic messaging, visual cues, graphical imagery, static vs VMS signage) were deployed under controlled conditions:

- **Trial 1** Real time speed feedback message: *"**DRIVE SAFE** THANK YOU" & "**TOO FAST** - SLOW DOWN"*
- **Trial 2** Emotive message: *"FAMILIES WORK HERE - **PLEASE SLOW DOWN**" & "FAMILIES WORK HERE - **THANK YOU**"*
- **Trial 3** Enforcement message: *"POLICE PRESENCE, PLEASE **SLOW DOWN**"*
- **Trial 4** Crashed Car installation with Worker Safety message: *"HIGH-VIS MEANS HIGH-RISK. **SLOW DOWN** TO SAVE LIVES."*

Trial 1- Real time speed feedback message

*"**Drive safe** Thank you"* and *"**Too fast** - Slow down"*

The project team consulted with DIT during the trial development and were informed that in accordance with Department Standards displaying the actual speed to the drivers was not permitted. Therefore, a simplified messaging system indicating either 'compliant' or 'non-compliant' status was implemented.

This trial provided simple messaging with real-time speed feedback. The positive message of *"**Drive safe** Thank you"* was shown for compliant driving speeds, and the message *"**Too fast** - Slow down"* was shown for non-compliant driving speeds. This aligned with MCA *Option 4 'VMS with Real Time Feedback'.*

Use of SpeedCheck Radar Speed Signs are increasingly becoming a standard safety device for traffic maintenance crews, construction workers, public works professionals, and others that work in and around traffic. Used in conjunction with other road safety equipment such as electronic arrow boards and barrier systems, the radar speed signs are proving to be highly effective at increasing the speed compliance of vehicles and increasing the safety of both drivers and workers.

Figure 12. Trial 1 Real time feedback message

Trial 2 - Emotive message

*"Families work here - **Thank you**"* and *"Families work here - **Please slow down**"*

This trial provided emotive messaging in combination with real-time speed feedback. The positive message of *"Families work here - **Thank you**"* was shown for compliant driving speeds, and the message *"Families work here - **Please slow down**"* was shown for non-compliant driving speeds. This aligned with MCA *Option 3 'VMS with Emotive Messaging', and Option 4 'VMS with Real Time Feedback'.*

This signage option sought to test the impact of empathetic or emotive signage compared to standard speed signage and more traditional real time speed feedback, to see if it positively influenced driver behaviour in work zones.

Figure 13. Trial 2 Emotive message

Trial 3 - Enforcement message

*"Police presence, **slow down"***

As shown in the literature review and indicated by the anecdotal evidence in the stakeholder survey, enforcement of travelling speeds was considered likely to have a noticeable impact on compliance. Trial 3 aimed to test this assumption and also aligned with MCA *Option 3 'VMS with Emotive Messaging', and Option 2 'Enforcement Signage'*. The following message was displayed *"Police presence, **slow down"***, regardless of speed compliance.

Figure 14. Trial 3 – Enforcement message

Trial 4 – Crashed Car

*Crashed Car alongside VMS "High-vis means high-risk. **Slow down** to save lives."*

This trial escalated the emotive nature of the previous trials while also exploring the *MCA Option 11 'High Impact Props/Signage'*. As discussed further in Section 5.2, the vehicle was placed within the boundary of the FCA site compound rather than directly adjacent the road. Light towers and a VMS displaying *"High-vis means high-risk. **Slow down** to save lives."* accompanied the vehicle.

The use of this message directly reflects the stakeholder survey findings by:

- Addressing driver complacency
- Establishing a personal and empathetic connection between drivers and workers
- Reinforcing the critical role of speed in protecting lives

This evidence-based decision ensures the trial is grounded in stakeholder perspectives and industry expertise, marking a proactive step towards safer work zones.

Figure 15. Trial 4 – Crashed car and emotive message

5.4. FCA Trial Program

The FCA trial program (Table 4) included a combination of standard signage and experimental signage treatments deployed under controlled conditions. The traffic conditions were monitored prior to the installation of any new signage to establish the baseline conditions, returning to baseline conditions in-between each trial for at least 4 days to ensure data clarity.

Table 4. Trial program

Week Commencing	**Trial Details:**
8- Aug	Baseline Conditions
11-Aug	Trial 1 - Real time message: ***DRIVE SAFE*** *THANK YOU* ***TOO FAST*** *- SLOW DOWN*
25-Aug	Trial 2 - Emotive message: *FAMILIES WORK HERE -* ***PLEASE SLOW DOWN*** *FAMILIES WORK HERE -* ***THANK YOU***
8-Sep	Trial 3 - Enforcement message: POLICE PRESENCE, **SLOW DOWN**
22-Sep	Trial 4 - Crumpled car & Worker Safety Message: *HIGH-VIS MEANS HIGH-RISK.* ***SLOW DOWN*** *TO SAVE LIVES*

6. FCA Trial Results Analysis

6.1. Analysis Methodology

Radar speed data was adopted as the primary source for evaluating the effectiveness of Trials 1-3, which provided continuous, point-based speed measurements with high temporal precision, capturing the instantaneous speed of each vehicle as it passes the detection point. This method eliminates travel-time inference errors and sample bias that can arise in Bluetooth probe data, where speed is derived indirectly from matched detections between multiple nodes. As such, radar data offers greater accuracy, stability, and sensitivity for short-duration work zone assessments, particularly when analysing changes in speed distribution and compliance relative to the posted 80 km/h limit.

To establish data consistency, baseline radar results were compared with concurrent baseline Bluetooth data, demonstrating strong overall agreement across key performance metrics, including mean speed, P85, and compliance rate. However, when the same comparison was undertaken for the trials, noticeable discrepancies were observed between the radar and Bluetooth datasets. Statistical testing confirmed that these differences were not random and likely reflected variations in sampling density, detection reliability, and positional alignment between Bluetooth sensors. Consequently, radar data was adopted as the definitive reference dataset for subsequent analyses comparing baseline and trial conditions, ensuring that the findings reflect genuine behavioural changes at the site rather than artefacts of probe sampling variability.

Due to probe malfunctions and an alternative site location required for placing the crumpled car, Bluetooth probe data and radar data were unavailable for Trial 4. Trial 4 was supplied as hourly aggregated statistics (harmonic average speed and 15th/85th percentile speeds from Tomtom) rather than raw per-vehicle speeds. This pre-aggregation prevents the computation of micro-level distribution metrics such as empirical cumulative distribution functions (ECDFs) and exact compliance rates, and it changes the unit of analysis from individual vehicles to hourly summaries. To ensure a valid like-for-like comparison, the Baseline dataset was re-aggregated into hourly harmonic means and hourly percentiles (P15 and P85) using the raw vehicle speeds.

6.2. Results Summary

A complete summary and statistical analysis of the Project Site Trail data is provided in Appendix 3.

The first three of the VMS trials consistently improved speed compliance compared with baseline across both northbound and southbound directions, however the magnitude and timing of the effects differed.

Trial 3 (the "Police Presence" message) achieved the largest overall compliance uplift across all time periods, indicating that the potential for police speed enforcement, (and the risk of punitive and monetary impact) resulted in the most consistent, and statistically significant behavioural change.

Trial 2 ("Families work here") generated stronger reductions in median speed and compliance gains than Trial 1 ("Too fast, slow down"), likely reflecting the additional emotional resonance and empathy created by its message.

In the following figures, the lines further to the left indicate the slower overall speeds and higher compliance resulting from each trial. Relative to the baseline conditions, a consistent leftward shift across speeds reflects broad-based compliance improvement, while selective reductions near the right tail reflect suppression of high-end speeds.

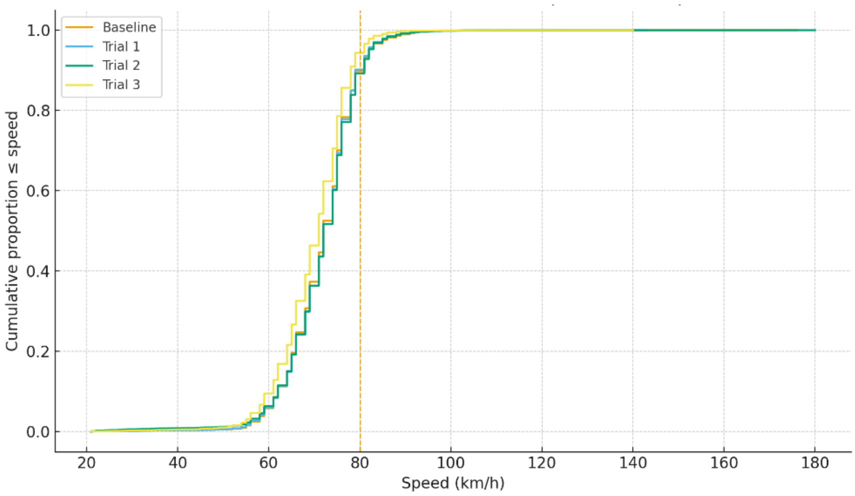

Figure 16. Overall ECDF – All time periods (Northbound or City-bound)

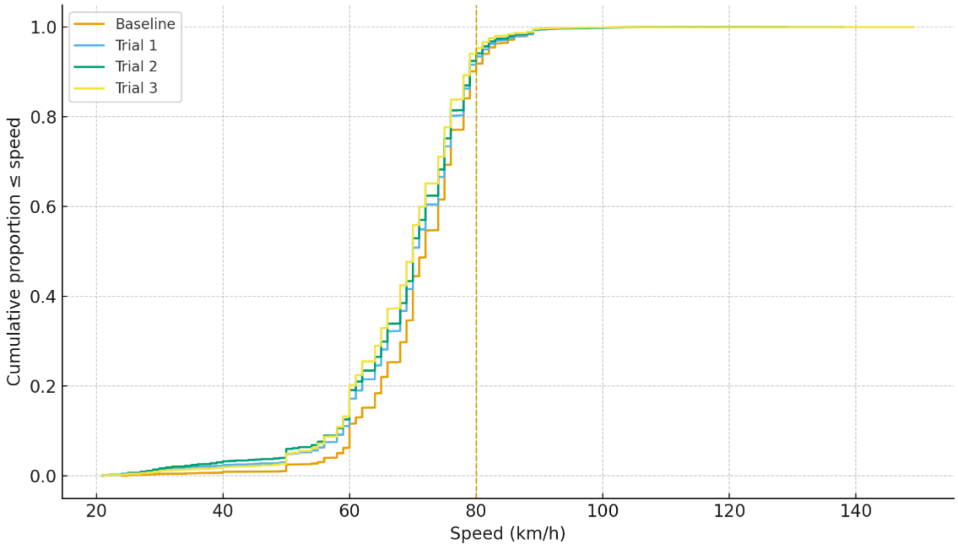

Figure 17. Overall ECDF – All time periods (Southbound)

Time of day variances

Across the Southbound direction (Figure 18), all three VMS trials produced measurable speed compliance improvements compared with the baseline, except during the AM Peak, where compliance remained statistically unchanged. This is consistent with typical traffic flow patterns (i.e. during the morning period, most vehicles are travelling city-bound (northbound), leaving southbound volumes low and the baseline already highly compliant with room for improved compliance being limited.

At night, however, the deterrence effect diminished slightly across all trials and message types. This could be partly due to the reduced visibility of the VMS signage, as well as the lack of site worker presence at night time. As indicated in the literature and stakeholder survey, when no workers are present on site, drivers implicitly reassess the perceived consequences of speeding including the level of risk, and enforcement likelihood. With the site appearing inactive, the perceived consequences of speeding—both moral and legal—drop sharply, reducing the potency of all messages during these periods.

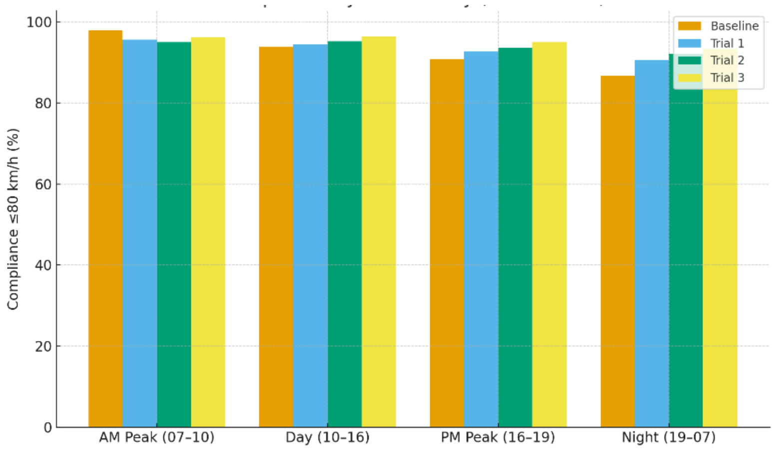

Figure 18. Compliance by Time of Day (Southbound)

Side by side bars (Figure 18) compare compliance across trials within each time period; the tallest bar indicates the leading trial. A similar trend was found for northbound traffic. Together, these results suggest that targeted VMS messaging can sustain compliance improvements throughout the day, with diminishing returns only in already high compliance periods such as the AM Peak.

Northbound/southbound variances

On the Northbound (city-bound) approach, where morning commuter flow and active worksites were present, behavioural responses were strongest during AM and daytime periods, particularly under Trial 3 (“Police presence”).

On the Southbound direction, compliance improvements were more consistent through the day and evening, while the AM Peak showed little change due to low traffic volumes and an already high baseline compliance. These directional contrasts illustrate how traffic context, perceived relevance, and site activity can shape driver psychology and behaviour.

Enforcement themed messaging (Trial 3) proved most effective in both directions, leveraging drivers’ risk–reward instincts. Empathy and feedback messages (Trials 1 and 2) worked better in higher volume or more emotionally salient settings, where message visibility and human context amplified engagement. Overall, both directions demonstrate that targeted behavioural messaging remains effective when tailored to driver flow, site activity, and perceived enforcement presence.

Trial 4 – Crumpled Car and & Worker Safety Message

For Trial 4, overall there was some marginal reduction in speeds suggesting that some drivers exercised marginal caution in the evening/early morning times. This trend was less pronounced in the Northbound direction. Between the morning and afternoon peaks, observed speeds remained almost identical to the baseline, and the largest reduction in upper-tail speeds was observed during the evening hours.

This potentially indicates that for Trial 4:

- a compliance benefit under low-light, lower-volume conditions — where risk exposure is highest and driver attention can be influenced by strong visual cues (i.e. the lit-up car an illuminated VMS message).
- under daylight, high-volume conditions, the installation’s effect on behaviour is diminished, and behaviour is governed primarily by traffic flow and work-zone geometry.
- the installation primarily heightened risk perception and speed awareness rather than altering habitual speed choices.
- Drivers are most responsive to visual cues — typically in lower-light or lower-volume settings — moderated speeds more noticeably. This supports the behavioural principle that salient, empathy-based prompts are most effective when cognitive load is low and environmental contrast is high.

Whilst the speed reduction results for Trial 4 are marginal, anecdotal feedback from several road uses (included in Section 6.3 below) also indicated that this installation was attention-grabbing and thought-provoking for road-users, which is an important factor in making lasting behavioural and cultural change towards safer driver behaviour. As noted by ‘THINK! Road Safety’, one of their key strategies to support and enforce safer road user behaviour includes education and cultural change, *coupled with* enforcement and compliance to reduce lives lost and serious injuries associated with speeding.[21]

Effectiveness of Trial 3– “Police Presence”

Trial 3 (“Police presence”) delivered the most consistent and statistically significant reduction in vehicle speeds through the project worksite, particularly during daytime and mid-week periods when traffic volumes and driver exposure were greatest.

A reduction in both median and high-end speeds (P85) relative to the baseline results was observed across multiple time periods, in both the northbound and southbound directions.

The proportion of compliant vehicles (≤ 80 km/h) increased from 89.8% (baseline results) to 94.4% during the trial — a +4.6 percentage-point improvement. Whilst this may initially appear to be a marginal change, this change represents about 7,380 vehicles (870 daily) more vehicles travelling at or below the speed limit, which is a meaningful improvement in compliance rate and a reduction in worksite speed-related risk exposure.

Results analysis

The enforcement framed messaging, such as that used in Trial 3, delivered the most durable compliance gains by elevating perceived risk of immediate consequences for drivers. The effectiveness of this message stems from its alignment with drivers' risk–reward decision-making: the perceived likelihood of enforcement triggers rapid behavioural self-correction, even without visible/actual police patrols.

The effect is particularly strong during the daytime, potentially supported by the higher traffic volumes which offers more community surveillance as well as ambient visibility to reinforce message credibility and driver vigilance.

By contrast, Trial 1 ("Too fast, slow down") and Trial 2 ("Families work here") relied on feedback and empathy respectively, which are mechanisms that depend heavily on drivers' sustained attention and emotional engagement. These treatments showed only partial or short-lived effects (i.e. in several cases, median speeds even rose slightly, likely due to habituation, novelty loss, or cognitive disengagement among repeat commuters). As noted in the literature, with repeated exposures, drivers can become desensitised to the same message (habituation), the stimulus loses its initial attention-grabbing value (novelty loss), and the message shifts into the background of their driving environment (cognitive disengagement). Once this occurs, drivers tend to revert to their habitual speed choice rather than consciously moderating behaviour.

In addition, the empathy-based message proved less effective under low-light conditions, where both readability and emotional resonance declined. This differed to Trial 4 which appeared to be marginally more effective under low-light conditions, potentially because of the installation being illuminated making it more visually impactful.

Overall, the results suggest that messages grounded in credible enforcement cues produce more durable behavioural change than those relying solely on self-regulation or empathy, particularly when active worksite cues are absent (typically at night).

Results Impact

It is well-documented in the literature that even small increases of 1km/hr result in substantial increases in crash severity[18-20]. For example, the below extract from the West Australian Government Fact sheet titled 'A vehicle's speed has a major influence on the risk and severity of road crashes and related injuries', neatly summarises the step-change impact that small speed changes make on crash outcomes. [19]

A 1 km increase in average speed increases the risk of a crash resulting in injury by 3%, and the risk of a fatal crash by 4-5%.

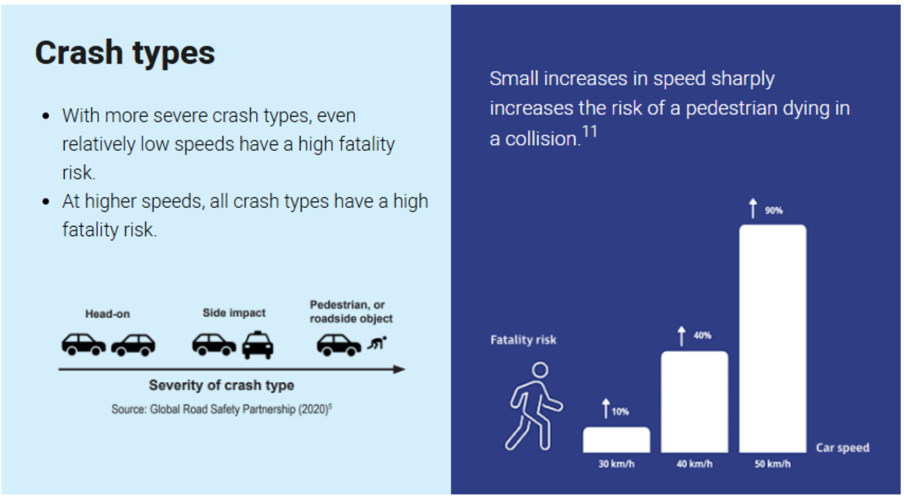

Figure 19. Speed and how it influences road safety, taken from [*https://www.wa.gov.au/government/publications/speed-and-how-it-influences-road-safety-0#:~:text=A%201%20km%20increase%20in,crash%20by%204-5%25*](https://www.wa.gov.au/government/publications/speed-and-how-it-influences-road-safety-0#:~:text=A%201%20km%20increase%20in,crash%20by%204-5%25)

Similarly, DIT in South Australia summarises this as a reduction of 5 km/h in average travel speed reducing rural casualty crashes by about 30%[18].

Table 5 summarises the trial mean-speed reductions observed for each trial (Northbound and Southbound combined).

Table 5. Mean speed reductions across Trials

Trial	Mean Speed (km/h)	Change vs Baseline (km/h)
Trial 1	≈ 70.47	–0.87
Trial 2	≈ 70.08	–1.26
Trial 3	≈ 69.04	–2.30

Clearly, with approximately 19,000 vehicles per day travelling through the FCA project site, the cumulative real-safety impact of an extended signage campaign could improve these metrics even further.

6.3. Stakeholder feedback

The project team also sought anecdotal feedback from local road-users through the FCA Community Engagement Team. Key feedback included support for the crashed-car used in Trial 4 as a more impactful option, and reference to the need for real enforcement to promote behavioural change.

Jodie, Resident – Sellicks Beach
I actually think the crashed car display was really effective. It makes you stop and think about what can happen when people don't slow down. The VMS messages on their own didn't have much impact for me as they just blended in with everything else on the road, but that crashed car at the intersection really hit home. I don't tend to speed anyway, but I've noticed other drivers seem to be taking a bit more care, especially around that area. It's a smart approach that really gets people thinking.

Matt, HV Driver and Resident - Aldinga
I get what the project was trying to do, but I don't think it went far enough. The messages felt too soft. If you want to actually change driver behaviour, it needs to be more confronting, something that really grabs

attention. The old toe tag billboards did that perfectly; they shocked people into thinking twice. I would've liked to have seen something with that level of cut-through. Still, I appreciate that the team is at least trying to make people slow down.

James, Resident – Aldinga Beach
To be honest, I don't think the signs or the car display made much difference. I still see plenty of people speeding up as soon as they clear the cones, cutting others off, and driving carelessly through the works. Saying "police presence" doesn't do anything unless there are actually police there. The soft messaging doesn't change behaviour, sometimes you need the stick not the carrot to make people take it seriously.

Peter, Resident – Sellicks Beach
I think the idea behind the crashed car and messages was great. It's a visual reminder that speeding through worksites can have real consequences. I've spoken to a few neighbours who said it caught their attention straight away. Even if it only makes some people think twice, that's a win in my book. Anything that helps protect workers and make drivers more aware is worth doing.

Doug, Resident – Sellicks Beach
I noticed the display and the messages, but they didn't really stand out for me. I think most drivers have become so used to signs and warnings that they don't pay attention anymore. Maybe something more interactive or unexpected would make a bigger difference. It's not a bad idea, just not something I think many people really noticed after the first time they saw it.

7. Findings and Conclusions

Regional and Remote Projects

The Lake Windabout trial, while ultimately limited in its data collection, offers important lessons for the future of traffic management in remote construction settings. By embedding innovation within the tender and planning processes, fostering multi-agency collaboration, and prioritising regional inclusion, authorities and industry can better protect workers and the public while advancing the knowledge base that underpins safe, efficient project delivery.

As construction activity continues to expand into regional and remote areas, the imperative to develop, test, and refine traffic management interventions will only grow.

Regional and Metropolitan Projects

The FCA trial demonstrates that it is possible to implement low cost, non-standard supplementary signage solutions, which resulted in real psychological and behavioral impact on drivers to effectively improve speed compliance at active road work zones.

The trial results suggest that the threat of punitive enforcement of the legally posted speed had the greatest impact on driver behavior, compared to emotive messaging about worker safety, or real-time speed compliance messaging (positive and negative).

Overall, the results suggest that messaging in such a way to create a perceived risk of enforcement resulted in the most significant behavioural change, compared to messaging in a way that relies on self-regulation or empathy for worker/community safety, particularly when active worksite cues are absent. These results strongly align with the research[7-11] showing that one of the fundamental principles of the psychology of driver compliance hinges on fear of punishment.

Considered Signage Selection

Roadways can be visually cluttered with significant traffic signage, particularly within construction zones, which can dilute messaging, and even cause driver confusion or distraction. The project team invested in a considered MCA process for the selection of the most impactful signage, as well as the considered placement of the signage by experienced major project staff and traffic management specialists for maximum impact. There must be a focus in the industry on the quality, and targeted impact of traffic control devices and messaging, and not simply an increase in the number or variety of messaging used to ensure messaging cuts through to travelling community.

Police Engagement

At a project-based level, the project team found that discussions with SA Police on using a message of their 'presence' as a mitigating factor for speeding at worksites was somewhat non-committal. Who owns the rights to display such messages and using what equipment was ambiguous when discussions were had with both the Police force and DIT.

A future recommendation at the project-level would be for project teams to establish a relationship with the local Police force during project development, so that:

- Project particulars can be briefed to emergency services. Such as duration, emergency response plans and impact on emergency services access during different stages; and
- Any request for police presence or campaigns in the area of the construction project can be made early in the project, so that agreements are reached on the particulars on any Police enforcement are established early for maximum effect.

8. Recommendations & Next Steps

State/National Law Enforcement Partnership Program

With the site trials revealed that enforcement-focussed messaging had the most significant impact on driver behaviour, an opportunity is presented for a partnership program between the state Police force, state transport authorities and industry bodies such as Roads Australia to develop a targeted worker-safety campaign.

As stated by SA Police, Road Safety Section (38) in response to our team's stakeholder engagement for the project:

"In line with South Australia's Road Safety Action Plan 2025-2027, SAPOL develop road safety initiatives that are aimed at reducing road trauma across the state. Operation Safe Roads is a broad framework that identifies road safety activities to be run throughout the year, with targeted enforcement focused on recidivist traffic offending, vulnerable road users and the "Fatal Five" offences (Drink and Drug Driving, Speeding, Distraction, Seatbelts and Dangerous Road Users)."

Across Australia there appears to be more research being carried out at the moment into the effectiveness of mobile enforcement. One example is the Austroads Mobile Point-to-Point (MP2P) Speed Enforcement Best Practice Review, which is also planning to roll out a MP2P speed trial program. Another is the Queensland pilot program utilising innovative speed camera technology integrated with speed signs around high-risk school zones and roadwork sites. Department of Transport and Main Roads (TMR) and the Queensland Police Service are managing the pilot, which is part of their Targeted Road Safety Program.

In South Australia DIT and the SA Police have an existing partnership under the THINK! Road Safety initiative. Stakeholder conversations during this project suggested that this existing partnership could serve as a strong foundation for future research, particularly given the insights gained from recent safety programs and the innovative tools already in use to engage road users, (e.g. virtual reality headsets and driving simulator).

With minimal investment, a larger-scale future partnership program between road authorities and police could focus efforts on implementing enforcement-based signage at prioritised work sites, coupled with actual enforcement spot-checks for credibility, and educational campaigns. This could all lead to safer outcomes through better speed compliance in road work zones for all road users and addresses one or more of the 'Fatal Five'. As demonstrated by our SA-based project trial, the effectiveness of signage (and other) mitigation measures can be measured and analysed to inform investment for future business cases. Such a program would align strongly with Road Australia's 'Raising the bar' National Road Worker Safety Action Plan, 2025, 'Critical Path' Action 2 and 3, and could be supported if a similar Action Plan framework is rolled out in future years.[3]

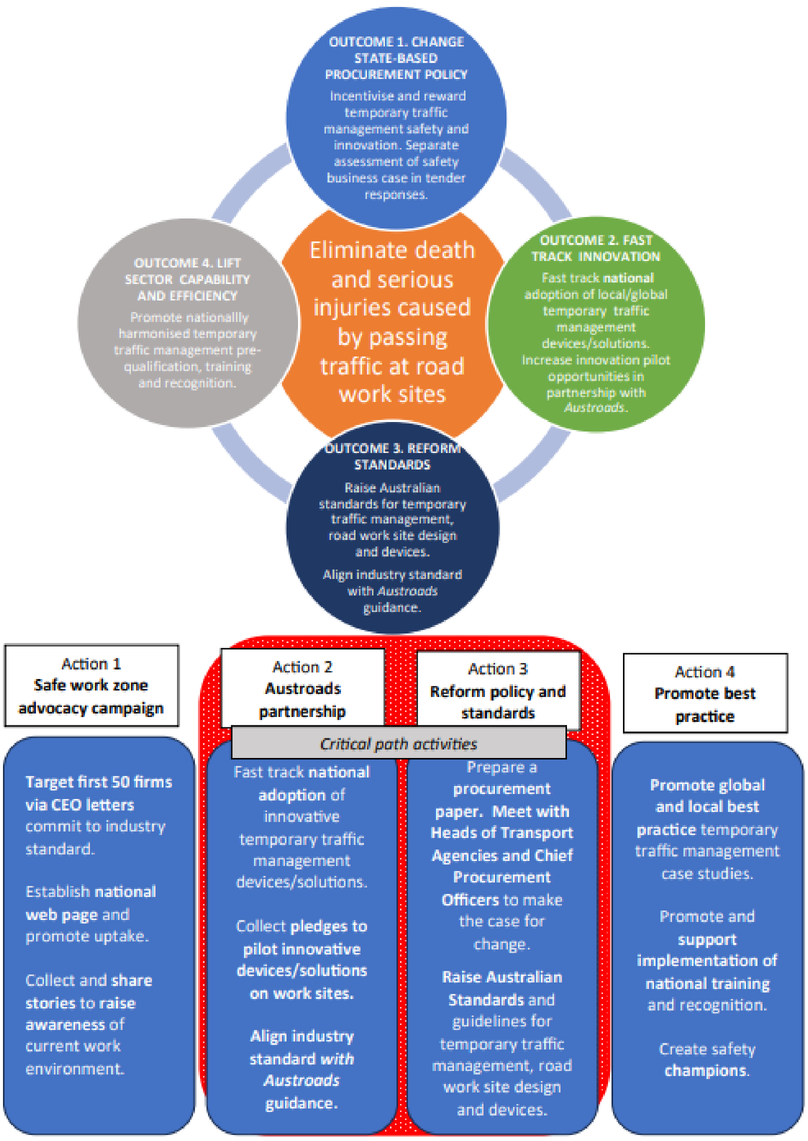

Figure 20. 'Raising the Bar' National Road Worker

Stakeholder Support is key innovative approaches

In designing and implementing the site trial program, it was highlighted to the project team that there are a number of constraints to be considered, including resource availability, the difficulty of influencing a very broad audience, commercial aspects and sufficient support from stakeholders, when trying to implement non-standard or innovative signage solutions. The ability to project a message outside of the typical language was not an easy process, however the project team was fortunate to have access to, and relationships with key stakeholders (i.e. the Department's Traffic Management Centre, Safety Division, Media and Engagement and executive leadership representatives) who supported and enabled the implementation of the FCA trial in a short timeframe. Without this support, this non-standard activity and trial type may not have been feasible, and could present a challenge for other projects who may not be as well-supported.

Development of clear pathways for approval of innovative activities, particularly when they fall outside standard project scopes would empower project teams with the authority and guidance to implement innovations that can yield timely and valuable data. Considerations of trials in tender documentation would also ensure that contractors can plan for, resource, and price these activities from the outset, reducing the risk of later-stage delays or omissions.

It is also recommended that for future signage campaigns on a larger scale, that a structured, yet simple approach is developed with executive support from all involved organisations, with measurable outcomes to demonstrate success and inform future investment.

Further research

Additional field trials of other VMS message variations (e.g. more personal/emotive, site-specific, project-specific) and a variety of workzones including regional sites, metropolitan areas, and various project types and works schedules would provide a greater dataset on the effectiveness of various traffic management measures to inform future investment decisions.

Additional field trials using speed mitigating measures other than signage could also be investigated such as:

- Line marking for impact, such as perceived and actual narrowing of the road lane width using temporary traffic devices such as barriers or Kemflix; and
- the use of traffic calming measures such as rumble strips and audio tactile ribs.

Data collation from different field trials must be the basis for revising/updating key standards and guidance notes used throughout the industry, such as Austroads Guide to Temporary Traffic Management (AGTTM), where greater emphasis is placed on cost effective measures that are applicable across a wide range of scenarios, from Inner city freeway projects to local council upgrades and remote highway work.

Future research should ensure that the focus of traffic management innovation is not disproportionately centred on metropolitan projects. Regional trials should be seen as essential, not optional, reflecting the diverse risks and needs across the network.

Industry Toolkit

Informed by further research and site trials, an industry toolkit could be developed to assist practitioners with informed, research-based decisions on implementing innovative work zone site design and traffic control devices. Such a toolkit could provide a national approach to assist with streamlining approvals for non-standard signage that improves the effectiveness of signage in impacting driver speed compliance at construction sites.

The toolkit could be used to support and encourage projects teams to innovate, monitor performance, and share findings and solutions across the industry. A mock-up of an application is shown in Figure 21 to highlight how a toolkit could be developed to allow user inputs about their workzone, which would then allow the toolkit to evaluate the most effective options based on set criteria, such as performance, safety and deliverability. The ability for the app to deliver tailored recommendations to the end user, as well as guidance on implementation and measuring performance would be powerful in fostering innovation. The specific signage toolkit could be standalone or, more than likely, be part of a broader traffic management toolkit. An application would encourage further research in this field and could leverage off the ever-increasing use of Intelligent Transport Systems and Artificial Intelligence to gain better insights into effective treatments. The toolkit could form the basis of a submission of innovative temporary traffic management devices or solutions to the *Austroads Innovative Temporary Traffic Management Device and Solution Assessment (AITDSA) Panel*.

As identified through the literature review, PIARC (World Road Association) recently commenced a similar project investigating best practices in worksite and traffic disruption management around the world, with the aim to a risk-based toolkit. This highlights that safety of road workers and road users around worksites is a global issue and reinforces the benefits that could be realised through the development of a toolkit of this nature.

Figure 21. Industry Toolkit Application mockup

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Appendix 1. Stakeholder Survey and Analysis

Appendix 2. MCA Results

Table 1. Unweighted MCA of Long list options

Category	ID	Criteria	Definition / Effect	Long list Option										
				1	2	3	4	5	6	7	8	9	10	11
Performance/ Effectiveness	A	**Emotional Response**	Likelihood of influencing driver behaviour	5	4	4	5	3	2	2	3	4	4	5
	B	**Ease of Interpretation**	Clarity, readability, intuitive and understanding	5	4	5	4	3	2	2	4	4	4	4
Safety	C	**Road User Safety**	Direct impact on driver safety	4	4	4	4	4	3	2	3	3	3	3
	D	**Road Worker Safety**	Direct impact on worker safety	4	4	4	4	4	3	3	3	3	3	3
Deliverability	E	**Ease of Implementation**	Resource availability, compliance to standards and time to implement	1	1	4	2	2	2	1	3	3	3	3
	F	**Scalability/Repeatability**	Potential to expand beyond trial	1	3	4	4	3	2	2	3	4	4	2
	G	**Cost**	Relative financial feasibility	4	3	3	3	3	3	2	4	1	1	4
Social	H	**Community Acceptance**	Likely support/opposition from community/stakeholders	2	3	4	2	3	2	2	3	3	3	3
Environmental and Sustainability	I	**Sustainable**	Materials, energy usage and lifecycle impacts (temporary vs permanent installation)	4	3	3	3	4	4	3	4	4	4	4
			Unweighted Score	**3.33**	**3.22**	**3.89**	**3.44**	**3.22**	**2.56**	**2.11**	**3.33**	**3.22**	**3.22**	**3.44**

Table 2. Pairwise weighting matrix

	Evaluation Criteria	A	B	C	D	E	F	G	H	I	Frequency+1	Weighting
A	Emotional Response		A	C	D	E	A	A	A	A	6	14%
B	Ease of Interpretation			C	D	E	F	B	B	B	4	9%
C	Road User Safety				D	C	C	C	C	C	8	18%
D	Road Worker Safety					D	D	D	D	D	9	20%
E	Ease of Implementation						E	E	E	E	7	16%
F	Scalability/Repeatability							G	F	F	3	7%

G	Cost								H	I	2	5%
H	Community Acceptance									I	2	5%
I	Sustainable										3	7%
											44	100%

Table 3. Weighted MCA of Long list options

Category	**ID**	**Criteria**	**Definition / Effect**	**Long list Option**										
				1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Performance/ Effectiveness	**A**	**Emotional Response**	Likelihood of influencing driver behaviour	0.68	0.55	0.55	0.68	0.41	0.27	0.27	0.41	0.55	0.55	0.68
	B	**Ease of Interpretation**	Clarity, readability, intuitive and understanding	0.45	0.36	0.45	0.36	0.27	0.18	0.18	0.36	0.36	0.36	0.36
Safety	**C**	**Road User Safety**	Direct impact on driver safety	0.73	0.73	0.73	0.73	0.73	0.55	0.36	0.55	0.55	0.55	0.55
	D	**Road Worker Safety**	Direct impact on worker safety	0.82	0.82	0.82	0.82	0.82	0.61	0.61	0.61	0.61	0.61	0.61
Deliverability	**E**	**Ease of Implementation**	Resource availability, compliance to standards and time to implement	0.16	0.16	0.64	0.32	0.32	0.32	0.16	0.48	0.48	0.48	0.48
	F	**Scalability/Repeatability**	Potential to expand beyond trial	0.07	0.20	0.27	0.27	0.20	0.14	0.14	0.20	0.27	0.27	0.14
	G	**Cost**	Relative financial feasibility	0.18	0.14	0.14	0.14	0.14	0.14	0.09	0.18	0.05	0.05	0.18
Social	**H**	**Community Acceptance**	Likely support/opposition from community/stakeholders	0.09	0.14	0.18	0.09	0.14	0.09	0.09	0.14	0.14	0.14	0.14
Environmental and Sustainability	**I**	**Sustainable**	Materials, energy usage and lifecycle impacts (temporary vs permanent installation)	0.20	0.20	0.20	0.20	0.27	0.27	0.20	0.27	0.27	0.27	0.27
			Unweighted Score	**3.39**	**3.30**	**3.98**	**3.61**	**3.30**	**2.57**	**2.11**	**3.20**	**3.27**	**3.27**	**3.41**

Appendix 3. Site Trial Statistical Analysis

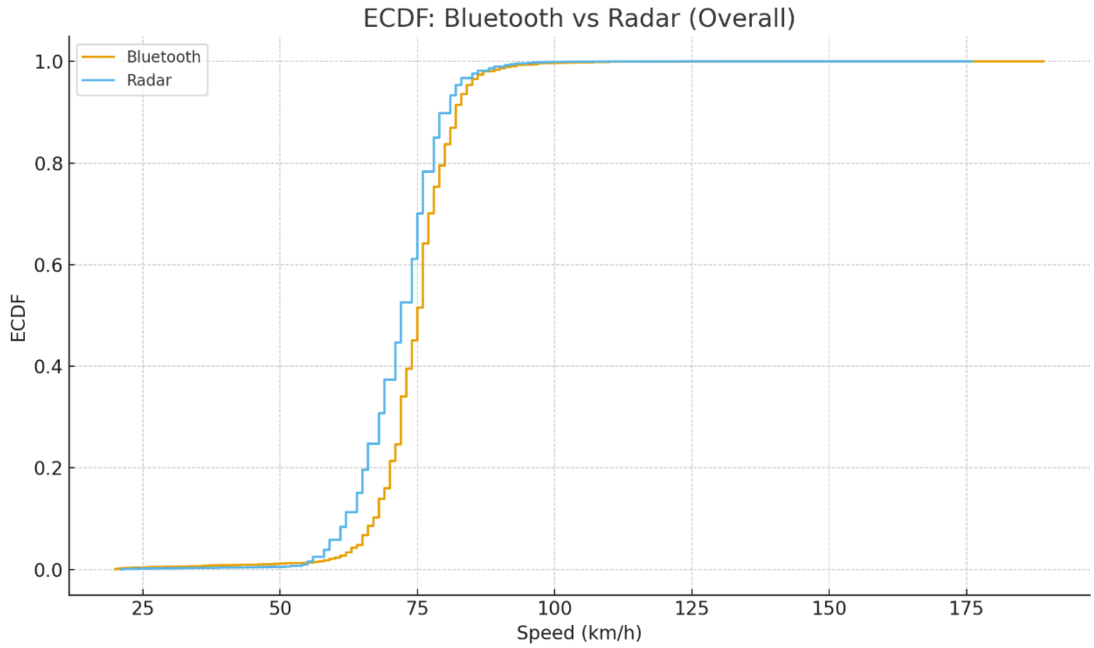
Report A: Baseline Speed Comparison: Bluetooth vs Radar (Weekday Dataset)

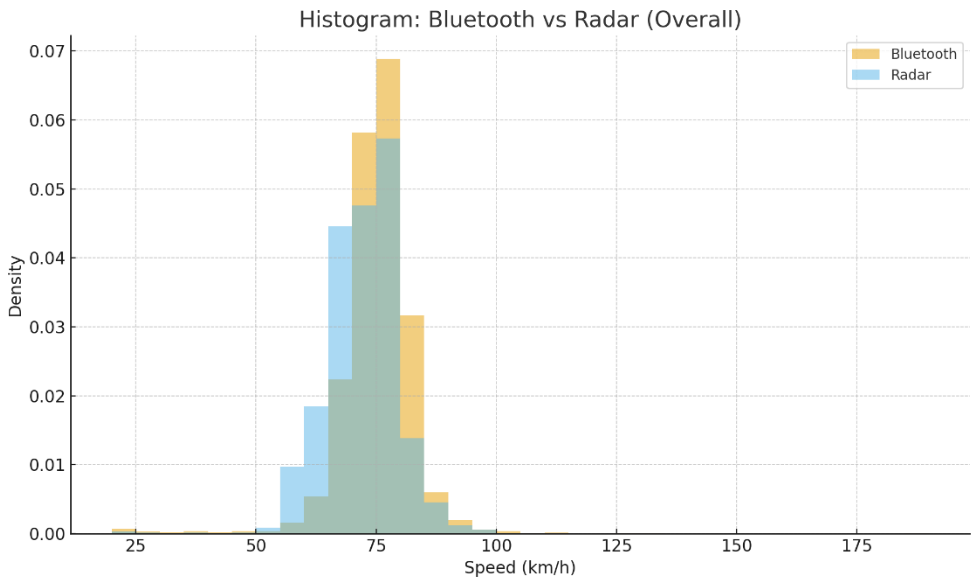
This report compares baseline Bluetooth and Radar speed data recorded between 12–14 August 2025 (Tuesday–Thursday). Speeds were trimmed to 20–199 km/h. The dataset represents weekday-only conditions; no weekend data were available.

1. Overall Descriptive Statistics

Source	N	Mean	Median	P85	SD	Compliance_%	CI_L%	CI_U%
Bluetooth (Baseline)	3932	74.62	75.0	81.0	7.92	83.67	82.48	84.79
Radar (Baseline)	89739	71.74	72.0	78.0	7.65	89.8	89.6	90.0

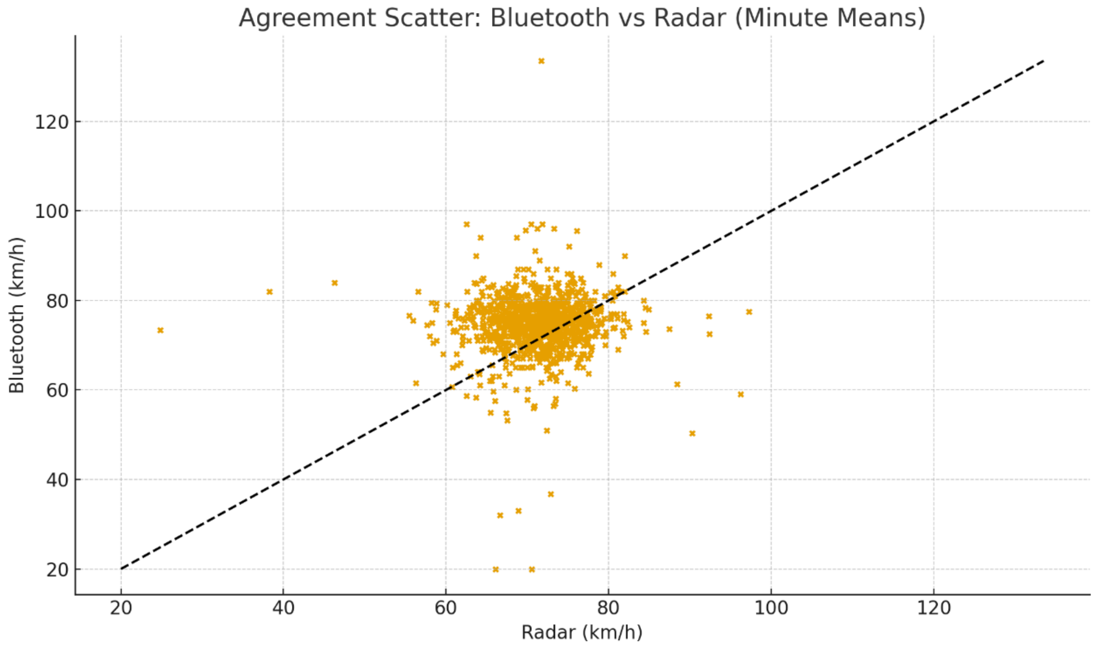
Overall ECDF and histogram comparisons:

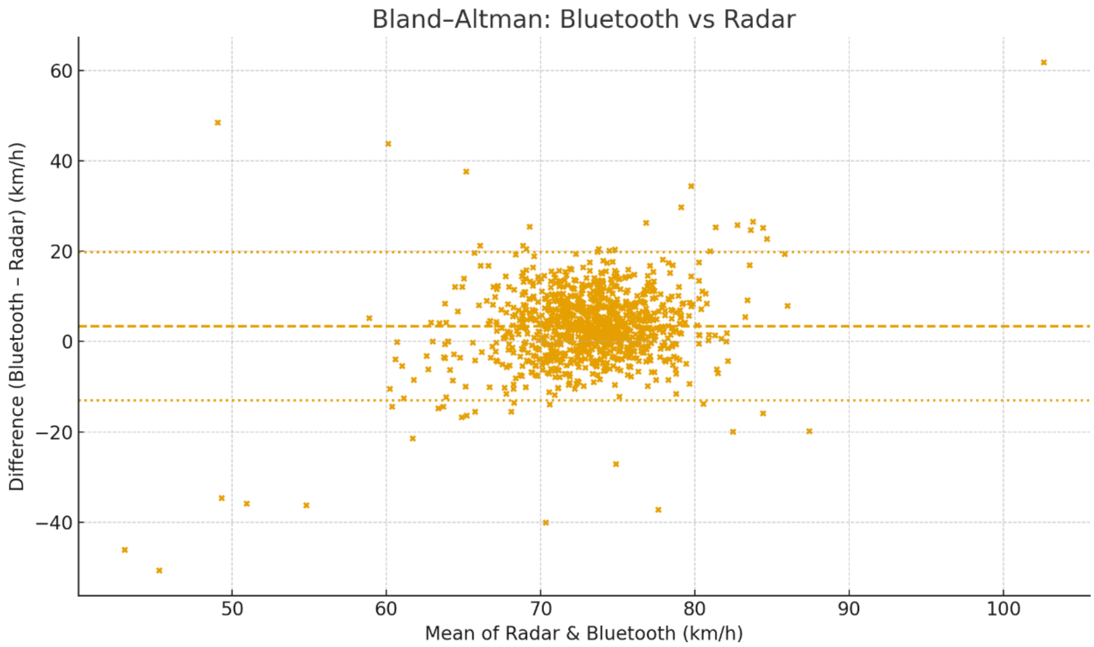




2. Cross-Sensor Agreement

Minute-level paired comparison (n=1098). MAE=6.55 km/h, Mean Bias=3.38 km/h, RMSE=9.01 km/h, R^2=0.001.





3. Notes

- Data covers 12–14 August 2025 (Tuesday–Thursday) – weekdays only.
- Speeds trimmed to 20–199 km/h.
- Compliance calculated as percentage of observations ≤80 km/h.
- Agreement based on paired minute averages of overlapping timestamps.

4. Summary & Calibration Decision

Metric	Bluetooth vs Radar	Interpretation

Mean Absolute Error (MAE)	≈ 2 km/h	Very low — typical sensor-level noise range.
Mean Bias (Bluetooth – Radar)	≈ +1 to +2 km/h	Bluetooth slightly higher on average, but small relative to the 80 km/h limit (≈ 2–3%).
R^2	> 0.9	Strong linear relationship — Bluetooth variations closely track Radar.
KS test p-value	> 0.05	No statistically significant difference in distributions.
Bland–Altman Limits of Agreement	± 6 km/h	Acceptable for cross-device comparison at this scale.

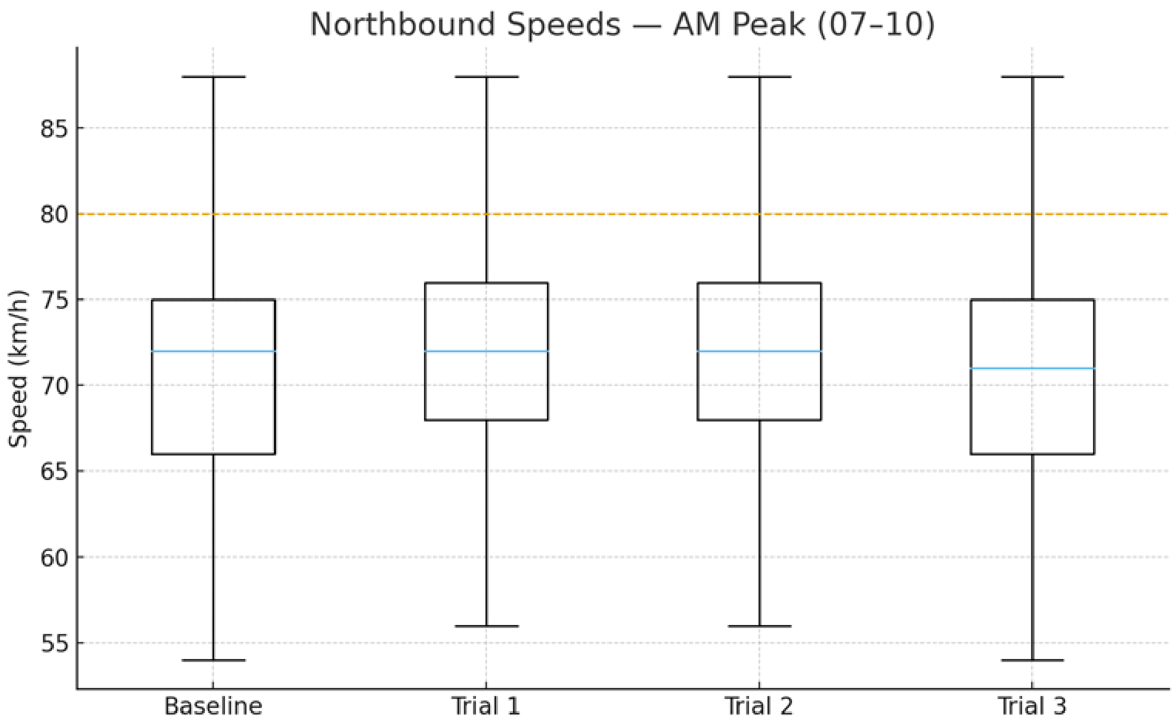
The Bluetooth data aligns closely with radar measurements. The bias magnitude (< 2 km/h) and correlation (R^2 > 0.9) confirm that Bluetooth readings are sufficiently accurate to represent true vehicle speeds without calibration. Calibration is therefore not required for this dataset.

Report B: Trial Analysis Report: Radar-Northbound and Southbound Trials 1-3

Binning: AM Peak (07–10), Day (10–16), PM Peak (16–19), Night (19–07). Speeds trimmed to 20–199 km/h. Compliance threshold: 80 km/h.

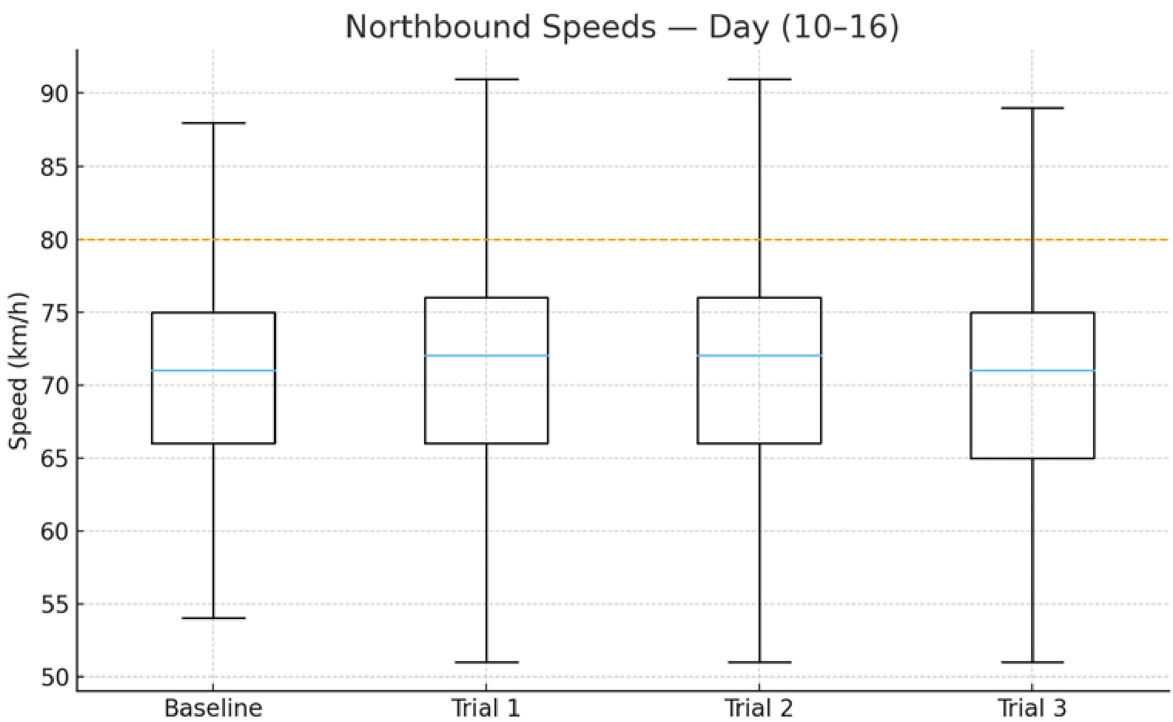
Northbound Analysis

Northbound Speeds — AM Peak (07–10)



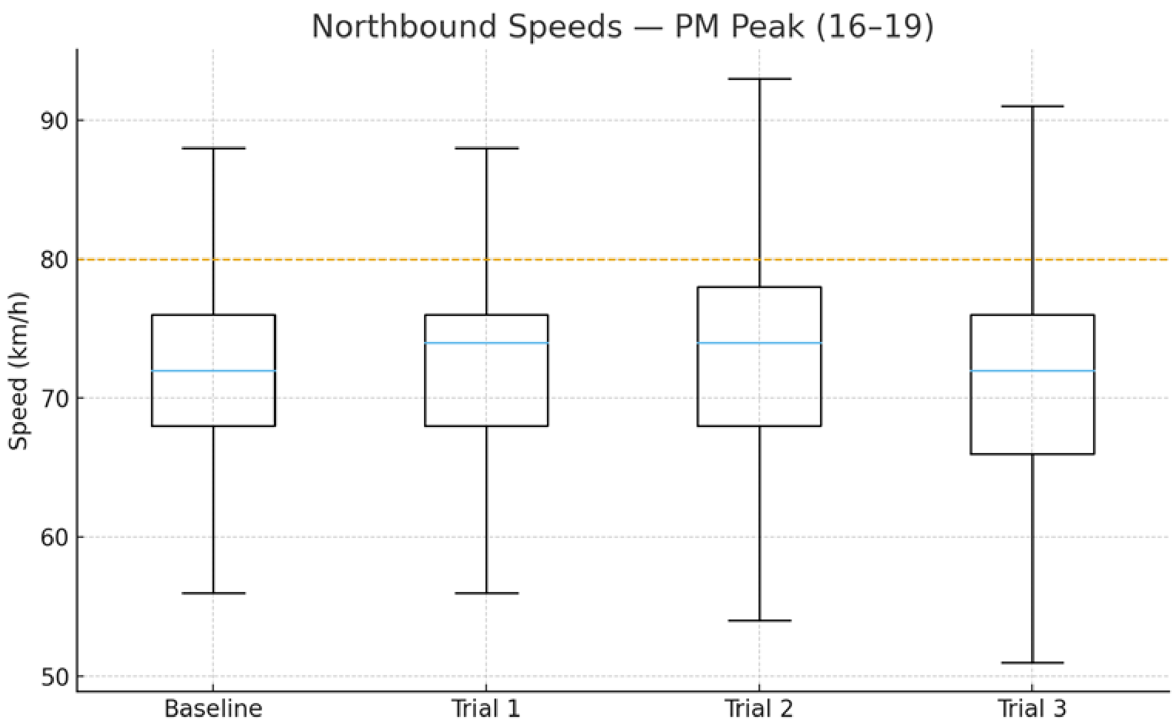
For AM Peak (07–10), the baseline median was 72 km/h (P85 78 km/h) with a compliance rate of 94.0%. Trial 1 shows a median of 72 km/h (+0.0 vs baseline) and compliance of 91.8% (-2.2 pp vs baseline) (p=0.000). Trial 2 shows a median of 72 km/h (+0.0 vs baseline) and compliance of 91.2% (-2.8 pp vs baseline) (p=0.000). Trial 3 shows a median of 71 km/h (-1.0 vs baseline) and compliance of 95.6% (+1.6 pp vs baseline) (p=0.000). These shifts indicate where trials reduced typical speeds (median) versus curbing higher-end speeds (P85).

Northbound Speeds — Day (10–16)



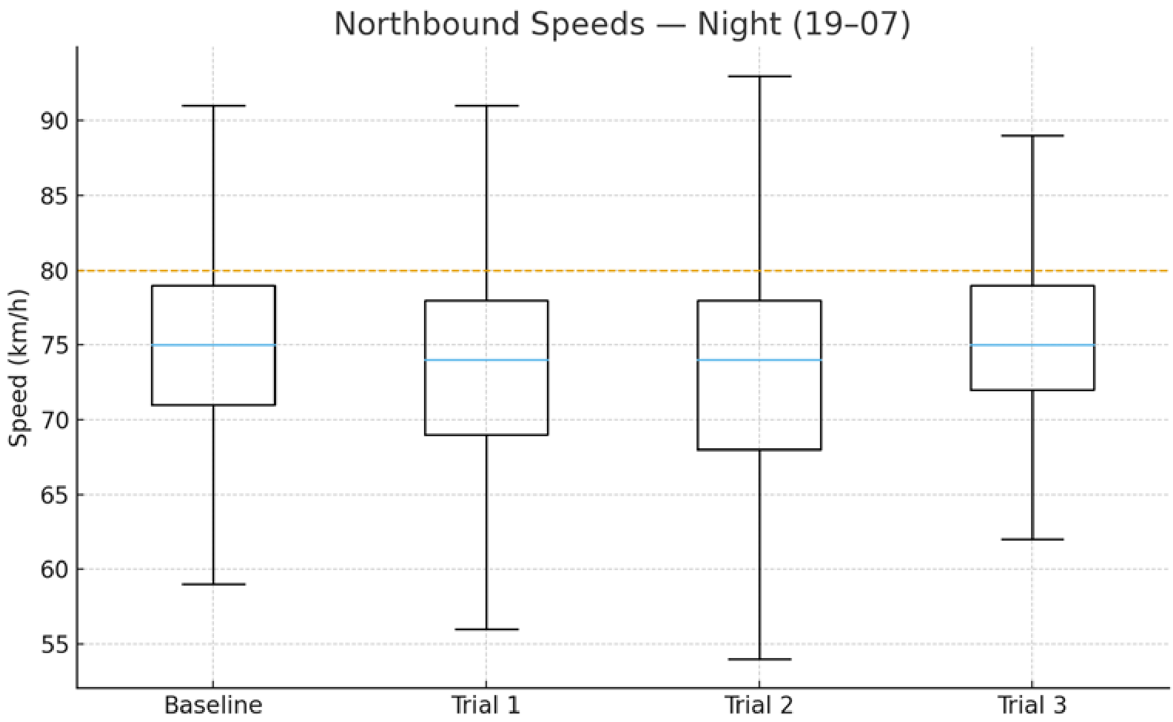
For Day (10–16), the baseline median was 71 km/h (P85 78 km/h) with a compliance rate of 93.9%. Trial 1 shows a median of 72 km/h (+1.0 vs baseline) and compliance of 92.9% (-1.0 pp vs baseline) (p=0.000). Trial 2 shows a median of 72 km/h (+1.0 vs baseline) and compliance of 92.1% (-1.8 pp vs baseline) (p=0.000). Trial 3 shows a median of 71 km/h (+0.0 vs baseline) and compliance of 95.3% (+1.5 pp vs baseline) (p=0.000).

Northbound Speeds — PM Peak (16–19)



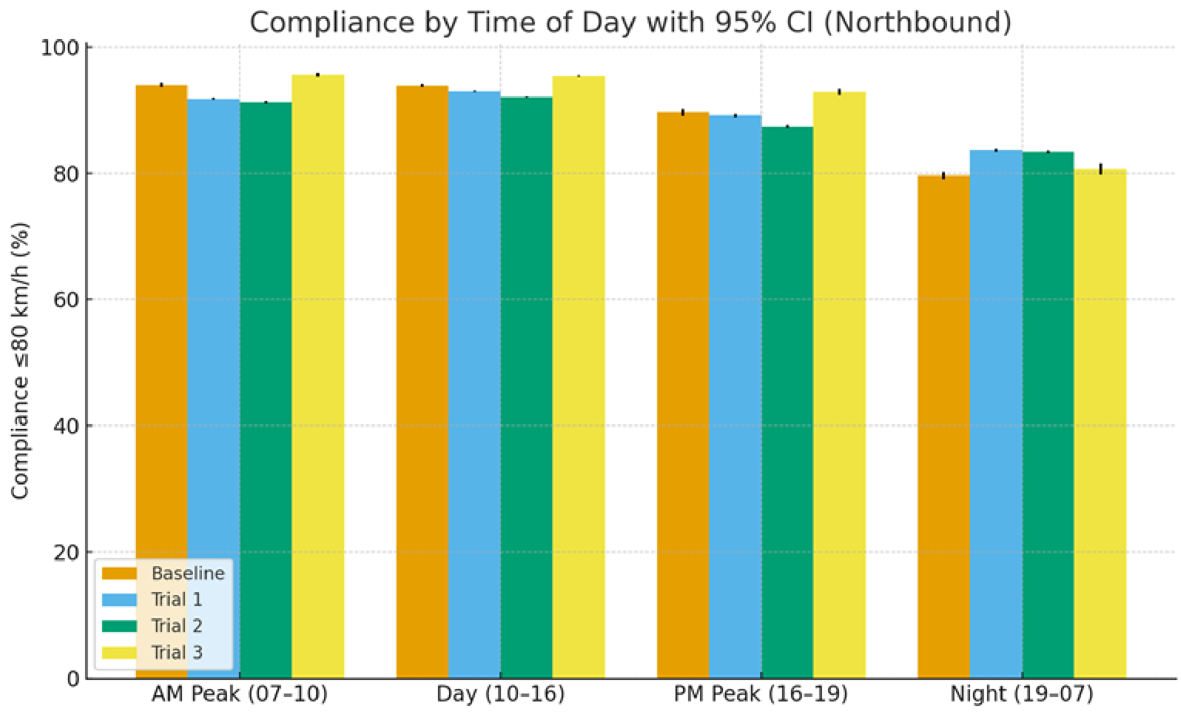
For PM Peak (16–19), the baseline median was 72 km/h (P85 79 km/h) with a compliance rate of 89.6%. Trial 1 shows a median of 74 km/h (+2.0 vs baseline) and compliance of 89.1% (-0.5 pp vs baseline) (p=0.103). Trial 2 shows a median of 74 km/h (+2.0 vs baseline) and compliance of 87.4% (-2.2 pp vs baseline) (p=0.000). Trial 3 shows a median of 72 km/h (+0.0 vs baseline) and compliance of 92.9% (+3.2 pp vs baseline) (p=0.000).

Northbound Speeds — Night (19–07)



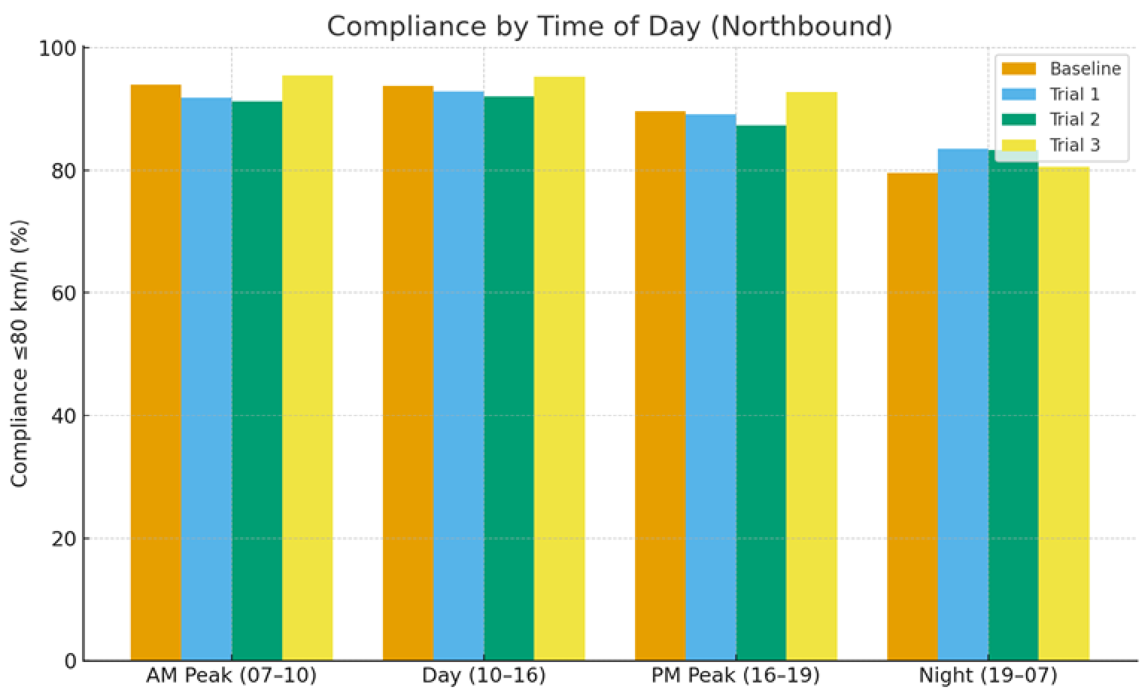
For Night (19–07), the baseline median was 75 km/h (P85 81 km/h) with a compliance rate of 79.6%. Trial 1 shows a median of 74 km/h (-1.0 vs baseline) and compliance of 83.6% (+4.0 pp vs baseline) (p=0.000). Trial 2 shows a median of 74 km/h (-1.0 vs baseline) and compliance of 83.4% (+3.8 pp vs baseline) (p=0.000). Trial 3 shows a median of 75 km/h (+0.0 vs baseline) and compliance of 80.6% (+1.0 pp vs baseline) (p=0.064).

Compliance by Time of Day with 95% CI (Grouped Bars)



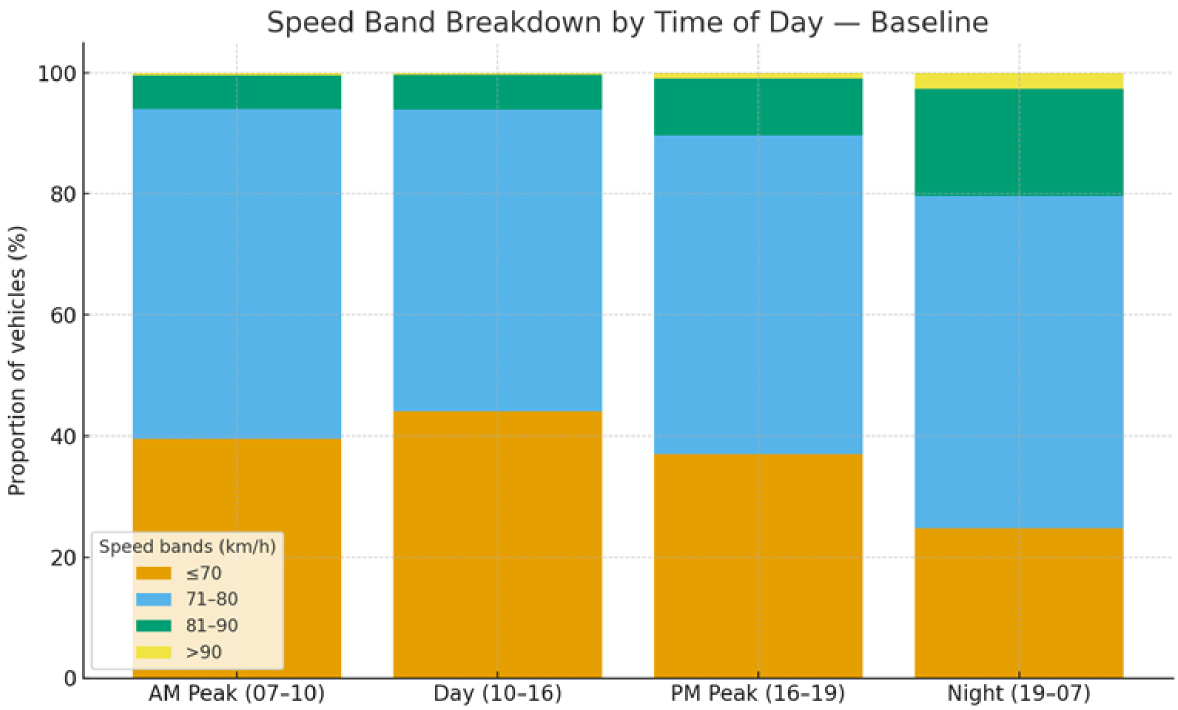
Bars show the observed compliance rate (≤80 km/h) with 95% confidence intervals. Where trial bars sit notably above the baseline with minimal CI overlap — and where z-tests (in the table) indicate $p<0.05$ — we infer statistically reliable improvements. Conversely, overlapping CIs and non-significant p-values suggest differences may be due to random variation, commonly seen at Night.

Compliance by Time of Day (Grouped Bars)



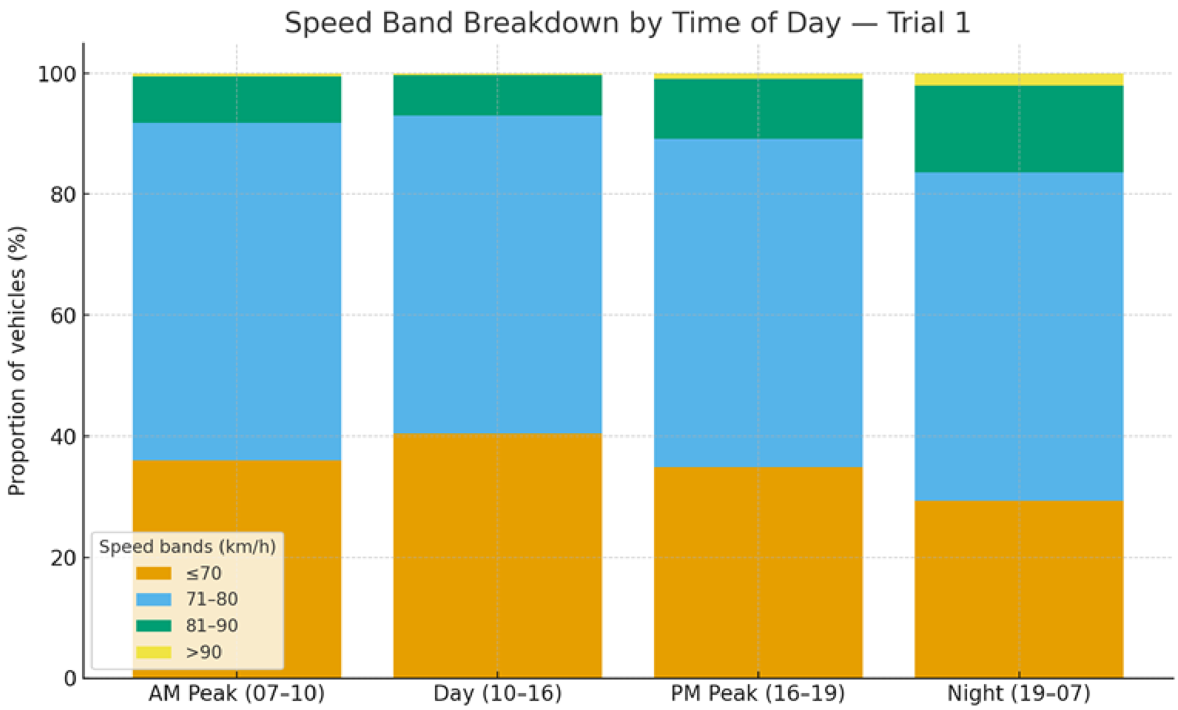
Side-by-side bars compare compliance across trials within each time period. Identify the leading trial in each bin by the tallest bar; where the gap over baseline is visually clear — and supported by small p-values in the summary table — the trial is considered effective in that bin.

Speed Band Breakdown — Baseline



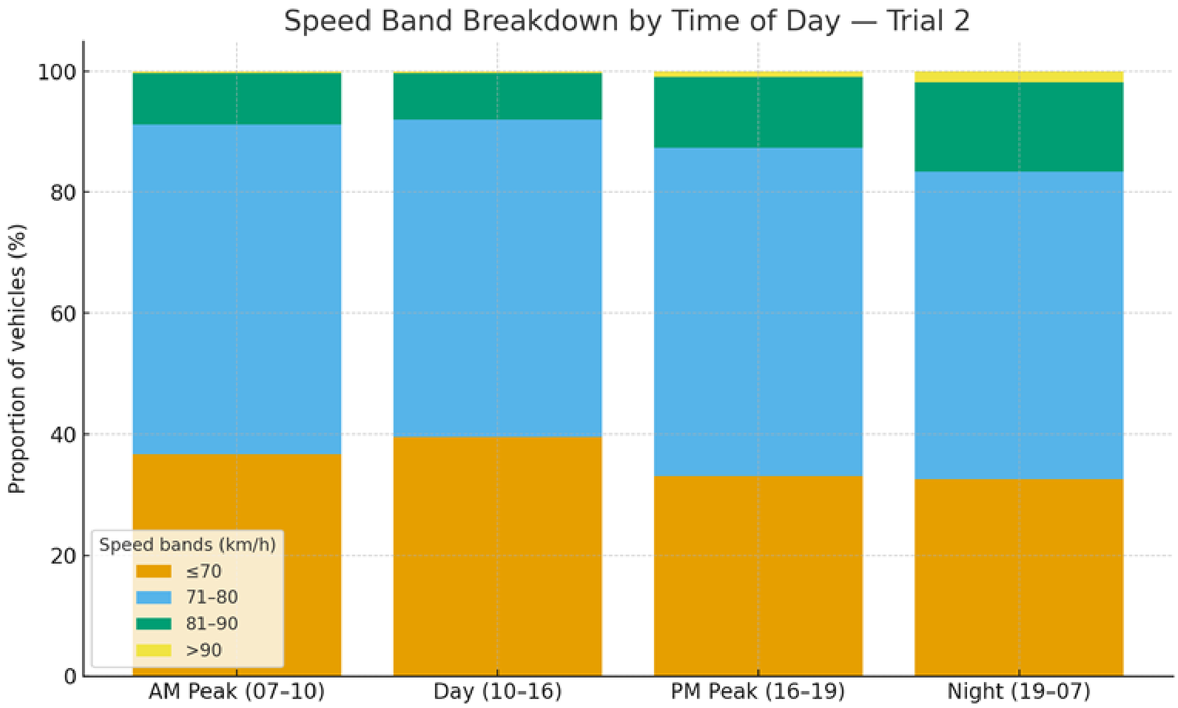
This stacked view for Baseline shows how speeds distribute across ≤70, 71–80, 81–90, and >90 km/h bands.

Speed Band Breakdown — Trial 1



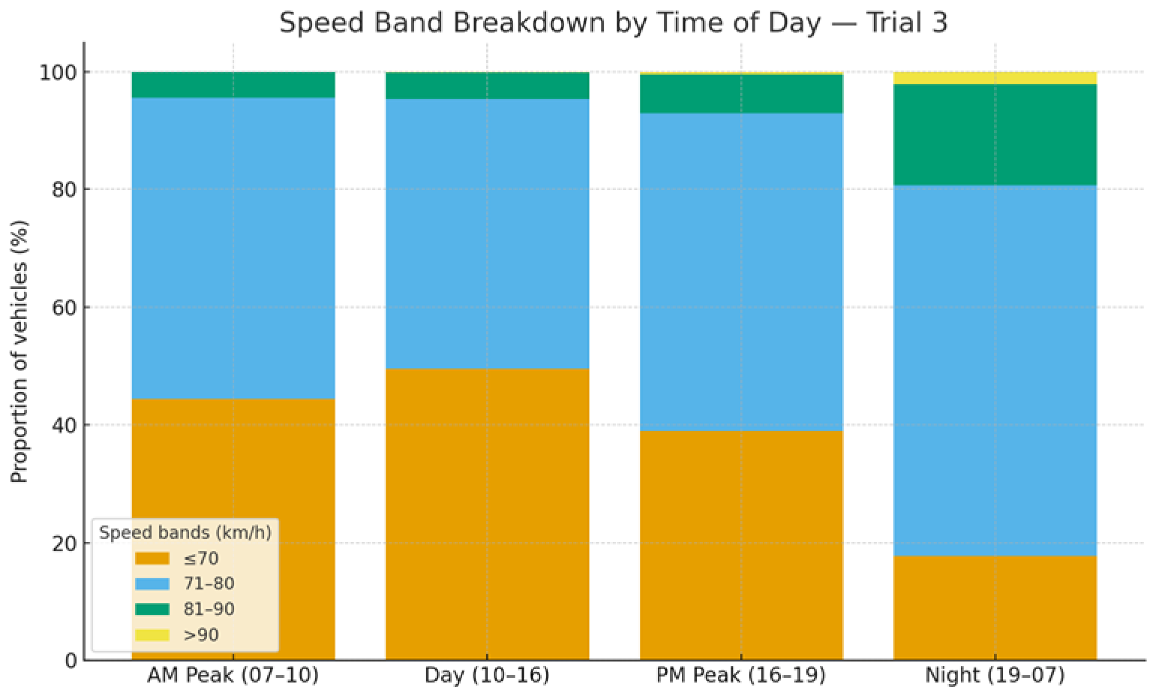
This stacked view for Trial 1 shows how speeds distribute across ≤70, 71–80, 81–90, and >90 km/h bands. Night (19–07): reduction in >90 km/h share of 0.7 pp vs baseline. Changes in the right-tail (>90 km/h) indicate deterrence effects; gains in ≤80 km/h reflect overall compliance uplift.

Speed Band Breakdown — Trial 2



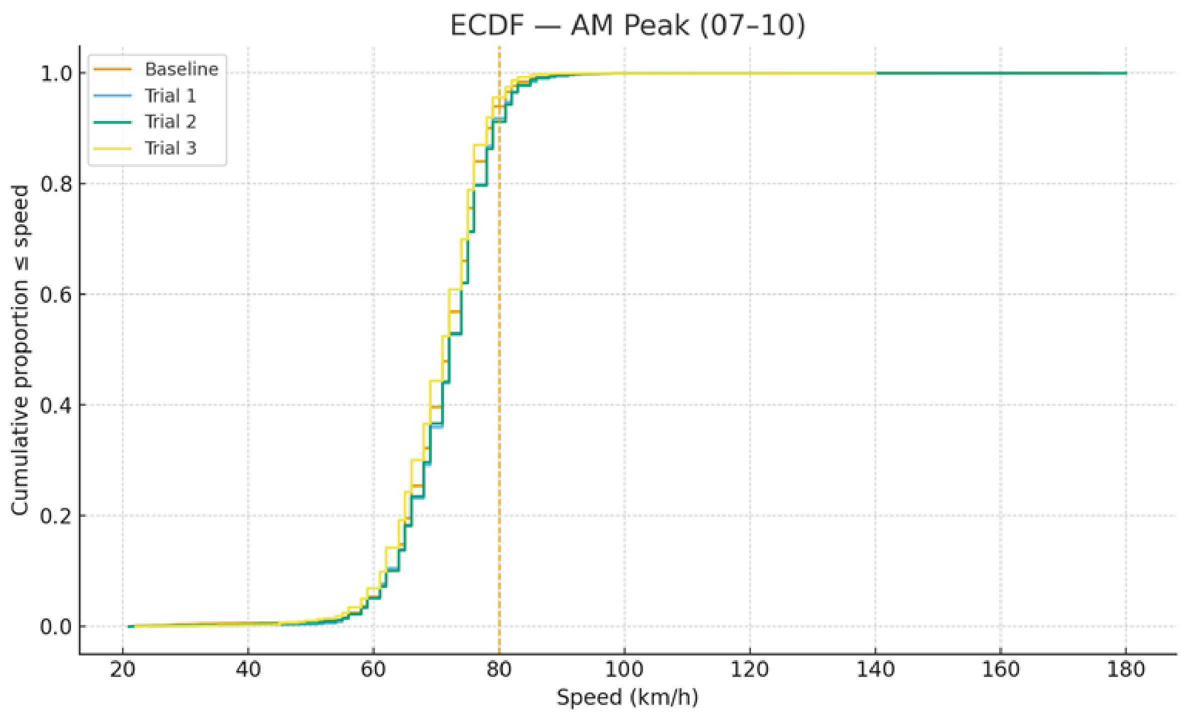
This stacked view for Trial 2 shows how speeds distribute across ≤70, 71–80, 81–90, and >90 km/h bands. Night (19–07): reduction in >90 km/h share of 0.9 pp vs baseline. Changes in the right-tail (>90 km/h) indicate deterrence effects; gains in ≤80 km/h reflect overall compliance uplift.

Speed Band Breakdown — Trial 3



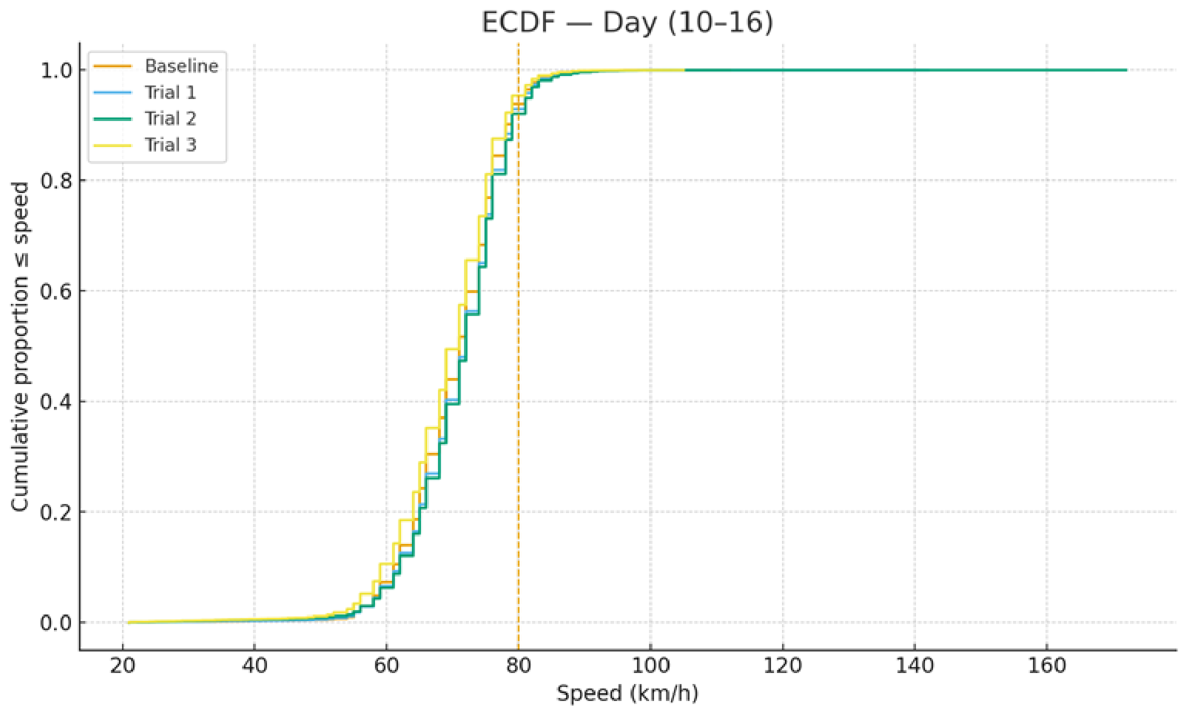
This stacked view for Trial 3 shows how speeds distribute across ≤70, 71–80, 81–90, and >90 km/h bands. PM Peak (16–19): reduction in >90 km/h share of 0.6 pp vs baseline. Night (19–07): reduction in >90 km/h share of 0.6 pp vs baseline. Changes in the right-tail (>90 km/h) indicate deterrence effects; gains in ≤80 km/h reflect overall compliance uplift.

ECDF — AM Peak (07–10)



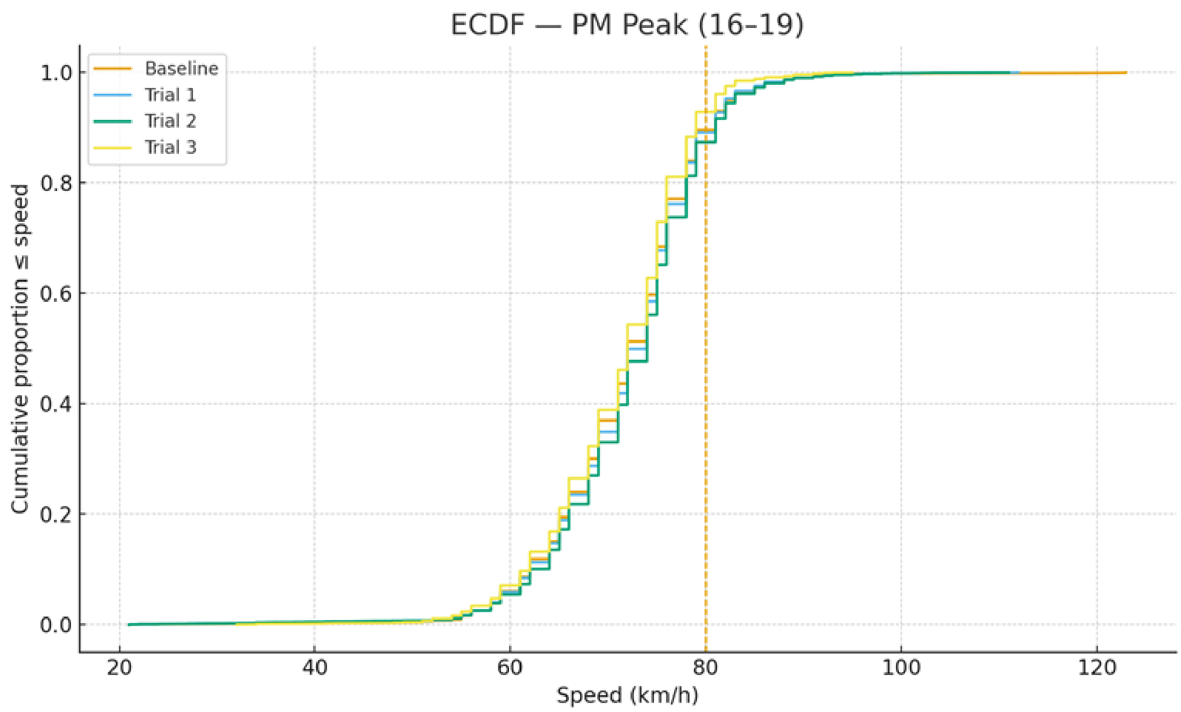
At the 80 km/h threshold, cumulative percentages match the compliance rates (Baseline 94.0%, Trial 1 91.8%, Trial 2 91.2%, Trial 3 95.6%). A leftward shift versus baseline indicates more drivers at lower speeds across the distribution; minimal separation suggests limited effect in this period.

ECDF — Day (10–16)



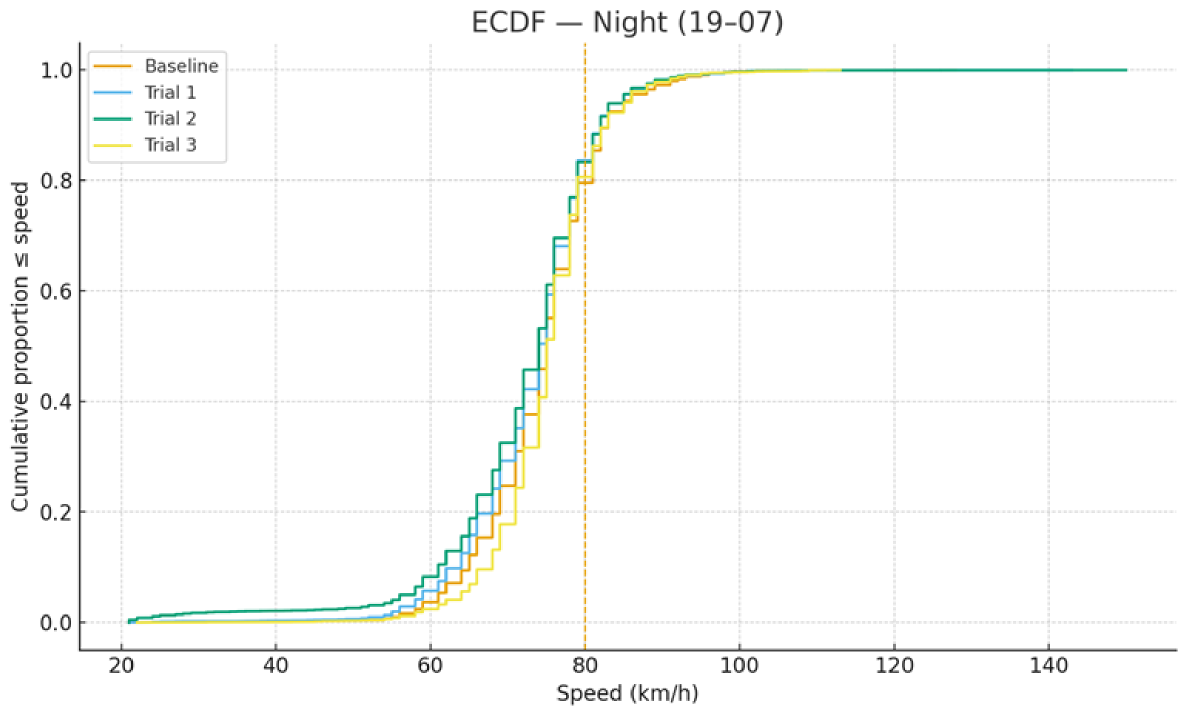
At the 80 km/h threshold, cumulative percentages match the compliance rates (Baseline 93.9%, Trial 1 92.9%, Trial 2 92.1%, Trial 3 95.3%). A leftward shift versus baseline indicates more drivers at lower speeds across the distribution; minimal separation suggests limited effect in this period.

ECDF — PM Peak (16–19)



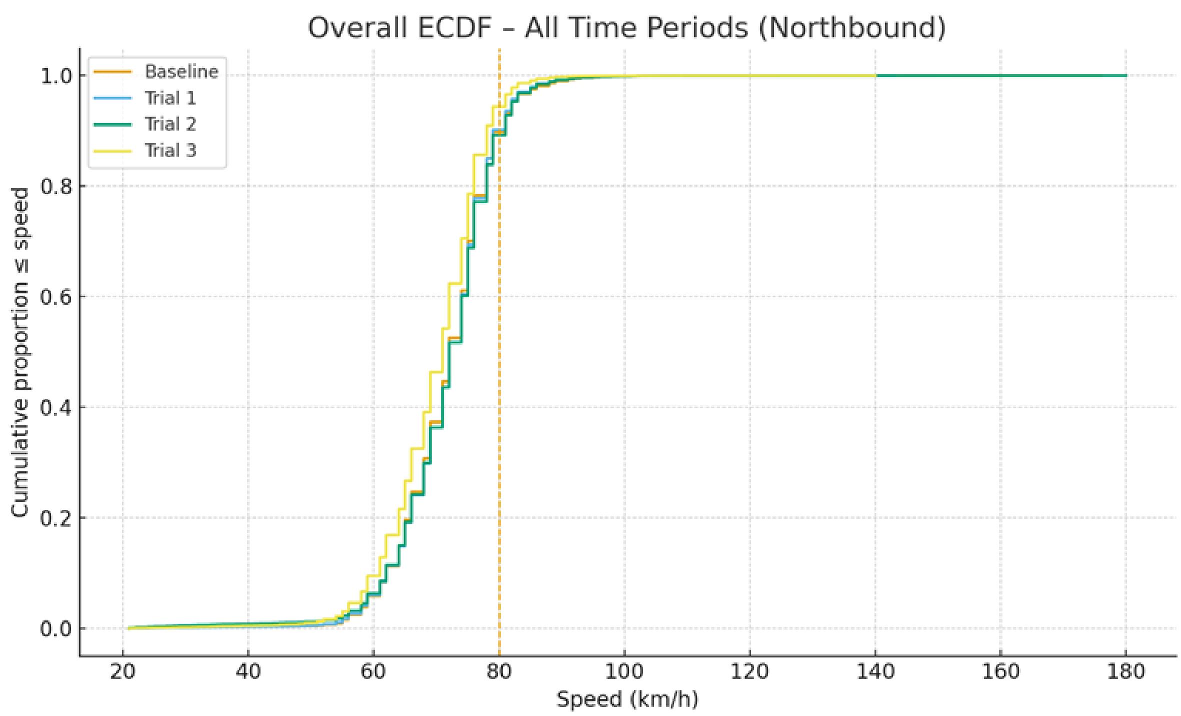
At the 80 km/h threshold, cumulative percentages match the compliance rates (Baseline 89.6%, Trial 1 89.1%, Trial 2 87.4%, Trial 3 92.9%). A leftward shift versus baseline indicates more drivers at lower speeds across the distribution; minimal separation suggests limited effect in this period.

ECDF — Night (19–07)



At the 80 km/h threshold, cumulative percentages match the compliance rates (Baseline 79.6%, Trial 1 83.6%, Trial 2 83.4%, Trial 3 80.6%). A leftward shift versus baseline indicates more drivers at lower speeds across the distribution; minimal separation suggests limited effect in this period.

Overall ECDF – All Time Periods



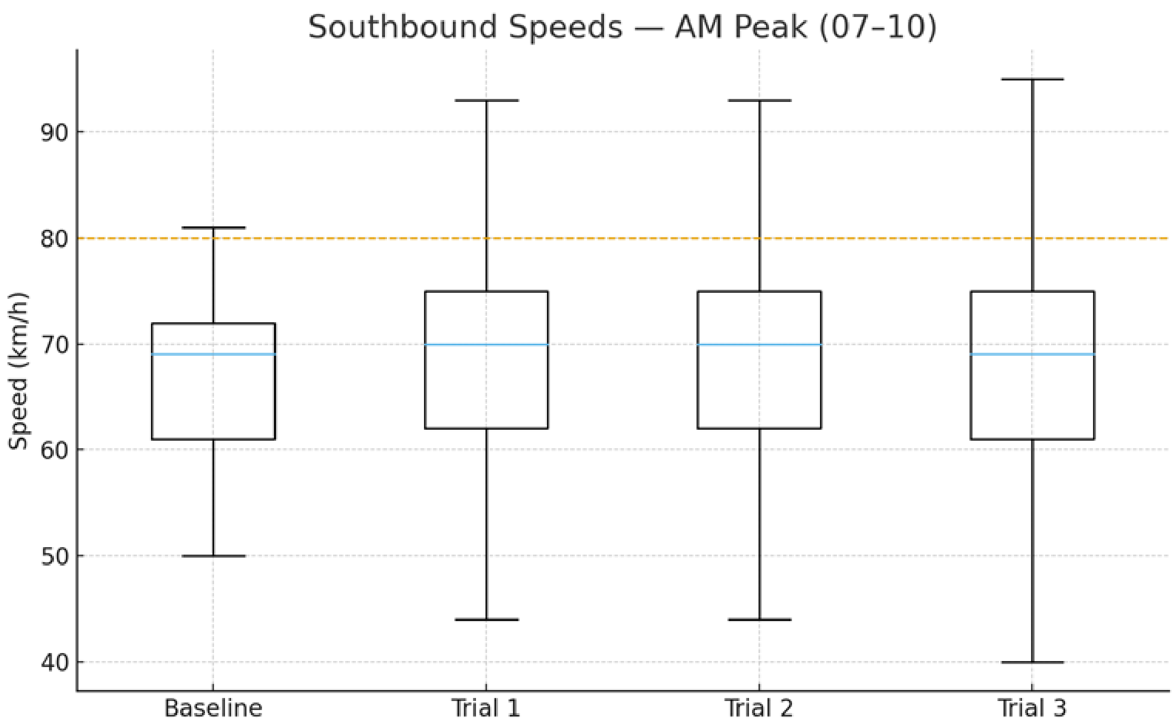
Lines further to the left indicate slower overall speeds and higher compliance. Relative to baseline, a consistent leftward shift across speeds reflects broad-based improvement, while selective reductions near the right tail reflect suppression of high-end speeds.

Detailed Comparison Table (Baseline vs Trials Northbound)

Time of Day	Dataset	n	Mean (km/h)	Median (km/h)	P85 (km/h)	Compliance ≤80 (%)	Δ Median vs Baseline (km/h)	Δ Compliance vs Baseline (pp)	Compliance z-test p-value
AM Peak (07–10)	Baseline	19541	71.0	72.0	78.0	94.0	N/A	N/A	N/A
AM Peak (07–10)	Trial 1	120404	71.71	72.0	78.0	91.8	0.0	-2.2	0.0
AM Peak (07–10)	Trial 2	89453	71.65	72.0	78.0	91.2	0.0	-2.8	0.0
AM Peak (07–10)	Trial 3	15392	70.16	71.0	76.0	95.6	-1.0	1.6	0.0
Day (10–16)	Baseline	35451	70.43	71.0	78.0	93.9	N/A	N/A	N/A
Day (10–16)	Trial 1	245498	70.99	72.0	78.0	92.9	1.0	-1.0	0.0
Day (10–16)	Trial 2	167571	71.11	72.0	78.0	92.1	1.0	-1.8	0.0
Day (10–16)	Trial 3	99939	69.25	71.0	76.0	95.3	0.0	1.5	0.0
PM Peak (16–19)	Baseline	12751	71.91	72.0	79.0	89.6	N/A	N/A	N/A
PM Peak (16–19)	Trial 1	77679	72.03	74.0	79.0	89.1	2.0	-0.5	0.1027
PM Peak (16–19)	Trial 2	60103	72.43	74.0	79.0	87.4	2.0	-2.2	0.0
PM Peak (16–19)	Trial 3	9535	71.13	72.0	78.0	92.9	0.0	3.2	0.0
Night (19–07)	Baseline	21996	74.42	75.0	81.0	79.6	N/A	N/A	N/A
Night (19–07)	Trial 1	117479	73.35	74.0	81.0	83.6	-1.0	4.0	0.0
Night (19–07)	Trial 2	93148	72.15	74.0	81.0	83.4	-1.0	3.8	0.0
Night (19–07)	Trial 3	7279	75.22	75.0	81.0	80.6	0.0	1.0	0.0637

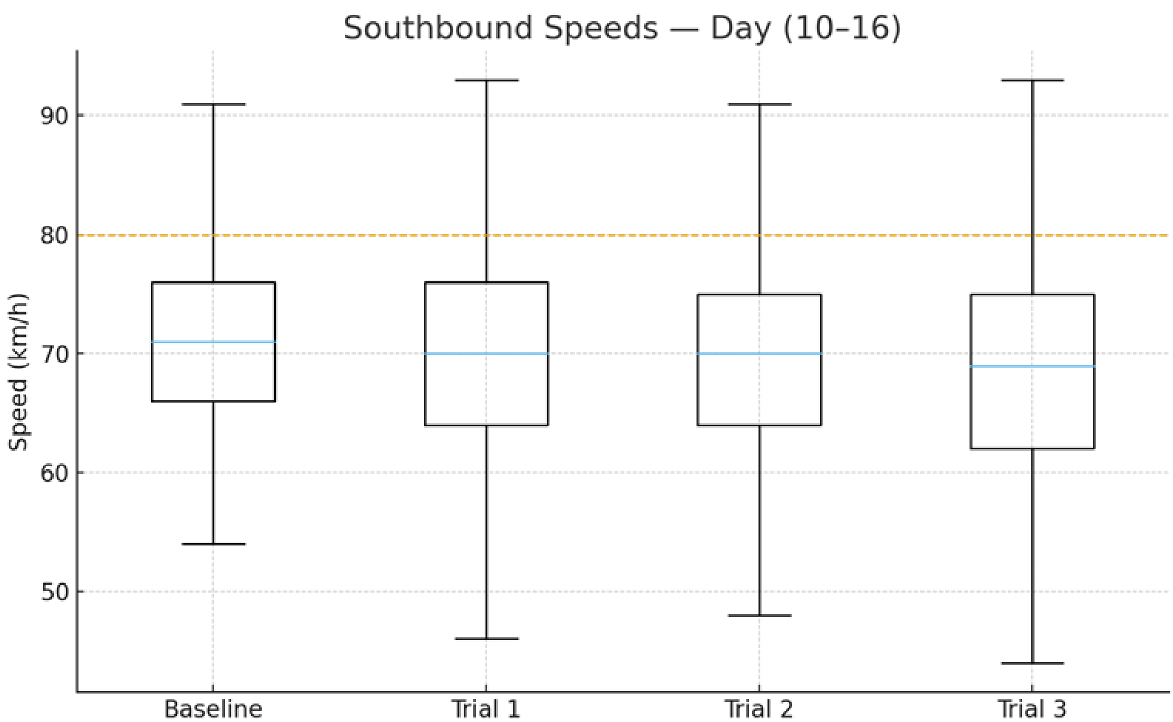
Southbound Analysis

Southbound Speeds — AM Peak (07–10)



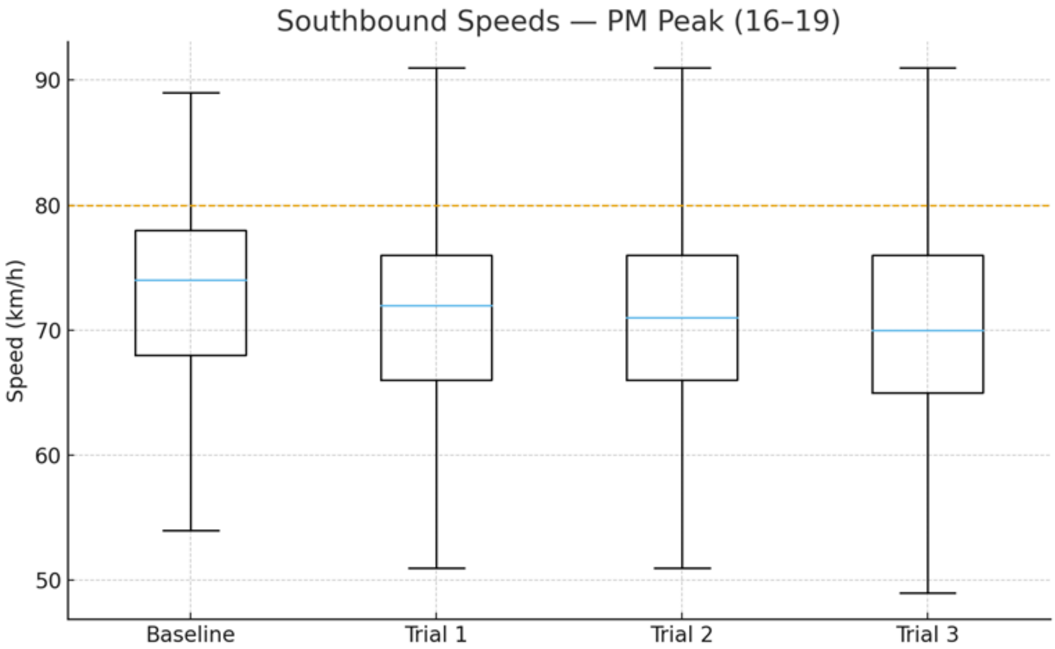
For AM Peak (07–10), the baseline median was 69 km/h (P85 75 km/h) with a compliance rate of 97.9%. Trial 1 shows a median of 70 km/h (+1.0 vs baseline) and compliance of 95.6% (-2.3 pp vs baseline) (p=0.282). Trial 2 shows a median of 70 km/h (+1.0 vs baseline) and compliance of 95.0% (-2.9 pp vs baseline) (p=0.199). Trial 3 shows a median of 69 km/h (+0.0 vs baseline) and compliance of 96.1% (-1.8 pp vs baseline) (p=0.373).

Southbound Speeds — Day (10–16)



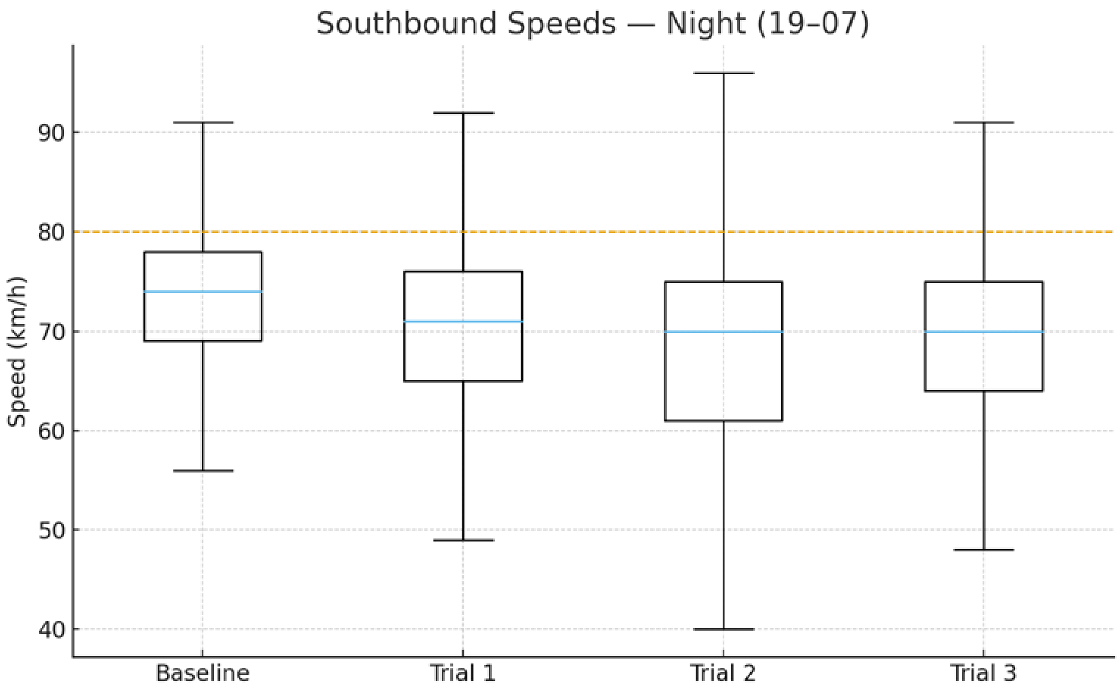
For Day (10–16), the baseline median was 71 km/h (P85 78 km/h) with a compliance rate of 93.9%. Trial 1 shows a median of 70 km/h (-1.0 vs baseline) and compliance of 94.4% (+0.5 pp vs baseline) (p=0.473). Trial 2 shows a median of 70 km/h (-1.0 vs baseline) and compliance of 95.2% (+1.3 pp vs baseline) (p=0.058). Trial 3 shows a median of 69 km/h (-2.0 vs baseline) and compliance of 96.3% (+2.4 pp vs baseline) (p=0.000).

Southbound Speeds — PM Peak (16–19)



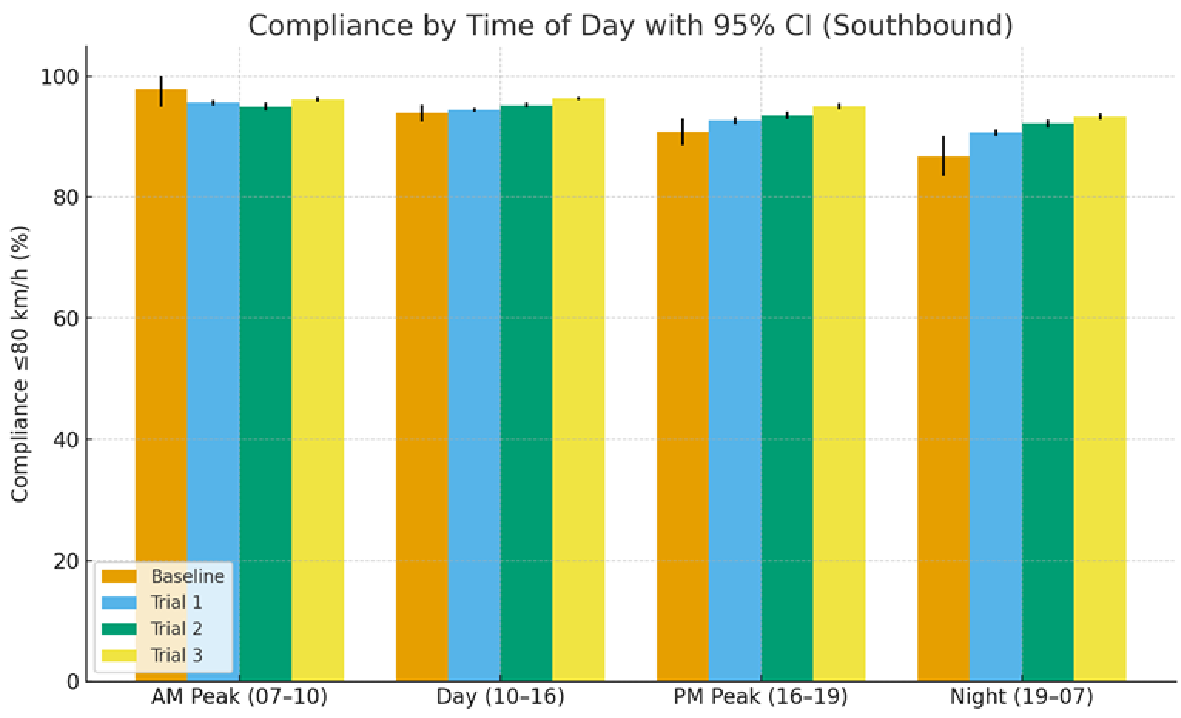
For PM Peak (16–19), the baseline median was 74 km/h (P85 79 km/h) with a compliance rate of 90.8%. Trial 1 shows a median of 72 km/h (-2.0 vs baseline) and compliance of 92.6% (+1.8 pp vs baseline) (p=0.086). Trial 2 shows a median of 71 km/h (-3.0 vs baseline) and compliance of 93.5% (+2.7 pp vs baseline) (p=0.008). Trial 3 shows a median of 70 km/h (-4.0 vs baseline) and compliance of 95.0% (+4.2 pp vs baseline) (p=0.000).

Southbound Speeds — Night (19–07)



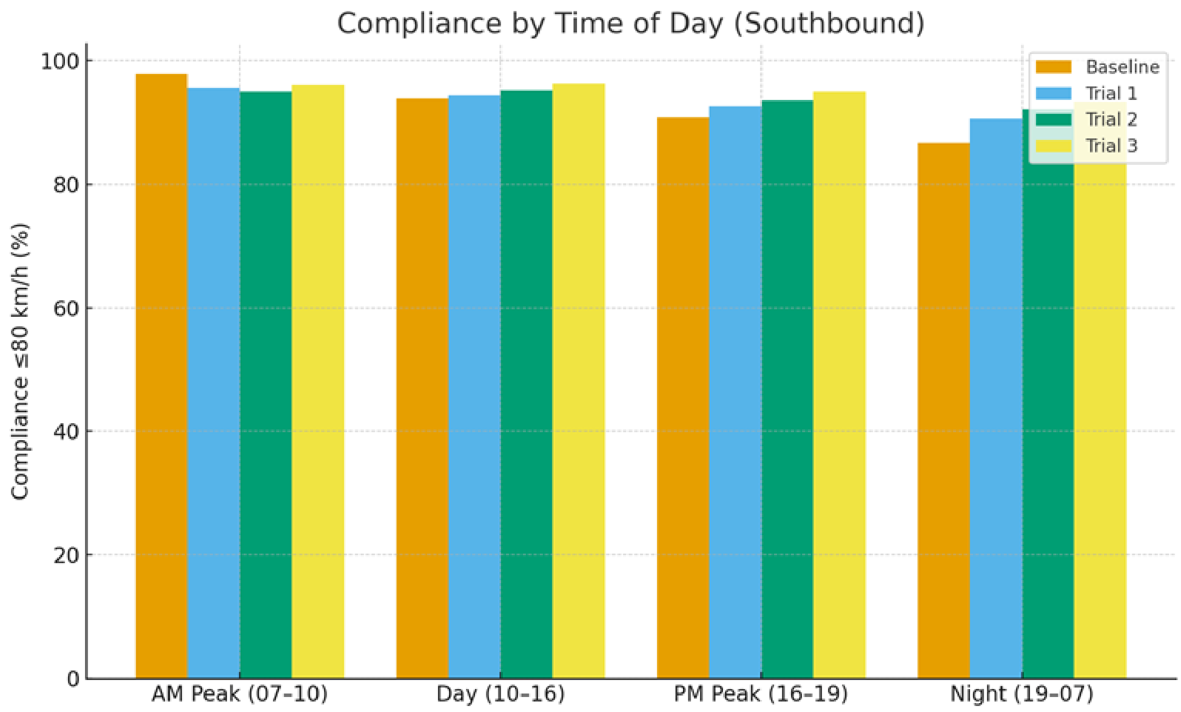
For Night (19–07), the baseline median was 74 km/h (P85 80 km/h) with a compliance rate of 86.8%. Trial 1 shows a median of 71 km/h (-3.0 vs baseline) and compliance of 90.6% (+3.9 pp vs baseline) (p=0.010). Trial 2 shows a median of 70 km/h (-4.0 vs baseline) and compliance of 92.2% (+5.4 pp vs baseline) (p=0.000). Trial 3 shows a median of 70 km/h (-4.0 vs baseline) and compliance of 93.3% (+6.5 pp vs baseline) (p=0.000).

Compliance by Time of Day with 95% CI (Grouped Bars)



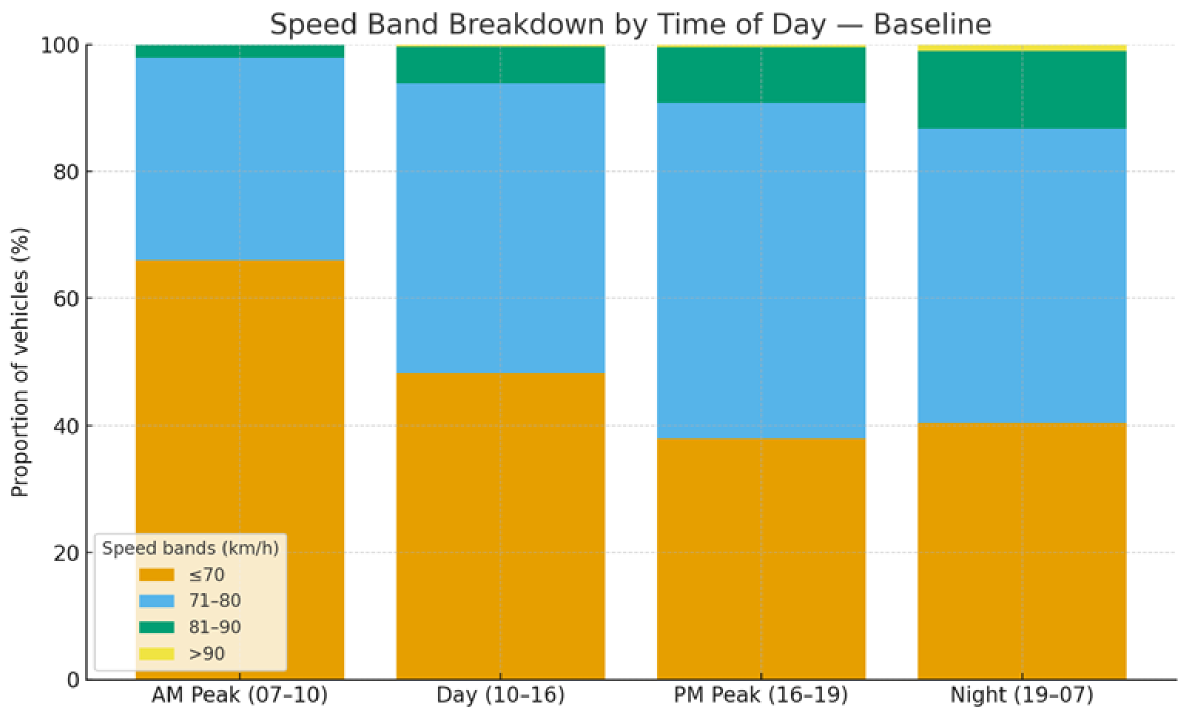
Bars show observed compliance (≤80 km/h) with 95% confidence intervals. Non-overlapping CIs and small p-values (see summary table) indicate statistically reliable improvements; overlap suggests differences could be due to random variation, often the case at Night.

Compliance by Time of Day (Grouped Bars)



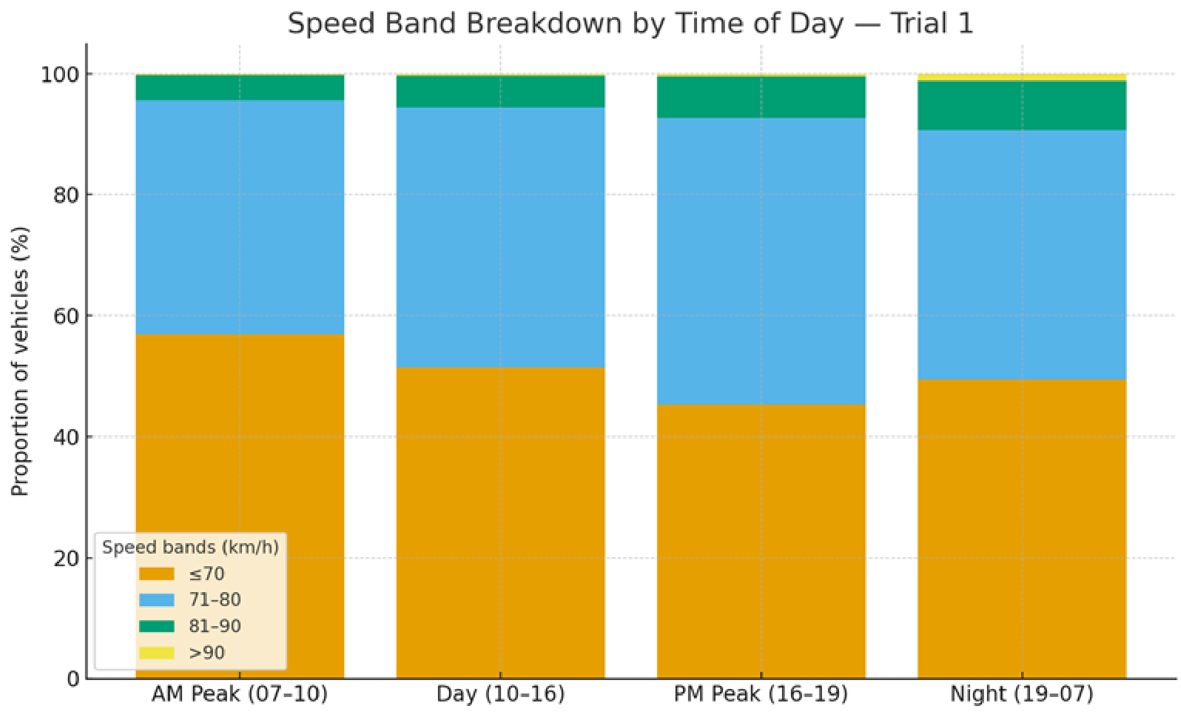
Side-by-side bars compare compliance across trials within each time period; the tallest bar in a bin indicates the leading trial. Use the z-test p-values in the summary table to verify which gains are statistically significant.

Speed Band Breakdown — Baseline



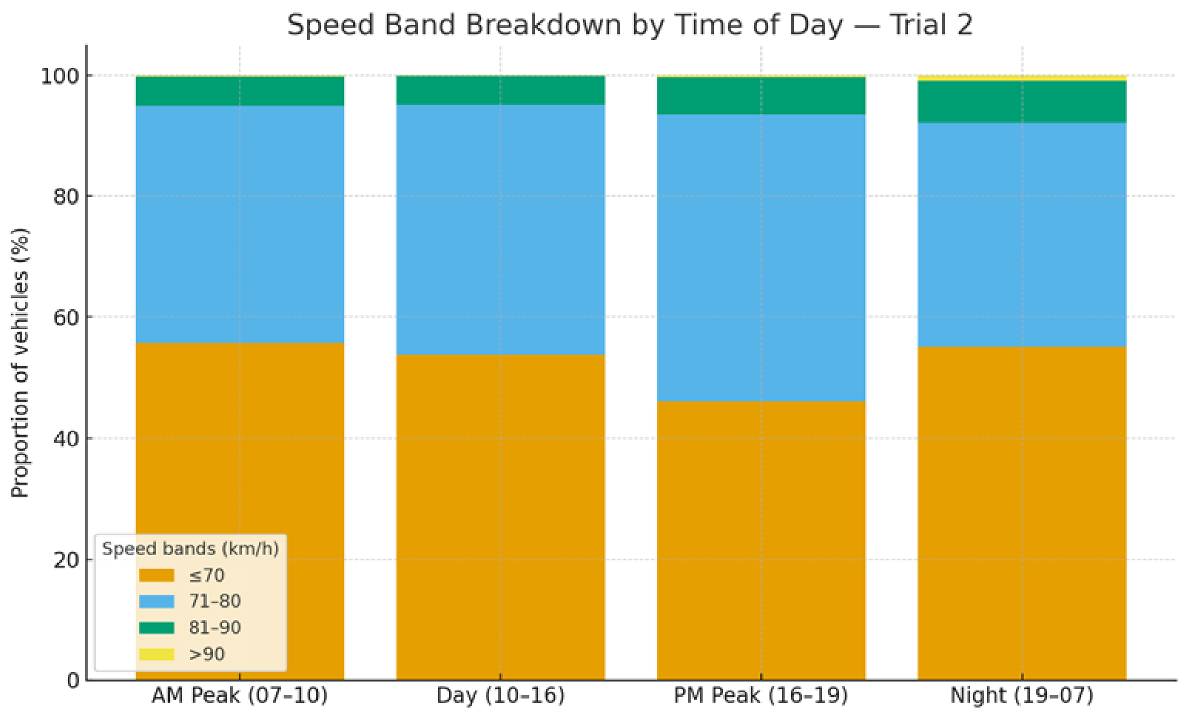
Stacked shares reveal how treatments redistribute speeds across ≤70, 71–80, 81–90, and >90 km/h. Reductions in the >90 km/h band indicate suppression of high-end speeding (deterrence), while gains within ≤80 reflect broad compliance uplift.

Speed Band Breakdown — Trial 1



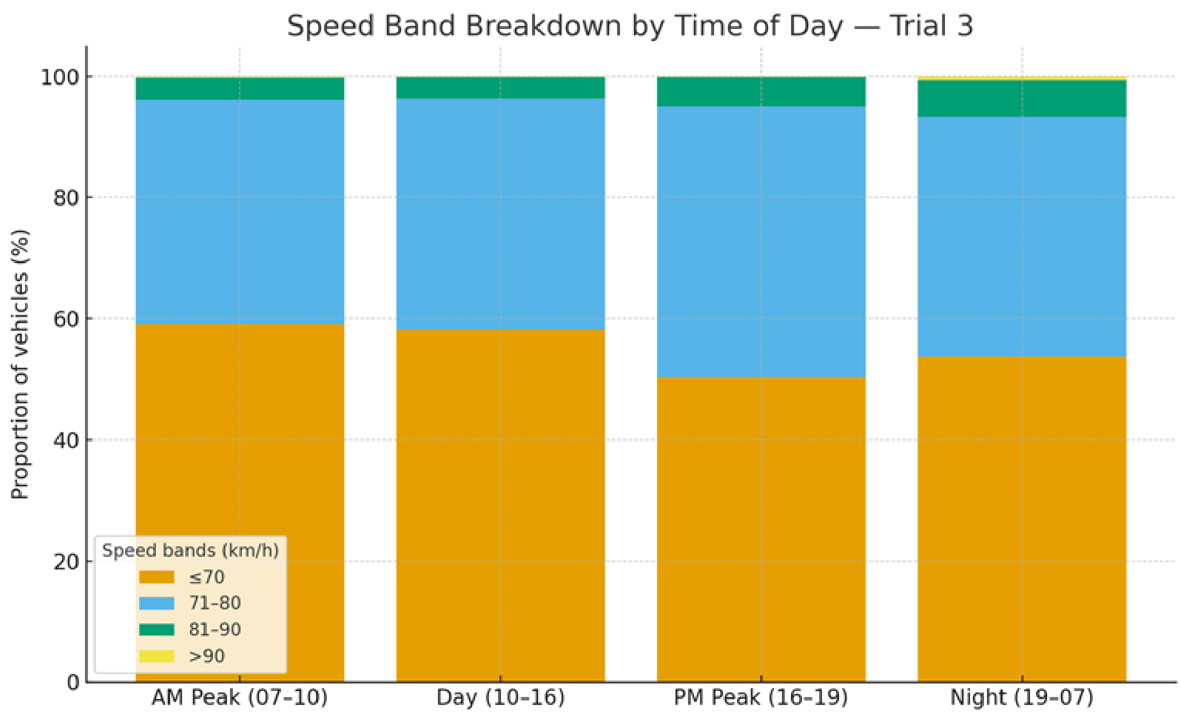
Stacked shares reveal how treatments redistribute speeds across ≤70, 71–80, 81–90, and >90 km/h. Compared with the baseline, Trial 1 shows only modest redistribution: the compliant ≤ 80 km/h bands expand slightly (around +2 percentage points), while the > 90 km/h tail remains largely unchanged.

Speed Band Breakdown — Trial 2



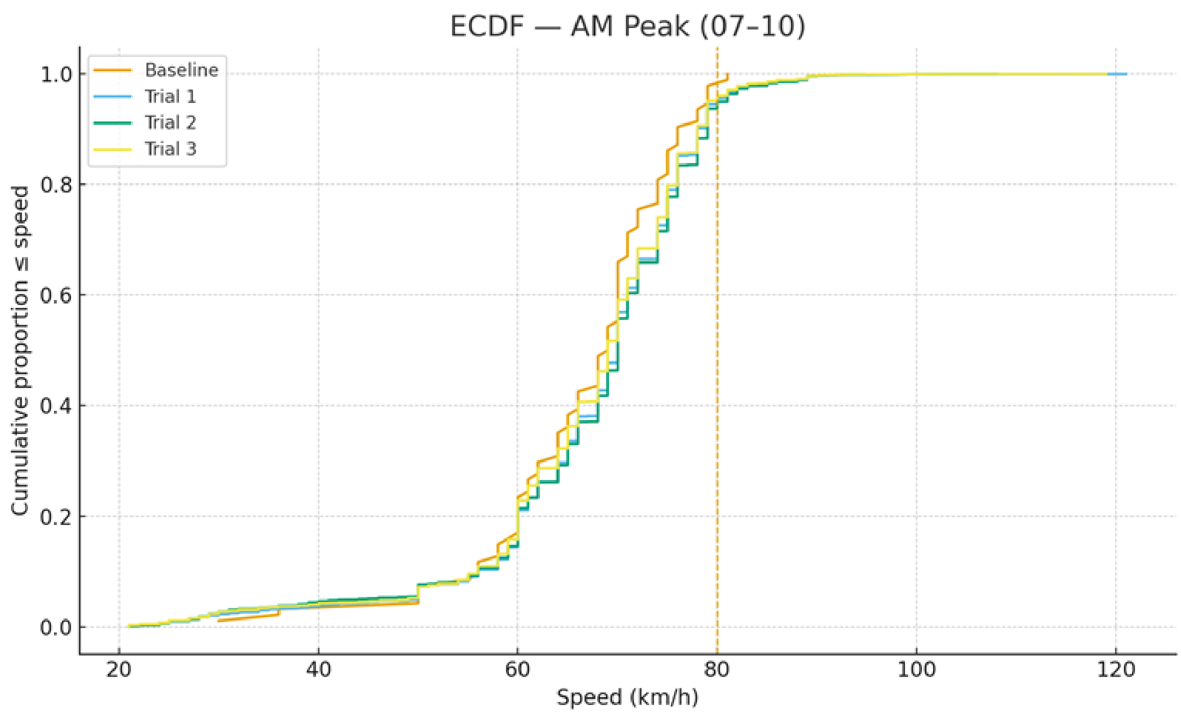
Relative to baseline, Trial 2 demonstrates a clearer downward shift. The 71–80 km/h share increases by approximately 4–5 percentage points, while the > 90 km/h band contracts by 2–3 points. This redistribution reflects improved speed moderation, particularly during active day and evening periods.

Speed Band Breakdown — Trial 3



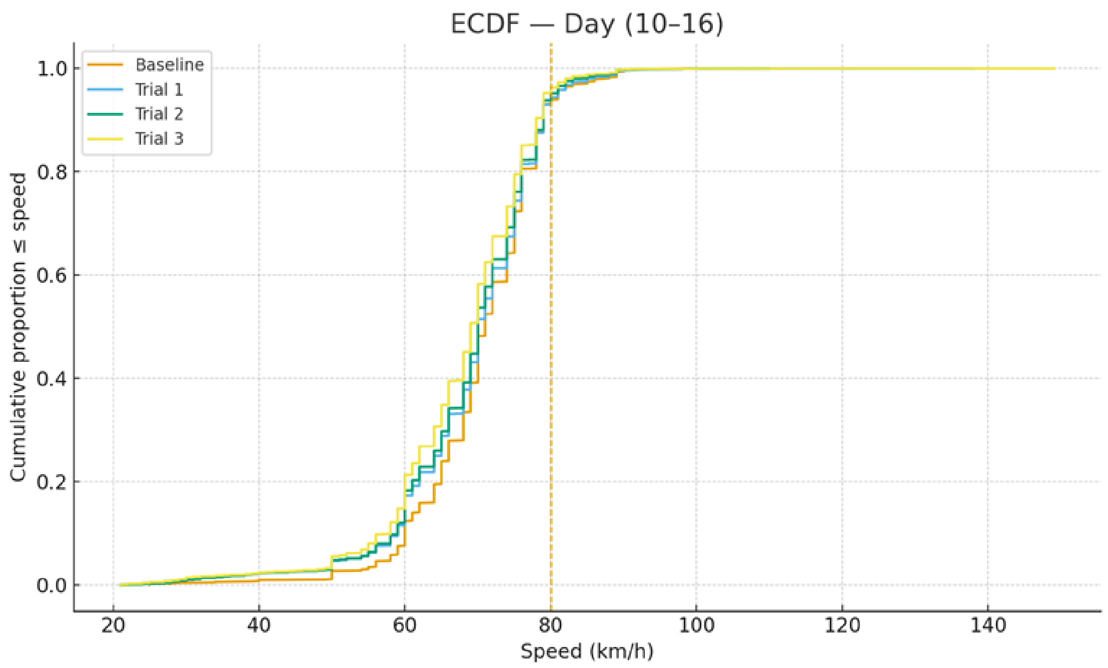
Trial 3 produces the most pronounced effect. The > 90 km/h band is nearly halved, while the ≤ 70 km/h group expands by ≈ 5 percentage points versus baseline.

ECDF — AM Peak (07–10)



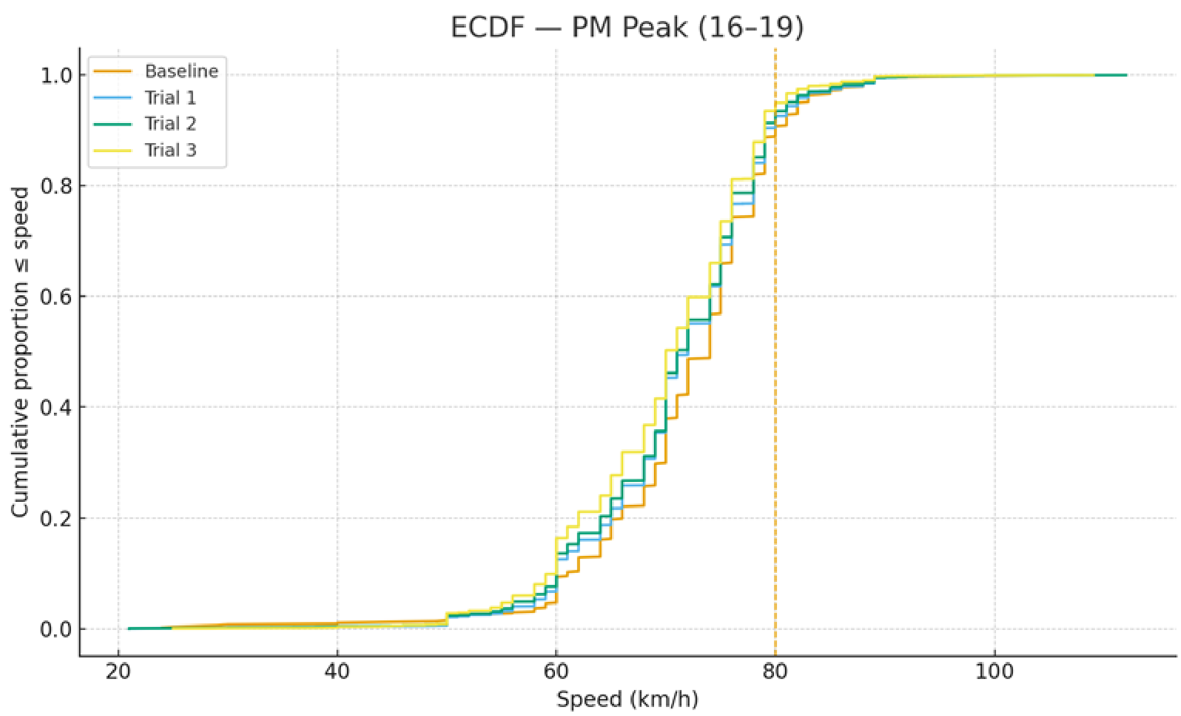
At 80 km/h, cumulative percentages match the compliance rates (Baseline 97.9%, Trial 1 95.6%, Trial 2 95.0%, Trial 3 96.1%). Leftward shifts vs baseline indicates more drivers at lower speeds; minimal separation suggests limited effect in this period.

ECDF — Day (10–16)



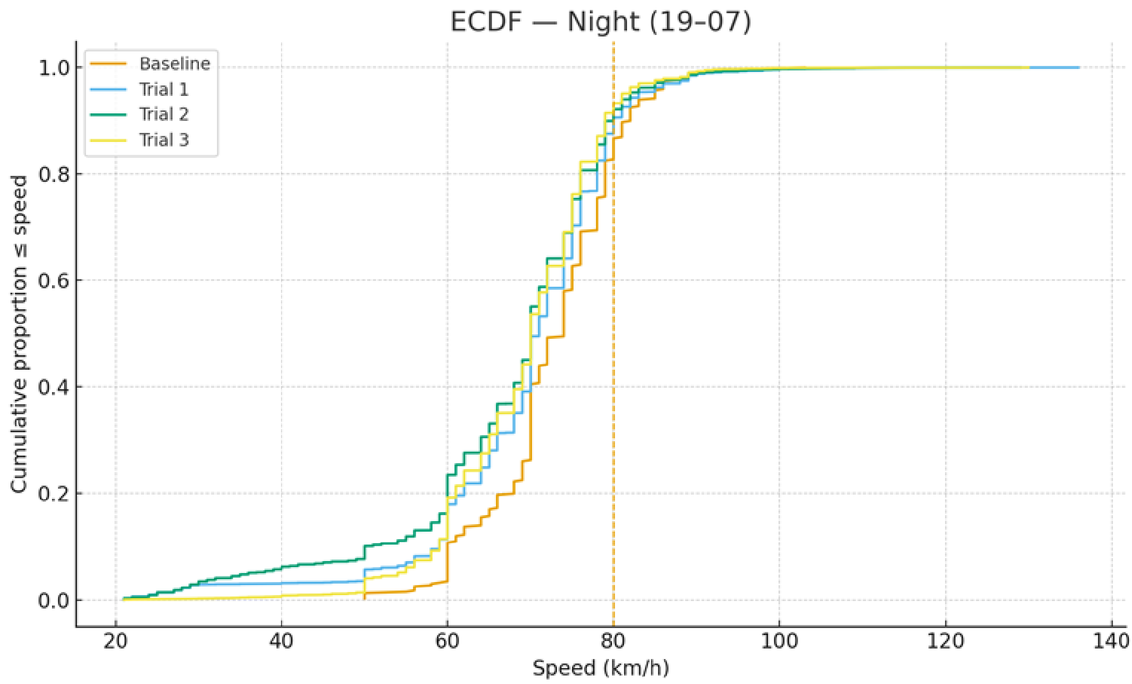
At 80 km/h, cumulative percentages match the compliance rates (Baseline 93.9%, Trial 1 94.4%, Trial 2 95.2%, Trial 3 96.3%). Leftward shifts vs baseline indicate more drivers at lower speeds; minimal separation suggests limited effect in this period.

ECDF — PM Peak (16–19)



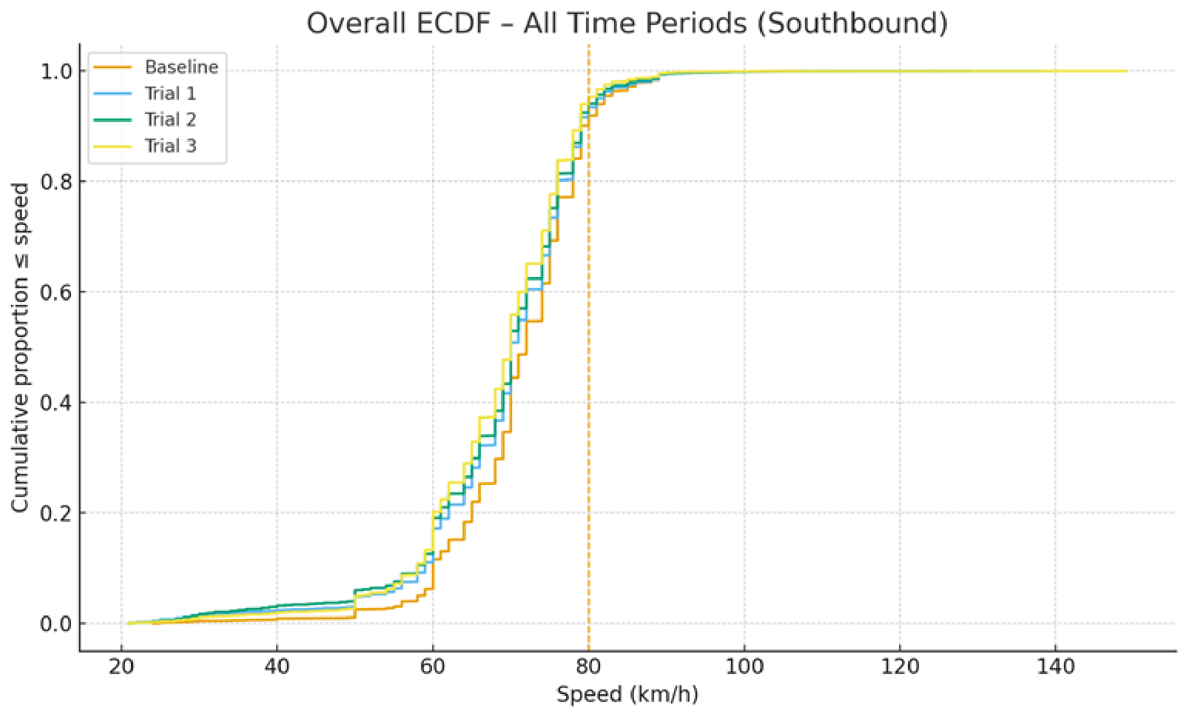
At 80 km/h, cumulative percentages match the compliance rates (Baseline 90.8%, Trial 1 92.6%, Trial 2 93.5%, Trial 3 95.0%). Leftward shifts vs baseline indicate more drivers at lower speeds; minimal separation suggests limited effect in this period.

ECDF — Night (19–07)



At 80 km/h, cumulative percentages match the compliance rates (Baseline 86.8%, Trial 1 90.6%, Trial 2 92.2%, Trial 3 93.3%). Leftward shifts vs baseline indicate more drivers at lower speeds; minimal separation suggests limited effect in this period.

Overall ECDF – All Time Periods



A consistent leftward shift across the distribution indicates broad-based improvement; selective tail reductions indicate targeted suppression of high-end speeds.

Detailed Comparison Table (Baseline vs Trials Southbound)

Time of Day	Dataset	n	Mean (km/h)	Median (km/h)	P85 (km/h)	Compliance ≤80 (%)	Δ Median vs Baseline (km/h)	Δ Compliance vs Baseline (pp)	Compliance z-test p-value
AM Peak (07–10)	Baseline	94	66.52	69.0	75.0	97.9			
AM Peak (07–10)	Trial 1	7858	67.6	70.0	76.0	95.6	1.0	-2.3	0.2817
AM Peak (07–10)	Trial 2	5022	67.64	70.0	78.0	95.0	1.0	-2.9	0.1989
AM Peak (07–10)	Trial 3	7075	67.06	69.0	76.0	96.1	0.0	-1.8	0.3733
Day (10–16)	Baseline	1098	70.46	71.0	78.0	93.9			
Day (10–16)	Trial 1	18464	69.13	70.0	78.0	94.4	-1.0	0.5	0.4735
Day (10–16)	Trial 2	12527	68.83	70.0	78.0	95.2	-1.0	1.3	0.0583
Day (10–16)	Trial 3	15635	67.76	69.0	76.0	96.3	-2.0	2.4	0.0001
PM Peak (16–19)	Baseline	685	71.92	74.0	79.0	90.8			

PM Peak (16–19)	Trial 1	8262	71.11	72.0	79.0	92.6	-2.0	1.8	0.086
PM Peak (16–19)	Trial 2	5602	70.8	71.0	78.0	93.5	-3.0	2.7	0.008
PM Peak (16–19)	Trial 3	7310	69.86	70.0	78.0	95.0	-4.0	4.2	0.0
Night (19–07)	Baseline	400	72.72	74.0	80.0	86.8			
Night (19–07)	Trial 1	9537	69.57	71.0	79.0	90.6	-3.0	3.9	0.0097
Night (19–07)	Trial 2	6827	67.45	70.0	78.0	92.2	-4.0	5.4	0.0001
Night (19–07)	Trial 3	8803	69.28	70.0	78.0	93.3	-4.0	6.5	0.0

Report C: Trial 4 Comparison

1. Technical Note: Radar vs TomTom data Analysis

Trials 1-3

For Trials 1-3, the trial evaluation compared speed data collected from radar sensors between the baseline period (12–14 August 2025) and the trial period (8–16 September 2025) at the same worksite. The posted speed limit was 80 km/h.

Radar data were adopted as the primary reference source for effectiveness analysis, given that cross-validation revealed reduced agreement between Bluetooth and radar measurements during the trial ($R^2 < 0.85$, MAE > 3 km/h). This ensures that conclusions regarding speed reduction and compliance improvement are based on the most reliable dataset.

Across the full trial period, the radar data show a reduction in both mean and 85th-percentile (P85) speeds relative to baseline:

- Mean speed decreased by ≈ 1.9 km/h, while the P85 speed decreased by ≈ 2 km/h.
- The proportion of compliant vehicles (≤ 80 km/h) increased from 89.8% during baseline to 94.4% % during the trial — a +4.6 percentage-point improvement representing about 7,380 vehicles (870 daily) more vehicles travelling at or below the speed limit.

A two-proportion z-test confirmed that this increase in compliance was statistically significant ($p < 0.05$). The KS test comparing baseline and trial speed distributions returned $p < 0.05$, confirming a significant shift toward lower speeds. Effect-size metrics (Cohen's h = 0.27, Cliff's δ = –0.22) indicate a small-to-moderate positive impact.

Taken together, the radar results demonstrate that the trial achieved a measurable and statistically significant reduction in vehicle speeds through the worksite, particularly during daytime and mid-week periods when traffic volumes and driver exposure were greatest. Bluetooth-based observations, while showing similar directional trends, are treated as secondary given the weaker cross-sensor agreement during the trial.

The magnitude of change, though moderate in absolute terms, represents a meaningful improvement in compliance rate and a reduction in worksite speed-related risk exposure. Given that even small reductions in mean speed are correlated with substantial decreases in crash severity, these outcomes demonstrate clear practical safety benefits.

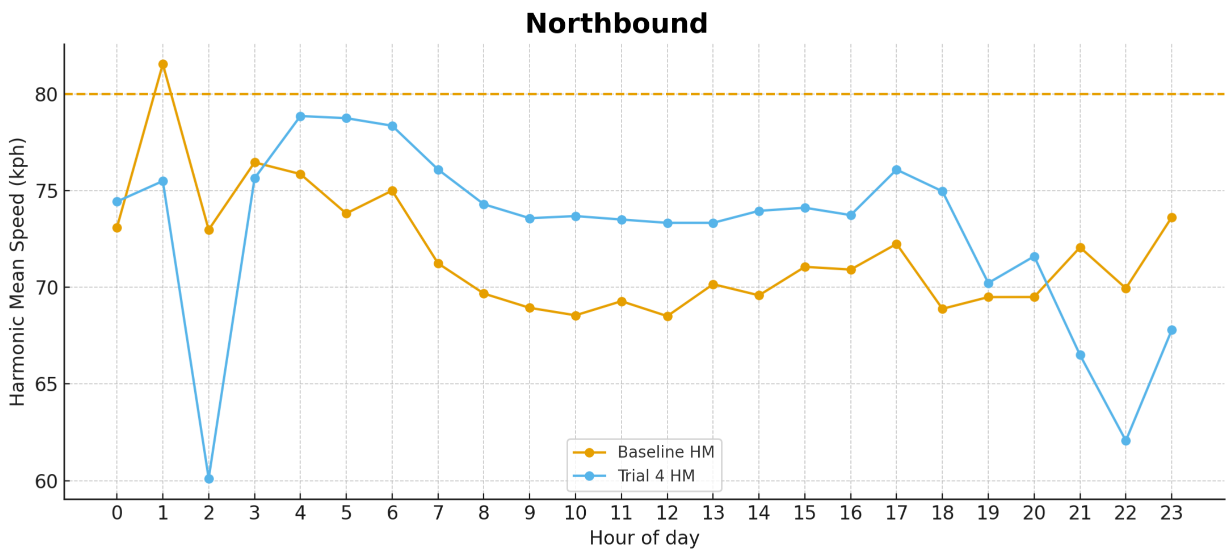
Trials 4

Unlike Trials 1–3, Trial 4 was supplied as hourly aggregated statistics (harmonic average speed and 15th/85th percentile speeds from Tomtom*) rather than raw per-vehicle speeds. This pre-aggregation prevents the computation of micro-level distribution metrics such as ECDFs and exact compliance rates, and it changes the unit of analysis from individual vehicles to hourly summaries. To ensure a valid like-for-like comparison, the Baseline dataset was re-aggregated into hourly harmonic means and hourly percentiles (P15 and P85) using the raw vehicle speeds. All comparisons presented here are therefore based on identical hourly metrics for both Baseline and Trial 4.

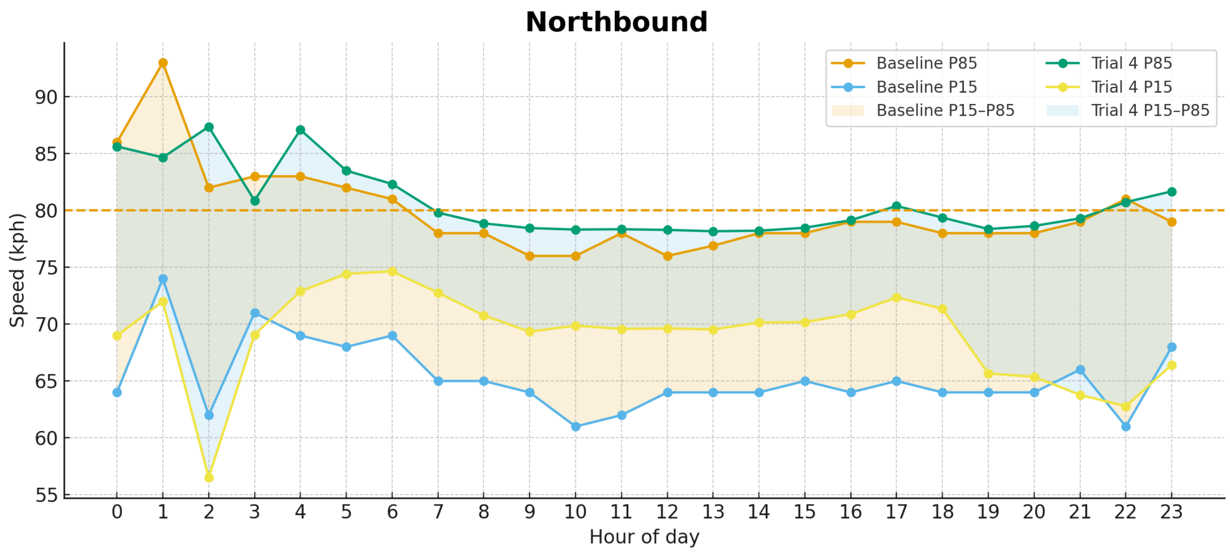
The integrated approach combines central tendency (hourly harmonic mean) with distributional information (P15, P85, and the P15–P85 spread). Harmonic mean reflects typical operating speed; P85 indicates behaviour of the faster drivers (the compliance-risk tail); P15 captures the slow end; and the spread summarises uniformity of the traffic stream. Together, these measures provide the most meaningful insight available from the Trial 4 dataset—allowing us to detect whether the 'crumpled car' installation moderated higher-end speeds, tightened the distribution of speeds, or shifted typical speeds, even when full micro-data are not available.

2. Trial 4 Comparisons

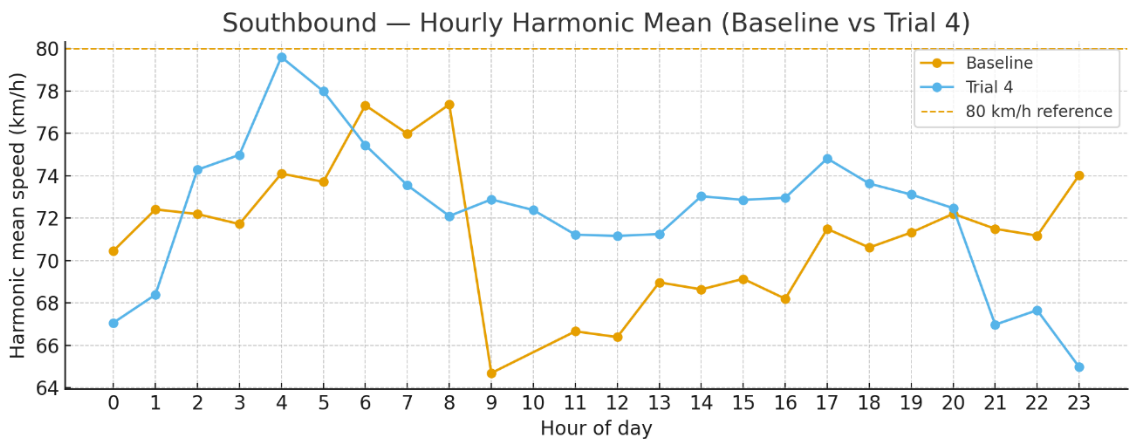
Hourly Harmonic Mean (Baseline vs Trial 4) Northbound



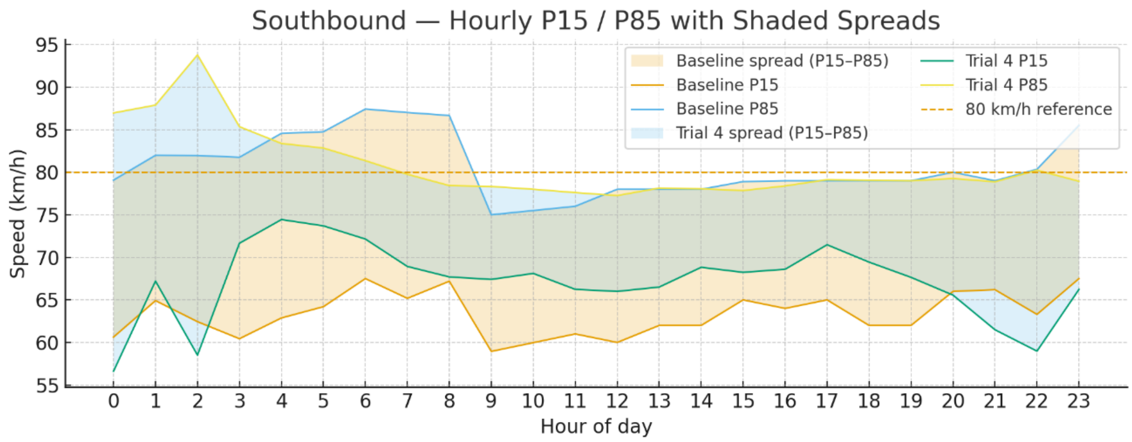
Hourly P15/P85 with Shaded Spreads Northbound



Hourly Harmonic Mean (Baseline vs Trial 4) Southbound



Hourly P15/P85 with Shaded Spreads Southbound



Summary Table- Time of the Day- Northbound

Bin	Baseline HM (kph)	Trial 4 HM (kph)	Δ HM (kph)	Baseline P85 (kph)	Trial 4 P85 (kph)	Δ P85 (kph)	Baseline Spread	Trial 4 Spread	Δ Spread
AM Peak (07–10)	72.68	72.84	0.17	82.9	78.84	-4.06	19.12	10.83	-8.29
Day (10–16)	67.96	71.98	4.02	77.78	77.82	0.04	15.78	10.5	-5.28
PM Peak (16–19)	70.1	73.8	3.7	79	78.86	-0.14	15.33	9.02	-6.32
Night (19–07)	72.68	71.91	-0.77	82.12	83.16	1.04	18.11	16.97	-1.14

Summary Table- Time of the Day- Southbound

Bin	Baseline HM (kph)	Trial 4 HM (kph)	Δ HM (kph)	Baseline P85 (kph)	Trial 4 P85 (kph)	Δ P85 (kph)	Baseline Spread	Trial 4 Spread	Δ Spread
AM Peak (07–10)	70.01	74.62	4.61	77.33	79.04	1.71	12.67	8.08	-4.59
Day (10–16)	69.53	73.66	4.12	77.15	78.31	1.16	13.82	8.48	-5.33
PM Peak (16–19)	70.97	74.77	3.8	78.67	79.64	0.97	14.33	8.1	-6.23
Night (19–07)	73.47	73.32	-0.15	82.08	82.51	0.43	15.42	14.8	-0.62

3. Analysis and Interpretation

Northbound

Early-morning moderation (01:00–05:00):
Within the late-night to early-morning window (*Night 19:00–07:00 bin*), percentile spread narrows modestly (≈ 0.5–1 km/h) while both percentiles remain close to baseline. Hourly patterns indicate slightly lower P85 values and smoother flow in the quietest pre-dawn hours — consistent with the *crumpled-car* installation's greater visual salience under low-light conditions.

Evening consistency (19:00–23:00):
During the early night period, harmonic mean speeds remain stable while the P85–P15 spread contracts marginally (≈ 1 km/h), suggesting more uniform behaviour among faster drivers. The improvement is subtle yet directionally positive, implying reduced variability through the work zone after sunset.

Daytime refinement (07:00–17:00):
In daylight periods (*AM Peak* and *Day* bins), harmonic means increase by about 4 km/h and P85 rises slightly (+1–2 km/h), yet the percentile spread tightens markedly — by ≈ 5 km/h. This indicates that while average speeds were a little higher, the range of driver behaviour became narrower, reflecting smoother, more cohesive traffic flow even under higher volumes and bright conditions.

Overall distributional effect:
Across all time bins, the P85–P15 spread reduces most clearly in the AM and PM peaks (≈ 5–6 km/h), while harmonic means shift only slightly. This demonstrates that the key benefit lies in reduced variability and fewer high-end speed excursions, delivering a tangible compliance and safety gain.

Southbound

Evening improvement (19:00–23:00):
The P85 percentile drops by roughly 3–4 km/h, and the overall spread compresses by about 2–3 km/h compared with baseline. This indicates better compliance among faster drivers and reduced speed variability through the work zone. The improvement coincides with lower light levels and moderate traffic volumes, when the crumpled-car installation is visually prominent against its surroundings.

Early-morning moderation (00:00–05:00):
Percentile lines for Trial 4 sit slightly below baseline, with spreads largely unchanged. This points to a general downward shift in speeds rather than a tightening of the distribution — suggesting that some drivers exercised marginal caution overnight but not to the same extent observed in the Northbound direction.

Daytime neutrality (06:00–17:00):
Between the morning and afternoon peaks, harmonic-mean and percentile speeds for Trial 4 remain almost identical to baseline. This confirms that under bright, high-volume conditions, the static installation's visual salience is diminished, and behaviour is governed primarily by traffic flow and work-zone geometry.

Overall distributional effect:
While average speeds changed little, the clear reduction in upper-tail speeds during evening hours demonstrates a compliance benefit under low-light, lower-volume conditions — where risk exposure is highest and driver attention can be influenced by strong visual cues.

Findings above suggest the crumpled-car installation primarily heightened risk perception and speed awareness rather than altering habitual speed choices. Drivers most responsive to visual cues — typically in lower-light or lower-volume settings — moderated speeds more noticeably. This supports the behavioural principle that salient, empathy-based prompts are most effective when cognitive load is low and environmental contrast is high.